DESIGN OF A UK PORT FACILITY FOR IMPORT OF WOOD PELLETS FOR POWER PLANT USE.

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ABSTRACT: Ramboll has for a UK client been engaged as special adviser in the design and development process of a biomass import terminal at the Port of Immingham with a throughput capacity of between 3 and 6 million tonnes of wood pellet per year.

Ramboll have been involved in the consideration and examination of possible solutions in particular with respect to Fire and Explosion risk assessments and mitigations of the wood pellet unloading, handling, storage and rail on-loading facilities.

Ramboll has further advised with regard to dust control, ATEX / DSEAR and facilitated the HAZID and HAZOP processes and the development of the Functional design specification, P&IDs and CE-marking.

The Import terminal is currently under construction and is expected to be commissioned in two stages during the spring and autumn of 2014.

Keywords: Biomass, wood pellet, transport, storage, logistics, supply chain.

1 INTRODUCTION

There is currently a major move in the direction of existing coal fired power plants substituting their fuel with biomass, being subject to Bioconversion. This turns out to be a very rapid and cost effective way of introducing biomass into the production of electric power and hence reduce the CO_2 emission.

Currently the most popular biomass fuel to be used for larger power plants is wood pellets. There are several reasons for this:

1. It is possible to procure fuel from a worldwide sourcing market
2. The energy density is so high that transportation costs are not prohibitive
3. The technology has been proved to work on large plants over a reasonable long time span.

Though the pellets are stable it is recognised that one should be relatively careful during the entire transportation path from the pelletizing plant until the power plant where they are to be used. Under various conditions the pellets may self-ignite and the dust generated from the handling processes is prone to be explosive.

In particular some of the power plants being or to be Bioconverted are located inland and are dependent on carefulness throughout the whole logistic chain: sea carrier, ports and rail carriers. Due to the characteristics of wood pellet all chains will most likely have to update their installations in order to be able to handle the pellets in a safe manner.

The amounts of wood pellets to be used in power plants calls for several ships to be unloaded per week. Also, this results in a number (10 to 12) trains per day to be loaded and sent to the power plant. Therefore, an intermediate storage of suitable size is required to make the unloading-loading operation run smoothly. Due to the characteristics of the wood pellets (to be kept dry and exhibits a fire/explosion issue), the facilities for the whole installation must be designed with the utmost care. It is also a consideration that the facility must be in operation 24 hours per day round all year round to ensure a stable fuel supply of the power plant.

This paper introduces some of the important issues considered when designing the new biomass import terminal at the Port of Immingham, the Immingham Renewable Fuels Terminal – IRFT, will be capable of handling between 3 to 6 Million tonnes of wood pellets per year.

This paper has a main focus on risk and safety issues related to the design of the terminal. There are of cause also other issues involved in the design, energy usage, economy, O&M, operability and flexibility. The safety issues are primarily concerning personal safety, loss of operability (continued operation), loss of equipment, and loss of material (wood pellets) – in that order.

2 CRITERIA

DRAX, a major nearby coal fired power plant (6 units of 660 MW electricity corresponding to approximately 10 GW thermal input) is Bioconverting three of its units into wood pellets firing. The IRFT terminal will support this planned Bioconversion. The power station is located some 80 km from the Port of Immingham so the pellets are to be transported by rail from the port.

The pellets to be burned at the power station are procured on the world market and shipped in. Thus the port must have facilities for unloading relatively large ships (from 25000 dwt to 75000 dwt Panamax). The port must have facilities for intermediate (short term) storage of the biomass and for loading the pellets to trains. The capacity of the terminal storage is 100.000 tonnes but with provisions for future updates. It is to be noticed that the size of the store is important for the total throughput of the terminal due to the operational differences of the unloading/loading characteristics of the incoming and outgoing vessels/trains.

Initially, the capacity of the IRFT terminal was set to 3 Million tonnes pr annum of wood pellets. Approximately, this corresponds to 10 daily full load trains consisting of 23 wagons each holding 115 m^3 of pellets.

