

APPLICATION OF DSEAR TO A BULK HANDLING FACILITY

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In order to comply with the new DSEAR legislation, the Fire Division of the Building Research Establishment (BRE) was commissioned to undertake a risk assessment and hazardous area classification exercise on the Port of Tilbury grain terminal and animal feed bulk handling facilities. This paper describes the detailed examination of the operations at the site that were undertaken in order to identify the hazardous substances used, the potential ignition sources and the existing explosion prevention and protection methods employed. An assessment was made as to the likelihood of an ignition and the severity of an incident should an explosion or fire occur with the grain materials, to enable a risk factor to be calculated for each operation at the terminal. Hazardous area zone diagrams were produced for all the process areas on the site. Guidance was given to reduce the risks and on choosing the correct electrical and mechanical equipment to be used in the different hazardous areas.

KEYWORDS: bulk handling, DSEAR, grain, spontaneous combustion, dust explosion, fire.

BACKGROUND

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) came into force on 9th December 2002, although a limited number of requirements concerning explosive atmospheres came into force on 30th June 2003. DSEAR applies to all workplaces including domestic dwellings where work activities are carried out. The purpose of DSEAR is to protect the safety of workers who may be at risk from dangerous substances that can cause explosions, fires and energy-releasing events such as runaway reactions. DSEAR implements two European Directives: ATEX 137 (99/92/EC) and the non-health aspects of CAD (98/24/EC).

Dangerous substances include all gases, vapours, mists and dusts that can form explosible atmospheres, and also all substances that may give rise to spontaneous combustion or exothermic reactions such as materials stored in bulk and oxidisers. A key point to note is that in assessing whether a substance comes under the DSEAR regulations, will depend not only on the properties of the substance itself but also how its is used. For example, a material that is stored well below its flashpoint would not come under DSEAR, but if it is used at or above its flashpoint then it would come under the regulations.

Compliance with DSEAR requires the user to undertake a number of key activities, these are:

- Undertake a risk assessment
- Eliminate or reduce the risks from dangerous substances
- Conduct a hazardous area classification exercise
- Make arrangements to deal with accidents, incidents and emergencies

- Provide information, instruction and training to employees
- Co-ordinate implementation activities where two or more employers share a workplace

INTRODUCTION

BRE was commissioned by the Grain Terminal of the Port of Tilbury London Ltd to act as consultant explosion/fire safety engineers on the implementation of the DSEAR legislation to the operations of the grain, animal feed and fertilizer handling operations at Tilbury Docks.

The project covered both the grain handling terminal, which comprises four loading/unloading marine towers on the Thames, concrete silos with a capacity to store 100,000 tonnes, steel silos of capacity 20,000 tonnes and the associated conveying equipment. Also located on the Docks site, and included in the work, are four bulk storage sheds used for animal feed and fertiliser.

An initial assessment was made of the site activities and existing information to identify where work would be required in order to comply with the regulations. Due to the large scale of the operations and the number of different materials handled not all the identified work areas could be implemented straightaway. Hence, a number of high priority jobs that would need to be started immediately (2003/4) were highlighted, these were:

1. Risk assessment of the grain handling and bulk storage sheds
2. Hazardous area classification
3. Safety of equipment (electrical and mechanical)

Further work items to be undertaken in the next financial year (2004/5) where also identified, these were:

4. Dust explosion and self-heating information on selected materials
5. Provision of training for employees

OVERVIEW OF OPERATIONS

The Grain Terminal — Port of Tilbury London Ltd imports, exports and stores grain. It was built in 1969. Ships are loaded and unloaded at the quayside located in the Thames, which is accessed from the shore via a jetty. Grain can also arrive and leave the terminal by road and rail.

Four marine towers are located on the quayside which contain the equipment for loading and unloading the ships. Each of the marine towers is independently controlled by its operator, the remaining movement of the grain around the plant is largely controlled remotely from a central control room. Grain is supplied and removed from the marine towers via open belt conveyors located in covered galleries which pass from the main silos to the quayside via a jetty.

Grain transported from the quayside to the shore is taken up to the top of the required silo storage bin via a bucket elevator. At the top of the silo another belt conveyor takes the grain and discharges it into the required silo via a tripper unit, which facilitates the discharge of the grain into the silo.

