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Net Heating Value versus High Heating Value

by

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There are a number of factors to understand in "high heating value" vs "net heating value" (also sometimes referred to as "lower heating value"). US industries mostly look at lab results which are almost always "high heating value". In laboratory data no adjustment has been made for moisture except that on a weight basis water does not contribute to the heating value. So a higher moisture fuel will have a lower "high heating value" simply because it has less fuel. The real issue is what happens to the water during the laboratory test vs actual combustion. In the bomb calorimeter used for the test the water is recondensed after it is vaporized so any heat that went into the vaporization comes back out and is "counted". In most real combustion processes the water vapor remains in the vapor state so the vaporization of the water uses some of the heat content of the fuel - thus the phrase "net heating value".

It is also important to understand that the water can come from two different sources. One is actual contained water - coal, waste derived fuels, and some other fuels can have considerable contained water - sometimes as much as 20-30%. (Green wood is even higher.) 10% moisture hits the heating value with about a 105 BTUs/lb penalty - as an example. The other source of moisture is from the actual chemical conversion of the hydrogen in the fuel to water. In the bomb calorimeter this moisture condenses and again produces a small amount of heat that is counted in the "high heating value". This can be much larger than contained moisture.

Ash is not a factor in any of this. Some of the components in ash can contribute to heating value if they are oxidized during combustion - metals would be an example - and in that case might not be counted in the bomb calorimeter test since they might not be heated high enough in the calorimeter to combust. Most ash has no impact but does lower the "high heating value" by virtue of not being a contributor to the fuel value.

The formula for converting a "high heating value" to "net heating value" is found below:

$$NHV = HHV - 10.55(W + 9H)$$

Where:

NHV = net heating value of fuel in BTUs/lb,
HHV = higher heating value of fuel in BTUs/lb,
W = Weight % of moisture in fuel, and
H = Weight % of hydrogen in fuel.

Hazardous Waste Fuels and the Cement Kilns

The Incineration Alternative

By

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The integration of two seemingly diverse technologies; management of hazardous wastes and production of cement, appears to be having a profound effect on both industries:

- Study after study has been warning of severe consequences of shortfalls in the nation's capability for hazardous waste management. Yet today, many types of liquid wastes are in significant demand for use as supplemental fuel.
- Cement manufacturing plants can evaluate different sources of new revenue for their facilities by providing waste management services. Usually, each new source of revenue also helps lower plant fuel or raw material costs in the never ending effort to remain competitive in a well-established and mature market.

Because of this, the small generator of liquid hazardous wastes such as spent solvents and various paint process residues finds his fees for off-site waste disposal services have actually gone down or remained constant, rather than escalating massively as had been predicted.

The large volume waste generating plant that properly segregates and manages spent solvents, paint residues, and similar good Btu value materials can also take advantage of this competitive situation among the waste management options available to the plant.

The Cement Industry

Cement manufacturing is one of the largest mineral commodity industries in the United States, with an estimated production capacity of greater than 73 million metric tons annually. The principal chemical elements required for the production of cement are calcium, silicon, aluminum, and iron. Calcium is provided typically from limestone usually mined on or close to the plant site. Silicon and aluminum come from clay, shale, slate, and/or sand. Iron can come from a variety of sources including iron ore or steel mill scale.

The cement industry is very capital intensive and depends largely on construction activity for a steady source of product demand. Energy costs can account for to 40 percent of the total cost of cement manufacturing. Conversion to coal was started in the 1970's. In 1972, only 39 percent of the industry's energy was supplied by coal. Currently, over 90 percent of the installed capacity uses coal as the primary fuel.

The Cement Kiln and Energy

A medium size rotary cement kiln has an enormous appetite for energy, consuming up to 300 million Btu/h (Figure 1). Holnam's kiln in Clarksville, MO, is the largest in the world, with a 25ft. (7.6m) diameter kiln 760 ft. (231m) long. When the plant was built in the 1960's, the kiln was the largest piece of moving equipment ever constructed.

Raw materials enter the feed end of the rotary kiln and are "baked", undergoing chemical changes as they progress through the unit. Typical kiln residence times for raw materials range from one to three hours. Figure 2 shows the kiln's temperature profile.

Energy typically comes from coal, as mentioned. But it is not uncommon today to see used tires, spent solvents, blended paint wastes, used oil, petroleum residues, wood chips, agricultural wastes such as rice hulls, and many more sources of energy routinely in use.

