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Garrison to Halibut



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GARRISON TO HALIBUT

ARRISON, WILLIAM LLOYD (1805–1879), U.S. antislavery leader, was born in Newburyport, Mass., on Dec. 12, 1805. His parents were from the British province of New Brunswick. The father, Abijah, a sea captain, drank heavily and deserted his home when William was a child. The mother, whose maiden name was Lloyd, is said to have been a woman of high character, charming in person and eminent for piety. William had little education but made the most of his opportunities. He was set to learn the trade of a shoemaker, first at Newburyport, and then, after 1815, at Baltimore, Md. Then he was apprenticed to a cabinetmaker at Haverhill, Mass., but ran away. In Oct. 1818, when he was 12, he was indentured to Ephraim W. Allen, proprietor of the Newburyport Herald, to learn the trade of a printer. He soon became an expert compositor, and after a time began to write anonymously for the Herald. His communications won the commendation of the editor, who had not at first the slightest suspicion that Garrison was the author. He also wrote for other papers with equal success. His skill as a printer won for him the position of foreman, while his ability as a writer was so marked that the editor of the *Herald*, when temporarily called away from his post, left the paper in his

The printing office afforded him an opportunity to increase his meagre education. He was enthusiastic about liberty; the struggle of the Greeks to throw off the Turkish yoke enlisted his sympathy; and at one time he seriously thought of entering the West Point academy and fitting himself for a soldier's career. His apprenticeship ended in 1826; when he began the publication of a new paper (actually the old one under a new name), the *Free Press*, in his native place. The paper, whose motto was "Our Country, our Whole Country, and nothing but our Country," was an intellectual force, but was too radical for Newburyport, and the enterprise failed.

Garrison then went to Boston, where, after working for a time as a journeyman printer, he became the editor of the *National Philanthropist*, the first journal established in America to promote the cause of total abstinence from intoxicating liquors; but a change in the proprietorship led to his withdrawal before the end of the year. In 1828 he established the *Journal of the Times* at Bennington, Vt., to support the re-election of John Quincy

Adams to the presidency of the United States. This paper also died within a year. In Boston he had met Benjamin Lundy (q.v.), who had for years been preaching the abolition of slavery. Garrison had been deeply moved by Lundy's appeals, and after going to Vermont he showed the deepest interest in the slavery question. Lundy was then publishing in Baltimore a small monthly paper, the *Genius of Universal Emancipation*, and he went to Bennington and invited Garrison to join him in the editorship.

Garrison first accepted Lundy's views of gradual emancipation, but soon changed to total and immediate freedom for slaves when he joined Lundy in Baltimore in 1829. Lundy believed that the Negroes, on being emancipated, must be colonized somewhere beyond the limits of the United States; Garrison held that they should be emancipated on the soil of the country, with all the rights of freemen. Garrison saw that it would be idle to expose and denounce the evils of slavery, while responsibility for the system was placed upon former generations, and the duty of abolishing it transferred to an indefinite future. His demand for immediate emancipation fell like a tocsin upon the ears of slaveholders. The Genius, when it became a vehicle for this dangerous doctrine, was feared and hated. Baltimore was then one of the centres of the domestic slave trade, and upon this traffic Garrison heaped the strongest denunciations. He was prosecuted for libel by the owner of a slave-carrying vessel, was fined \$50, and, in default of payment, committed to jail.

John Greenleaf Whittier, whose first poems Garrison had published in the *Free Press*, interceded with Henry Clay to pay Garrison's fine and thus release him from prison. Clay responded favourably, but before he could act Arthur Tappan, a philanthropic merchant of New York, contributed the necessary sum and set the prisoner free after an incarceration of seven weeks. The partnership between Garrison and Lundy was then dissolved by mutual consent, and Garrison resolved to establish a paper of his own, in which he could advocate the doctrine of immediate emancipation and oppose the scheme of African colonization. He first proposed to establish his paper at Washington, in the midst of slavery, but on returning to New England and observing the state of public opinion there, he came to the conclusion that little could be done in the south while the nonslaveholding north was lending its influence for the sustenance of slavery. He determined, there-

fore, to publish his paper in Boston, and set himself to the task of awakening an interest in the subject by lectures in some of the principal cities and towns of the north. In Boston, then a great cotton mart, he tried in vain to procure a church or vestry for the delivery of his lectures, until a group under the leadership of Abner Kneeland (1774–1844) proffered him the use of their small hall. He accepted it gratefully, and delivered in Oct. 1830 three lectures, in which he unfolded his principles and plans.

On Jan. 1, 1831, without capital and without a subscriber, he and his partner, Isaac Knapp (1804-43), issued the first number of the Liberator, avowing their "determination to print it as long as they could subsist on bread and water, or their hands obtain employment." Its motto "Our Country is the World-our Countrymen are Mankind" shows his changed viewpoint. The paper, in addition to favouring abolition, attacked war, alcoholic liquors and tobacco, and assailed freemasonry, capital punishment and imprisonment for debt. The editor, in his address to the public, uttered the words which have become memorable as embodying the whole purpose and spirit of his life: "I am in earnest-I will not equivocate—I will not excuse—I will not retreat a single inch —and I will be heard." For many months Garrison and his partner made their beds on the floor of the room in which they printed their weekly paper, and where Mayor Harrison Gray Otis of Boston, in compliance with the request of Gov. Robert Y. Hayne of South Carolina, "ferreted them out." Otis decided, however, that the paper could not be suspended. In the same year (1831), \$5,000 reward was offered for Garrison's arrest and conviction under the laws of Georgia. The Liberator, though in constant financial difficulties, exerted a mighty influence, and lived to record not only President Lincoln's proclamation of emancipation, but the adoption of an amendment to the constitution of the United States forever prohibiting slavery.

Garrison was a pacifist, and sought the abolition of slavery by moral means alone. He knew that the national government had no power over the system in any state, though he thought it should bring its moral influence to bear in favour of abolition. His idea was to combine the moral influence of the north, and pour it through every open channel upon the south. To this end he made his appeal to the northern churches and pulpits, beseeching them to bring the power of Christianity to bear against the slave system, and to advocate the rights of the slaves to immediate and unconditional freedom. When they did not respond, he denounced them, and by 1840 had become very unorthodox. The first society organized under Garrison's auspices, and in accordance with his principles, was the New England Antislavery society in Jan. 1832. The same spring Garrison issued his Thoughts on African Colonization, in which he showed from official documents that the American Colonization society was organized in the interest of slavery, and that in offering itself as a practical remedy for that system it was guilty of deception. Garrison was deputed by the New England Antislavery society to visit England for the purpose of counteracting the influence there of agents of the Colonization society. He went in the spring of 1833, and was received with great cordiality by British abolitionists. He took home with him a "protest" against the American Colonization society signed by William Wilberforce and other abolitionists in England.

Garrison's visit to England enraged the proslavery people, and when he returned in September with the "protest" against the Colonization society, and announced that he had engaged the services of George Thompson as a lecturer against American slavery, there were fresh outbursts. The American Antislavery society was organized in December of that year (1833), the declaration of its principles coming from Garrison's pen. The activities of this society and Thompson's lectures aroused such fury that, in the autumn of 1835, Thompson was compelled to return secretly to England. He had announced that he would address the women's antislavery society in Boston, and a mob gathered. Not finding him, it seized Garrison and dragged him through the streets until he was rescued and given protection in the jail until he could leave the city in safety.

The abolitionists of the United States were a united body until 1839–40 when division occurred. Garrison countenanced the ac-

tivity of women in the cause, even appointing them as lecturing agents; moreover, he believed in the political equality of the sexes, to which a strong party was opposed upon social and religious grounds. His attack on the churches caused dissent. Many believed that Garrison injured abolitionism by causing it to be associated in men's minds with these unpopular views on other subjects. These differences led to the organization of a new national antislavery society in 1840, and to the formation of the Liberty party (q.v.) in politics (see Birney, James Gillespie). The two societies sent their delegates to the world's antislavery convention in London in 1840, and Garrison refused to take his seat in that body, because the women delegates from the United States were excluded. The discussions of the next few years served to make clearer than before that the constitution of the United States supported slavery; and Garrison came to the conclusion that its proslavery clauses were immoral, and that it was therefore wrong to take an oath for its support. Because of this, Garrison burned the constitution, denouncing it as "a covenant with death and an agreement with hell." He chose as his motto, "No union with slaveholders," and thereafter worked for peaceful disunion. When in 1861 the southern states seceded from the union and took up arms against it, he saw clearly that slavery would perish in the struggle and that the constitution would be purged of its proslavery clauses. He therefore ceased to advocate disunion, and devoted himself to hastening the inevitable event. His services at this period were recognized and honoured by President Lincoln and others in authority, and the whole country knew that the agitation which resulted in the abolition of slavery was largely due to his uncompromising spirit and indomitable courage.

In 1865 at the close of the war, he declared that, slavery being abolished, his career as an abolitionist was ended. He counseled a dissolution of the American Antislavery society, insisting that whatever needed to be done for the protection of the freedmen could best be accomplished by new associations formed for that purpose. The Liberator was discontinued at the end of the same year, after an existence of 35 years. He visited England for the third time in 1846, and again in 1867, when he was received with distinguished honours, public as well as private. In 1869 he became president of the Free Trade league, advocating the abolition of custom houses throughout the world. In 1877, he again visited England, and declined every form of public recognition. He died in New York on May 24, 1879, at the age of 74, and was buried in Boston, after a most impressive funeral service, four days later. In 1843 a small volume of his Sonnets and Other Poems was published, and in 1852 appeared a volume of Selections from his writings and speeches.

One of Garrison's sons, William Lloyd Garrison (1838–1909), was a prominent advocate of the single tax, free trade, woman's suffrage and of the repeal of the Chinese Exclusion act, and an opponent of imperialism. Another son, Wendell Phillips Garrison (1840–1907), was literary editor of the New York Nation from 1865 to 1906.

BIBLIOGRAPHY.—The great authority on the life of Garrison is the thorough and candid work of his sons, W. P. and F. J. Garrison, William Lloyd Garrison, 1805–1879: the Story of His Life Told by His Children (4 vol., 1885–89). See also Russel B. Nye, William Lloyd Garrison and the Humanitarian Reformers (1955); Ralph Korngold, Two Friends of Man (1950).

GARROTE (Span. for "cudgel"), an appliance used in Spain and Portugal for the execution of condemned criminals. The execution was performed originally by twisting a cord or bandage on the criminal's neck by means of a rod or stick (whence the name) until strangulation occurred, but later a mechanically operated metal collar with a screw that penetrated the base was adopted. "Garroting" is the name given in England to a form of robbery in which the victim is suddenly throttled from behind, which became rather common in the winter of 1862–63. An act of 1863, imposing the penalty of flogging in addition to penal servitude for this offense, had the effect of stopping it almost entirely.

GARRYA, the single genus of attractive, broad-leaved, evergreen, treelike shrubs of the family Garryaceae consisting of several Californian, Mexican and Central American species closely.

related to the dogwood family, Cornaceae. Their male and female flower-bearing catkins occur on separate plants, are pendant, several inches long and somewhat woolly—hence the common name silk-tassel tree. Pulpy berries develop on female catkins.