There are two types of silos at the terminal. The original reinforced concrete silos have a total capacity of 100,000 tons and range in capacity from 60 to 1000 tonne (height from 100 ft to 150 ft). An additional set of ten steel 2000 tonne capacity silos were recently installed to increase the storage volume.

Grain is discharged from the older silos via conveyors located in the basement underneath the silos. Manual opening of the discharge valves from the required silo is required, this is the only grain handling operation at the site not remotely controlled. The new silos have remote discharge capability onto chain link conveyors. Grain that is discharged from the silos is then taken either to one of the four adjacent flour mills, via conveyors, or taken to the lorry loading area at the front of the main silo building to be discharged into lorries. Grain may also be taken out from the silos, via a series of open belt conveyors, to marine tower 2 or to a system of loading spouts for loading into ships.

A plan of the operations is provided as Figure 1.

In a separate location at the Tilbury Docks site there are four bulk storage sheds. These hold animal feed stuffs and fertilizer in large quantities before being loaded into lorries. There is one very large new shed, which is loaded from ships via a crane with a bucket and a hopper discharge unit with a conveyor that feeds into the shed through openings in the side wall. The other three sheds are located a short distance away in a much older building and are considerably smaller. These are similarly loaded from ships via a crane with a grab bucket, which empties into a hopper and then is loaded into a lorry which takes the material into the shed to await distribution (see Figure 2).

RISK ASSESSMENT

INFORMATION GATHERING

Due to the extensive nature of the site and operations at Tilbury, the process was separated into twenty two sections and each section analysed in turn.

The first stage of the project was to gain a detailed analysis of the process operations. This involved numerous site visits to observe the working of the processes, with the assistance of the site engineer to explain in detail the mechanisms involved. Information and engineering drawings were provided by the company on the processes used, the layout of the plant and the installation of the existing explosion protection equipment.

IDENTIFICATION OF HAZARDOUS SUBSTANCES

Grain terminal

At an early stage in the project it was necessary to identify all the materials that are handled on the site that would be regarded as a "hazardous substance" for the purposes

