Reception and Storage of Refused Derived Fuels

Dirk Lechtenberg, MVW Lechtenberg, Germany, describes the basic requirements and available technologies for the receipt and storage of refuse derived fuels (RDF).

When using refuse derived fuels (RDF) in a cement or lime plant, a new reception and storage system usually has to be built.

Truck reception

Widely varying reception systems are used for alternative fuels arriving at cement or lime plants via Walking Floor or tipper trucks. These systems include deep bunkers, flat bunkers and unloader conveyers, all with differing discharge systems. For short-term test application, mobile unloading stations (docking stations) are also used.

The truck unloading capacity should be very rapid, irrespective of the storage and volumes in use, with a maximum of 30 – 45 min unloading time per truck. Truck unloading times are heavily influenced by the conveying capacities of the downstream conveying units (for example, discharge belts). When unloading into deep bunkers, unloading times depend on the unloading procedure of the tipper or Walking Floor truck. As a result, more rapid unloading is possible.

Such unloading systems, well known in the raw material or coal sector, often have a maximum unloading capacity of two trucks, which is equivalent to 200 m^3/h. The advantage is erection on even ground, with a need for foundation work. When erecting unloading conveyors, an enclosed building is often dispensed with. As a result, considerable soiling of the surroundings by loose alternative fuels should be anticipated. A matched unloading height must also be configured, otherwise unloading of large containers is frequently problematic.

Choosing a flexible truck reception method is important. Vehicle heights of 6 m must be expected with container vehicles, whilst this figure can reach 12 m with tipping-trailers. For this reason, the initial cost advantage of such 'on the ground' unloading systems attracts further building measures (enclosed delivery) and subsequently higher investment in the long-term.

Several companies offer a further unloading system. This concept means the vehicles are unloaded on even ground in a kind of unloading bay. An open chain conveyor, which is mounted on wires, lowers itself over the material and conveys it into a storage bunker. Assuming such structures are possible, unloading in deep bunkers has significant advantages for a rapid unloading procedure and subsequently for the handling of larger volumes of alternative fuels. Especially with enclosed systems, where

Table 1. Storage capacity dependent on alternative fuel consumption		
Calculation of fuel storage volume (recommendations)		
Substitution volume	Storage volume	
(tph)	(t)	(m^3)
3	200	600
5	360	1200
10	720	2400
(Source: MVW Lechtenberg)		

trucks are unloaded in an enclosed hall equipped with dedusting systems, the latter protect against dust emissions and possible contamination of the environs. The deep bunkers can be conceived so that they are only used for truck unloading or linked directly to a bunker storage. In the deep bunker screw conveyors, walking floors, scraper chain conveyors or a hall crane take care of onward conveying.

Sampling can be performed by truck drivers during unloading without being exposed to the elements.

The disadvantage of the deep bunker without a crane is that, when unloading, unsuitable alternative fuels or contaminated materials (e.g. foreign matter that was still on the truck, such as truck floorboards, wood and sticks) would have to be painstakingly removed from the deep bunker. This leads to considerable downtime and, as a result, higher costs. However, this can also happen with all other unloading systems if no visual monitoring is performed by the loader or producer of the alternative fuels.

Mobile unloading stations are often used to receive and dose alternative fuels on a test basis. The advantage of this technology is comparatively economic and quick erection while also benefiting from a compact, enclosed construction method. In many plants using small substitution volumes, long-term utilisation is possible, especially if two of these docking stations are coupled together in order that a continuous operating method is guaranteed. The downside is that the low storage capacity is limited by the truck's own load capacity as well as by the required 'just in time' delivery.

The docking stations consist of unloading hopper, which is coupled directly to a walking floor trailer. The trailer's walking floor is driven via an hydraulic unit and fills the unloading hopper automatically, controlled via a filling level indicator unit. The alternative fuel is fed to the weighing system from the unloading hopper by means of a trough chain or screw conveyor, which volumetrically or gravimetrically prepares the exact dosed amount of alternative fuels for the onward, largely pneumatic transport.