The leaves of different species vary from light to dark green on top, are hairy or downy on the lower surface and have smooth to wavy margins. Two California species, *Garrya elliptica* and *G. fremontii*, have been horticulturally adapted.

BIBLIOGRAPHY.—L. H. Bailey, Standard Cyclopedia of Horticulture, vol. ii (1928); M. F. Moseley, Jr. and Richard M. Beeks, "Studies of the Garryaceae. I. The Comparative Morphology and Phylogeny," Phytomorphology, vol. v, pp. 314–346 (1955). (R. M. Re.)

GARSHIN, VSEVOLOD MIKHAILOVICH (1855–1888), Russian short-story writer. Born Feb. 14 (new style; 2, old style), 1855, in the district of Bakhmut, province of Yekaterinoslav, the son of a retired army officer, he was educated at the St. Petersburg Mining institute. In 1877 he enlisted as a private to serve in the Russo-Turkish War, which inspired his first story, Chetyre dnya (1877; "Four Days")—one of a number in which he expresses his horror of war. Many of his other stories, such as Krasny tsvetok (1883; "The Red Flower"), which describes a maniac, show his skill in handling morbid subjects and reflect his hypersensitivity. Though his output was small, Garshin's stories helped to awaken general interest among Russian authors in the short story. He committed suicide in St. Petersburg on April 5 (N.S., March 24, O.S.), 1888. (R. F. HI.)

GARSTANG, JOHN (1876-1956), British archaeologist, whose extensive experience in the middle east culminated in his excavations at Mersin, Turk., during 1937-47, was born at Blackburn, Lancashire, on May 5, 1876. While a mathematics scholar at Jesus college, Oxford, he became interested in Romano-British archaeology, publishing Roman Ribchester (1899). In 1902 Garstang became reader in Egyptian archaeology at the University of Liverpool, and from 1907-41 was professor of archaeological methods and practice there; he was instrumental in establishing the Liverpool Institute of Archaeology. Garstang went to Egypt in 1899, working under Sir William Matthews Flinders Petrie. During the next 15 years he excavated in Egypt, Nubia and Asia Minor, becoming an authority on the Hittite civilization. A standard work, The Land of the Hittites (1910), was revised as The Hittite Empire in 1927. His excavations at the ancient Ethiopian capital, Meroë (1910-14), revealed evidence of Roman occupation.

During World War I Garstang served with the Red Cross. In 1919 he was appointed first director of the British School of Archaeology at Jerusalem, and in 1920 took charge of the Palestinian department of antiquities, retiring from both positions in 1926. His work at Jericho, 1930–36, first indicated the great antiquity of the site. He made major discoveries concerning the Neolithic and Bronze Age settlements.

Garstang's work at Mersin was interrupted by the outbreak of World War II, and the report, *Prehistoric Mersin*, appeared in 1953. The significance of his Anatolian studies was recognized by Garstang's appointment as first director of the British School of Archaeology at Ankara, 1947–48, and as president from 1949 until his death at Beirut, Lebanon, Sept. 12, 1956. (J. M. WI.)

GARTOK (GARYARSA) is the capital of Ngari (Ari) district in the western Tibetan highland. Ngari was the birthplace of the native pre-Buddhic Tibetan religion, Bon Po, a mixture of exorcism and primitive worship, and was also the scene of the Buddhist renaissance in the 11th century. Gartok, on the upstream of the Indus, is the western gateway to Tibet. A caravan route leading to Leh and Simla in India through the Shipki pass has existed for centuries. Gartok is joined to Ngachuka via Zhikatse, and to Polur and Khotan in Sinkiang by modern highways. The Taklakot or Taklakhar highway, 157 mi. long, links Gartok with Pulanchung (Puran Tzong), a rich agricultural region on the south.

Gartok, once a desolate town in winter, was considerably built up after the Chinese Communist occupation of Tibet. A large garrison force is stationed in the region. New banks, post offices, schools, general stores and hospitals have been constructed along the Gar river. During the warm season, a brisk barter trade is carried on between the nomads from the northern plain, the Zhikatse merchants and the traders from India and Nepal. Regular fairs are held throughout the summer, attracting as many as 2,000 people daily, with hundreds of tents littering the bare plain and hillside during the night. (T.-L. S.)

GARUT, a town and district of West Java, Indon., is the centre of a well-cultivated region. Pop., town (1957 est.), 55,850; district (1961) 924,543. The town, 2,300 ft. above sea level, is charmingly laid out and is an agricultural trade centre. It lies 30 mi. S.E. of Bandung. The district forms a plateau around which are grouped magnificent mountains, some volcanoes, with mountain lakes and hot springs. Among places of interest are the crater of the Papandajan, a volcano still active, which blew out the greater part of one side of a mountain in 1772, killing thousands of people and destroying much of the surrounding countryside; the Kawah Kamodjan, a group of pools of boiling mud, geysers and fumaroles; the Telagabodas or White lake, in a forest setting; the Kawah Manuk or Bird's crater; the lakes of Bogendit and Leles and the hot springs of Tjipanas; the lake of Pandjalu and Mt. Tjikuraj. Garut district is noted for its tea, rubber and cinchona plantations but is better known as a health resort area. The district, formerly part of the Dutch West Preanger residency, was occupied by the Japanese from March 1942 to the end of World War II. (E. E. L.; X.)

GARY, ELBERT HENRY (1846–1927), U.S. jurist and chief organizer of the United States Steel corporation, was born on Oct. 8, 1846, near Wheaton, Ill. He studied law first in the office of his uncle, Col. Henry Vallette, and then at the Union College of Law in Chicago, from which he was graduated in 1867. In 1869 he began his law practice in Chicago. He was elected judge of Du Page county in 1882 and again in 1886. During this period he also frequently held court in Chicago and Cook county and occasionally presided over important cases in other counties throughout the state of Illinois. He was three times elected president of the town of Wheaton and, on its becoming a city in 1890, served as mayor for two terms.

A leader and authority in corporation law and insurance matters, he became general counsel and a director in a number of large railroads, banks and industrial corporations, including steel and wire companies. In 1891 he was one of the organizers of the Consolidated Steel and Wire company. In 1898, upon the organization of the Federal Steel company, with the financial backing of J. P. Morgan and Company, he became its first president and retired from legal practice. This company was merged in 1901 with the U.S. Steel corporation, which was then organized with a capital stock exceeding \$1,000,000,000, then by far the largest industrial corporation in the world. Gary was elected chairman of the executive committee and later chairman of the board of directors and of the finance committee, and continued to be chief executive officer during 26 years of remarkable development of the steel industry and growth of the corporation.

The steel mills and town of Gary, Ind., were laid out in 1906 by the U.S. Steel corporation and later named in his honour. By the time of Gary's death, the town had grown to be a city of more than 100,000, with enormous and varied mills for the manufacture of iron and steel products. As chairman of U.S. Steel, he advocated and established many measures for the welfare of the employees of industrial corporations, including stock ownership by them and participation in profits, high wages and safe, sanitary and pleasing surroundings. He was always a strong advocate and a firm upholder of the open shop. During his chairmanship the 7-day week and the 12-hour day for labour in the steel mills were abolished. He died in New York city, Aug. 15, 1927.

(J. A. Fa.; X.)

GARY, one of the largest cities in Indiana, is located at the southern end of Lake Michigan. The city's history began in 1906 with the construction of the huge steel mills and various subsidiary plants of the United States Steel corporation. Since the building of the municipality was included in the plans of the steel company, Gary was a "city by decree." Gary was incorporated as a town in 1906 and became a city in 1909. It was named for

States Steel.

In 1905 and 1906 the steel company purchased 9,000 ac. of sand ridges and swamps which included a frontage of more than seven miles on Lake Michigan. The location was selected because of its position midway between the iron ore beds of the north, accessible by water, and the coal region of the south. The steelworks were constructed along the lake shore and the city was located to the south. The Gary Land company, a subsidiary of the steel corporation, platted and laid out its part of the city, constructed the streets and sidewalks, installed the sewage system and built the water works and electric plant. In Dec. 1908 the first blast furnace was fired, and the production of steel began early the following year. Subsidiary plants of the United States Steel corporation, American Bridge, American Sheet and Tin Plate and National Tube mills were located in the vicinity, and a large manufactory of portland cement was established. Manufacturers of screws and bolts, steel springs, automobile bodies and chemicals also established plants in the course of the years. However, Gary is essentially a one industry city; it has periodically suffered economic hardship when steel production has declined and when the huge mills have been shut down by strikes, as during the 116-day strike in the fall of 1959, which was finally settled in Jan. 1969.

Culturally, Gary was the scene of the establishment by William A. Wirt of the work-study-play school, more popularly known as the platoon school, a significant development in the history of public-school education. The city is served by an extension centre of Indiana university. The park system includes a public beach on Lake Michigan. The population soared, reaching 178,320 in 1960; for comparative population figures see table in Indiana: Population. In the 1950 census Gary was treated as a part of the Chicago metropolitan area; in 1960 it was designated a central city of the Gary-Hammond-East Chicago standard metropolitan statistical area, comprising Lake and Porter counties, pop. 573,548, a part of the Chicago standard consolidated area. See CHICAGO: Population: Metropolitan Area. (P. ME.)

GAS, a general term for one of the three states of aggregation of matter; also more specifically applied to coal gas. See ANES-THESIA AND ANESTHETICS; CHEMISTRY: Physical Chemistry; GAS INDUSTRY; CHEMICAL WARFARE. See also references under "Gas" in the Index volume.

GAS CHAMBER, a method of execution used in the United States, introduced in an effort to provide a more humane way of killing condemned criminals; it was first used in Nevada in 1924. It consists of a sealed chamber into which poisonous fumes are injected. The condemned man is strapped in a chair in the lethal chamber and is killed by inhaling the fumes. If the prisoner breathes deeply, his death is almost instantaneous and painless, but many resist by holding their breath or by taking short, slow breaths, and some observers claim that these prisoners suffer very much. By the second half of the 20th century nearly one-fourth of the states prescribed the gas chamber as the method of execution.

See also Capital Punishment; Concentration Camps: Nazi Germany (R. G. Cl.)

GASCOIGNE, GEORGE (c. 1530-1577), English poet, was one of the most talented of the writers who flourished during the early Elizabethan period, before Edmund Spenser's Shepheardes Calender (1579) gave a new direction and impetus to English poetry. The son of Sir John Gascoigne of Cardington, Bedfordshire, he attended Trinity college, Cambridge, began the study of law at Gray's Inn in 1555, and thereafter pursued careers as a politician, country gentleman, courtier, soldier of fortune and man of letters, achieving moderate distinction in each. He was M.P. for Bedford in the parliaments of 1557-58 and 1558-59. In 1561 he married Elizabeth Breton, a widow, and thus became stepfather to the poet Nicholas Breton. On his paternal estate he became involved in litigation, mainly because of his extravagance and debts, was once imprisoned in Bedford jail and gained a reputation for disorderly living. From 1572 to 1574 he served with English troops in the Low Countries and obtained a captain's commission, ending his military career as a repatriated prisoner of war. In 1575 he helped to arrange the celebrated entertainments provided for

Judge Elbert H. Gary, chairman of the board of directors of United Queen Elizabeth I at Kenilworth and Woodstock, and in 1576 went to Holland as an agent in the royal service. Gascoigne died at Bernack, near Stamford, on Oct. 7, 1577, and was buried at Stamford. Among his personal friends were many of the leading poets, courtiers and court ladies of his day, notably the poets George Whetstone, George Turberville and Edmund Spenser and the literary patron Lord Grey of Wilton.

