Fighting Fire

Following on from his overview of available technology for the reception and storage of alternative fuels in the March 2012 issue of *World Cement*,

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focuses on the basic legal and technical requirements involved in this excerpt from the *Alternative Fuels and Raw Materials Handbook for the Cement and Lime Industry*.

Basic storage requirements and fire protection

Although alternative fuels are widely used in the European cement industry, they are still considered 'exotic' fuels, without defined guidelines and standards for reception and storage. Existing BREF documents and even national permitting regulations do not often define such standards, instead referring to other standards such as those for the storage of plastic waste or for waste processing plants.

Irrespective of which system is selected by cement or lime plants, aside from the investment costs, the most important parameters are:

- Unloading volume/hour.
- Unloading height, i.e. flexibility for various vehicles and container types.
- Maintenance complexity.
- Costs/t.

Fire protection

As is the case with fossil fuels, special attention must be paid to fire-protection when storing alternative fuels. Various projects have shown that in many countries there are no clear legal guidelines for the storage of alternative fuels. Starting from the planning period, local regulations (if present) must be strictly observed or must include applicable guidelines for storage of fuels such as plastic waste. Various studies also deal with fire protection and the explosion potential of solid materials, such as the 'BIA Report 13/97, Combustion and Explosion Characteristics of Dust'.[1]

The basic principles of fire protection, as well as an example of an alternative fuel storage facility in a German cement plant, will be outlined in this article.

Fire protection evaluation with a storage facility example

The following examples originate from an extract by Dr Ross Umwelt-Societät, Germany.[2]

Complying with operational regulations, wood residues and waste wood, as well as combustible recyclable materials made of plastic, rubber, textiles, paper and composite fractions that have a particle size of <15 mm or 25 mm, are kept in a secondary fuels storage facility. It involves high-calorific material with a calorific value of 11 000 kJ/kg – 18 000 kJ/kg (wood residues and waste wood) as well as 22 000 kJ/kg – 40 000 kJ/kg maximum (combustible recyclable materials). By means of preparation processes (selection, mixing, pre-shredding) at the supplier's premises, contaminants are removed and the qualities prescribed by the operator are produced.

The burning behaviour of secondary fuels is largely determined by the following factors:

- Calorific value.
- Homogeneity.
- Particle size and particle size distribution.

- Specific surface area.
- Heat conductivity.
- Ignition temperature and responsiveness.
- Storability.
- Specific weight and bulk weight.
- Flow resistance in bulk.
- Calorific value of the combustible fraction.
- Percental composition of combustibles, ash and water.
- Volatile constituent content, contaminant content.
- Ash melting point.
- Oxygen supply.

In order to achieve consistent operational conditions in the kiln and to ensure consistent product quality, it is in the interest of the purchaser to use a mixture that is as homogeneous as possible in its composition and that will maintain its availability (storage) as a result. Despite pre-treatment of secondary fuels, the water content can be considered relatively high, at up to 35% for wood residues and waste wood and up to approximately 25% for combustible recyclable materials. After assessment, the prescribed quality guidelines for secondary fuels ensure undisrupted operation.

For the purpose of fire protection, a fire protection rating of the stored fractions or fraction mixtures is indispensable. All in all, there are five different fire classes, marked by the capital letters A, B, C, D and F (according to DIN EN 2 or DIN 14406 (i.e. German standards). The following materials are assigned to the respective fire classes:

- Fire class A: solid, ember forming materials, mainly organic in nature (e.g. manufactured wood products, paper, coal, textiles, rubber and plastics).

Storage facility with overhead crane for homogenisation and feeding of alternative fuels.

- Fire class B: liquid or liquescent materials (e.g. petrol, solvents, oils, synthetics, varnish, tar and paraffin).
- Fire class C: gaseous materials, also under pressure (e.g. propane, hydrogen and natural gas).
- Fire class D: metals (e.g. aluminium, magnesium and lithium).
- Fire class F: edible and cooking oils.

As can be seen, the solid, mainly carbon-bearing materials such as wood, manufactured wood products, paper, coal, textiles, rubber and plastics belong to fire class A. This ensures that the secondary fuels defined according to this elaboration are subject to fire class A, too, and can therefore be extinguished using the same agent. If materials from another fire class became part of the subsequently produced secondary fuel, reclassification to another fire class would have to be undertaken. In this context, after the elaboration of structural fire protection, water is employed as the extinguishing agent. During extinguishing, the reaction with the agent forms acid containing gases (e.g. HCI and HF). The significance of this is discussed later under 'Description of the materials that can arise in the case of a fire'.

