DESTRUCTIVE FORCES ON REFRACTORIES IN A WASTE INCINERATION ENVIRONMENT

The refractory environment inside an incinerator is subject to a combination of destructive forces. These forces include high temperature, thermal shock, chemical attack, abrasion and erosion, and general mechanical abuse.

HIGH OR EXCESSIVE TEMPERATURE

Because incinerators must burn many different waste materials, the Btu value of the fuel can vary quite a bit from week-to-week or from hour-to-hour. Upset conditions can be caused by any number of equipment failures during operation. Temperature excursions might be caused by occasional additions of highly combustible or explosive materials to the fuel. Some operators try to blend their fuels to some extent, so that the overall heat and temperature will not vary as much. From a refractory life standpoint, this is desirable.

It should also be noted that the maximum use temperature of a refractory in a reducing atmosphere may be 100°F to 300°F lower than the same refractory in an oxidizing atmosphere. Generally, ceramic materials soften and melt at lower temperatures where there is a deficit of oxygen.

Characteristics needed to resist excessive temperature include high alumina content and/or a high degree of mullite formation in the refractory product, as well as a high original firing temperature.

THERMAL SHOCKING - RAPID TEMPERATURE CHANGES

Thermal cycling and shocking will be relatively mild in a continuing operating mode, and much more severe if operated 1-2 shifts/day and cooled down rapidly overnight and on weekends. In some incinerators, a dramatic air- or water-quench is part of the planned operation, to reduce the volume and temperature of gases introduced into the air-cleaning portion of the system. As discussed previously, sudden changes in fuel can result in thermal shocking conditions. Sudden heating from high-energy fuels can be damaging, and so can sudden cooling from low-energy or very wet fuels. All these conditions will affect refractory life.

Characteristics needed to resist thermal shocking include high strength, relatively coarse particle size, moderate or high porosity, and low or optimum coefficient of thermal expansion to match operating conditions.

CHEMICAL ATTACK BY ALKALIS

When relatively clean hydrocarbon fuels are burned, the products of combustion are water vapor and carbon dioxide. Waste fuels are characterized by having a high amount of ash after combustion. This ash is generally high in alkali (sodium, potassium, calcium) which will react with refractory materials.

In this reaction, alkali can penetrate refractory linings and condense in the pores. This may occur at temperatures in the range of 1400-2200°F. Once inside the refractory, alkali reacts with the refractory itself and forms an alkali-aluminum-silicate. This reaction creates a region of low density inside the lining. The change in density is accompanied by a localized volume change in the refractory. This volume increase often cannot be contained, and partial or complete failure due to cracking and/or spalling may occur.

At higher temperatures, the alkali-aluminum-silicate melts, and forms a glassy slag. As temperatures increase further, it becomes more fluid. This slag is a eutectic mixture, which has a lower melting point than any of its original components. The slag will adhere to the surface of the lining, and continue to dissolve the refractory as more ash contributes more alkali to the system. If this slagging occurs at or below the bed of feed material, the slag - and the dissolved refractory - may be carried downstream. When this occurs, the lining thickness will be steadily eroded away.

Characteristics needed to resist alkali attack include low porosity, high chemical purity, and optimum chemistry for the operating conditions. The best way to minimize refractory damage is to try to confine reactions to the surface, thus slowing reaction rates.

CHEMICAL ATTACK BY ACIDS

During the combustion reaction, existing sulfur compounds will be partially transformed to sulfur dioxide. Anywhere that conditions allow the condensation of water from the combustion gases, the sulfur dioxide will combine with the water to from sulfuric acid. Similarly, chlorine compounds will become hydrogen chloride gas or - in water - hydrochloric acid. And fluorine compounds will form hydrogen fluoride, or hydrofluoric acid.

Acid will destroy the calcium portion of the calcium aluminate bond found in castables. Hydrofluoric acid will also destroy the silicate bond found in brick or cured plastics.

Acids or acid formers that remain in the gaseous state are much less damaging than acids that condense into the liquid state. For that reason, most designers try to get outer shell temperatures of about 350°F during normal operations, to avoid water condensation and acid attack on the steel shell. This should also prevent condensation in the refractory at the same time.

Characteristics needed to resist acid attack include low calcium oxide content and low porosity in the refractory.

ABRASION AND EROSION

Wherever feed materials or airborne particles pass over the surface of the refractory, the surface can be abraded or chipped away. At higher temperatures, the same dynamic action can be characterized as erosion, because both the feed and the refractory - or reaction products from both - may be partially converted liquid.

Characteristics needed to resist abrasion and erosion include high strength, fine grain size, high density and low porosity.

MECHANICAL STRESS AND ABUSE

Refractory linings should be considered "protective" rather than "structural" components of an incinerator system. While they resist high temperatures and insulate the metallic shells and structures they're protecting, they do not have as much strength at higher temperatures.

A common cause of refractory failure is cracking or spalling, due to inadequate allowance for permanent and reversible thermal expansion. Of course, too much allowance for thermal expansion can result in refractory linings that don't fit tight and fall out.

When large, heavy items are dropped on the surface of a refractory lining as part of the waste feed process, strength limits can be exceeded.

When monolithic linings are used (refractory castables or plastics) some metallic and/or ceramic anchoring system must be used to attach the lining to the shell or structure.

Characteristics needed to resist mechanical stress and abuse include high strength along with a low or optimum coefficient of thermal expansion, matched to the support structure.

COMBINATION OF EFFECTS

As with all refractory applications, there is some interaction with these destructive forces where the combined effect is worse than the sum of the individual effects.

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