COAL-HEAT, FORMERLY MID-WEST COAL RETAILER

A Century of Progress in Fuel Technology

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FUEL technology deals with that orderly arranged group of facts, derived from observation and correct thinking, which have to do with the major combustibles used in the arts. Although the subject is old, the term is of recent origin, coined since we began to depend so largely upon the burning of fuel to produce power.

Man's mastery of fire has proceeded by irregular advances. He probably first used it to protect himself from the rigors of an unfriendly climate, and then to make his food more palatable and healthful. Later, fire gave him better weapons and developed his arts. Of late, it has given him a tireless substitute for human and animal slaves and a degree of power over his environment beyond the imagination of ancient poets.

At some time during the past one hundred years the energy derived from fuel by means of heat engines surpassed for the first time the energy obtained from all other sources. This extensive enslavement of fire is one of the major characteristics of the past century. It is probably the most disturbing factor that ever impinged against a well-established culture. It has provided conditions at once the hope and the despair of the present generation.

The Status of Fuels in 1833

If, one hundred years ago, the term "fuel technology" had been used, it would have applied to a relatively simple group of fuels and facts.

The common fuels of that time were wood, anthracite, bituminous coal, and charcoal. The wooded portions of the continent were still being attacked to make smooth fields for farms. In many places wood was still a nuisance to be rid of. In 1828 it was estimated that of the total consumption of fuel 80 per cent was wood, 3 per cent charcoal, 2 per cent bituminous coal, and 14 per cent anthracite.

An English writer as late as 1840 said:

> The common fuels in the cities and towns of the United States consists chiefly of wood, of which there are various kinds. The best is the celebrated hickory tree, which commonly fetches a price equivalent to about twelve shillings per load; it is a desirable fuel and does not soon die out. Oak billets are next in esteem, and sell for nine shillings; gumwood, dogwood and pinewood are an inferior description of firing and fetch six or seven shillings the load, according to circumstances.
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> The quantity to be accounted a load is fixed by law, and the logs, which are about four feet long on the cart, are sawed off into short billets, previous to being piled in the cellars of the consumer by the hawker of the fuel, or some person who accompanied him with a saw on his back.

Many of us recognize this picture and took part in the sawing in much more recent times.

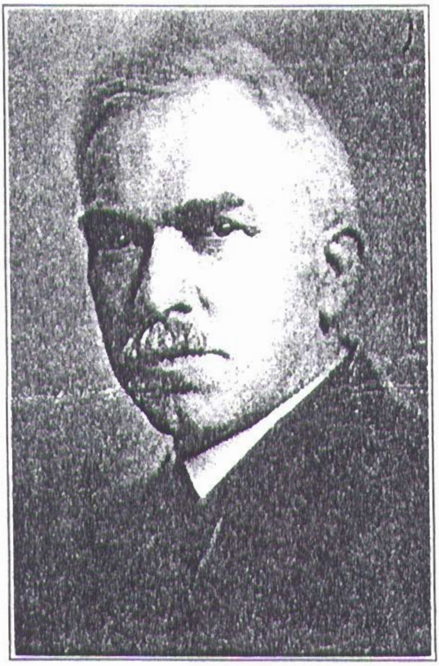
In 1833, Walter R. Johnson, professor of natural philosophy and physics, University of Pennsylvania, advised that a house could be heated by a single furnace in the cellar and that the system had been used in some public buildings and to a very limited extent in private dwellings. In urging the adoption of this new method he referred to inefficient fireplaces and disclosed that both New York and Philadelphia expended the enormous sum of 1,200 and 1,500 thousands of dollars annually for combustibles. He believed that the gradual introduction of mineral fuel, especially anthracite, would probably produce some changes in domestic arrangements. Thus prophecy was amply fulfilled. Some form of centralized heating of houses is now nearly universal.

The cost of wood was largely that of transportation so that as nearby forests disappeared the cost of heat began to be a serious item of expense in the larger towns and in some industries. In 1831 there were in the United States 939 small furnaces and forges producing 191,536 tons of pig iron, all using charcoal for fuel. Coal had been tried and was considered a failure.

Some Change

In 1835 a gold medal was offered by the Franklin Institute to the person in the United States who would manufacture the greatest quantity of iron in one year using bituminous coal or coke as fuel, "the quantity to be not less than 20 tons." Coke was much used in England and rails for the budding railroads were being imported because coke-made iron in England was so much cheaper than charcoal-made iron in America.

