RDF Fire Hazards Mitigation

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Experience has shown that power station conversions to a new fuel using the same materials handling methods and equipment, designed for the previous or original intended fuel, without a proper fire engineering re-evaluation of plant suitability (for the properties and behaviors of the new fuel) is not a safe option. Many times, the detection and suppression equipment is presumed adequate, whereas a complete technical evaluation is required. Given that RDF fires are extremely difficult to extinguish it should be remembered that fires could last for days or even weeks. Additionally, given the correct circumstances, the effluent from RDF smoldering fires within a pile can lead to explosion(s), possibly causing severe injuries and even the loss of life. In addition, there are also business considerations due to the subsequent severe interruptions, not forgetting the importance of the security of electricity supply. The difficulties of RDF fire hazards mitigation begin with the notoriously problematic factor of discovery of a fire within the storage pile; they then, more often than not, continue throughout the entire fire-fighting operations process.

Keywords: Refuse Derived Fuel ; RDF ; RDF fire ; RDF explosion

1. Fire Detection

From the authors' own experience, it can be stated that deep-seated silo fires are particularly challenging to detect, especially during the incipient and medium stages (hours and days) of the fire, and certainly before any physical (visual or olfactory) signs appear [1]. Deep-seated fires can smolder for some time, and measuring (certain) gas concentrations (such as CO and CO_2) in combination with temperature monitoring is currently the most common method of detection used to establish the presence of fire within indoor fuel storage (silo or building) [2].

Through experience, this method shows that ignition deep within the pile puts limitations on the claimed effectiveness of any multi-gas detection commonly used in silo head spaces [1].

By its nature, the detection is commonly aimed at the introduction of an ignition source through the fuel route (which is more likely during filling operations); therefore, any burning is expected to be nearer the surface. Hence, these volatiles can build up unnoticed in conjunction with the present accelerating self-heating process in the surrounding area until becoming totally oxygen-controlled [1][2]. Further complications to detection exist in the form of hardened plastics (bonding and clustering RDF pellets), that can form caps within the pile, due to prolonged repeated cycles of heating (from smoldering) and cooling (during the oxygen-controlled phase) The caps formed within the RDF pile block the volatiles from rising with sufficient quantity and buoyancy to activate the detectors in the top of the silo head space.

Generally, indoor or enclosed self-heating fires are deep-seated and not detectable until the fire is reasonably well-developed and the headspace or basement of the storage structure starts showing the incipient stages of fire or starts filling with combustible and/or incomplete combustible gases. Of course, in external storage piles, where the gases can simply disperse, this is less of a problem [3].

Therefore, a method to achieve earlier detection would be an important component of any recommendations proposed for the improvement of fire safety protection. It is only by studying the trends within fire, along with the effluent measurements and temperatures, that we might be able to gain an earlier indication of possible abnormal conditions within RDF fuel pile bulk storage.

Such an advantage would allow operators to deal with abnormal conditions sooner, resulting in a more timely (and consequently, probably more effective) intervention.

2. Fire-Fighting and Fire Suppression

Suzuki et al. [4] conducted a study on the extinction of an RDF pile and observed traits of fire growth and extinction to try and create a foundation for fire control. They found that RDF pellets clustered when heated, due to the plastics contained in the pellets melting and working as a bonding agent.

When applying water to the fire, the bonded/clustered pellets were cooled and formed a coating which prevented water from penetrating the pile; the pellets underneath (within the pile) remained hot with continued oxidation, and when exposed to air again, flaring, heat and smoke re-emanated from the pile [4].

Therefore, fire-fighting an RDF pellet fire is unlike most fires and generally water jets should not be used. Experience shows that a water spray is only suitable for indoor RDF surface fires to prevent flaring, and only for short periods of time, due to the possibility of the swelling or unravelling of pellets and the hazard of extra structural stress to the weight loading, due to the retention of water within the pellets or unraveled material that could possibly impact structural integrity.

There is also another reason for limiting water. In an experiment by Persson [5], involving a silo and biomass pellets, he warns about adding water due to concerns that in certain circumstances this could contribute to the formation of explosive combustible gas. This water–gas reaction, $C + H_2O \rightarrow H_2 + CO$, occurs when fire-fighting water comes into contact with temperatures above 700 °C, resulting in the production of hydrogen [6].

Hogland and Marques [7] carried out a study on storage to instigate spontaneous combustion within an RDF storage pile. This was to assess the feasibility of the long-term storage of waste fuel. The RDF part of the experiment disclosed that spontaneous combustion was observed after approximately 6 months. Their observations were important, as they indicated that no flaming ensued unless an effort was made to excavate the fire, as excavation would reenergize the flaming to burst forward. They also deducted, not unreasonably, that this would denote that the pyrolysis within the pile was oxygen-limited, further reinforced by the specific stench of gases associated with incomplete oxidation and partial combustion of hydrocarbon mixtures. Fire service attempts to extinguish the fire with water onto the pile were unsuccessful and the wetting produced polluted fire–water run-off. After 3 days the fire accelerated, and the original pile was broken down and spread out. This turned out to be the most effective and efficient way of extinguishing the fire, with the fire then burning out within 5 days.

In summary, it is clear that having a ready, easy way of emptying the storage facility would be advantageous and even crucial. This would assist in decreasing the risks during fire-fighting operations, and would also help to reduce potentially hazardous and costly protracted incidents. It should be stressed that during emptying operations (as the empty head space volume increases), this must be controlled and nullified from the buildup of explosive gases. It is suggested that this could be done with hi-expansion foam and/or nitrogen gas.

In power generation facilities, this can be applied to fires in bunkers or silos. The hi-expansion foam should be applied from the top into the headspace to prevent buildup of fire effluent gases, whilst nitrogen gas should be applied through the bottom. Both hi-expansion foam and nitrogen systems are best served via a preinstalled fitted system, but in older facilities these measures can still be deployed and applied with the use of mobile foam generators or, in the case of nitrogen, by lance [6].

It should be remembered that silo fire-fighting is a difficult and specialized skill, and the basis of any silo fire safety strategy should always be to prevent the introduction of an ignition source, whilst at the same time being aware that hot spots can develop in any part of the material. Moreover, whilst conventional convection within a storage pile has a tendency of ascending and descending, if an air source (providing oxygen) to the fire comes from another direction (top, below or side, i.e., from basement galleries), this will cause smoldering to move from the ignition towards the air source, and if this is in a downward direction, this can potentially create capped cavities or effluent gas-filled voids within the stored RDF pile. Fascinatingly, forensic investigations into silo fires have evidenced long fingers of carbonized material stretching and being drawn towards gaps and available air sources [8].

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