An aerial overview of the terminal can be seen in Figure 1.

A vessel is seen in the upper right corner of the figure and the red line across is the conveyor for transporting the biomass from the vessel, through the store (the four circles) to the rail load out station at the lower left corner of the picture.

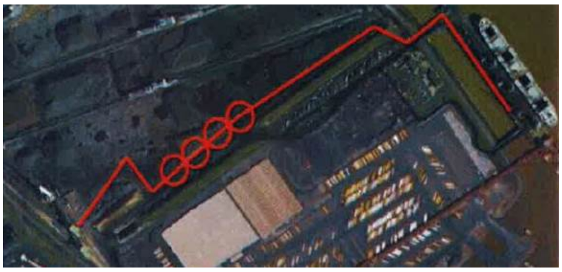

Figure 1. Biomass import terminal at the Port of Immingham from above.

The harbor facility was readily available as was an access to the rail infrastructure beyond the ports boundary. Almost anything in between from vessel unloader, conveying systems, stores, and rail load out facilities constitutes the four key design elements of this project.

Since wood pellet is a fuel and as such can burn and in particular the dust generated by handling the pellets can be easily ignited with a fire or even an explosion hazard as a consequence, it has been very important during the project to assess all kinds of risks involved when operating the facility. The involvement of Ramboll in the project was initially primarily to provide a fire safety strategy and a preliminary hazardous area classification. At a later stage this has been extended to general risk evaluation and management and to ensure compliance with ATEX guidance and fire regulations.

2.1 Client Criteria

The IRFT terminal will be designed to handle a throughput of 3 Million tons per annum of wood pellet and other pelletized biomass. The facility will unload the pellets from vessels, transport it via conveyor systems to storage facilities and reclaim the biomass pellets from the storage facilities for onward transportation via a rail load-out facility. As an operational option, the off-loading and conveying system are also designed to handle coal.

The two Continuous Ship Un-loaders (CSU's) are capable of discharging biomass pellets from vessel to conveyor and or road transport. Vessel capacities range from 25000 dwt to 75,000 dwt Panamax or new Woodchip Carriers.

The rated capacity for the CSU is 1,200 tph, giving a combined maximum throughput of 2,400 tph. The conveying system between the CSU and the Storage facilities is rated to the combined maximum CSU throughput.

The Storage Facility consists of four circular storage silos each having a capacity of 25,000 tonnes at a bulk material density of 0.6 tons/m^3 giving a total Terminal Storage capacity of 100.000 tonnes.

Downstream of the Storage Facility there are Lorry Load-in and Rail Load-out facilities. The Lorry Load-in facility is designed to receive imported biomass pellets from road vehicles (BuIk tippers) and convey them through to the Rail Load out silo. This system is designed to handle approximately 800 tph.

The Rail Load-Out system consists of a silo providing storage equivalent to one full train load of material. The Facility is required to receive trains of maximum length approximately 500 meters (24 wagons + locomotive), with a wagon volume of 115 m^3 and capable of a payload of circa 1600 tonnes per train. The Rail Load-out facility is located to provide a train length to pass through from East to West and be continuously loaded at a traveling train speed of 1 km/h. The facility is designed to weigh, load and tare weigh the trains within the duration of 90 minutes.

Auxiliary terminal features include:

- Product sampling
- Weighing
- Tramp metal detection and removal
- Vacuum cleaning facilities throughout
- Dust extraction and containment systems
- Transfer point Spark detection and suppression systems
- Conveyor Fire detection and suppression systems
- Conveyor Condition monitoring systems
- Storage Facility fire and explosion protection and suppression systems
- Gas detection, Thermal Imaging and Temperature systems within the storage facility.

There is an option IRFT2 for a further increase of the size of the terminal storage volume from 100,000 tonnes to 200,000 tonnes.

2.2 Legal requirements

It is essential that the whole of the terminal conforms to all relevant norms and legal requirements. Further to this it should be noticed that using Best Available Technology (BAT) to a large extent one could obtain an even better (and safer) performance of the system(s).