Material and reaction characteristics

In the case of wood residues and waste wood, as well as combustible recyclables, a heterogenic mix of various fractions is involved, whose contaminant, foreign matter and pollutant content has been reduced to an environmentally compatible, safe and process-wise, optimised degree by targeted pre-selection, as well as by pre-sorting and possible additional preparation steps. The main fractions and their material contents, particularly the problematic materials, are described below.

Paper and cardboard

Paper and cardboard largely consist of the following constituents:

- Cellulose.
- Fillers such as gypsum, talc and calcium carbonate, as well as magnesium carbonate and zinc sulfate.
- Synthetic resins.
- Starch.
- Glues.
- Water glass.

The heavy metal contents that are to be found in this fraction mainly originate from printed paper.

Wood

The elementary wood constituents are carbon (50%), oxygen (43%) and hydrogen (6%), in addition to phosphorous, nitrogen, sodium, potassium, calcium, sulfur and other basic materials that are present in small amounts. For example, the material composition works out at 40 – 60% cellulose, 20 – 25% hemicellulose, 20 – 30% lignin and around 2 – 7% mineral materials, proteins, oils and resins, as well as tanning agents and colourants.

The so-called wood-based materials, from which the fuel potential of the wood residue and waste wood fraction is mainly drawn, are considered to be different to untouched wood. Particle boards, with a basic composition of woodchips and glue, are one of the most important representatives of this group. The problem is that these materials are usually lacquered, veneered or coated in plastic or contain wood preservatives. For example, pentachlorophenol (PCP) has been used since 1930 in industry (textile, leather, mineral oil, adhesive industry) and in agriculture as a biocide. By comparisons of analytical data on various wood types, it has been concluded that increased chlorine content results from wood treated with chlorine-bearing wood preservatives.

Open storage of shredded tyres.

Table 1. Example of a storage volume estimation[2]

Fraction	Proportion of the fraction, weight percent	Storage density, t/m³	Volume, t
Wood	62.5	0.25	327.25
Paper and cardboard	7.5	0.15	39.27
Plastics	7.5	0.15	39.27
Textiles	7.5	0.15	39.27
Composite	7.5	0.15	39.27
Rubber	7.5	0.15	39.27
Total	100	-	523.6

Plastics

Plastic is to be understood as a carbon bearing material constructed of macromolecules. One differentiates between thermoplastic (deformable), duroplastic (hard and brittle) and elastomer (rubber-like). From the point of view of a possible fire-load, the following plastics should be mentioned: polyolefines (e.g. polyethylene PE, polypropylene PP), polystyrol, polyvinyl chloride PVC as well as polyvinyldenchloride PVCD. Chlorine content is characteristic of PVC and PVCD, and is elevated in the case of PVCD. The proportion of chlorine-containing plastics is restricted to a stipulated maximum value of 1 weight percent. Other plastics that present a risk on burning are polytetrafluorethylene PTFE with a small proportion of fluorine (plant operator restricted to maximum 0.05 weight percent), polyamide PA and polyacrylonitrile PAN with nitrogen content (restricted to maximum 5 weight percent), polycarbonate PC and silicone.

Textiles

For environmental reasons, zinc, chrome and chlorine are the contaminants that need to be mentioned in this group of materials. The contents account for a maximum 0.1 (Zn), 0.012 (Cr) or 1 (Cl) weight percent.

Material volumes

The storage volumes of the individual fractions of recyclable combustibles, as well as the composition of the wood residues and waste wood portions, cannot be exactly determined, as it is mainly dependent upon the suppliers. However, it can be assumed that the volumes vary greatly. Table 1 provides an example of storage volume estimation. As can be seen, the average proportions of combustible, recyclable materials – with the exception of wood – are generally equal.