Some of these systems are equipped with automatic volume measurement and indicator systems so that logistics companies are automatically informed about the filling level status and thus the necessary change of trailer.

Suppliers of such systems are, among others, Di Matteo Fördertechnik and Schenck Process. These simple 'starter' systems have proven themselves many times and can sometimes be rented long-term from the suppliers for trial purposes. The disadvantage is the open configuration, which means that one should anticipate fuels flying around during bad weather. Furthermore, direct sampling during unloading is particularly difficult as it is only possible from above in the truck. This type of sampling, however, leads to false test results. As a result of dehomogenised alternative fuels during transport, the light, mainly (high in calorific value) film constituents lay on top and the heavier or wet constituents congregate below on the vehicle itself.

Certain alternative fuels, such as animal meal, can be delivered in bulk tankers and be pneumatically conveyed into a storage silo. Care must be taken to use cooled conveying air, otherwise the fat contained in the animal meal liquifies, leading to adhesions and clogging.

Storage of alternative fuels

In spite of the economic trend not to maintain large stored volumes and to switch storage to 'on the road' or to the producers and suppliers, it will not be possible to manage without storage of alternative fuels, irrespective of their type.

Basic requirements

One of the basic storage requirements for alternative fuels is to calculate the necessary storage volume. In the case of waste derived secondary fuels, a bulk weight of approximately 250 – 300 kg/m^3 should be used as a basis for calculations. The decisive factor is the bridging period for storage. Again, this period depends on the method of delivery and distance to the supplier. This necessary gap-bridging period needs to be accommodated in case of unplanned kiln stoppages in order to be in a position to receive vehicles that are already en route and to offer intermediate storage for such materials.

Substitution volumes are also a critical aspect. Generally, a storage volume should be selected that can bridge the gap for at least two working days' requirements. This also has an effect on quality assurance as the alternative fuel volumes accepted on the previous day may still need to be analysed and cannot yet be released for consumption. Furthermore, a larger storage volume should be selected to bridge the gap on weekends, national holidays and on days when deliveries are not possible. In order to perform blending and homogenisation of the approved fuel volumes it is also important to check how regularly deliveries by different alternative fuel suppliers take place.

Homogenisation

Often cement and lime plants receive alternative fuels of various quality parameters or in various forms or methods of delivery. Receiving alternative fuels from different suppliers is also possible. One should strive to keep these various materials separate, until suitability has been confirmed by means of organoleptic, visual or analytical evaluation. After clearance has been given for usage, homogenisation should take place. This homogenisation is required in most cases to achieve, for example, consistent calorific or other combustion and product characteristics.

The rule 'first in, first out' must be adhered to. This is critical for safety and fire protection reasons in order to avoid possible self-ignition of long-term stored alternative fuels.

If contents include contaminants (like stones and metals) that are not ascertained on delivery, the 'first in, first out' technology is advantageous for quality assurance reasons, as otherwise the cause or supplier can no longer be identified.

The climatic conditions of alternative fuel storage should also be considered. For example, the moisture content of fluffy RDF is problematic during winter storage. During longer stoppages, alternative fuels stored in unheated silos or storage halls can turn into frozen blocks.

For the removal and refeeding of off-specification batches that do not satisfy quality criteria, the appropriate mechanism should be available to manage the situation. Alternative fuels must also be protected from vermin (rats and insects) for contagion-prevention measures.

Apart from the investment costs, fixed costs for operation and maintenance must be calculated and taken into account when deciding to invest. What appears to be an attractive offer often turns out to be considerably more expensive in the long run.

In addition, the product characteristics of alternative fuels must be taken into account when designing storage capacities and characteristics. The product characteristics, particularly relating to safety and storage designation, must be checked in the greatest of detail. These product characteristics are detailed individually in the fact sheets of the various alternative fuels.