The terminal and all sub-systems are assessed for compliance to all relevant Directives as a part of the CE marking.

3 ORGANIZATION

The EPC contractor for the construction of the terminal is GRAHAM Construction Ltd.

They are being supported in the design, supply, construction, and commissioning by the following main subcontractors:

- HBPW – Consulting Engineers for all civil and structural design,
- Whitwick Engineering for the design and supply of conveyors, transfer towers, rail load-out facility, and road load-out and load-in facilities
- Cargotec for the design of the CSUs including all systems and explosion relief systems within the CSU's
- Lectec for all electrical installations and deluge systems
- Firefly for spark detection equipment
- Stuvex for explosion relief panels
- Fike for fire isolation systems
- Ramboll as special advisor, see below

Ramboll was signed to undertake a Fire Safety Strategy based on state of the art knowledge on similar installations and an overall review of design proposals to ensure compliance with required standards, legal requirements, ATEX guidance and fire regulations, CE regulations etc.

4 APPROACH

Due to the size of the project, the risks involved, the possible consequences on staff, economically, and image-wise of eventual accidents a very thorough risk assessment and a risk management analysis has been performed together with all involved stakeholders. In particular the involvement of all parties including the future operating staff has been a key issue.

Of all, it is better to predict and prevent that an incident happens. Thus considerable effort has been invested in avoiding risks.

To mention a few: As stated dust is a serious source of risk for an explosion - thus to avoid the formation of dust during the mechanical handling of the pellets it is important and proper design throughout the handling process and in particularly transfer points are required. Similarly, the removal of the by-the-fact generated dust before it settles is important and a proper design of dust removal measures was required. In the design of more passive installation such as structural steel structures also horizontal surfaces that allow dust to deposit needs to be avoided where and when possible.

Further, serious considerations have been invested into ensuring that in case an incidence occurs it is rapidly detected and that the consequences can be mitigated throughout the whole series of events that may be the result of the first incidence.

To ensure un-interrupted operation of the terminal under all circumstances various strategies for continued operation have been evaluated in the event of various in-cidences.

4.1 Risk management

The project has been executed with a risk based design approach based on structured risk identification processes and semi-quantitative risk assessments throughout all engineering disciplines and project phases. Continuous Risk management and follow up has been done concurrent with the risk assessments and the engineering of the terminal.

Risk Assessments have been conducted with contribution from all relevant parties including contractors, engineers, experts within biomass handling, ATEX/DSEAR experts, end customer as well as end operator staff.

Risk assessments have been conducted in a structured way, starting with evaluation of the conceptual design followed up by very detailed risk assessments of the proposed detailed design. The risk identification processes has used both What If analysis as well as HAZOP studies.

Safety Integrity Level (SIL) requirements of protection functions based on electric and electronic equipment has been assessed with Layer Of Protection Analysis. SIL assessments resulted in a maximum requirement of SIL 2 for the Instrumented Safety System.

The risk assessments have been conducted with reference to a Risk Acceptance Matrix (RAM) giving tolerable and non-tolerable values for risk levels in the system. All risks have been mitigated to a risk level that is acceptable or justified as As Low As Reasonably Practicable (ALARP).

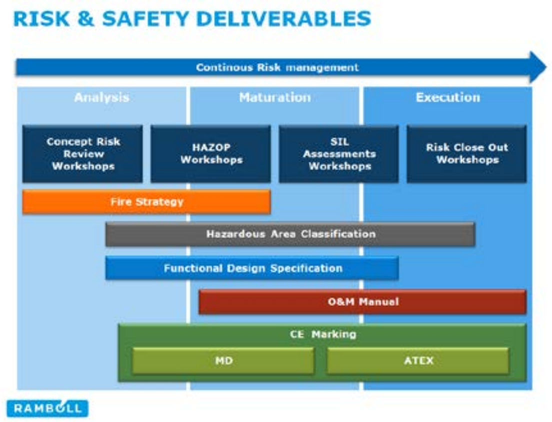

Figure 2. Ramboll main deliverables to management of risk and safety on the plant.