Gascoigne was a skilled literary craftsman, and his work is memorable for its versatility and vividness of expression and for his treatment of events based on his own experience; but his chief importance is as a pioneer of the English Renaissance, with a remarkable aptitude for domesticating foreign literary genres. He foreshadowed the English sonnet sequences with groups of linked sonnets in his first published work, A Hundreth Sundrie Flowres (1573), a collection of verse and prose. In The Posies (1575), an authorized revision of the earlier work which had been published anonymously, he included also "Certain Notes of Instruction," the first treatise on prosody in English. In The Steel Glass (1576), one of the earliest formal satires in English, he wrote the first original nondramatic English blank verse. In subject, however, The Steels Glass is traditional; it is an attack, in the spirit of Piers Plowman, on the worldliness, corruption and Italianate manners of the aristocracy, and a defense of native feudal virtues. In two amatory poems, the autobiographical "Dan Bartholomew of Bath" (published in A Hundreth Sundrie Flowres) and The Complaint of Philomene (1576), Gascoigne developed Ovidian verse narrative. the form used by Shakespeare in Venus and Adonis and Lucrece.

"The Adventures of Master F. J.," published in A Hundreth Sundrie Flowres, was the first original prose narrative of the English Renaissance. Probably because of embarrassment caused by the factual elements in this tale of love intrigue in an English country house, Gascoigne revised the work; and it appeared in The Posies as "The Pleasant Fable of Ferdinando Jeronimi and Leonora de Valasco," purportedly a translation from the Italian, with the more libidinous passages removed. Another prose work, The Spoil of Antwerp (1576), is an early example of war journalism, characterized by objective and graphic reporting.

Gascoigne's Jocasta (performed in 1566) was the first Greek tragedy to be presented on the English stage. Translated into blank verse, with the collaboration of Francis Kinwelmersh, from Lodovico Dolce's Giocasta, it derives ultimately from Euripides' Phoenissae. In comedy, Gascoigne's Supposes (1566?), a prose translation and adaptation of Ariosto's I Suppositi, was the first prose comedy to be translated from Italian into English. A dramatically effective work, it provided the subplot for Shakespeare's The Taming of the Shrew. A third play, The Glass of Government (1575), is a didactic drama on the prodigal son theme. Together with several moralistic works in traditional forms of verse and prose on such commonplace themes as the vanity of human life, the sinfulness of man and the evils of drunkenness, it rounds out the picture of Gascoigne as a typical literary man of the early Renaissance, who never lost contact with native tradition as he made his periodic excursions into foreign literature to bring back new forms and themes.

The standard edition is The Complete Works of George Gascoigne, edited by J. W. Cunliffe, published in two volumes (1907-10). The original version of his first published work was reprinted in George Gascoigne's "A Hundreth Sundrie Flowres," edited by C. T. Prouty (1942).

See C. T. Prouty, George Gascoigne, Elizabethan Courtier, Soldier, and Poet (1942); S. A. Tannenbaum, George Gascoigne, a Concise and Poet (1942); Bibliography (1942). (L. A. Sk.)

GASCOIGNE, SIR WILLIAM (c. 1350-1419), chief justice of England under Henry IV, was a practising lawyer in 1374, and became sergeant-at-law before 1391, when he was retained as a councilor by Henry Bolingbroke (afterward Henry IV). During Henry's banishment (1398-99) Gascoigne acted as one of his attorneys. His services were rewarded (Nov. 1400) when Henry IV appointed him chief justice of the king's bench. In June 1405 he refused the king's insistent demand that he pronounce sentence of death on the rebel leaders, Richard Scrope, archbishop of York, and the earl marshal Thomas Mowbray. Gascoigne maintained

that a royal court could not try a bishop and that Mowbray had a right to trial by his peers. The famous story of Gascoigne's committal of Prince Henry (afterward Henry V) to jail for contempt rests on no contemporary authority and was first related by Sir Thomas Elyot in 1531. After Henry V became king, Gascoigne was superseded as chief justice (March 29, 1413) and thereafter dropped into comparative obscurity, although he still served on a number of assizes and commissions and was in no sense disgraced. He died on Dec. 17, 1419, and was buried in Harewood parish church, Yorkshire, where his effigy can be seen. (C. D. R.)

GASCONY (Fr. GASCOGNE; Med. Lat. WASCONIA or VASCONIA), a region of southwestern France, which in the last centuries of the ancien régime was merged with Guienne (q.v.) in the gouvernement of Guienne-et-Gascogne. At its greatest extent, in the early middle ages, Gascony may be regarded as extending from the western Pyrenees northward to the Gironde estuary and from the Bay of Biscay eastward to the lower Garonne valley and even across the upper Garonne; but the northern area, with Bordeaux, was finally regarded as part of Guienne, while in the southwest French Navarre and Béarn were separated from the gouvernement. The Gascon areas of the gouvernement corresponded approximately to the modern départements of Landes, Gers and Hautes-Pyrénées, with parts of Lot-et-Garonne, Tarn-et-Garonne, Haute-Garonne, Ariège and Basses-Pyrénées (qq.v.).

During the period of Roman rule in Gaul, the southernmost areas between the Pyrenees and the Garonne, predominantly Iberian rather than Celtic in ethnic composition, had been detached from Aquitania (see Aquitaine) to form the separate province of Novempopulana. Taken from the Visigoths by the Franks after the battle of Vouillé (A.D. 507), this country was overrun from A.D. 561 by the Vascones or Basques from beyond the Pyrenees (see BASOUE); and in 602 the Frankish kings recognized Vasconia or Gascony as a duchy under the national leader Genialis. In the latter half of the 7th century the Gascon duke Lupus I extended his power over adjacent areas. In the 8th century, however, the Carolingians, having imposed Frankish authority over Aquitaine, were able to set up the march of Bordeaux as a frontier countship to watch over Gascony. The duke Lupus II recognized Frankish suzerainty in 769, and the title "prince of the Gascons" is recorded in 801 for Lupus Sancho (probably Lupus II's son). Seguin I, a count of Bordeaux whom the Carolingians tried to set up as duke of the Gascons, was displaced in 816, after which Lupus Sancho's son Aznar is found styled "count of Hither Gascony." On Aznar's death (836) his brother Sancho Sanchez or Mitarra made himself duke. Sancho Mitarra's son Garsia Sancho (d. 926) dispossessed his cousin Arnaldus in 887 and is recorded with the style "count and marquis on the borders of the Ocean" in 904. Finally, in the latter half of the 10th century, Garsia Sancho's grandson William Sancho (d. 997), duke of all Gascony, became count of Bordeaux also. Bazadais (the country round Bazas) and Agenais (east of the Garonne) likewise passed into Gascon hands in the same period.

On the death of William Sancho's son Sancho William in 1032 a war of succession broke out. Gascony was eventually won, in 1052, by Guy Geoffrey, husband of Sancho William's sister Brisca and, from 1058, duke of Aquitaine. Thus in the 12th century Gascony passed with the Aquitanian inheritance to the Plantagenet kings of England. Though Henry III of England in 1259 acknowledged himself as the French king Louis IX's vassal for Gascony as part of the duchy of Guienne, Edward I's jurists were able to claim that Gascony, as distinct from Aquitaine, had previously never been a French fief but was either a fief of the Holy Roman empire or an allodial possession of the dukes. In fact throughout the years of intermittent warfare between England and France up to the definitive French reconquest at the end of the Hundred Years' War (q.v.), Gascony remained the kernel of English power in southwestern France. The dukes' authority, however, had for centuries been only nominal over large areas of the original duchy: Béarn (q.v.) had early shaken off all suzerainty before it was orientated first toward Foix, then toward Navarre; and Armagnac and Albret (qq.v.) pursued practically independent policies.

GAS ENGINE: see Internal-Combustion Engine.

GAS INDUSTRY. The gases produced for utilization as sources of heat and energy in private residences and industry include manufactured gas (e.g., coal gas, water gas, producer gas, blast furnace gas), natural gas and liquefied petroleum gas. This article deals chiefly with manufactured gas. For discussions of the other types of gas see NATURAL GAS and PETROLEUM. See also FUELS: Gaseous Fuels.

On a world basis, the use of manufactured gas declined as the use of natural gas and electricity increased. Major producers of manufactured gas in the early 1960s were West Germany, Great Britain, the United States, Japan, Czechoslovakia, East Germany, France, the Netherlands, Belgium and Italy. In about half of these countries, including Britain and the U.S., production had declined slowly in the preceding five years while in the others it was static or had increased slightly. In the U.S. in the early 1960s, the amount of natural gas marketed was almost 50 times greater than the amount of manufactured gas produced. In Britain, however, practically all of the gas consumed was manufactured gas.

The principal use for manufactured gas originally was the illuminating of streets and interiors of buildings, but electricity eventually became the chief illuminant. Gas then came to be used chiefly for space heating, cooking and the firing of industrial furnaces. (X.)

Most manufactured gas is made from coal, although coke, oil and other starting materials also are used. The process of carbonization, or coking, in which coal is heated in an absence of air, was in the 1960s still the most important method for producing fuels derived from coal, but other gaseous fuels were being manufactured by methods known as gasification; *i.e.*, water gas made by the action of steam upon red-hot coke and producer gas made by blowing air, usually mixed with some steam, through a deep bed of hot coke or coal. Coal gas has the highest heating value, averaging about 500 B.T.U. per cubic foot; water gas averages about 300 B.T.U. but may be enriched with oil vapours (carbureting; Table I) up to or above the value for coal gas. The heating value of producer gases is much lower (120–160 B.T.U. per cubic foot)

Table I.—Properties of Coal, Water and Producer Gases

Properties	Coal	Wate	r gas	Producer gas	
		Straight (blue)	Carbureted	From coal	From coke
Composition Oxygen. Carbon dioxide	0.4% 2%-4%	4.7%	0.4% 5.6%	4%	5%
Unsaturated hydrocarbons. Carbon monoxide Hydrogen Methane Nitrogen	2%-4% 8%-18% 29%-54% 20%-50% 4%-9%	41% 49% 0.8% 4.5%	7.0% 30.5% 37% 14% 5.5%	0.4% 29% 12% 2.6% 52%	29% 11% 0.5% 54.5%
Heating value B.T.U. per cubic foot Density (relative	475–560	295	500	163	132
to air=1)	0.4-0.48	0.55	0.63	0.87	0.90

because about one-half or as much as two-thirds of their volume is made up of nitrogen contained in the air used for gasification. In Great Britain, the manufactured gas, or town gas, distributed for public supply after purification is coal gas or coal gas mixed with straight or enriched water gas. In some cases, coke oven gas also may be added; this is essentially similar to coal gas in that it is produced by carbonizing coal, but the process is different because it is directed more to the production of coke than of gas. Producer gas is used mainly for large-scale industrial furnaces, including in particular the retorts used for the manufacture of coal gas. A broad comparison of the properties of these gases is given in Table I. (See also Carbonization, Low-Temperature; Coal and Coal Mining: Preparation and Uses of Coal; Coke, Coking and High-Temperature Carbonization.)