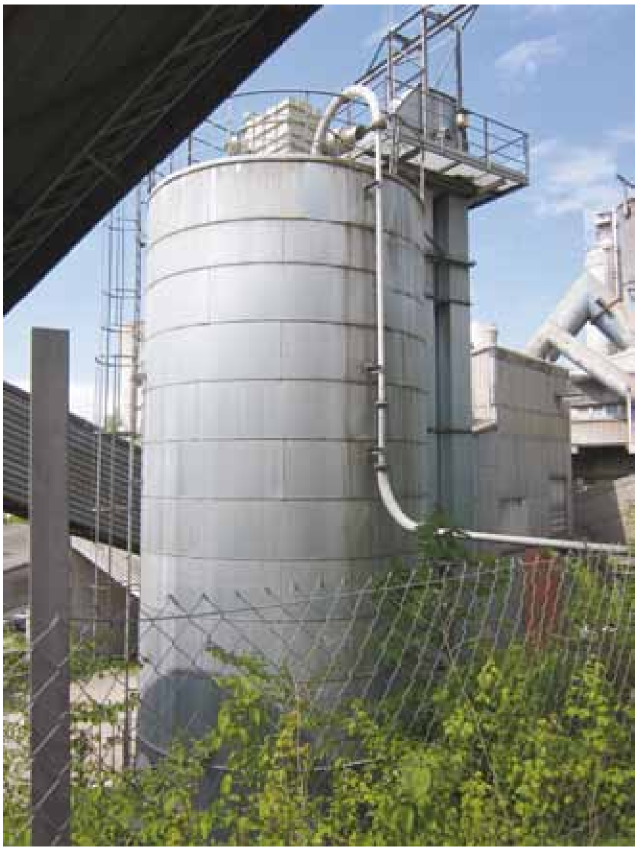
Description of the materials that can arise in the case of a fire

It should be stated in advance that the materials arising in a secondary fuel storage facility in the case of fire vary widely. An exact description is, therefore, very difficult and can only be achieved by making certain assumptions. The number of fires in comparable storage facilities is modest and experiences from these are only transferable to a limited degree. The majority of information is taken from experiences in thermal recycling plant storage installations where largely heterogeneous household waste is stored. Owing to the heterogeneity of the waste materials, fires in such storage installations may cause complicated emission scenarios. The transfer of such experiences to secondary fuel storage installations is permissible if, during final discussions, one considers the defined material content in the secondary fuel as opposed to that of largely heterogeneous household waste. Concentrations, as well as the proportion of various resulting products, can vary greatly depending on the fire and situation.

According to predominant expert opinion, when describing materials that have been subject to fire, it is sensible to assume two scenarios. First is the so-called open fire. If extinguishing measures are not commenced immediately, this type of fire can spread rapidly and generate a significant amount of heat. Great importance is attributed to timely fire detection and a short response time for fire-fighting. The second type of fire – the smouldering fire – is more critical with regards to its resulting products and fire-fighting. In parallel to smouldering fires, as a rule, open fires also subsequently occur if the fire spreads to the surface. During combustion, the most significant factors are burning temperature, oxygen supply and response time. In order to define the worst case scenario for a risk assessment, the following input parameters are assumed in both possible fire scenarios:

- Content of contaminants in the materials due to be stored is defined within maximum acceptance values.

Silo storage: appropriate for free-flowing bulk materials.



- Maximum formation rates of possible pollutant gases relating to relevant materials in the discussed fire scenario.
- Ruling out thermal effects (vertical dispersion) on the position of the emission source.

The prescribed quality parameters, which are guaranteed by a pre-selection of the treated fractions and the treatment process, are monitored. The formation rates of contaminated gases are largely determined by the secondary fuel's material potential, the mass burning rates, the burning temperatures and the disruption of the burning process. The following paragraphs outline which compounds can arise out of the various types of fires.

The composition of secondary fuels that consist of various fractions plays a significant role in the type of products that are formed. While it is relatively straightforward to estimate the fire gas composition of burning untreated wood or paper, one can expect formation of the different respiratory poisons during the combustion of derived timber products or of coated and printed paper.

While a few plastics (e.g. PE) combust to form carbon dioxide and water, almost without smoke, and give off less emissions than wood, others release significant amounts of smoke and toxic substances such as hydrogen chloride, heavy metals and – limited by the chlorine content – dioxin, which can endanger employees, the civilian population and the environment. Plastic fires are linked to considerable smoke development, which can inhibit orientation. The required extinguishing measures can sometimes take place after a melt-out of the heat discharge surface areas due to elevated heat development and the opening of doors. However, this situation is enhanced by opened gable areas, which, if operation is in compliance, secure natural air circulation.

Those who come into contact with potentially toxic substances and contaminants in the smoke, such as the emergency services, must take appropriate protective measures, as they are respiratory poisons and partially skin-resorptive. The burnout of halogenated plastics (fluorine, chlorine, bromine) causes the limited development of aqueous acids, such as hydrochloric acids and hydrofluoric acid, from incorporating humidity and extinguishing water. These are toxic and caustic. In pyrolysis processes (in oxygen deficiency cases), especially when many plastics smoulder, polycondensensated or polyaromatic hydrocarbons develop (PAH), such as benzene, naphthaline, butadiene, benzopyrene, biphenyl or acrylonitrile. PVC burns at temperatures between 200 ˚C and 300 ˚C, while eliminating HCI. In the case of complete combustion, the proportions of HCI are lower. Limitation occurs as a result of the definition of chlorine content in the fuel.