Storage depths, such as material densities of waste derived alternative fuels, should not exceed 4 – 5 m, as a danger of excessive compaction and agglomeration of the material exists. Finally, for fire protection reasons, a greater storage depth should not be reached as the danger of self-ignition increases. Product characteristics are also negatively influenced by compaction. Short-term storage with greater storage depths, such as in a silo, is feasible, but this is always accompanied by the risk of longer storage and subsequent compaction periods through unplanned stoppages.

Generally, alternative fuels should be stored dry. Firstly, because product quality should not be reduced through additional moisture, and secondly because moisture contained in organic products can lead to decomposition processes (composting and aerobic or anaerobic fermentation) with dangerous decomposition products (methane gases).

In order to evaluate the risk of self-ignition or development of an explosive air mixture, the alternative fuels need to be analysed.

The risk assessment of the explosion measurements must contain a survey and an evaluation, including the following elements:

- The plants, the substances used and the processes.
- The probability of the existence of an explosive atmosphere and the duration (zone classification).
- The probability of equipment and electrostatic discharge being able to react as an ignition source.
- The expected extent of the consequences.

Figure 1. Unloading station with vehicle steering device. Manufacturer: Schenck Process Group T/A Redler, UK. ***(Source: MVW Lechtenberg).***

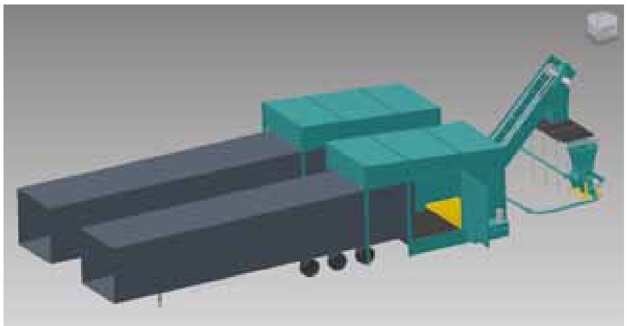

Figure 2. Double mobile docking station for walking floor trucks. Manufacturer: Di Matteo Fördertechnik. ***(Source: Di Matteo Fördertechnik).***

- Steps taken or to be observed on the basis of the factors mentioned above.

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

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

Each storage facility should be easily accessible for maintenance and repair work. Suppliers should be notified

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of planned shutdowns, during which no alternative fuels can be used in plenty of time so that no storage of contents needs to be maintained during the routine work.

For the storage size, it is the storage volume that is looked upon as it must be sufficient for maximum three-days' requirement.

For storage, various technologies are available:

- Storage in the form of bulk material in an enclosed hall (further conveying and feeding by means of wheel-loaders).
- Storage in one or more silos.
- Storage in the walking floor system.
- Storage in a deep bunker with discharge systems.
- Storage in bunker systems (standing on the floor) with belt or chain discharge systems.
- Storage in a bunker with crane discharge.
- Storage in special storage boxes.

Storage as bulk material in an enclosed facility

The simplest and most common storage system is open storage of alternative fuels in a hall. The alternative fuels delivered by truck are tipped into separated sections in an enclosed hall. Quality control can be performed here. If necessary the accepted materials can then be homogenised using a wheel-loader. This is sensible if the alternative fuels are procured from different suppliers. The alternative fuels are subsequently loaded into a feed hopper assisted by a wheel-loader.