The main divisions of this article are as follows:

- I. The Gas Industry in Great Britain
- II. The Manufacture of Gas
 - 1. Retorts
 - 2. Purification
 - 3. Water Gas
 - Producer Gas
 Blast Furnace Gas

6. Modern Trends in Gas Manufacture III. Gas Supply in the United States

1. The First Gas Plants

2. Growth and Changes in the Industry

3. Natural Gas

4. Liquefied Petroleum Gases

5. Storage of Gas

I. THE GAS INDUSTRY IN GREAT BRITAIN

Coal gas, when used as an illuminant, burns with a characteristic yellowish luminous flame. The earliest demonstration of this property has been variously ascribed to Jean Pierre Minckelers of Belgium, to Philippe Lebon of France and to Lord Dundonald and William Murdock of Great Britain; but William Murdock is usually given entire credit for being the first to apply coal gas on any considerable scale. Murdock set up a small experimental plant in 1795, lighted a Soho (Birmingham) factory by gas a few years later and in Feb. 1808 was awarded the Rumford medal of the Royal society of London for his invention as described in a paper read before the society.

In 1813 the foundation was laid for the London and Westminster Gas company, soon to become the famous Gas Light and Coke company. It possessed three manufacturing stations with 15 mi. of mains, and Westminster bridge was lit by its gas. Gas lighting was introduced in Bristol in 1823, by which time the Gas Light and Coke company in London was producing nearly 250,-000,000 cu.ft. of gas annually for distribution through 122 mi. of street mains. Rapid expansion followed, so much so that the gas companies that had sprung up in the metropolis and in the provinces are recorded as "innumerable" in 1860. Public supply was governed by many local and general acts of parliament. With the advent of electric lighting in 1882 the industry encountered serious competition, which appeared to threaten its existence. In fact, however, the severe shock that it experienced was a stimulus to the industry to look elsewhere than to lighting for the disposal of its products, and the great potential market available to gas in its capacity of a heating medium was soon recognized. The year 1920 stands out as epoch making in the history of the industry; in that year the Gas Regulation act was introduced, the main provision of which was to make it obligatory to charge for gas on the basis of its declared and attested heating value; furthermore, gas had to be supplied at a minimum pressure of 2 in. water gauge in mains or services of 2 in. or more in diameter. These and earlier regulations, including the requirement that gas should be entirely free from the poisonous and objectionable gas hydrogen sulfide, fully protected the interests of the consumer. At that time the annual production of gas in Great Britain had risen to 250,000,-000,000 cu.ft., and there were 7,000,000 consumers (4,250,000 supplied through prepayment or "slot" meters) receiving gas through approximately 40,000 mi. of mains.

On May 1, 1949, the gas industry passed into national ownership in accordance with the provisions of the Gas act of 1948. Many of the provisions of the acts that previously had nationalized the coal and electricity industries were repeated, but there was one significant difference: the larger measure of decentralization and regional responsibility accorded to the gas industry.

Twelve area boards were constituted to assume the ownership of 1,037 undertakings for the nation. The area boards were separate, corporate bodies, each charged with the prime duty of developing and maintaining an efficient, co-ordinated and economical system for the supply of gas and coke and to develop and maintain efficient methods of recovering the by-products of gas manufacture.

At the same time parliament decided that a central body, the Gas council, was needed to represent the industry as a whole and to be responsible for such matters as capital finance, labour relations, research and ethers calling for central action. The Gas council was to consist of a chairman, a deputy chairman and the 12 chairmen of the area boards; its duty was to advise the minister of fuel and power on questions affecting the industry and generally to assist the area boards in exercising their statutory functions. Thus, after about 140 years of progressive expansion, the gas industry was unified under its central council but at the same time

possessed a regional structure that was acknowledged to be well suited to its particular requirements and conducive of the best service to its consumers. Research was specified to be one of the council's responsibilities, and its obligation in this respect was interpreted as being the search for fundamental knowledge and the development of new ideas up to and including the pilot-plant stage. Large-scale plant development and the normal improvement of appliances were entrusted to the area boards and the plant manufacturers. A permanent committee, including scientists from outside the industry, was set up to advise the council on methods of research. Research stations were established in London and Birmingham; in addition, the council contributed to a number of research associations engaged in work of interest to the industry. It also maintained the industry's close association with the University of Leeds and with the British Ceramic Research association.

As result of research aimed at finding more economical methods for producing gas, an experimental plant that used low-grade coal was built at Westfield, Fife, Scot., in 1961. A similar plant was planned at Coleshill near Birmingham. Oil gasification plants were built at several places, including the Isle of Grain, Kent. A plan for shipping methane from the Sahara was being considered in the early 1960s.

In Great Britain early in the second half of the 20th century the approximately 375 gasworks supplied about 13,000,000 customers with about 600,000,000,000 cu.ft. of gas annually. Half of this amount was used in homes and half in industrial and commercial establishments. About three-fourths of the household gas was used for cooking while the rest was used for space heating, water heating and other purposes. Most British homes were supplied with manufactured gas of the coal gas type except in some remote rural areas where bottled liquefied petroleum gas was used. The industries and businesses that used gas were generally those that required accurately controlled temperatures.

II. THE MANUFACTURE OF GAS

In Murdock's apparatus coal was contained in an inclined iron retort heated by a fire burning on a grate below. Cast-iron retorts were used for a long time in the early days of manufacture. Charged with the coal to be carbonized, the retorts were heated by small coal to temperatures of about 600°-700° C., much lower than those used in modern practice. At this point it is convenient to consider the principles involved in the carbonization process.

Coal is the term applied to those rocks in the earth's crust produced by the decay of plant remains and accumulated many millions of years ago. Coal is thus a complex mixture of organic substances that so far cannot be recognized except in broad terms. The essential elementary constituents are carbon, hydrogen and oxygen, with small quantities of nitrogen and sulfur and some incombustible matter—the ash. When heated out of contact with air, the coal more or less fuses and partially decomposes. Gaseous products of decomposition force their way through the plastic mass and give it a honeycombed structure. As the temperature of the mass increases, the coal becomes less fusible and is transformed into a porous solid known as coke. Further heating drives off more gas and results in shrinking and hardening of the coke. The volatile matter evolved in the lower-temperature stages is rich in easily condensable tarry matter and gaseous hydrocarbons. At temperatures above 800° C. the volatile matter is principally hydrogen, with some carbon monoxide.

The manufacturing process thus consists essentially in driving off the volatile products by heat, leaving the solid residue of coke in the retort for subsequent extraction. The volatile matter, or crude gas, leaves the retorts at a temperature usually between 700°-800° C.; at this temperature the gas is heavily charged with steam (derived from hydrogen and oxygen in the coal as well as from actual moisture) and with condensable tarry vapours, hydrocarbons, some sulfur-containing gases, some hydrogen cyanide and ammonia. These constituents must be removed before the gas is distributed to consumers.

When the gases enter the collecting main they are cooled so that condensation takes place; and this is further assisted by

TABLE II.—Composition of Coal Gas

	Н			
Gases	Horizontal	Vertical retorts		Low tempera-
	retort	Without steam	With	ture
Carbon dioxide Unsaturated hydrocarbons Oxygen Carbon monoxide Hydrogen Methane Nitrogen	2.0% 3.1% 0.5% 8.0% 50.6% 28.1% 7.7%	2.2% 2.3% 0.4% 10.3% 49.5% 28.5% 6.8%	3.4% 1.8% 0.7% 15.1% 49.3% 21.2% 8.5%	4.5% 3.8% 0.2% 8.3% 29.1% 49.1% 5.0%

washing with water. Water from condensation or from washing dissolves part of the ammonia and other constituents, forming "ammonia liquor." As a consequence of the condensation process, the volatile matter is divided into three portions; two, the tar and the ammonia liquor, are liquid, but they do not mix; the third is the gas itself, which, after further purification from tar fog, residual ammonia and hydrogen sulfide, is ready for distribution.

The proportions of gas, coke, tar and liquor vary according to the particular method used for carbonization and to the nature of the coals carbonized. In broad terms, however, the yield of these products per ton of coal processed in horizontal retorts is about 14 cwt. of coke, 10 gal. of tar and 30 gal. of liquor, the last representing a recovery of approximately 25 lb. of ammonia as sulfate. Table II shows the composition of coal gas according to the method of carbonization employed. The tar is composed of pitch (61.3%), creosote oil (13%), carbolic oil (12.1%), light oils (9.4%), crude naphtha (2.6%) and water (1.6%). The liquor, when horizontal retorts are used, yields for every 100 ml. of its volume 1.5 g. of fixed ammonia; 0.5 g. of free ammonia; 0.25 g. of sulfide as H_2S ; 0.01 g. of cyanide as HCN; 0.1 g. of thiosulfide as S; 0.2 g. of thiocyanate as CNS; and 0.25 g. of phenols as C_6H_5OH .

Of the various circumstances that determine the quantities and compositions of the tar, liquor and gas, the temperature at which the coal is carbonized is particularly important. The low-temperature products are those resulting from the first processes of breakdown in the coal. The high-temperature products contain many of the substances formed by the secondary decomposition of the primary products, brought about by subjecting them to a higher temperature. The difference shows itself very plainly both in the gas yield, which is much higher for high-temperature working, and in the nature of the gas, which contains much more hydrogen and less of the easily decomposable compounds of carbon and hydrogen. The tar is usually smaller in amount for high-temperature working. when it is characterized by the presence of the so-called aromatic hydrocarbons of the benzene type, which are products of secondary decomposition and are absent from low-temperature tars. The increased yield of gas in high-temperature working is partly due to the secondary decomposition of some of the more decomposable tar constituents, although it is mainly accounted for by an extensive formation of hydrogen peculiar to high-temperature working.

1. Retorts.—The volume of gas obtainable by working in iron retorts was limited by the properties of this material. An important advance was made when fire clay was substituted for iron, as

HORIZONTAL RETORTS

WASTE GAS

STEP
GRATE
PRODUCER

RECUPERATOR

MAIN FLUE

FIG. 1.—CROSS SECTION AND LONGITUDINAL SECTIONS OF A SETTING OF SIX HORIZONTAL RETORTS

a higher temperature was permissible. Further improvements of a radical character followed when, in the heating of these retorts, gas firing and the recuperative principle could be employed.

Recuperative.—The principle of the recuperative retort will be

understood from fig. 1, which shows a setting of

-shaped

horizontal fire-clay retorts. They are heated by producer gas made by passing air through a deep layer of red-hot coke. This gas, meeting hot air immediately under the retorts, burns around them and carbonizes the coal contained therein. The waste gases, after heating the retorts, do not, however, pass away directly to a chimney, as in older methods of "direct" firing, but are turned downward into the recuperator, where they pass along channels in which they are only separated by a thin fire-clay partition from air traveling upward to meet the gas. In this way some of the heat is abstracted from the waste gases and restored to the air used for combustion. Consequently, less heat leaves the setting and a higher temperature can be attained together with economy in fuel. This system of carbonization in horizontal recuperative fire-clay retorts rapidly became standard practice and remains so to some extent, although horizontal retorts are now obsolescent. It enabled an average gas yield of 10,000 cu.ft. of gas per ton of coal to be obtained; and it lowered the proportion of fuel required for heating the setting from 25%-30% of the weight of coal carbonized to 15%-20%.