Corrosive products can endanger the civilian population (e.g. in administrative buildings), as well as posing a risk to the fire service and their equipment, the environment and even building structures. The fact that acid is not only present in gas form is of major significance. Using water as the extinguishing agent can cause aqueous acid to form. As a result, it is more difficult to get an exact measurement.

It must be assumed that small amounts of phosgene and chlorine form, though these are negligible in terms of their environmental and safety significance. No clear judgement on the subject can be found in the relevant literature.

Fire gases during a fully developed fire

An open fire is a fire that has developed in a non-compliant hearth or which has spread beyond its boundaries and may spread under its own power. The combustion temperature of an open fire is approximately 600 ˚C. Assuming an adequate oxygen supply, the following compounds will develop:

- Carbon dioxide.
- Nitrogen oxides.
- Vapour.
- Sulfur oxides.
- Metal oxides.
- Hydrogen chloride.
- Hydrogen fluoride.

Unloading zone for RDF pellets.

The carbon monoxide content, allowing for its acute toxicity in an open fire, must be taken into account at a fire gas proportion level of approximately 3%.

Fire gases in a smouldering fire

In this type of fire, burning of material in its solid state occurs through a beam of light from the combustion zone rather than from the presence of a flame. As smouldering fires occur with powders, fine wooden fibres and plastics in particular, they have to be handled with great care. The development of low temperature carbonisation gas coupled with conditional powder charge can, in the worst case scenario, involve the risk of a flash fire and the possibility that an open fire will develop during the formation of an explosive flame.

The burning temperature, at around 300 ˚C, is half that of an open fire. Apart from the already mentioned resulting products from a fully developed fire, additional products develop in an oxygen-reduced atmosphere (oxygen deficiency) as a result of the incomplete burning of organic materials, such as an increased proportion of carbon monoxide and hydrocarbons (e.g. butadiene and benzene, naphthaline, biphenyle and acrylonitrile).

Verification of infrastructural fire protection

Ingenieurbüro Kranz, Germany, inspected the same secondary fuel storage as described above, resulting in various measures that are to be taken for the storage of alternative fuels, as are listed in the following sections.[3] This is merely an example, as local legal regulations and laws must be strictly observed.

Preventing ignition sources

The parameters listed below require evaluation for all kinds of alternative fuel storage:

- Fire load.
- Fire resistance period.
- Smoke and heat exhaust vents.
- Fire water supply.
- Retention of fire water.

Engines and electric installations

All engines and electric installations have to be classified and assembled according to the protection system DIN 40 050, page 1, dated August 1, 1970 and the IEC 144 into the protection class IP 54 (German standards). The first key characteristic will indicate the degree of protection needed against disturbance and foreign objects (i.e. protection from dust settlement). The second key characteristic indicates the degree of protection from water (in this case, protection from sprinkled water).

Light devices
Electrical installations that can cause heat generation, such as light devices, have to be arranged in a way in which they cannot ignite the material in stock. The installation of tank lights (with light protection) inside and outside of the hall is possible.

Electric cables
All electric cables and installations have to be fuse-protected according to established regulations. The electric power supply line of bridge cranes, for example, has to be carried out with trailing cable.

Earthing
Earthing against static charge must be provided. In the case of pneumatic conveyor systems, all metal parts of the installation as well as the loading and unloading trucks and containers must be connected in an electric conductive manner in order to prevent static charging.

Lightning protection system
According to DIN 57 185 and VDE Directive 0185 (German standards), lightning protection systems have to be planned and erected with such parts and materials in such a way that buildings, people and material assets are protected for as long as possible.

Cable ducts
Electric cables in cable ducts have to be protected with covers so that combustible material does not come into contact with potentially hot cables. The cables should be large enough in order to prevent heating.

Protective zones
During normal working hours nobody should enter the storage building. If it is necessary to have employees in the storage area (e.g. for loading or maintenance purposes) then protective areas must be erected.

Secure electricity supply
An alternative electricity supply must be available, and should be triggered within 15 seconds of the loss of the general electricity supply. The intensity of illumination has to be a minimum of 1 lux around the escape route axes. The alternative electricity supply must be capable of ensuring that all safety measurements can be performed for at least one hour.

Extinguishing installations
The stationary extinguishing system is an installation that is always ready to use. It can supply extinguishing media (water) through stationary pipework (dry riser) using appropriate feeding devices. This installation can be put into action manually or automatically.

Preventing a potentially explosive atmosphere
Fine ground sawdust can lead to a potentially explosive atmosphere during handling. By planning forced ventilation a potential explosion can be avoided.