Cement Raw Materials

The silicon, aluminum, and iron needed as cement process ingredients do not always have to come from clay, shale, and sand found in a quarry. Power plant fly ash and boiler ash have raw material characteristics. Spent aluminum potliner is both an energy source and a raw material substitute candidate.

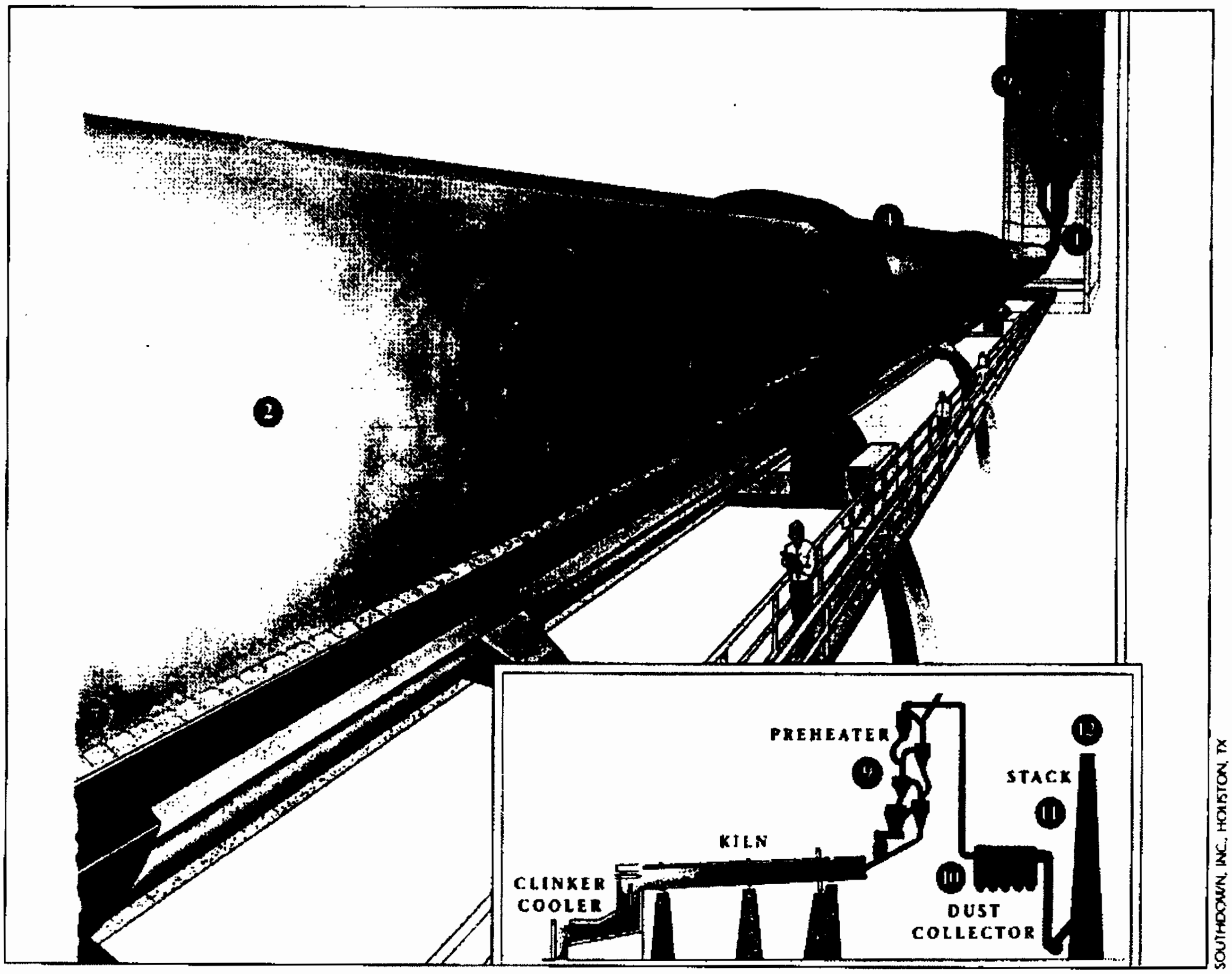

Figure 1 - Preheater Dry Process Cement Kiln

What Happens to Ash from Burning Coal or Other Fuels?

A cement kiln produces no ash. The inorganic components from the fuel bond with the inorganic compounds of the clinker or kiln dust. Lead, barium, chromium, nickel, and other metals become a fixed part of the cement structure.