Although excellent in many ways, the horizontal retort setting as so far described had the disadvantage of requiring heavy labour for hand charging. This drawback has been to some extent neutralized by the use of mechanical charging machines. Other methods were, however, coming forward by which the aid of gravity could be invoked for the moving of the coal and coke during carbonization and some other advantages secured. In the second half of the 20th century new installations were invariably of the vertical retort type.

In normal horizontal retort practice it may be assumed that for every 100 heat units contained in the coal carbonized 24 will appear in the gas, 42 in the coke available for sale after the heating of the retorts has been provided for and 5.6 in tar, which means that 71.6 of the original 100 heat units have been obtained in the available useful products of carbonization. Otherwise expressed, the thermal efficiency of the carbonization process so conducted is 71.6%, 28.4% having been used and lost in the manufacture. In modern large installations of vertical retorts, higher values would usually be attained.

Vertical.—The simplest form of the vertical retort was one in which the retorts were all set vertically (instead of horizontally, as in the past) and, being filled with coal, were heated until the whole of the charge had been carbonized, after which it was withdrawn. This so-called intermittent vertical system was patented in England by J. Bueb in 1904 after previous trial at the Dessau gasworks. It had the advantage, as compared with the handcharged horizontal retort setting, of reducing labour and requiring less ground space for a given output. Another novel advantage was that the retort could be fully charged, thereby lessening the contact of the volatile matter with red-hot coke and the walls of the retort that gives rise to secondary decomposition. A further advance was made almost at once by the introduction of continuous working into the vertical retort system; instead of completing the carbonization of the whole charge before withdrawing any portion of the coke residue, a continuous feed of coal was made to the top of the retort and coke was continuously withdrawn from the bottom by an extraction mechanism. Fig. 2 illustrates a typical setting of vertical retorts. The heating gas from the producer passes through apertures, which can be regulated, into heating channels surrounding the retorts. The upper sections are heated by waste gases alone.

When the heating quality of gas came to be of paramount importance, the heating value per cubic foot superseded its illuminating power in "standard candles" as the statutory method of defining its quality. The British Gas Regulation act of 1920 introduced the sale of gas by the therm, a therm being 100,000 B.T.U., and allowed gas companies and authorities to specify the standard

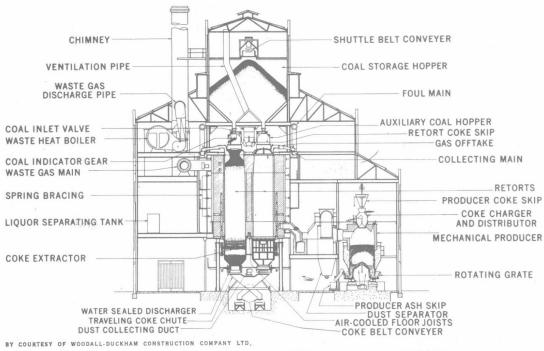


FIG. 2.—CROSS SECTION OF A CONTINUOUS VERTICAL RETORT INSTALLATION

quality in B.T.U. per cubic foot of the gas that they would supply (insistence, however, being rightly made upon the maintenance of that standard as all-important). These changes in the conditions of manufacture and of use, together with the new legislation, permitted and encouraged such developments in gas manufacture as make for more complete gasification of coal; i.e., for obtaining a larger proportion of its potential heat in the gas made.

Use of High Temperatures.—One method of achieving more complete gasification of coal was to work at a higher temperature. This, in turn, called for special attention to the quality of the refractory materials used in the construction of the retorts and their settings and led to an increase in the use of silica instead of fire clay in vital parts subject to the higher temperatures. In modern practice silica refractories are preferred for the walls of retorts (except for a few feet at the top and the bottom) because of their higher stability, strength and general durability. By such means, higher yields of gas per ton (13,000 cu.ft. per ton) have become common. The gas so made is rich in hydrogen but poorer in illuminating constituents than was the gas usually supplied for lighting purposes; it also is lower in calorific value (say 500 as compared with 600 B.T.U. per cubic foot).

Steaming.—Another widely used method of improving the yield in volume and thermal units is known as the "steaming" of continuous vertical gas retorts; it is carried out by introducing steam at the base where it can react with the red-hot coke. By this means an addition is made to the volume of gas by the interaction of carbon and steam; water gas is thereby generated.

An investigation by the joint research committee of the University of Leeds and the Institution of Gas Engineers, carried out on a Glover-West setting of continuous vertical retorts, showed that a lean coal gave 10,400 cu.ft. of gas per ton with a calorific value of 544 B.T.U. per cubic foot (gross) when steaming was not used. This corresponds to 56.5 therms in the gas per ton of coal carbonized. When steaming was employed, to the extent of 26.4% of steam on the weight of the coal used, the yield increased to 16,900 cu.ft. of gas with a calorific value of 447 B.T.U. per cubic foot, representing 75.7 therms in the gas made per ton of coal.

2. Purification.—As already indicated, the crude gas leaving the retorts contains materials that have to be removed in order to purify the gas before distribution and to recover by-products of commercial value. Many of these constituents are more or less easily condensed or washed out, and the appropriate plant consists of a train of vessels that vary widely in detail from one works to another but are essentially the same in principle. Fig. 3 shows diagrammatically the individual plant units in a typical gasworks

and the sequence of steps in the manufacturing process.

Gases travel from the retorts through an "ascension" pipe, which then bends over and dips below the liquid seal in the socalled hydraulic main, the seal being used to prevent access of air to the main when the retort is opened for charging and discharg-Some cooling and consequent condensation of tarry matter occurs in ascension pipes. It is usual for the gas from a number of retorts to be collected in a common hydraulic main. Easily condensable constituents gather there and in the foul main that leads to the condensers.

The condensers consist of nests of pipes cooled externally by air or water; the temperature of the gas within them is thus lowered, resulting in further condensation of both tar and water, which collect at the base of the pipes.

The next stage is the washing or scrubbing of the gas, in which further cooling and removal of constituents by solution in water are secured. There are many designs of washers and scrubbers but all act on the principle of obtaining the greatest possible contact between gas and liquid. In the Livesey washer, for example, the gas stream is repeatedly broken up and forced through water. In modern practice there may follow an electrostatic detarring for the complete removal of tar. Next in sequence are rotary or static washers, in which the gas is brought into intimate contact with water or weak liquor. Ammonia is completely removed from the gas at this stage, although a trace may be allowed to pass forward to preserve alkalinity in the purifiers used later for extracting hydrogen sulfide. Additional scrubbing, using suitable oil solvents, is needed if it is intended to remove volatile tar constituents such as benzene and toluene. The tar and liquor condensed at different points in the system are usually led away to a common well, but there is good reason to suppose that some separation of the various liquors is desirable because some may be more potent than others, with the result that the question of disposal is not equally easy for all liquors.

Hydrogen Sulfide.—It has already been mentioned that law requires the elimination of hydrogen sulfide from gas used for public supply. The final process of purification in ordinary practice is to pass the gas through iron oxide purifiers and thence to gasholders (storage tanks). The purifiers contain hydrated oxide of iron spread on grids. The oxide absorbs hydrogen sulfide rapidly, becoming converted into iron sulfide. The formation of

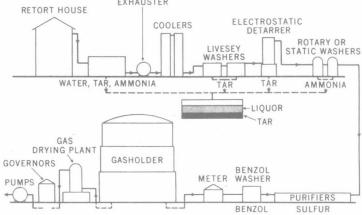


FIG. 3.—DIAGRAMMATIC LAYOUT OF A GASWORKS PURIFICATION SYSTEM

iron sulfide tends to render the material inactive for absorbing peratures, more tar is produced and the light oil fraction coming hydrogen sulfide but it can be reactivated by removal and exposure to air, or by admitting a little air into the gas stream so that regeneration takes place in situ. In both cases the sulfided material is reoxidized with the formation of free sulfur. When the sulfur content has risen to about 50%, the so-called spent oxide is removed and sold for sulfuric acid manufacture. Most of the sulfur in crude coal gas is present as hydrogen sulfide (about 1%) and is completely removed by this process. Smaller quantities of sulfur are present, however, in the form of organic sulfur compounds, which are not extracted to any extent by iron oxide but which may be reduced considerably in amount by special additional processes. In 1942 a special committee set up by the industry recommended that the organic sulfur should be reduced to 10 grains per 100 cu.ft. (about 0.01%) as a first step and that processes should be introduced to obtain lower figures as they became available. The recovery of benzol by oil washing simultaneously removes much of the organic sulfur so that additional processing is more the exception than the rule in general practice. Satisfactory methods for reducing the organic sulfur to, say, 5-6 gr. per 100 cu.ft. are available, however, and are applied when gas of exceptionally low sulfur content is needed. Such processes are frequently used to purify the gas after distribution to the consumer's works.

Ammonia.—Liquor containing the ammonia washed out of the gas is either sold as such or is used at gasworks for the production of ammonium sulfate. Distillation of the liquor with lime drives off ammonia, which may be absorbed in sulfuric acid to form the sulfate, which constitutes a valuable fertilizer. The quantity obtained at gasworks usually lies between 20 and 30 lb. of ammonium sulfate per ton of coal carbonized. The ammonia yield can be increased by steaming the retorts, but the liquor obtained is usually weaker because of the passage of undecomposed steam from the top of the gas retort into the gas. A weaker liquor has a lower commercial value if it has to be sent away for treatment and has the further disadvantage that after distillation for ammonia the residual liquor is greater in amount.

The direct method of recovering ammonia, in which the gas is passed through sulfuric acid for the absorption of ammonia, instead of effecting a separation of the ammonia liquor and distilling it, has found little application in gasworks.

The disposal of the residual liquor after distillation for ammonia, or sometimes of the crude undistilled liquor itself, presents the gas industry with a problem that is serious because of the stringent regulations designed to reduce the pollution of rivers and streams. Although liquor is relatively weak, it is nonetheless a strong trade effluent and its direct disposal into streams is prohibited. usual method is to feed it into the local sewer for eventual decomposition in bacteria beds. It has, however, long been known that the constituents of liquor throw an increased load on the sewage purification process, so that the rate at which liquor may be discharged into sewers has to be carefully controlled. Normally the maximum permissible discharge of spent liquor is about 0.5% of the dry weather flow of the sewage. Much attention has been given both to re-examining the amount of liquor that can properly be discharged into sewers and also to developing alternative methods of disposal, the latter being particularly directed to meet the needs of those gas (and coke oven) works whose situation is remote from suitable sewage disposal plant.

Tar.—The tar made at gasworks is subjected to a complicated process of distillation that resolves it into fractions that boil off in different temperature ranges, the fractions being afterward refined. These operations are usually carried out at separate tar distilleries. Among the many products made from tar are toluol, cresol, naphthalene and anthracene, which find application in the production of dyes, medicines, perfumes, disinfectants, solvents, plastics and paints. Tar oil is used for fuel and also for road construction, whereas distilled tar and pitch are used for many purposes; e.g., in connection with building materials, roofing felts, briquettes, etc.