The low investment required for such fuel storage is a definite advantage. Also, it is possible to keep various materials separate. On the other hand, disadvantageous effects are:

- Workplace protection: During unloading of alternative fuels as well as of further loading and homogenisation by means of wheel-loader, significant dust pollution can be expected. The wheel-loader must be equipped with an appropriate air filter unit complying with local regulations in order to protect the loader driver from excessive dust exposure.
- Fire and explosion protection: Significant dust pollution can lead to considerable risk of fire and explosion. Dust build-up on the loader (exhaust, motor) can self-ignite.
- Homogenisation: Alternative fuels in various qualities or from different suppliers cannot be homogenised adequately with a wheel-loader.
- Costs: Operational costs for this type of bulk storage of alternative fuels only consist of wheel-loader and driver costs. It must be taken into account that homogenisation and dosing of up to 10 tph is possible. As the installation must be operated around the clock, workforce downtime must be taken into consideration.

Storage in one or several silos

Traditional and proven storage in the cement and lime sector is also state-of-the-art for alternative fuels. Free-flowing bulk materials such as olive kernels, grain, meat and bone meal, sunflower shells and dried sewage sludge are routinely stored in silos.

Existing silos that are no longer required are frequently converted (for example raw meal, clinker and coal). This is open to criticism, as heavier-duty demands are frequently placed upon the extraction system as well as upon the fire and explosion protection system.

This conversion is also problematic owing to guarantee obligations. Indeed, which supplier would assume responsibility for guarantees on an existing complete silo installation if only small parts, such as the extraction system, are supplied? The silo cross-section in existing silos is often too modestly proportioned at the material outlet and can lead to bridge-formations of the stored alternative fuels. Silos with flat bottoms and circulating unloading screws have also proven themselves for fluffy RDF.

The discharge behaviour of alternative fuels in conjunction with moisture and particle size is often problematic, e.g. bridge formation as well as freezing in

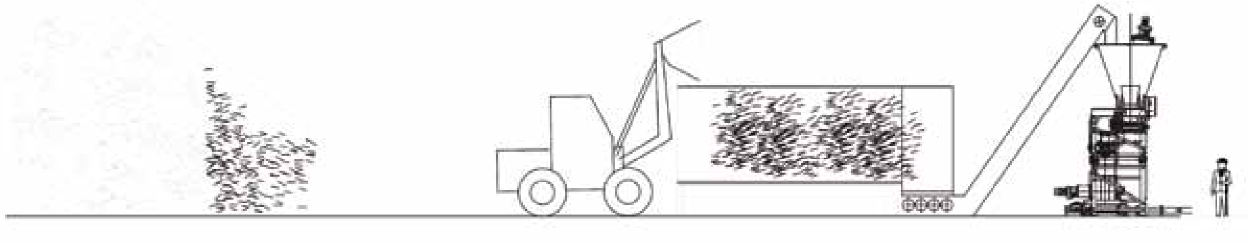

Figure 3. Open storage and wheel-loader feeding. ***(Source: FLSmidth Pfister GmbH, Germany).***

winter. Particle size specification for alternative fuels is also of significance with regard to storage properties. Long threads and magnetic strips often wind themselves tightly around discharge systems and lead to stoppages.

The advantages of silos are:

- Compact, enclosed structure (clean storage).
- Even large fuel volumes can be stored dry and safely.
- Simple fire protection and monitoring (CO monitoring).
- Easy to convert for explosion protection.
- Homogenisation of fuels possible from various silos.
- 'First in, first out' principle.
- Longevity.

Still, there are disadvantages:

- High investment costs for large silos.
- Risk of compaction if stoppages occur.
- Agglomeration in higher silos in conjunction with longer storage periods.
- Corrosion.
- Freezing of moist alternative fuels.
- Evaporation/thawing point.

What is important when dealing with silos is the exact compliance with alternative fuel specifications. Foreign matter, such as long fibres and stones, as well as higher water contents, can particularly lead to problems in silos. Flat-bottomed silos with circulating screw unloading are the recommended discharge method. Too narrow cross-sections on the discharge system can lead to undesired bridge formations. Furthermore, the silos must be furnished with appropriate explosion and protection devices.