Our furnaces were situated in the wooded districts of the Appalachian area near supplies of ore and limestone, but the forests were rapidly being depleted and costs were in-



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creasing. Some furnaces had shut down for lack of fuel. It was about 1840 before we learned how to make iron with our coals.

Robert Fulton's first steamboat, the *Clermont*, in 1807 "was fed with dry white pine wood," although the desirability of using coal was realized in the earliest stages of steamboat development. When Nicholas Roosevelt, in 1809, floated down the Ohio and Mississippi rivers to study the feasibility of organizing a steamboat line between Pittsburgh and New Orleans, he made arrangements to open coal mines along the Ohio River to supply coal for his boats. However, when the first steamer of this line was put into commission in 1811, it used wood.

Burned Wood

In 1833 there were less than 100 steamboats all together and up to 1836 the principal fuel for them in the United States was wood.

Typical of the time was experience with the new steamboats running between the island of Nantucket and the mainland. This was an important center for whale oil, used for lighting and lubrication, and the first steamboat of 80 tons began running to New Bedford in 1818. It burned wood. The third boat of 120 tons made a trip across Nantucket Sound using coal for fuel for the first time in June, 1831. Quoting from "The Story of the Island Steamers":

> This coal had been brought to the island in a sloop at the instance of Isaac Austin, and was dumped on the wharf in a small heap, where it was looked upon as a great curiosity. Upon Austin's suggestion, Captain Barker agreed to give the new fuel a trial under the boilers of the *Marco Bozzaris* and ten "barrel-loads" were placed aboard the boat. The steamer did not work well with it, however, for her boilers were made for the use of wood, and she could not be made to keep up steam with coal—much to the chagrin of Austin, who made the trip on the boat that day to witness the experiment. Thereafter wood was used as long as the steamer remained on the route, and under that fuel she is said to have performed admirably.

A century ago the idea of steam railroads was having its first boom. In 1830 there were about 40 miles in short lines. In 1832 there were completed or in progress 19 railroads with upward of 100 miles completed out of a projected length of 1,400 miles. Some of the vertical boilers of the first engines used anthracite, but with the rapid evolution of the locomotive, wood was depended upon for fuel because coal had proved to be hard on the boilers.

Coal has always been the scapegoat for poor furnace design and bad combustion habits and it is suspected that this early ill repute was no exception. Early boilers carried no steam gages and were fired until the safety valve lifted. When this occurred the firedoor was left open until the valve closed. That tube sheets and tube ends protested by leaking was laid to the bad effects of coal as giving too concentrated a heat instead of to bad practice, and for many years wood was therefore preferred.

The first discovery of coal in the

area now covered by the United States was made within 75 miles of Chicago. The French explorer Hennepin, in 1698, found coal near Ottawa on the Illinois River. In 1700 the coal area near Richmond, Virginia, was known and this was mined as early as 1775. This was the most productive coal field in the United States in the early part of the 19th century, reaching its maximum output of over 142,000 tons a year in 1833. This coal was quite generally distributed in the seaports along the North Atlantic coast.

In the Pittsburgh district a coal mine was worked in 1760 and with the advent of the first steam engine there in 1794, the demand for coal in that district increased rapidly. In 1825 the amount of coal used in this vicinity was 3,500 tons per year. It is recorded of some of these early mines in the hillsides above the river that the coal was tied up in raw hides and rolled down the hill to the river bank to be taken by barges to Pittsburgh. The pioneer miners of the Monongahela valley early began the use of dogs to assist them in hauling coal from the working places to the dump at the mouth of the mine.

In 1806 coal of a superior quality for blacksmithing was mined near the headwaters of the Tioga River and by 1833 was being carried by raft down the river to Corning, N. Y., from whence it was distributed to the regions to the east and west. In western Maryland coal was discovered in the Georges Creek district in 1804, but it was not until 1830 that the first shipments were made eastward on the Potomac River by means of barges. Coal was mined in a small way in the states of Illinois, Indiana, and western Kentucky for shipment to market and it was just being advertised for sale in newspapers in Indiana in 1832.

Even Advertised It

This shows that one hundred years ago bituminous coal mining was being carried on for the benefit of local communities but the industry was beginning to reach out boldly for more distant markets.

There was discovered near Wilkes-Barre, Pa., in 1762, a stone coal so hard to ignite and so slow to burn that it failed to take its proper place in the scheme of things for many years. A wood fire could be started on a bed of ashes and bituminous coal could be ignited and burned in the same way, but anthracite would not kindle or burn in that manner. To poke a wood or a bituminous coal fire was instinctive and soon became a habit, but it was necessary to let anthracite alone.