The average yield of tar by the ordinary gasworks process can be taken as 5% of the weight of coal carbonized. At lower tem-

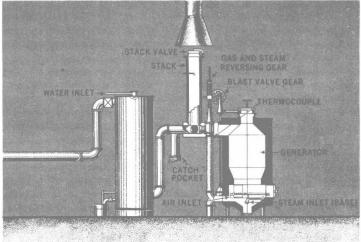
over on distillation is usually greater in volume.

3. Water Gas.—Limited gasification of coke in steam can be effected in the continuous vertical retort as already described, but complete gasification of carbon in coke is carried out in an entirely different type of apparatus known as a water gas plant. At high temperatures, carbon decomposes steam into hydrogen and carbon monoxide, but with an absorption of heat according to the equation $C + H_2O \rightarrow CO + H_2 - 56{,}145$ B.T.U. When the temperature of the carbon has been brought down by this absorption of heat, the reaction is altered with the production of carbon dioxide. An equilibrium tends to be established by the catalytic action of the solid carbon (and inorganic ash constituents) so that a ratio

 $\frac{\text{CO} \times \text{H}_2\text{O}}{\text{CO} \times \text{T}}$ may be set up between the gas constituents, the ratio $CO_2 \times H_2$ being constant for any one temperature but falling as the tempera-

ture becomes less. The reversible reaction occurring ($CO + H_2O$ \rightleftharpoons CO₂ + H₂) results in a higher carbon dioxide content of the gas as the temperature is lowered; and, moreover, since the velocity of gasification is rapidly lowered with falling temperature, the gas made with the same rate of steam supply comes to contain more undecomposed steam. Carbon dioxide lowers the calorific value of the gas and the steam requires condensation. The high temperature of the carbon can, however, be restored by stopping the steam and blowing with air, thus raising the temperature of the fuel bed and generating a producer gas.

The industrial process based upon this principle of alternately blowing a bed of coke with steam and air was developed by Gaillard (1849), Tessié du Motay and T. S. C. Lowe (1873) and is



BY COURTESY OF THE INSTITUTION OF GAS ENGINEERS

FIG. 4.—PLANT FOR PRODUCING BLUE WATER GAS

called the water gas process. The plant illustrated in fig. 4 is that of Humphreys and Glasgow. The coke bed, enclosed in a steel casing lined with firebrick, may be blown through the grate below by either air or steam. An arrangement of valves also enables the steam to be introduced above the coke for a "down run." The exact arrangement and time in the up run with steam, down run with steam and blowing with air are varied to suit the fuel and other conditions and constitute a cycle of operations that is carried out systematically and automatically in modern plants. The coke is blown with steam until, as the temperature falls, the carbon dioxide produced in the water gas is reducing its quality too far. During the steam blow, the water gas made is carried forward to a scrubber down which water is running and then goes forward to join the main gas stream of the works for removal of hydrogen sulfide. This water gas should have a calorific value of 300 B.T.U. per cubic foot. When the steam blast is replaced by air, in order to restore the high temperature in the fuel bed, the producer gas generated, being heavily charged with nitrogen, is not allowed to go forward to the scrubber but is turned up the stack as waste. Use of air continues until a satisfactory high temperature has been re-established in the fuel bed, when steam is again employed. The heaviest thermal loss in the process is that of the potential and thermal heat in the producer gas, but this is lessened in modern plants by the installation of a waste heat boiler.

It has been noted that the water gas made by the process described above has a calorific value approximating to 300 B.T.U. per cubic foot. It is known as "blue" water gas because of the characteristic colour of its flame and is definitely lower in grade than the coal gas made from retorts. The calorific value can be increased, however, by using some of the heat in the gases leaving the generator to crack oil (i.e., to convert it into permanent gas rich in hydrocarbons), so obtaining a "carbureted" water gas of enhanced calorific value. Fig. 5 illustrates a Humphreys and Glasgow plant used for the process. The gas from the generator passes through two chambers, a carburetor and a superheater packed with brickwork, which are raised to redness, some air being admitted for the combustion of the "blow" gas therein. The oil is run in from the top of the carburetor and should be of a grade that can be efficiently cracked under the conditions of the process. (In early stages of the development of the plant the oil was run directly upon the coke in the generator, but this was unsatisfactory for various reasons.) In this plant, blue water gas leaves the generator with a calorific value of 300 B.T.U. per cubic foot but leaves the superheater enriched by the carbureting to an extent determined by the amount of oil used. The thermal efficiency of the oil cracking in the plant is high, amounting to something like 90%; consequently the thermal efficiency of the carbureted water gas process is higher than that of the blue water gas process and increases with the amount of oil used. The extent of carbureting employed is influenced by this factor, by the price of oil and by the quality of the gas desired. In Great Britain, carbureting is usually continued until the calorific value of the carbureted water gas approximates that of the coal gas made at the same works, say 500 B.T.U.; but in the U.S. it has been usually carried much further. It is plain, too, that blue water gas, enriched by carbureting to the extent desired, can be used as a means of modifying the calorific value of the mixture of coal gas and water gas supplied from a works. The extent to which the coke made in a gasworks may be economically gasified and water gas supplied depends on relative capital and operating costs and the prices of coal, coke and oil.

The main advantages of a water gas plant are that it can be put rapidly into full operation to meet maximum demands and that the yield of gas per ton of fuel is high; for example, modern plants may give about 50,000 cu.ft. of 300-B.T.U. water gas or 70,000 cu.ft. of 500-B.T.U. carbureted water gas per ton of coke.

Modern carbureted water gas plants are entirely automatic with an annular boiler around the generator and self-clinkering grates. A regular quantity of coke is fed to the generator during each gasmaking cycle without interruption to the gasification process. Plants of large capacity are now virtually self-supporting in their requirements of steam.

BY COURTESY OF THE INSTITUTION OF GAS ENGINEERS

FIG. 5.—CARBURETED WATER GAS PLANT WITH WASTE HEAT BOILER

4. Producer Gas.—Producer gas is simple to manufacture and is the gas usually employed to heat steelmaking and other large industrial furnaces. When air is passed through a deep bed of carbon maintained at a high temperature, i.e., above 1,000° C., in such a way that complete contact with the carbon is attained and equilibrium is maintained, almost the whole of the carbon is obtained as carbon monoxide, according to the equation

$$C + \frac{1}{2} \{O_2 + 4N_2\} \rightarrow CO + 2N_2 + 29,000 \text{ cal.}$$

If the temperature is lower, even though the contact is complete and equilibrium is still attained, some carbon will be burned to CO_2 according to the equation

$$C + O_2 + 4N_2 \rightarrow CO_2 + 4N_2 + 97,000$$
 cal.

If, however, the high temperature has been maintained and the carbon entirely converted to CO, it is plain that the gas will consist of one-third carbon monoxide and two-thirds nitrogen, and the equation representing its formation may be called the ideal producer gas equation. If this producer gas is collected and burned with air, it will generate heat according to the equation

$$CO + 2N_2 + \frac{1}{2} \{O_2 + 4N_2\} \rightarrow CO_2 + 4N_2 + 68,000 \text{ cal.}$$

It will be seen that even if the whole of the heat generated in making the producer gas by converting the carbon to CO were lost, some 70% (actually $\frac{68}{97}$) of the total heat of combustion

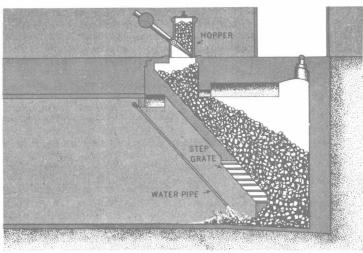
Table III.—Producer Gas as Modified by Steam

Steam saturation, temperature of bla	60° C.	70° C.	80° C.		
Percentage composition of gas: Carbon dioxide			5.25 27.30 16.60 3.35 47.50	9.15 21.70 19.65 3.40 46.10	13.25 16.05 22.65 3.50 44.55
Cal. value of gas, B.T.U.s per\gross . cu.ft. at 0° and 760 mm\net .	:	:	185.6 173.0	177.5 163.3	169.5 154.3
Yield of gas cu.ft. at 0° C. and 760 mm, per ton of coal			138,250	141,450	147,500
Steam added to blast, lb. per lb. of coal			0.45	0.80	1.55
Percentage steam decomposed			87.0	61.0	40.0
*Therms in gas per ton of coal (gross) .			256.6	251.1	250.0
*Weight of steam undecomposed per lb. of	0.09	0.31	0.93		
Therms in gas Therms in coal × 100			82.4	80.6	80.3

^{*}Not included in the original table.

of carbon to CO_2 would still remain available for use by its combustion of the gas. This large proportion of heat available for the second stage of the combustion of the carbon in burning carbon monoxide to carbon dioxide is the basis of producer gas practice.

Divergence in Composition.— There are various factors that cause divergence in the composition of producer gas from the ideal producer gas equation. In the first place, when coal is used as a fuel and is fed down on the fuel bed, it is at once subjected to a process of distillation or carbonization in the current of producer gas ascending from below, made by the action of the blast upon the carbonized fuel. Producer gas is in this way enriched to some extent with hydrogen and hydrocarbons, particularly methane, and the percentage of nitrogen is correspondingly diminished. More important, however, is the modification in composition brought about by the steam consequent upon a lower-



RAMBUSH'S "MODERN GAS PRODUCERS" (BENN BROS.)

FIG. 6.—SIEMENS SYSTEM FOR MANUFACTURE OF PRODUCER GAS

ing of the temperature of the fuel bed and the formation of water gas by interaction with carbon. The more steam is used, the lower the temperature and the greater the formation of carbon dioxide and hydrogen at the expense of carbon monoxide. The percentage of nitrogen is further lowered by the admixture with water gas. Moreover, as the quantity of steam is increased and the temperature decreases, the rate of steam decomposition by the carbon lessens and steam passes through the fuel bed undecomposed. The quantity of steam supplied is best controlled by the temperature of the mixed blast at a point well beyond the introduction of the steam, so as to allow a thorough mixing. The temperature of the blast rises with the proportion of steam. It will be understood that undecomposed steam, which begins to occur in quantity as soon as the saturation temperature of 60° C. has been exceeded, is an objectionable constituent in the producer gas, since it is thermally useless and would tend to prevent the attainment of high temperatures on combustion because of its high specific heat. W. A. Bone and R. V. Wheeler followed changes brought about in the composition and yield of producer gas by gradually increasing the proportion of steam, with results shown in Table III. The coal used was washed nut screened over a one-inch mesh.

As the saturation temperature was raised by more steam, the gas composition shows a rise in carbon dioxide from 5% to 13% and a change-over from a carbon monoxide producer gas, in which that constituent is dominant, to a hydrogen producer gas is explained. The nitrogen has fallen and the percentage of total combustibles has also fallen on account of the increase of carbon dioxide resulting from the lower temperature of the fuel bed. The calorific value of the gas has slightly diminished but the volumetric yield has increased, so that the yield in therms contained in the gas per ton of coal gasified shows little change. The weight of steam undecomposed per pound of coal has run up from 0.09 to 0.9 lb. per ton of coal.

Early Producer Construction.—It would appear that the earliest gas producers were deep shafts of brickwork, but the structure most closely identified with the successful establishment of this process of gas manufacture was devised in 1861 by K. W. (Sir William) Siemens; a diagram of his producer is given in fig. 6. It illustrates how the coal falls from the hopper and lies in the producer above the step grate. The producer was connected to a furnace, and the air for gasification was drawn through the fuel bed by natural chimney draft supplemented at times by a siphon effect, induced by the disposition of the main between producer and furnace.