Walking floor storage

In addition to the already described reception technology for alternative fuels by means of mobile walking floor docking stations, walking floors are employed more frequently for alternative fuels as high-capacity storage. Walking floor installations are now available in dimensions of up to 6 m wide x 40 m in length whereby a storage volume of up to 1200 m³ per walking floor is achievable at a recommended storage height of no more than 4 – 5 m. The compact construction method permits erection on even ground without any significant structural measures. The open construction method also facilitates access by means of wheel-loader or crane in order to remove out of specification deliveries.

Often, such moving floor systems are offered as a combination, for example, as an unloading bunker and simultaneous storage bunker, reducing the proportion of required mechanisation and lowering costs. From the moving floors the material is conveyed to a discharge belt or chain conveyor/screw conveyor. A counter-rotating roller at the walking floor's discharge makes even unloading possible.

Advantages of the moving floor storage technology:

- Medium investment costs compared to other storage systems.
- Larger storage volume possible.
- Modular construction method, extendable as required.
- Open construction method (maintenance, removal of out of specification loads).

Figure 4. Mobile docking station and walking floor truck. Manufacturer: Schenck Process GmbH, Germany). ***(Source: MVW Lechtenberg)***.

- Fire and explosion protection that is simple to implement.
- Simple maintenance.
- Longevity.

Disadvantages of using the moving floor – as long as the discharge system is correctly conceived and the fuel complies with the specifications – are not known so far.

Storage in a deep bunker with discharge systems

As a rule these systems feature an enlarged reception bunker. The trucks unload directly into a deep bunker that has a volume of approximately 1 – 3 truck loads (100 – 300 m³). This is adequate for low substitution rates.

The discharge from the bunker takes place via screws or other discharge systems such as chain conveyors, which must be robustly constructed.

The susceptibility to disruption of such bunkers is clearly a decisive factor if out-of-specification loads or foreign matter are unloaded into the bunker and need to be painstakingly removed by hand. Unloading on screw systems is problematic as, depending on the method of construction, the entire weight of the alternative fuels falls with its full might onto the screws from a height of several metres. Under some circumstances this ongoing stress can lead to damage. Disruptive materials (such as wooden balken, truck planks and similar objects), which reach the deep bunker owing to lack of monitoring prior to truck loading, lead to immediate screw damage. As long as the RDF comply with specifications, this does not need to happen. Nevertheless, while dealing with waste and fuels, human actions and as a result, human errors, have to be anticipated.

Due to these issues, only such deep bunker combinations (reception and discharge) are considered as appropriate if a device for extraction of disruptive materials is fitted or if the materials are not directly unloaded onto screw conveyor systems.

Combinations of deep bunkers with walking floor discharge systems have proven themselves many times over. Apart from deep bunkers with discharge systems (such as walking floor, screws or robust chain conveyor systems) floor mounted flat bunkers with the above mentioned discharge

Figure 5. Unloading zone in the bunker and halls with automatic cranes. Manufacturer: ATS Group Water Materials Handling. ***(Source: MVW Lechtenberg).***

Figure 6. RDF storage system. Manufacturer: Vecoplan. ***(Source: MVW Lechtenberg).***

systems have also proven themselves. However, with the latter only a modest storage volume is possible owing to the limited depth available (approximately 100 – 300 m^3).

Storage in a bunker with crane unloading

Crane and bunker systems have proven themselves many times in the cement and lime industry for all types of raw materials, fuels and additives. In the sphere of alternative fuels, especially waste-derived fuels, bunker systems have proven themselves many times over in combination with loading and unloading cranes. High investment costs are the disadvantage which, on closer inspection, actually prove to be acceptable. Such bunker systems, whose costs mainly comprise the tax deductable outlay for long-term hall and bunker construction, have a long lifespan and the fixed running costs are relatively low.

As a rule bunker systems with unloading cranes are installed deep in the ground or are adapted to the geographic average ground slope. Trucks unload directly into the enclosed deep bunkers. A crane extracts the delivered material from the unloading area and blends it with the alternative fuels located in the bunker. In a further step the fuels are fed to a receiving bunker (generally with a walking floor or in a screw bunker).