These simple facts of technique stood in the way of the successful general use of the stone coal. A few blacksmiths could use it as it would burn if provided with a blast, but the general opinion was that it was not good as a domestic fuel. In the early days of the 19th century a number of experiments were made with anthracite on a grate and it was considered a noteworthy fact that it burned with ordinary chimney draft.

Charcoal for industry was getting scarce during the war of 1812 and bituminous coal from Virginia could no longer be had so that renewed efforts were made to use anthracite in the Pennsylvania district. Progress was slow. Added to skepticism about the coal there were serious transportation problems, but by 1833 these handicaps were sufficiently removed so that more than 487,000 tons were marketed in that year.

Lost Its Lead in 1870

We may say, then, that 100 years ago we were on the threshold of a most remarkable development of this most remarkable coal. About the year 1820 the use of anthracite first exceeded that of bituminous coal and it was not until 1870 that anthracite lost its lead. During that half century this supreme fuel put an enduring stamp upon the domestic and industrial habits of the northeastern states. Fear of a shortage of charcoal was laid to rest.

There was no coke industry 100 years ago. As early as 1810 coke had been made in ricks by methods closely resembling those used in making charcoal, the yield being about 55 to 60 per cent. The Pennsylvania Society for the Promotion of Internal Improvements sent an observer to England in 1825 to study developments in coke making. But the first coke ovens in the Connellsville district were not erected until 1841. Although coke was being made and used successfully in England, it was slow in getting started in America.

In 1833 petroleum was known as a medicine and as a nuisance. In the valley of the Little Kanawha there was a spring from which 50 to 100 barrels of petroleum were collected annually. Small quantities were found in springs and streams in the Allegheney River district and in Kentucky. A little was collected and sold as Seneca Oil for 50 cents for an 8-ounce bottle. When it was found in the salt wells of the Ohio valley it was considered a nuisance.

Natural gas was a curiosity. Fredonia, N. Y., a few miles from the shore of Lake Erie, had a supply of natural gas that was conveyed through a ¾-in. lead pipe from a shallow dug well. In 1829 the village adopted a town seal on which was depicted a five-jet gas burner. But natural gas as a fuel in quantity came in more than twenty years later with the petroleum development in the fifties and sixties.

Gas in Baltimore in 1816

Lighting by manufactured gas was a rapidly growing industry in 1834; London had 168,000 gas lamps and employed 2,500 people in the business. In America, the first manufactured-gas company was organized in Baltimore in 1816. Gas lighting began in Boston in 1822 and in New York in 1833. Coal from the Richmond basin was being used for gas making and the technology of this art was just beginning in this country. It was replacing whale oil and lard oil in public lighting.

Glass works had been abandoned in several localities for lack of charcoal and the industry was centering largely around Pittsburgh where coal had been used from the beginning of the industry. The use of coal was one of the outstanding features of the first successful glass house erected in the Pittsburgh area in 1797.

Other factories before this and long afterward used wood for heating the furnaces. The Kensington plant used each year in the furnaces, in addition to wood and coal, about 15,000 barrels of resin from North Carolina. In 1831 whale oil at 30 cents per gallon was being used for lighting and the rapid increase in price was stimulating the development of substitutes. The distillation of oil from coal to produce coal oil or kerosene for use in lamps had not yet begun.

The general picture presented by these random notes is that of a country depending largely upon the forests for fuel except where population was concentrating and where industry had used up the available supply within an economic distance. Bituminous coal was not uncommon in coastal cities and was in local use in places that were later to prove great coal centers, such as the Pittsburgh, Richmond, and Blossburg districts, but the country as a whole used in a year something less than is now produced in a quarter of a day.

Wanted Cheaper Fuel!

We were on the threshold of a great expansion in anthracite mining and this coal became the dominant fuel in the northeastern portion of the country which held the principal manufacturing districts of the time. The need for cheaper and better fuel was being generally felt and was producing a profound effect upon transportation. It was an important factor in starting the great canal development which gave us 5,000 miles of canals.

This movement was halted, however, by the more rapid introduction and development of railroads. Railroads, steamboats, and gas works were as yet but small users of fuel in the modern sense. The coke industry and coal-distillation industry for the production of coal oil were to be future developments. Petroleum and natural gas as products of industry were not dreamed of.

Steam engines were still novel and limited in total power and there was no hint of the internal-combustion engine. Wood, bituminous coal, and charcoal were much used without grates. Stoves with grates, burning anthracite, for domestic heating and cooking were a novelty and the subject of much invention.