Pressure Producers.—Although producers based essentially on Siemens' simple design were in widespread use, the demands of industry for higher outputs per unit of space and grate area led to the development of producers that work under a positive blast of air and steam. The modern gas producer is essentially of the design shown diagrammatically in fig. 7. The generator is a cylindrical body provided with a grate or tuyère through which the air-steam blast is admitted at the bottom and with an outlet

for gas at the top. The generator is water-jacketed, with the object of preventing adhesion of clinker and at the same time raising the steam needed to saturate the blast. Fuel for a run of about six hours on full load is contained in a feed hopper, from which it falls into the producer through several chutes arranged so as to ensure uniform distribution and to prevent segregation. The Koller grate is a series of superposed cast-iron rings; space between the rings forms horizontal ports through which the blast is distributed evenly. The grate is secured to a revolving ashpan designed to continuously shear the bottom from the column of ash, break up lumps of clinker and discharge both over a plow bolted to the sealing ring. Steam from the annular boiler passes into a vapour box and thence to the air-blast pipe. Blast is supplied by a blower and is measured by a Venturi meter; it is then saturated with steam at any desired temperature and admitted to the producer from beneath the grate. Satisfactory operation of a gas producer depends upon keeping the distribution of blast and ascending gas current as uniform as possible across the section of the fuel bed, so as to give proper contact in all parts with the descending fuel. For this purpose the producer may be provided with holes through which pokers may be inserted to keep the fuel bed level and free from channels that would tend to short-circuit the gas stream. Some designs incorporate mechanical revolving

In many cases the producer gas can be used hot direct from the generator without further cleaning; the advantage gained is that the sensible heat (i.e., as shown on the wet-bulb thermometer) in the hot gases is retained. When a clean gas is required (as, for example, in a gas engine) the gas must be cleaned and cooled. This is usually effected by means of a washer cooler containing water sprays, in which dust and some tar are removed. Next, a centrifugal washer takes out most of the remaining dust and tar;

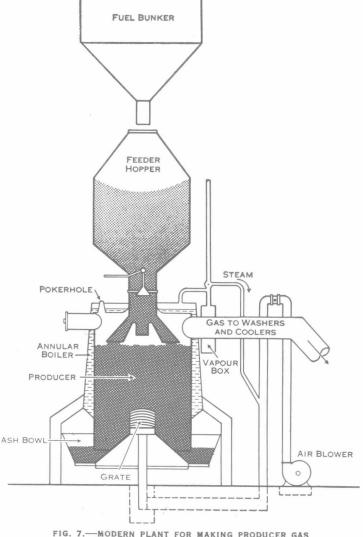


FIG. 7.-MODERN PLANT FOR MAKING PRODUCER GAS

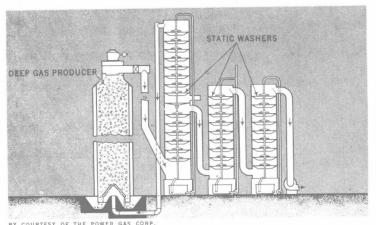


FIG. 8.—DEEP FUEL BED PLANT FOR RECOVERING AMMONIA FROM PRODUCER GAS

the gas then passes through a moisture eliminator and then to a dry scrubber in which the final removal of dust is accomplished. This scrubber may consist of an oxide box to remove hydrogen sulfide.

In the past, by-product recovery from producer gas was practised on a considerable scale, and modified designs and processes were developed to obtain larger yields of ammonia and tar than were normally obtainable. The essential feature was the use of a very deep fuel bed of coal (12 to 14 ft.) at a lower temperature, which favoured high yields of tar and ammonia. The recovery process called for a rather elaborate plant, the main features of which are indicated in fig. 8. The gas is washed, freed from ammonia and cooled by passing in turn through three Lymm static washers, the ammonia being absorbed in weak ammonium sulfate solution maintained slightly acid. Gas leaving such a plant was ready for furnace use but needed more thorough cleansing by tar extractors and scrubbers before its use in engines. With such plants, coal could be gasified to yield an average of 122,000 cu.ft. of 178-B.T.U. gas per ton, with a recovery of 90 lb. of ammonium sulfate and 21 gal. of tar per ton of dry fuel gasified. A few such plants still remained in use in the 1960s, though the type was by then obsolescent.

5. Blast Furnace Gas.—Blast furnace gas is a low-grade gas with a calorific value of about 95 B.T.U. produced on a large scale as the inevitable by-product of the smelting of iron. The blast furnaces used for the production of pig iron may be regarded as very deep, air-blown gas producers giving a gas containing about 27% of carbon monoxide and 11% of carbon dioxide, with 60% of nitrogen. The cleaned gas is used for steam raising and power production; for furnace firing it usually needs to be mixed with a richer gas.

6. Modern Trends in Gas Manufacture.—The processes described above represent what by the middle of the 20th century had long been established as standard practice; but much attention had meanwhile been paid, especially in the later years of the period, to methods of completing the gasification of coal in one process instead of carbonizing it first and then gasifying the coke residue in a separate generator.

Alternative methods for making gas, particularly from coals of poorer quality than had been used hitherto, then came to assume great importance to the industry because of the increasing scarcity of the special coals needed for the manufacture of gas and coke by orthodox methods. Furthermore, oil fuels became so plentiful and cheap as to demand attention as raw materials for gasmaking on a greater scale. The pattern of the future industry could be seen as a system of interlinked large stations of high efficiency, preferably situated at or near the coal fields and operating processes best suited to the coal available. However, the object of complete gasification methods is to process the coal solely into gas with no solid residue other than ash; the extent to which such processes could be effectively introduced depended upon the balance needed between the supply of gas and of coke (it should be pointed out in this connection that the new emphasis on minimiz-

ing atmospheric pollution was bound to result in a greater demand for smokeless fuels, such as coke). But complete gasification methods, being efficient and flexible, seemed certain to find extensive application in the gas industry.

Most of these processes depend upon a combination of carbonization and generation of water gas. In the modern plant of Humphreys and Glasgow, the blow takes place in the lower part of the generator, the blow gases being led to the carburetor via an annulus surrounding the generator. Available heat in the blow gases is stored in the carburetor and superheater and used to assist carbonization of the coal by transference back to the generator. Part of it may also be used for carbureting. A back-run produced by admitting steam to the top of the superheater and then to the base of the generator gives water gas; the heat in this gas then carbonizes coal in the upper part of the generator. In another part of the run, steam admitted to the generator base, this time without superheat, generates hot water gas, which again passes through the coal in the upper part of the generator. This gas also can be fed to the carburetor if desired. The yield may be from 175 to 190 therms of 345-B.T.U. gas per ton. The plant is designed to gasify coal, coke or any mixture, with subsequent enrichment by oil as may be desirable.

Considerable importance was attached to finding a means of developing these processes and applying them on a large scale. The availability of low-cost oxygen stimulated the development of methods in which the gasification of solid fuels is carried out in oxygen and steam. In Germany and elsewhere, from about 1945, the Lurgi process of gasification in steam and oxygen under pressure was successfully applied on a large scale to lignites (young coals unsuitable for carbonization by orthodox means). process came to be accepted as having many attractive features for the manufacture of town gas: it can make use of small coal of high ash content and of weakly caking coals unsuitable for carbonization; the plant operates at very high output; and the gas can be readily freed from sulfur and is available at pressure for long-distance transmission. For Great Britain, the search for new gasification processes was given first place in the research program of the Gas council (the former Gas Research board). An important achievement of the British work was the demonstration that the considerable proportion of methane characteristic of Lurgi gas was not due to the synthesis under pressure from carbon monoxide and hydrogen produced on gasification but resulted directly from the hydrogenation of coal, a reaction that proceeds vigorously under pressure. As a consequence, the possibility of manufacturing gas comparable in quality with town gas by gasification methods adapted to favour hydrogenation appeared to be most promising, although many technical problems would have to be solved before large-scale application could follow.

New processes for the direct gasification of oil, without recourse to water gas production, were adopted by certain area boards in Great Britain. The plant developed by the North Thames Gas board and installed at their Southend works produces a rich gas by the partial combustion of oil. Another process, devised by the South Eastern Gas board and installed in its own area and also within the North Eastern board's area, generates gas by the catalytic decomposition of oil. Other methods include the Onia-Gegi, giving an oil gas (from 300 to 1,000 B.T.U.) by the cyclic catalytic cracking of heavy oil, and the Geim process for the continuous production of gas (from 370 to 470 B.T.U.) by the thermal cracking of gas oil. The synthesis of gases rich in methane by hydrogenating coal under pressure was an important objective of the search for new gasmaking processes. (J. W. C.; A. L. Rs.)

III. GAS SUPPLY IN THE UNITED STATES

1. The First Gas Plants.—Following the discovery of gasmaking from coal and the unparalleled success of gaslighting in one or two European cities, gaslighting got its start in the United States in Baltimore, Md. Although there were a few isolated instances of gas being used previously by individuals in other cities, introduction of gaslights in Rembrandt Peale's museum in Baltimore in 1816 proved to be such a success that the city council passed an ordinance on June 17, 1816, permitting Peale and others

to manufacture gas, lay pipes in the streets and contract with the city for street lighting. The first recorded demonstration of gas in the United States was in Philadelphia, Pa., in Aug. 1796. The gas was manufactured by M. Ambroise and Co., Italian fireworkers and artists. In 1812, David Melville of Newport, R.I., lighted his home and the street in front with gas that he manufactured. He also lighted a factory at Pawtucket, R.I., and induced the government to use gas at Beaver Tail lighthouse.

2. Growth and Changes in the Industry.—By the second half of the 20th century the gas industry had grown into one of the key industries, showing remarkable ability to adapt itself to meet severe competition, changing raw materials, and drastic economic and labour conditions, while constantly maintaining and expanding its service. When the illumination market was lost after the invention of electric lighting, the gas service emerged as a heat producer; when the severe labour and raw material inflations and dislocations caused by World War II threatened the manufactured gas service and solvency, the industry maintained and expanded its markets by drawing more natural gas from transcontinental pipelines.

The first public utility gas was manufactured by heating a high-volatility coal in a metal retort and subjecting the resulting gas to cooling and purification. A water gas process was introduced later. This injected steam over the coal, which was heated externally. The work of Thaddeus Lowe, a Union balloon officer in the Civil War, made possible the economic manufacture of water gas in internally fired machines. This became the basis of the modern carbureted and blue water gas processes. By-product coke oven gas supplemented and often supplanted coal gas and water gas. Internally fired oil-gas processes were invented and developed. Prior to World War II these were used very little in the United States except on the west coast. Even there prior to World War II the use of oil-gas was declining as natural gas became available.

All these changes were dwarfed by the change from manufactured gas to natural gas. This tremendous exploitation of natural gas followed the discovery and proof of large reserves of natural gas in the midcontinental and southwestern areas in the 1920s. In 1925 seamless electrically welded steel pipe made the transportation of oil and gas for long distances economically feasible. The change was particularly striking after World War II when transcontinental petroleum pipelines became available for gas transmission and the economic inflation and short labour supply made public utility gas manufacture based on solid fuels generally uneconomic.