4.2 Fire and explosion management

The nature of the risks when handling wood pellets combined with the experiences from hazards occurred in the industry calls for special focus on mitigation of the fire and explosion risks. The strategy for managing these risks comprises a 360° approach of mitigation activities, including, Hazardous Area Classification, extensive cleaning requirements, prevention of ignition sources, automatic and semi-automatic fire detection and extinguishing systems, explosion venting, explosion suppression and automatic fast reacting explosion segregation systems.

The IRFT project has been a significant step up in both quality management and technical solutions compared to previous wood pellets facilities, which is a direct consequence of an increase in the number of incidents and hazards on similar plants seen over the last number of years.

4.3 Fire strategy

Much effort has been put into developing a fire strategy in order to define the overlying requirements and strategies regarding fire, explosion, fire spreading, ATEX, escape ways etc. The fire strategy has been presented to the local fire authorities and accepted by all stakeholders.

The terminal has been designed and erected to comply with the requirements of the fire strategy.

5 DESIGN FEATURES

As the terminal is vital for the steady and reliable supply of fuel to DRAX it is extremely important that it is fully operational at all times. On the other hand, when dealing with wood pellets as a fuel it is an expensively learned lesson that it can burn and eventually will burn also under unwanted circumstances. It is therefore necessary to prepare for the worst.

Wood pellets will inevitably produce some dust when they break up during a mechanical treatment like the one they are exposed to during ship unloading, transfer from one conveyor belt to another, loading into silos, unloading from silos and loading into trains. Dust in a gas mixture can be a source for an explosion when ignited or a dust layer settled on surfaces can fuel a fire initiated hot parts (rollers, bearings, welding slags etc.).

It is also an experience that within a compact layer of wood pellets a smoldering fire can emerge due to either the heat generated from a biological or thermal degradation of the pellets. For either of these, the humidity of the pellets is so important that any sort of wetting at any time should be avoided. Since wood is an excellent insulation material, a smoldering fire can remain undetected for days or weeks within a large store of wood pellets. During that time the nest of glowing material will slowly develop and tend to move upwards in the store. The development is limited by slow oxygen diffusion into the fire. When it eventually reaches the top of the store a fire will break out with serious consequences or the fire will break out when the material is emptied out through the bottom of the store.

With the above in mind, the fire safety strategy is based on the following principles:

- Do anything possible to avoid both a fire and/or an explosion to start at all
- Equip the facility with detectors to be alarmed in good time in case a fire is on its way and be able to monitor important parameters during the whole cause of the event
- Make sure that in case of an explosion the risk of damages to staff and construction is as limited as possible. Typically, an explosion will result in a fire to follow.
- In case a fire breaks out it is important to have installations that can effectively mitigate the fire with the least possible damages to staff, structures and other values.
- Design the construction to avoid fire and explosion propagation best possible.
- Also consider various options in the design such that the facility can maintain operability despite parts of it have been subject to an accident.

Though the above statements seem simple it takes serious expertise and experience to transform these principles into practical design of both the facility and its operational procedures. In particular the operational procedures are as important as the construction itself since carelessness will overrule any good intentions put into the design.

5.1 Dust control and other precautions

The below Figure 3 shows from another installation how dust can be a problem. In case the roller bearings get stuck (to some extent) the conveyor belt and the roller will heat up due to friction and when the belt is stopped the hot roller may ignite the belt and the pile of dust located next to it. The consequences following may turn out to be fatal.

Figure 3. Dust formation near a conveyor belt (from another installation).

Another similar example is shown in Figure 4, also from another installation. For many hours of operation the layer of dust will do no harm, but in case the equipment develops some additional heat, the dust layer could be the initial cause of a major accident.