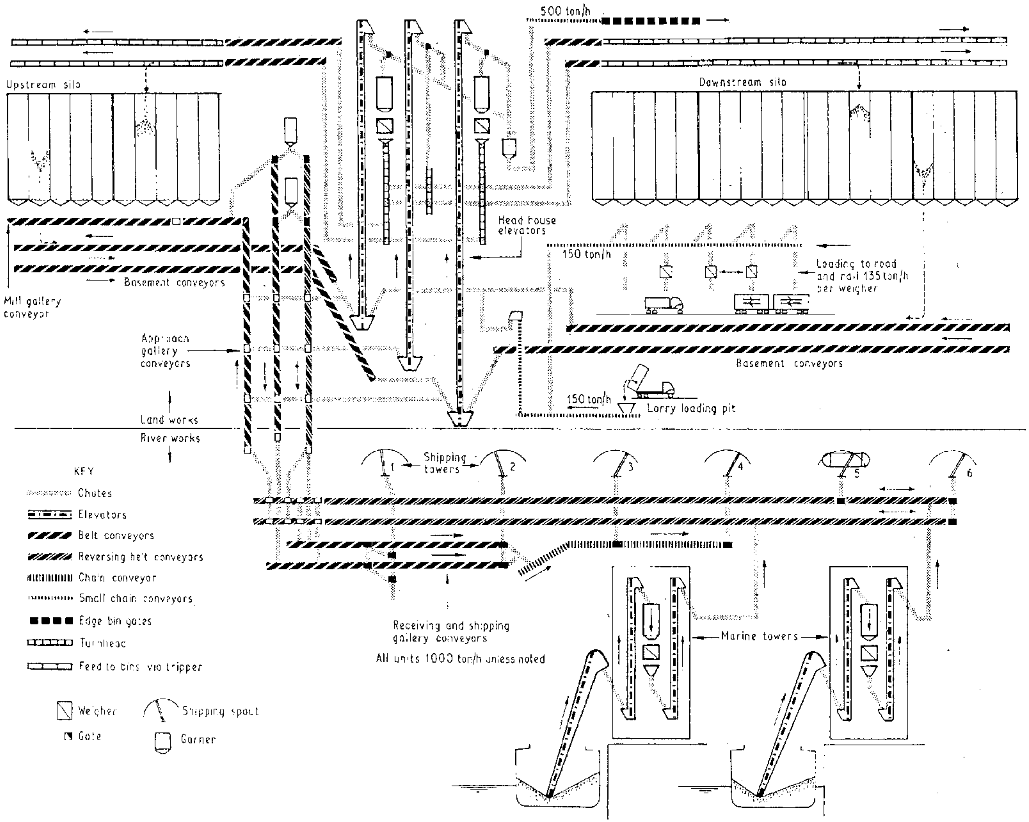

Figure 1. Grain terminal flow diagram

Figure 2. Animal feed and fertilizer off-loading

of DSEAR. This comprised sixteen materials handled at the grain terminal (excluding the bulk storage sheds):

- Canadian Western Amber Durum wheat (CWADS)
- Canadian Western Red Spring wheat (CWRS)
- Dark Northern Spring wheat (DNS)
- English barley
- English wheat
- Feed beans
- Feed peas
- French maize
- French wheat
- German wheat
- Oats
- Soya beans
- Waxy maize
- Semi wet maize

- Rape seed
- Spanish Durum wheat

The products listed above are all organic foodstuffs, and as such, will be liable to combustion under certain conditions leading to fires and/or dust explosions. In order assess the risk posed by these materials some quantitative information was required on their ignition properties.

All these materials are not handled on a daily basis, but will be present at various times depending on the shipments that arrive. A search of published information was undertaken to determine fire and explosion information from previous tests. These are detailed in Table 1. The term "ND" indicates no data available and where a range of

Table 1. Published ignition data for grain terminal products

Product	LIT (°C)	MIT (°C)	MEC (g/m^3)	MIE (mJ)	Kst (bar m/s)	Combustion class
CWADS*	290	370	60	ND	112	3
CWRS*	290	370	60	ND	112	3
DNS**	290	350–490	30	>10	65–120	4
English barley	ND	370–400	50–125	>15	83	2–4
English wheat	290	350–490	30	>10	65	
Feed beans	ND	ND	ND	ND	ND	ND
Feed peas	ND	ND	ND	ND	ND	ND
French maize***	410–460	530–780	30–500	300–3000	0–200	3
French wheat**	290	350–490	30	>10	65–120	4
German wheat**	290	350–490	30	>10	65–120	4
Oats	350	410–430	750	>10	14	3
Soya beans	265–440	440–800	60–250	>10000	47–110	1–4
Waxy maize	ND	ND	ND	ND	ND	ND
Semi wet maize	ND	ND	ND	ND	ND	ND
Rape seed	380	420	450	ND	ND	5
Spanish Durum wheat**	290	350–490	30	>10	65–120	4

*Data is for "Canadian Wheat" in reference 1.
**Data is for "Wheat" in references 1 and 2.
***Data is for "Maize" in reference 1.

values is given, it signifies a number of samples tested with results within the range specified.

Bulk storage sheds
The following products are stored at the bulk storage sheds at the docks, which are situated a short distance from the main grain terminal:

- Palm kernel extraction
- Palm kernel expellor
- Hippro Soya
- Sun pellets
- Ammonium nitrate
- Brazilian soya pellets
- Wheat feed pellets
- Cotton extraction

The dust cloud ignition data provided for these materials in Table 2 below has been gathered from published sources[1,2].

For many of the materials handled in the grain terminal operations there is no data, or where data fields in Tables 1 and 2 have been filled-in, in many cases it is using generic data (where * is used) from published sources[1,2].

Data from the actual materials handled is required for a risk assessment. However, this information was not available at the time and so the published generic data, given in Tables 1 and 2, for the materials present on the site were used in the risk assessment. For products where no information was been found in the literature, they were assumed to have ignition properties the same as granular foodstuffs.