Forced ventilation
Due to the forced hall ventilation by means of a baghouse filter, a minimum of three air changes can be guaranteed. The air volume in the storage area needs to be changed at least three times per hour.

Smoke exhaust vents
According to DIN 18 232, Part 1 (3.2.) (German standard) smoke exhaust vents must allow for the rescue of persons and animals, as well as the protection of material assets, by creating a smoke free layer above the ground. Besides, smoke exhaust vents should enable fire fighting immediately by venting the smoke.

Fire water supply
The requirement for an adequate water supply is based on: the shape and measurements of the room that needs to be protected; the kind of object at hand; the type and quantity of the goods to be protected; the height and the kind of stock being kept; the effect of the wind. The water requirement should be between 5 and 60 litres per minute and square metre.

The water supply needed for the area of a room requiring protection (or for an object or a division into groups for the areas of the groups or objects) has to be available, depending on the fire risk, for between 5 minutes

Table 2. Example of analyses of RDF[4]

Average or mean value	Grain size as median value (50% finer, 50% larger), μm	Average lower explosion limit, g/m³	Average explosion/ ignition temperature, ˚C	Average glowing temperature settled dust, ˚C
1. Wood dust of 10 different material numbers	75.4	65.56	498.75	321.25
2. Plastics/paper from 28 different material numbers	101.36	58.39	479	No glowing but paper melting at 300 ˚C
3. Average from 1 + 2	88.38	61.98	488.88	-

(e.g. in the case of a fire of a current transformer) and 60 minutes (in the case of cooling, even longer periods of time might become necessary).

Alarm system/early warning system

When designing the storage hall, early warning systems, as well as appropriate and rapid extinguishing facilities, have to be given the greatest of attention in order to keep the structure, neighbouring installations and the environment intact. With this early detection planning, and by providing extinguishing facilities for a fire in its earliest stage, the release of emissions can also be avoided.

Early detection with infrared camera

The storage area for alternative fuels, such as wood chips, as well as the feed hopper in the storage area, have to be monitored by a thermographic system. This thermographic system consists of an infrared camera with software to evaluate the images captured. The coloured monitor should be installed in the central control room. This system can locate selective rises in temperature and alarm thresholds can be programmed with the processor that sends acoustic and optical signals to the control room staff. Another method of detecting fires is with a CO monitoring or thermometer system.

Extinguisher and fire detector

Depending on the fire risk and the size of the storage building, an appropriate quantity of extinguishers has to be provided. If the extinguishers are not clearly mounted or placed where they can be seen, their location must be marked by a red F in a square white box with a red frame. A sufficient number of extinguishers also has to be present in the entrance areas. Their exact position is determined together with the fire authority.

Fire detectors, such as ionisation smoke detectors, are not suitable or appropriate as early warning instruments in the planned storage hall as the distance of the detector from the material is too great and the detector would not identify danger until too late. Furthermore, there is a risk that whilst using fire detection systems a false alarm could be activated due to a temporary, non-explosive generation of dust.

Explosion protection in secondary fuel storage facilities

The risk assessment for explosion verification must contain a survey and an evaluation covering:

- The plants, the substances used and the processes.
- The probability of the existence of an explosive atmosphere (zone classification).
- The probability of equipment and electrostatic discharge being able to react as an ignition source.
- The expected extent of the consequences.
- Steps taken or to be observed on the basis of the above mentioned aspects.

If necessary, the following administrative steps are to be taken:

- Classification of the explosive areas.
- Marking of the explosive areas.
- Instruction, education and qualification of the employees.
- Instructions in writing.
- Special permissions to hot work (ignition sources).
- Procedure for cleaning, inspection, repair and maintenance.
- Coordination (including visiting workers).
- Emergency, evacuation and exercise plans.
- Control prior to startup.

In order to evaluate the risk of self-ignition or the development of an explosive air mixture, the alternative fuels need to be analysed accordingly. Specialist companies that have a dust explosion test laboratory at their disposal must perform this evaluation. Samples need to be tested for:

- Determination of the minimum ignition energy of dust cloud (MIE).
- Explosion pressure development (P_{max}).
- Maximum rate of pressure rise $(dp/dt)_{max}$ in a 1 m^3 vessel for the "Kst value".
- Minimum ignition temperature of dust deposits (self-ignition).[1]

Table 2 provides data for the risk evaluation of some alternative fuels.

Irrespective of which storage technology is chosen, close attention must be paid to fire and explosion protection. Last but not least, special arrangements need to be made for insurance reasons. The authorities and the area surrounding the fuel storage site require detailed impact assessments.

References

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