The advantages of the bunker system with crane unloading are manyfold:

- Aeration of the hall is easy to achieve (low dust pollution).
- 'First in, first out' is easy to achieve.
- Fully-automatic control and homogenisation of alternative fuels.
- Large storage volume possible.
- Fire detection devices possible (CO and temperature).
- No odour nuisance.
- Various alternative fuels can be stored separately or homogenized.
- Crane maintenance work can be easily performed without disrupting alternative fuel dosing (as long as the receival bunker is adequately sized).

As mentioned, the high investment costs are a disadvantage. Various crane manufacturers (such as Demag, Danish Cranes and Kone) have developed fully-automatic crane systems that permit exact blending of materials as well as storage.

If larger volumes of alternative fuels are to be used, such deep bunkers with the crane system are always the right choice. As the crane cables and hydraulics need regular maintenance, it is important that a maintenance area for the crane can be installed. Using oversized guide and hoisting ropes, as they are subjected to considerable stress by their continuous employment, is strongly recommended. From various projects with large RDF substitution volumes, operational costs of around €0.3/t RDF have been observed (based on German wage and energy costs).

Storage in special storage boxes

Meanwhile, storage technology has evolved from the wood sector and is also frequently offered for storage of RDF. Indeed, often it is already in use. The basic principle is simple and, according to producers, this system offers the option of mixing different fuel types. It is a modular system where material delivered by truck is conveyed mechanically to a bunker system via a trough chain conveyor.

Trough chain conveyors feature various lockable apertures from which fuel is conveyed into the bunker. In this manner separation of the fuels is possible. In these simple systems fuel is conveyed through the open scraper chain conveyors, which subsequently scrape the material out of the bunkers.

Advantages of this box technology include:

- Low investment costs with wood construction method (but disadvantages regarding fire protection).
- Reception and blending of various alternative fuels.

- Large storage volume with adequate number of boxes.
- If the storage volume per box is limited to one truck load the 'first in, first out' principle is possible.
- Rapid unloading and conveying is possible.

These storage systems are available in a wide variety of sizes. Also, storage heights of up to 15 m and lengths of up to 30 m are offered. This would correspond to a storage volume of up to 2000 m^3 per bunker at the maximum available conveying width of 4.5 m. It is highly advisable to avoid storage of fluffy RDF at a material depth of up to 15 m owing to both fire protection and material compaction reasons.

Possible disadvantages of this storage system are:

- Maximum storage height is often exceeded.
- Fire protection is problematic with wood construction method.
- High construction costs when employing concrete construction method.
- Maintenance of the open discharge systems generally only possible when bunkers are empty.
- Moving parts (chains, conveyors) in the material lead to high levels of impurity and wear.
- Hanging systems (wires) are individually hung – maintenance is more problematic.
- High compaction when using too great material thicknesses (construction method only recommended to 5 m).
- Bunker clearing often problematic if no loading vehicles can be driven into the boxes.

Employing such systems makes sense when handling smaller conveying volumes. However, the construction costs are frequently very high when using the concrete construction method. The expected lifespan while operating continuously with RDF is yet to be determined.

Whichever storage system is used, it is critical to adhere to both the basic requirements, such as the possible inherent characteristics relating to the type and procurement of the alternative fuels, as well as to the health and safety, environmental and pertinent safety conditions and the legal requirements. Often, owing to the characteristics of these alternative fuel products, greater demands are placed upon the storage and conveying technology than is the case for uniform raw materials and fossil fuels. This should be taken into account when designing the overall storage technology. It can also be assumed that desired higher substitution rates can only be achieved with reliable technology.

Notes

This article is an abridged excerpt from LECHTENBERG, D. (ed), *Alternative Fuels and Raw Materials Handbook for the Cement and Lime Industry* (2011).