Table 2. Published ignition data for bulk storage sheds

Product	LIT (°C)	MIT (°C)	MEC (g/m^3)	MIE (mJ)	Kst (bar m/s)	Combustion Class
Palm kernel extraction	ND	ND	ND	ND	ND	ND
Palm kernel expellor	ND	ND	ND	>30	ND	ND
Hippro soya*	265	460	100	ND	ND	4
Sun pellets	ND	ND	ND	ND	ND	ND
Ammonium nitrate	melts	520	ND	ND	ND	1
Brazilian soya pellets	435	440	100	ND	ND	1
Wheat feed pellets	ND	ND	ND	>1000	ND	2
Cotton extraction**	ND	ND	30	ND	ND	4–5

* Data is for "soya" in reference 1.
** Data is for "cotton" in reference 1.

It should be noted that these products initially arrive at the terminal as grains, seeds or pellets. Most of the materials will naturally contain a certain quantity of fine dust, some more so than others. The dust created during the transportation of the products around the terminal is either due to this dust that is already present, or is due to attrition of the materials as they are transported. During visits to the grain terminal it was observed that some products created a greater quantity of fine dust than other materials, particularly during conveying on open belt conveyors.

All these samples were identified as either causing a dust explosion/fire hazard or a self-heating hazard. A priority list for testing was drawn up by the Grain Terminal, based on the most frequently handled materials.

HAZARD IDENTIFICATION

Once all the information has been gathered, the next stage was to identify the hazards arising from the use of the dangerous substances in the process conditions. This was done by examining in detail the operations of each section of the terminal operations:

- Goods vehicle unloading area and conveying area (Figure 2).
- Marine Towers used to load and off-load shipping, via marine leg elevators and pneumatic suction, before being weighed and loaded onto open belt conveyors.
- Open belt conveyors used to transport the grain around the site.
- Centre House building containing offices and open belt conveyor start/end.
- Head House building containing bucket elevators, turnheads and scales.
- Cupola floor area above the silos where grain is transferred on conveyors from the bucket elevators and loaded into the silos via tripper units.
- Basement area below the silos (Figure 3) where grain is unloaded onto open belt conveyors from transfer to the Mills, shipping or road vehicles.
- Silos (new steel and older concrete) where grain is stored until required.
- Lorry loading and unloading areas.
- Bulk animal feed and fertilizer stores.
- Stairways and lifts in the Centre and Head House buildings.
- Dust extraction units at various locations.

For each section a description of the work activity was written, the potential sources of ignition were identified and the existing explosion prevention and protection measures were analysed as to their suitability.

RISK EVALUATION

In each section of the work activity on the site, the various processes that make up that work activity were evaluated. The purpose of this exercise is to enable those areas where the risk is greatest to be easily identified. The evaluation was based on the following strategy.