Figure 4. A layer of dust on a piece of equipment

Since it is impossible to completely avoid the formation of dust during the mechanical handling of the wood pellets in the system other measures are considered in order to avoid the possible consequences of dust. Within zones with a high dust load, this is essentially the transfer points there are vacuum filters and settlement zones. Further to this a regular household cleaning in these areas are to be performed according to the manual for operation and maintenance.

5.2 Fire detection and suppression

There exists on the market a large array of systems able to detect a premature fire based on a variety of different techniques: direct temperature measurements, temperature measurement by thermal images, particle measurements, measurements of different gas components (O_2, CO, NOx, etc.), ionic sensors, spark detectors, and so on. In most cases it is important to use more than one measuring principle in order to have them cover the weak sides of each other. It is the job of an experienced fire engineer to design the system in detail.

Detecting a fire risk in one place is one thing; another thing is the proper actions to take not only in the neighboring areas but for the facility as a whole. To mention one simple decision in case of the detection of a possible problem: which conveyor belts should continue operation in this specific situation and which belts should be stopped? This requires an in-depth analysis of the situation to decide. Also, for some wood pellets a temperature of 45°C could be a sign of something going on, in particular if the temperature is rising at an alarming rate; on the other hand, in some cases pellets are delivered from the ship at a temperature of up to 60°C - An issue to be considered.

There are a variety of ways also to deal with a fire; a fire on top of a store is for sure one thing. A smoldering fire within a store is a different thing. And certainly a fire in or on a transport conveyor is a third thing. Each of these would need expedite action but in very different ways and with very different means. In the store one could either inertise using Nitrogen or CO_2 or one could spray water or a water mist on top of the store. The inertization could be done either from the top or from the bottom and is preferred from water spaying since large amounts of water will ruin the pellets in the store and there is a risk that the swelling pellets could ruin the store.

In the conveyor galleys and in the transfer towers spaying with water is the most practical option. There is not much pellet material to ruin and it is much too easy for the inertization gas to escape the area since the galleys are not air-tight. Whenever water is used a strategy for drainage must be incorporated.

Finally, it is important to have a strategy for an emergency emptying of the store. For example, in case a smoldering fire has been detected in the store, some cooling with an inert gas has been going on for some time and it is assumed safe to empty the store; this should be performed in a safe way to a safe place. Afterwards the store must be carefully inspected to ensure that it is safe to bring it back into normal operation.

5.3 Explosion venting, suppression and segregation

The transfer towers are installed with vacuum cleaning systems where the filter houses could be an initial place for an explosion. In order to prevent serious damages on the transfer tower in case an explosion occur it is built with several explosion relief panels to ensure that the over pressure from the explosion is vented into a safe (external) area.

Other areas prone to explosions like the top of silos area equipped with similar panels. Further, storage siloes are equipped with automatic sequential explosion suppression systems combined with ultra-fast reacting isolation slide gates to avoid explosion propagation between storage siloes and conveyor systems.

Typically, in case an explosion occurs a fire will follow, and therefore it is important that the firefighting equipment is of a quality that allows it to survive the initial explosion.

6 CONCLUSIONS

Handling and transportation of large volumes of wood pellets is a delicate matter where the utmost care must be incorporated both into the construction of the different types of equipment and into the procedures used for operating and servicing the equipment.

Over last couple of years there have been several headlines in the press on biomass storages catching fire. In the design of such systems it is therefore important to involve advisors with actual practical experience that could both guide on how to avoid accidents and also in case accidents do happen how are damages minimized and what is the strategy for continued operation.

7 ACKNOWLEDGEMENTS

Ramboll would like to thank both Graham Construction Ltd. and Associated British Ports (ABP) for their cooperation in developing this paper.

8 NOMENCLATURE

ABP – Associated British Ports
ALARP - As Low As Reasonably Practicable
BAT - Best Available Technology
CSU - Continuous Ship Un-loaders
IRFT - Immingham Renewable Fuels Terminal
O&M – Operation and maintenance
RAM - Risk Acceptance Matrix
SIL - Safety Integrity Level