Developments in Combustion and Testing

The practice of numbering patents began in 1833. Of those numbered from 1 to 100 the records of 12 are completely lost because of fire, but of the remaining 88, eight were for cook stoves, heaters, or fireplaces, one for a furnace for warming buildings, one for a vertical boiler, and one for a removable firebox for locomotives. Thus one-eighth of the inventions of the time were in the field of fuels. The removable firebox seems to have been an effort to remedy the disadvantage of the slow ignition of anthracite coal.

The inventor claimed "the preparing of a fire in a grate which may be transferred from the place where it is made to the proper place under the boiler of a locomotive." The locomotive was to be serviced with a new live fire at suitable intervals in its journey.

There was no lack of keen observation about incomplete combustion, especially of bituminous coal. The smoke nuisance was already old. In the Richmond basin, however, where people usually enjoyed good health, this happy state was credited by the inhabitants to the beneficial effect of the mineral fuel which they so largely used.

Rational Theory of Combustion

A little more than one hundred and fifty years ago, fire ceased to be an element. The discovery of oxygen made possible the formulation of a rational theory of combustion. Books of the period of 1833 expressed the chemistry of fuel burning in its newest and simplest elements. The need for an adequate amount of air at the right place and at the right temperature was well understood by the natural philosophers of the time. The split bridgewall to admit supplementary air to burn gases in the combustion space was already old to a few, but these ideas were still novel to the great majority of fuel users.

Count Rumford had interested himself in simple matters of heat production, heat transmission, and the design of kitchen equipment, and these subjects were deemed worthy of a place in philosophical transactions. In 1796, while residing in London, he presented $5,000 to the American Association of Arts and Science for the biannual award of a premium for the most important discovery or most useful improvement on heat or light made in America.

One contestant for the Rumford prize, Marcus Bull, read a paper before the American Philosophical Society on April 7, 1826, entitled "Experiments to determine the comparative quantities of heat evolved in the combustion of the principal varieties of Wood and Coal used for Fuel in the United States; and also to determine the comparative quantities of Heat lost by the ordinary apparatus made use of for their combustion."

Studied Comparative Values

For a calorimeter Bull used a small room in which the operator could burn fuel in a small stove, the air of the room being heated to a temperature ten degrees warmer than the air surrounding the room. Heat was dissipated from the thin walls of the room and the length of time that the required temperature could be maintained with equal weights of various fuels was used as a comparative measure of the respective heating values. Shellbark hickory wood was used as the standard of comparison.

Awkward as this method of testing would appear today, it is interesting to note that in comparing the relative heating values of seven woods, hickory, oak, beech, maple, birch, chestnut, and white pine, Bull's results put them in the same relative order of merit as we would today with our available information. He was not so fortunate in the order in which he placed anthracite, charcoal, coke, and Georges Creek bituminous coal, which present information would list in the order of bituminous coal, charcoal, anthracite, and coke.

Bull made a claim for the Rumford prize and there was much discussion and criticism of his work. It brought out a number of pamphlets by the interested parties in accordance with the custom of the times. The committee, however, decided against the claim on the ground that the work was not of sufficient accuracy.

The awkwardness of the prevailing phrases, units, and terms of the time make strange contrast with those we use today. In an old cyclopedia of the time, "fuell" is defined as "the pabulum of fire, or whatever receives and retains fire, and is consumed or rendered insensible thereby." Fuels were then classified under five heads, fluid, peat, charcoal, coke, and wood or pit coal in the raw state. Since both wood and pit coal gave a "copious and bright flame" they were classified together. The need for close classification of coals came later.

The performance of steam engines was measured by the effective work performed compared with the amount of fuel supplied, usually measured by the bushel. The true potential value of fuel was masked by all the exigencies of combustion in unfavorable environment and inaccuracies of unit measurement. This led to some controversies that make interesting reading today. The best of the experimenters were often misled.

Sold by Bulk

Anthracite was sold by weight and bituminous coal usually by bulk. Bituminous coal was calculated by the chaldron in the east, by the barrel in the south, and by the bushel at the mine. The number of bushels per ton varied through wide limits. We had (and still have) two weights called a ton, but the chaldron, weighing anywhere from 3,360 to 2,500 lbs., has disappeared and the bushel of five pecks and tons varying from 36 to 25 bushels no longer vex us. It was the day of the vulgar fraction and of the rule of proportion. Technical quantities were expressed in what seems quaint language today. Heat quantities had been measured by the amount of ice that could be melted, by the rise in temperature of a volume or a weight of water, and in Bull's work by the time a given weight of fuel could maintain a room at a temperature of 10 F. above the external atmosphere. The weight of water that could be evaporated from and at 212 F. was just coming in as a measure. Not long before this time Rumford had used the terms "abduction," "recession," and "pulsation" where we now use the words "conduction," "convection," and "radiation" in the transfer of heat.