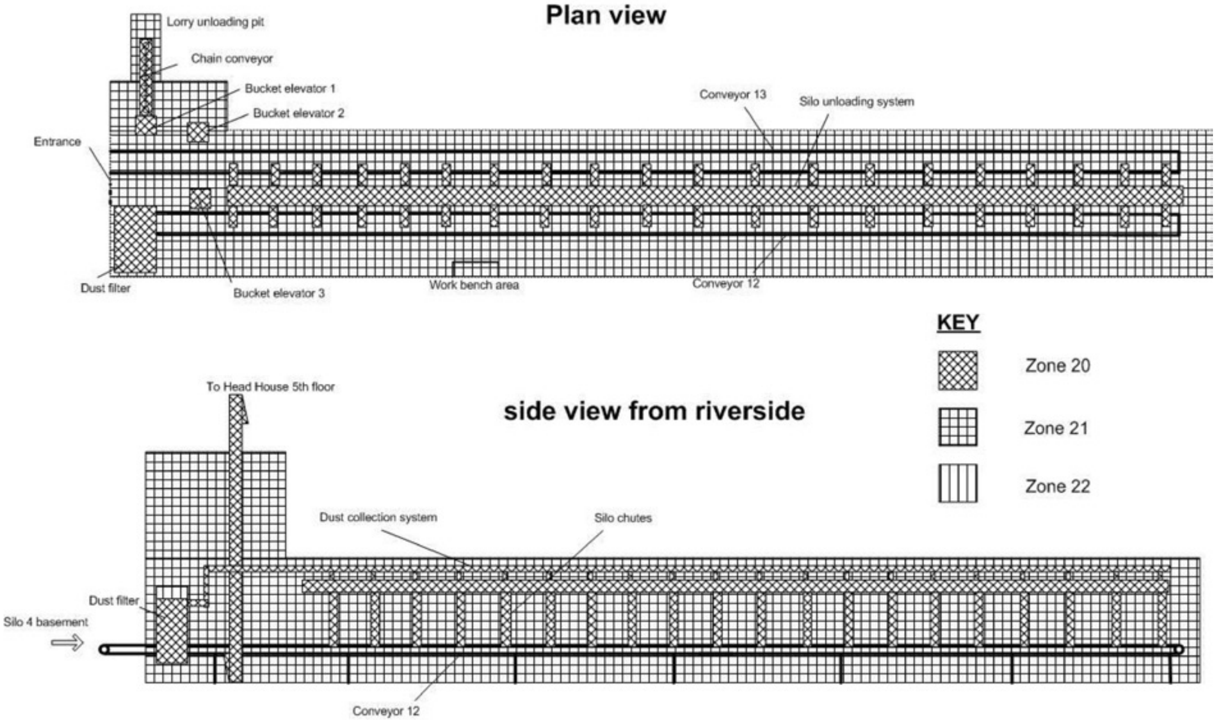

Figure 3. Example of hazardous area zoning – silo basement area

The likelihood value is assessed from how likely is it that a dust explosion or fire may occur.

Likelihood	*Value*
An incident occurs frequently (every 1000 hours of operation)	3
An incident occurs infrequently (every 1000–10,000 hours of operation)	2
An incident is extremely rare (>10,000 hours of operation)	1

The severity value is an assessment of the consequences of an incident. This includes personnel safety, process equipment damage and buildings damage.

Severity	*Value*
Death or major injury to personnel	3
Major plant and/or buildings damage	3
Minor injury to personnel	2
Localised plant and/or buildings damage	2
No injuries or no personnel expected to be present	1
Superficial damage to equipment and/or buildings	1

The risk factor is calculated by multiplying the likelihood by the severity to arrive at a risk factor for each area.

Score	*Risk level/action*
6 to 9	High risk — High priority, action required urgently to reduce the risk.
3 to 5	Medium risk — Medium priority, action required to reduce risk unless good reason.
1 or 2	Low risk — Low priority, action should be considered to reduce risk further if possible.

The evaluation was presented as a Table, an example of which is shown in Table 3 below. The comments highlight the main reasons taken into account in allocating the likelihood and severity score.

RISK REDUCTION AND COMPLIANCE

Once an evaluation of the risks in each area was completed it was possible to then provide advice on the actions required to reduce the risks and to ensure compliance with DSEAR was achieved. Typical actions required included:

- A check on the use of electrical and mechanical equipment to ensure suitability for the zone in which it is to operate.

Table 3. Example of risk evaluation

Area	Likelihood	Severity	Risk factor	Comments
Grain off-loading area	1	1	1	Few personnel present (HGV driver) Two open sides for lorry access — good ventilation. Dust cloud duration short and low concentration. Low probability of propagation to other process areas and equipment. Electrical/mechanical equipment needs assessing.
Conveyor pit area	1	1	1	No personnel present during operation. LEV is used to remove dust cloud. Propagation possible into small bucket elevator. Electrical/mechanical equipment need assessing.
Dust collection system (LEV)	1	2	2	Maintenance personnel and operating staff may be present within explosion relief emission zone during operation. Dust clouds in high concentration will be present during operation, but the risk of an ignition is low.
Conveyors/elevators	1	1	1	Low probability of maintenance and operating personnel present. Dust clouds and deposits may be present. Electrical/mechanical equipment need assessing.

- A check to ensure good earthing of the plant. With further precautions against static considered if any of the materials handled are found to have minimum ignition energies below 100 mJ.
- Some existing explosion vents need to be relocated to ensure their correct operation due to restrictions on opening.
- Some explosion vents open too near to equipment or buildings that would cause damage to the equipment or building should the vent be used. This will require some re-engineering of the vent location.