By the 1960s intrastate and interstate transportation of natural gas by major pipelines had become so far-flung that, except in Maine, Vermont and Hawaii, there was practically no major city in the United States beyond the reach of natural gas supplies.

Long-distance transmission of natural gas changed the engineering and economic problems of the gas industry. It involved heavy investments in long pipelines and, in many cases, the substitution of high thermal value (natural) gas for medium thermal value (manufactured) gas. These changes led to major new developments in gas manufacturing processes, storage and sales. The large investments in long pipelines favour the use of these lines at high load factors; thus natural gas becomes the base gas or the base material for gas manufacture. Off-peak sale of natural gas to industry at attractive rates is favoured with shutoff agreements at times of peak public demands.

A number of oil-gas processes have been designed and developed to utilize the cheaper grades of heavy oils. In many situations component parts of abandoned water gas equipment have been built into the new oil-gas machines. Other studies have developed new equipment as well as new processes for the purpose. In general, such heavy oil-gas making machines use oil and air internally to create the heat they require, then inject oil and steam into the heated zone to make the gas. Partial combustion with air is sometimes simultaneously employed to increase the volume of the gas made. The cycle is then continued by returning to the heating phase, followed by another gasmaking phase. Good heat economy and good heat distribution within the machine are obtained in the

same phase by heating alternately in a forward and a reverse direction, followed by making gas in the forward and reverse directions. The incoming oil, air and steam are preheated regeneratively by waste heat from the outgoing products, thereby securing good thermal efficiencies.

Where mixed gases of a total thermal content less than that of natural gas are distributed, or where liquefied petroleum gases are used for enrichment, natural gas, liquefied petroleum gases, gasolines and petroleum oils may be reformed in machines of the water gas or oil-gas type to greater volume, lower thermal content and controlled combustion characteristics and gravity to meet production and mixing needs. The reforming processes may involve partial combustion, pyrolysis or reaction with steam or some combination of these. Reforming, with enrichment of the reformed gas with liquefied petroleum gases or refinery oil gases, may also be used to meet peak loads on natural gas systems.

Unique in post-World War II gasmaking processes was the development of catalytic reforming. The feed stock may be natural gas, propane, butane, refinery oil gases or natural gasoline. The reforming is carried on in chrome-nickel alloy tubes heated externally, usually with light fuel oil. The tubes are filled with a nickel oxide catalyst, and the reforming gas zone is maintained at a temperature of about 982° C. The type of reformed gas depends upon the relative proportions of air and steam in the feed mixture. Pyrolysis of the feed mixture is not attempted. The ultimate capacity depends upon the rate of deposition of carbon, excessive carbon being objectionable. The unit is very flexible. The reformed gas, usually of 180 to 350 B.T.U. per cubic foot (at 15.5° C. and 30 in. mercury barometer saturated with water) with a specific gravity from 0.52 to 0.65 referred to air, is then enriched with undecomposed feed stock. The unit can produce a perfectly matched gas that can be used as 100% replacement of the regular utility sendout. The automatic controls and flexibility of this continuous process permit feeding directly into the distribution system. A minimum of labour is required, capital investment is low, purification of the gas is not necessary and there are no tars and no waste disposal problems. As the plant produces no smoke or dust it can be tolerated in residential locations.

3. Natural Gas.—Although natural gas had been noted in the United States before manufactured gas was introduced, it was not used commercially until long after manufactured gas was distributed.

There is a record of a "Burning Spring" in 1775 near Charleston, W.Va., on land that George Washington dedicated as a public park. In 1821 the first natural gas well in the United States was drilled to a depth of 27 ft. near a "burning spring" at Fredonia, N.Y. In 1854 the first deep gas well, approximately 1,200 ft. deep, was sunk at Erie, Pa. In 1859 Edwin L. Drake began the petroleum industry at Titusville, Pa. Natural gas is frequently associated with petroleum in the earth's crust and its pressure serves to drive the oil to the surface. Oil men in early days ignored natural gas. The gas liberated from the oil at the surface was piped to a flare and burned as a gigantic torch. Wells that gave gas only were flared and allowed to burn themselves out over the years.

The first natural gas corporation in the United States was the Fredonia Gas Light and Water Works Co., organized in 1858. In 1873 Titusville was supplied with natural gas through a two-inch iron pipe five miles long. In 1870 a burning well at Bloomfield, N.Y., was extinguished and connected to a 25-mi. pipeline of white pine logs bored with an eight-inch hole. In 1872 this gas was turned into the mains of the Rochester Gas Co., but the venture soon failed.

By the early 1960s there were about 70,000 gas wells in the United States; these, with gas producing oil wells, accounted for the annual marketing of about 13,500,000,000,000 cu.ft. of gas. (See also NATURAL GAS.)

4. Liquefied Petroleum Gases.—The liquefied petroleum gases, propane and butane, have been obtained from natural gas condensates at wellheads, in compression operations or at low-temperature points in "wet" gas transmission systems. A very important source has been the crude natural gas gasoline extracted

from natural gas by oil absorption. The enriched gasoline-oil mixture is stripped with steam, and the vapours from the crude gasoline are then fractionally distilled. These hydrocarbons are also recovered in petroleum refining and petroleum cracking operations.

Propane alone has sufficiently high vapour pressure at the customary temperatures prevailing over the United States to permit it to be distributed as a gas without admixture. Butane, however, requires a carrier gas. For single consumer installations beyond gas mains a mixture of propane-butane compressed into steel cylinders is sold as bottled gas. Where a number of consumers are to be supplied, propane alone may be distributed by small mains. Communities that are too small to warrant a gas plant may be served with a butane-air mixture in which the content of air must be sufficiently high to avoid condensation of butane from the mixture, but the air content must always be much less than 91.59% and the butane must be more than 8.41% by volume under ordinary atmospheric pressure to prevent explosions. Air content usually does not exceed 67%.

Butane-air gas may be mixed with natural gas under some peak load conditions to assist in meeting consumer demands. A butane-air plant can be instrumented so that it is operated, controlled and safeguarded completely by automatic devices; consequently its small demands for labour and supervision make it very suitable for service to isolated small communities.

5. Storage of Gas.—The generation and transmission of gas for meeting variable demand loads, *e.g.*, in a public utility, possess an important advantage over electricity in that gas can be stored in large quantities economically, whereas electricity must be generated and transmitted as consumed. This permits gas generating units and long-distance transmission units to be designed for average rather than peak conditions, thereby reducing markedly the capital investment required.

For example, the long-distance transmission of natural gas is maintained at a high load factor in the summer season by moving large gas supplies to storage pools near the customers. Depleted gas fields or natural geological formations of porous rock completely capped by an impervious rock formation can be used for this purpose. They may have storage capacities of billions of cubic feet.

(W. J. Hf.)

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GASKELL, ELIZABETH CLEGHORN (née STEVENson) (1810-1865), English novelist, short-story writer and the first and best biographer of Charlotte Brontë, was a writer of courage and compassion with an instinctive grasp of the storyteller's art. She began her distinguished literary career only in middle life. The daughter of William Stevenson, who was successively Unitarian minister, farmer, editor of the Scots Magazine and keeper of the treasury records, she was born in Chelsea on Sept. 29, 1810; her mother died early, and she was brought up from infancy by her maternal aunt, Mrs. Lumb, in Knutsford, Cheshire, spent two years at an efficient boarding school at Stratford-on-Avon, and then lived with her father and an uncongenial stepmother until his death in 1829. When visiting relatives in Edinburgh she met, and married in 1832, the Rev. William Gaskell, Unitarian minister of Cross Street chapel, Manchester, five years her senior. They collaborated in what was intended to be the

from natural gas by oil absorption. The enriched gasoline-oil first of a series of verse "Sketches Among the Poor," published anonymously in Blackwood's Magazine (Jan. 1837).

Domestic life claimed Mrs. Gaskell's time but not all her thoughts (the Gaskells had six children of whom four daughters lived to grow up). Her first novel, Mary Barton: a Tale of Manchester Life, developed slowly, reflecting the temper and events of the 1830s, the period of Chartist agitation, and was written mainly in 1845-46, when the death of an infant son had intensified her sense of community with the suffering poor and her desire, as she said, to "give utterance" to their "agony." Delayed by hesitant publishers, the appearance of the novel in 1848 proved well-timed; although it was published anonymously, it won her immediate and widespread fame and an entry to intellectual circles outside Manchester. She had already published short stories in Howitt's Journal (under the name "Cotton Mather Mills") and elsewhere, and in the next few years contributed to many other periodicals. Dickens, whom she met in 1849, was eager to have her as a contributor to his Household Words; "Lizzie Leigh," another Lancashire tale, appeared in 1850, in the first three numbers, followed by two tragic stories, "The Well of Pen-Morfa" and "The Heart of John Middleton," and in 1851-53 the eight sketches subsequently revised and combined as Cranford (1853). There and in the related "Mr. Harrison's Confessions," which first appeared in the Ladies' Companion in 1851, the isolated countrytown society of an earlier generation is presented as a microcosm of life. A vivid chapter of social history, demonstrably faithful to memories of Knutsford (a place which was old-fashioned even then and long remained so), the book is yet more remarkable for its mastery and subtlety of tone, serenely avoiding both the sentimental and the satiric. Writing to John Ruskin, one of its many admirers, in the last year of her life, Mrs. Gaskell said it was the only one of her books she cared to read again.

In her next two novels she again drew attention, though without letting the raised voice of propaganda disturb her art, to neglected claimants upon sympathetic understanding; in Ruth (1853) she proposed an alternative to the seduced girl's usual fate in contemporary life and fiction, while dealing perceptively with the moral, domestic and social dilemmas of the dissenting minister who rescues her. In North and South (Household Words, Sept. 2, 1854–Jan. 27, 1855), she modified the emphasis of Mary Barton by making her hero a factory owner and setting Manchester life in a wider context; it is the most balanced and assured of her earlier novels. But publication as a weekly serial proved irksome both to her and to Dickens as editor, and the novel was revised and enlarged by several chapters for publication in two volumes in 1855.

Among the many friends attracted by her writing and her delightful personality was Charlotte Brontë, who died in 1855 and whose biography Mr. Brontë urged her to undertake. The Life (1857), written with warmhearted admiration and insight and an unforced narrative skill disposing a mass of firsthand material, is one of the few literary biographies that is at once a work of art and a well-documented interpretation of its subject. But with characteristic impulsiveness she committed some minor indiscretions which brought vexatious controversy, and the work was at first less widely acclaimed than it deserved. For a time she concentrated on the writing of magazine stories of diverse length and subject, including the supernatural; the longest, My Lady Ludlow (Household Words, June 19-Sept. 25, 1858), included in the collection Round the Sofa (1859), is an artfully linked chain of retrospect leading back to life in a noble household 60 years earlier.

All Mrs. Gaskell's 30 or so tales were collected in volumes published between 1854 and 1865. The most outstanding is *Cousin Phillis* (which first appeared in the *Cornhill Magazine*, 1863–64), a sad love story of common life; often, and justly, called "an idyl," it is also a technical triumph of first-person narrative. Like most of her later work, it returns to the past, her share in contemporary problems now taking the form of energetic works of relief in Manchester in the period of unexampled hardship resulting from the American Civil War. This took toll of her health, but her writing remained resilient, exemplifying what a Victorian