As the fuel burns, the heat causes the molecules of fuel, air, and raw materials to break apart. The molecules then recombine and bond together to form stable mineral compounds plus carbon dioxide and water vapor.

Where Do the Hazardous Wastes Come From?

Generally, the cement manufacturing company does not directly operate the program for marketing, distribution, mixing, and blending of waste derived fuels. These functions of sourcing and supply are handled by a new group of operations known as fuel blenders. Many fuel blenders also provide solvent recycling services.

During the early history of the waste fuels programs, the majority of the materials originated from solvent recycling facilities and consisted of process still bottoms, distillation cuts, and other fractions or residues from solvent recovery work.

As separate stand alone fuel blending units were located at the cement plant, direct bulk loads from major factories and plants could be added. A few of the locations have also added capabilities to receive waste materials in smaller container sizes.

Candidate materials for the hazardous waste fuel/waste derived fuels program include:

- Almost every residue from industrial or commercial painting operations from spent solvents to paint solids including all of the wash solvents and pot cleaners
- Metal cleaning fluids-originally these materials were primarily solvent based mixtures and blends. Currently, the fuel blenders are being asked to evaluate for use more of the metal working and machining lubricants, coolants, cutting fluids, and the like.
- Electronic industry solvents-Since these materials tend to be the higher value chlorinated/fluorocarbon solvents, the fuels program generally sees the residues from recovery processing of these high cost materials, rather than the spent solvent itself. Oils and resins that are separated during recovery processing have excellent fuel values, and the trace metals contained become part of the cement clinker.
- Automatic aftermarket operations-- Safety-Kleen Corp. reports serving over 400,000 customers nationwide including automotive body shops, maintenance departments and repair shops through its parts washer program. The dirty cleaning solvents picked up regularly typically get recycled with the clean solvent going back into parts washer service and residues sent for waste fuels use.

The list of candidate materials for use in a waste fuels program continues to expand. Regulatory pressures, economic considerations, shrinking traditional solid waste disposal capabilities, and a host of similar factors are reflected in the constant change of the candidate waste fuel universe. For example, filter cake is a relative newcomer to the waste fuel program. Historical management for this waste material has been land disposal.

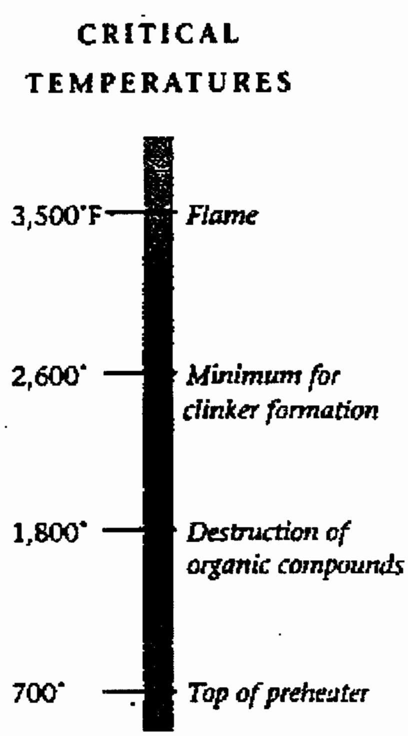

Figure 2 - TemperatureProfile Preheater Dry Process Cement Kiln

How Does the Waste Fuel Candidate Evaluation Program Work?

The plant or factory wishing evaluation of its waste stream will generally fill out a waste fuels evaluation form or will be assisted in document preparation by the sales representative from the fuel blenders/solvent recycling company.

A representative sample is collected for evaluation by the fuel blender. Many times the laboratory evaluation will be conducted at a central corporate facility where the analysis can consider toxic metals concentrations, priority pollutant levels, energy value, viscosity, and the other parameters important for fuels handling.

Fuels Program Economics

The waste stream generator always wants to know whether or not the material has economic value since the use will be for fuel purposes or at least a part of the waste stream will end up as fuel.

Coal delivered to the cement plant at $30 per ton with average energy value

[redacted]

of 11,250 Btu/lb provides 1 million Btus for $1.33. For waste derived fuel to compete with coal on a cost/energy basis, the delivered value is only 11¢gal (fuel energy content 85,000 Btu/gal). This does not provide adequate revenues to properly operate a Resource Conservation and Recovery Act (RCRA) facility and appropriate laboratory quality control tests.