It was not until the report of fuel testing by Prof. Walter R. Johnson in 1844 that tests and reports on fuels begin to have a familiar look to those of us who are interested in fuel technology. Professor Johnson had interested himself in fuel problems for some years as professor of natural philosophy and physics at the University of Pennsylvania. An appropriation made by Congress to the Navy Department in 1841 authorized the Secretary of the Navy to make experiments in the cause of national defense, and Secretary A. P. Upshur instituted an inquiry on fuel primarily on account of the difficulty which had been experienced and the complaints which had been made relative to the qualities of the coals procured for the naval service. Some few experiments on the subject had previously been made under the authority of naval officers but with means and appliances, it was stated, that were little calculated to afford the desired information.

Checked Up in 1843

Professor Johnson conducted the investigation at the Washington Navy Yard and made his report in November, 1843. He was ingenious in devising methods, sound in the principles of the day, and was a prodigious worker. More than 40 different coals are reported upon in a 600-page volume, much of the information being good today. Proximate and ultimate analyses were made, evaporation performance recorded, flue gases analyzed, and ignition and clinkering characteristics noted. Gas analyses were made as a matter of interest rather than as a guide to combustion control.

For years English coals had been imported into this country, 90,000 tons in 1833, and these coals did not make a good showing in the tests. The report was called to the attention of the English Admiralty in a letter by a member of Parliament in which he wrote:

> The late Mr. A. P. Upshur of the United States was strongly impressed with the importance of determining the nature and qualities of the several coals in the United States with a view to their nse in the navy of that country; and in 1842-43 directed a course of experiments to be made on different kinds of coals of the United States, for the purpose of ascertaining their evaporation powers. I have only this day received from the United States the report of that inquiry, and I have the satisfaction of sending a copy of that report to your Lordship, that you may see the result of that inquiry.
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> They have decided by direct and practical tests the comparative usefulness of American and English coals as well as the relative value of the former in their numerous varieties; and I submit to your Lordship that a similar inquiry should be instituted into the comparative usefulness of the several kinds of English, Scotch, and Irish coals, with a view of ascertaining the best for the naval steamers of this country.

The letter called attention to the availability of "a public establishment perfectly qualified to apply the requisite direct and positive tests to the coals without delay."

It was in this way that coal testing was undertaken by the Director General of the Geological Survey of the United Kingdom, forming a precedent followed sixty years later by the United States.

More Recent Natural and Processed Fuels

It was entirely within the period of the past century that petroleum and natural gas were made available in quantity to the useful arts. The technology of their recovery, transportation, and use were developed within this period. It would be hard for the present generation to adjust its thinking to the entire absence of these raw materials.

To these new fuels have been added processed fuels each of which has a complicated and growing technology. The great industry of processing coal to produce coke, gas, tar, and other products has developed in this period with something of importance happening in every every decade for the past seventy years.

Continuous progress has been made in the manufacture of gas from coal through the whole of the century. It is recognized as one of the great industries based on fuel technology. The production of liquid fuels from coal by using high temperatures and pressures in a most complicated technology has been shown to be possible within the last few years. Another new comer is liquid gas from petroleum with a still younger technology.

Changes in Use and Expanding Technology

Whereas 100 years ago the heating of homes was perhaps the major use for fuel, today industry demands 85 per cent of the fuels used.

The great present uses for fuel are for transportation by railroads, boats, and automobiles; the development of electrical current and mechanical power in power plants; and the recovery and refining of metals as illustrated by our great steel industry.

In each of these fields fuel technology occupies an important place. But of all the changes the 100 years have brought, the most far-reaching and astounding has been the development of the internal-combustion engine, burning gaseous, liquid, and solid fuels behind a movable piston. This prime mover has made possible the subdivision of power in small efficient units, has made practical an individual transportation mechanism, and has given us the ability to fly and to proceed below the water. In these fields lie the romance of fuel technology.

In all of these fields there is a rapidly growing body of published information expressed in the terms of current scientific thought. Much painstaking research using most of the tools of modern science has been brought to bear upon fuel and combustion problems and the results published. Many methods of investigation have passed the pioneer stage and some have standard units and procedures. From all this it has been possible to arrange courses of study of fuels based on fundamentals and worthy of a place in a college curriculum so that the subject of fuel technology is a recognized subdivision of an engineer's training.