The results is that nearly all candidate waste streams move on a disposal fee basis unless part of the material has recoverable value as a solvent or can be reused as a material rather than processed for fuel use.

It is estimated that in excess of 200 million gallons of hazardous waste fuels were used in cement kilns during the last year. This represents a reduction of at least 800,000 tons of coal nationwide for a nationwide fuels savings of approximately $24 million.

Environmental Regulations

Nearly all of the materials considered "chemical wastes" move through the hazardous waste fuel system within the jurisdiction of the RCRA. Factories, plants, automotive body shops, and the considerable network of fuel sources generally are Environmental Protection Agency (EPA) registered hazardous waste generators. Truckers and collectors are registered as federal and state hazardous waste transporters. Hazardous waste manifests are used to track the material "cradle to grave".

Fuel blend points, broker collection and transfer locations, solvent recycling facilities, and fuel blend facilities at cement plants all have either notified EPA of their activities associated with waste fuels or are registered hazardous waste management facilities.

The combustion portion of waste fuel activity on the part of the cement plant currently fits within the jurisdiction of the plant's Clean Air Act permits rather than RCRA hazardous waste management regulations. EPA's pending concept is to regulate hazardous incinerators and the burning of hazardous waste fuels in furnaces and industrial boilers on an approximately equivalent basis.

Other miscellaneous cement plant waste fuel streams such as wood chips, used tires, rice hulls, and filter cake generally fit within a state's solid waste management regulations. Some materials can be state regulated special wastes or industrial wastes. In some cases the materials can be U. S. Department of Transportation hazardous materials during transportation.

How about Used Oils?

A considerable waste oil volume already moves through the hazardous waste fuel system, with the used oil collection and transport activities regulated in some states as special waste operations.

EPA's first ruling on adding waste oil to the regulated universe under RCRA was that the net impact on the environment would be worse rather than better. The court challenge resolved that EPA had to make its waste oil management evaluation strictly on technical or scientific factors and not social issues. Congress may end up making this decision via the RCRA reauthorization legislative process.

In general, the hazardous waste fuel system will be pleased to see more used oils managed via this method. The higher BTU value oils, petroleum fractions, and distillates will help in blending other liquids up to the desired average heating value for use in the cement kiln. The additional value will also help to "fill up" a larger and larger cement kiln fuel capacity.

Future Developments

Future expansion of the universe of candidate waste fuel streams for cement plants will more than likely emphasize solids. Cement plants are already expanding or modernizing their capabilities to introduce bulk solids into the combustion chamber. A number of cement plants are testing and/or constructing pyrolosis systems to be recycled for both fuel value as well as the silicon and aluminum present in most soils.

Low organic level aqueous streams are being evaluated. These can be matched with high Btu waste oils and readily introduced as cement fuel as long as the mixture remains constant.

Hazardous Waste Incineration vs. Cement Kilns

It is not uncommon for a cement kiln burning hazardous waste fuel as an energy source or as an energy/raw material source to be viewed by the general public as a hazardous waste incinerator. As thermal combustion units go, commercial hazardous waste incinerators are relatively small compared to cement kilns. Chemical Waste Management's new $100 million facility at Port Author, TX, shows a published rating of about 150 million Btu/h. The DuPont Co. has announced plans for a similar size unit at its Deepwater, NJ, plant. Holnam's single cement kiln in Clarksville, MO, uses about five times the combustion energy with a rating of approximately 800 million Btu/h.

Both types of facilities have an important part in America's waste management capability. The new hazardous waste incinerators are being designed to handle the acutely toxic, corrosive, and reactive waste streams generated by the chemical and allied industries. Cement plant waste fuel sourcing organizations generally avoid these types of materials due to the upstream collection and handling hazards.

Summary and Conclusions

Industry and EPA sponsored combustion performance testing nearly always supports a conclusion attesting to the effective handling of hazardous wastes by cement kiln. The natural time, temperature, and turbulent environment in a kiln's combustion chamber is ideal for destruction of organic components. Inorganic components are bound up in the structure of the product coming out of a kiln. Most plants already have massive particulate scrubbing as a part of Clean Air Act emissions compliance.

The chief concern in today's waste fuel management program centers on collection, processing, handling, quality control, and transportation issues. As the universe of candidate materials expands, increased attention will be focused on analytical testing for incompatibles, employee health and safety concerns, fire protection engineering, and the traditional practices promoting safe handling of hazardous chemicals.