- In some cases the areas in front of the explosion vents need to have restricted access. Only when the plant in not operational should personnel be allowed to walk in the area in front of the vents.
- In some areas work is required to reduce the dust leakage into the main operational floor area, to obtain a less hazardous area zone classification.

HAZARDOUS AREA CLASSIFICATION

As part of the risk assessment a hazardous area classification exercise was undertaken for each area of the grain terminal. This is a key requirement of DSEAR and is intended to ensure that electrical and mechanical equipment used in hazardous areas do not form sources of ignition. Hence, it should make the selection of equipment for hazardous areas unambiguous. There are two zoning systems used, one for gases and vapours, the other for dusts. The categories are:

Gases

Zone 0 — explosive atmosphere is present continuously or for long periods or frequently.
Zone 1 — explosive atmosphere is likely to occur in normal operation occasionally.
Zone 2 — explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Dusts

Zone 20 — explosive atmosphere is present continuously or for long periods or frequently.
Zone 21 — explosive atmosphere is likely to occur in normal operation occasionally.
Zone 22 — explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

It should be noted that in the case of dusts, layers, deposits and heaps have to be considered as a potential source which can form a flammable dust cloud.

For the grain terminal operations the only dangerous substances identified by the risk assessment were dusts.

Zoning diagrams were produced in which the type and extent of the zones were highlighted. A typical example of a hazardous area zone diagram is given in Figure 3.

SAFETY OF EQUIPMENT

Although a detailed examination of all the electrical and mechanical equipment was not within the remit of the project, general advice was provided for those items of equipment that were located in a hazardous area. It is a requirement of the regulations that facilities coming into use for the first time after 1st July 2003 will need to have hazardous area zones, in which only suitably rated equipment may be used. Existing facilities, i.e. those already in use prior to the 1st July 2003 have an additional 3 years grace for this activity to be undertaken. The suitability of the equipment for use in a particular hazardous zone was assessed where there was a need to replace old equipment.

For example, for new equipment advice was provided to ensure that the correct category of equipment (e.g. Group II category 2 for a zone 21) was procured for the area into which it would be installed.

Vehicles that are used in hazardous areas also need to be considered as potential sources of ignition. Inside the main bulk animal feed shed vehicles were used to move the material and to load it onto good vehicles. The area inside the main shed was zoned as a 21 area, due to the large quantities of dusty materials being moved and loaded, thus creating flammable dust clouds in numerous locations within the bulk shed. The vehicles used inside the storage areas need to conform with the hazardous area zone allocated. Guidance on the safety of industrial trucks in flammable dust atmospheres is given in BS EN 1755:2000[3]. Diesel engine vehicles are used in these areas.

CO-ORDINATION ACTIVITIES

DSEAR requires that where two or more employers share a workplace, the employer responsible for the workplace shall co-ordinate the implementation of the measures required to satisfy the regulations. In this particular case, the grain terminal operational site was not shared by any other employers. However, there is a direct feed from the grain terminal into four flour mills located further along the dock. Grain is transported by open belt conveyor and fed into the conveyor systems of the mills. A potential risk was highlighted of a dust explosion in one of the mill being propagated into the grain terminal via this route. Hence, some co-ordination was recommended between the mills and the grain terminal to ensure the risks from this, and also from an ignition from the grain terminal passing into a mill, are reduced to as low a level as possible.

FUTURE WORK

TRAINING

It is a requirement that all employees are provided with information and training on the safe use of the dangerous substances that are present in the workplace. A half-day training course, to be provided by BRE, for the employees at the terminal has been discussed, to highlight the potential hazards that may arise from the use of the substances. This will cover the existing processes at the terminal and examine different methods of preventing hazardous situations arising. Emergency procedures to adopt in the case of an incident will also be explained.

MATERIALS TESTING FOR EXPLOSION AND SELF-HEATING

The next stages of the project involve the dust explosion testing and self-heating isothermal investigation on a number of the hazardous materials identified from the risk assessment. The information gained from these tests will then be used to refine the risk assessment as appropriate.

RISK ASSESSMENT

The final copy of the risk assessment/area classification report issued to the Port of Tilbury is acknowledged to be correct at the time of issue. However, it is recognised that it is a "living" document. Changes and modifications to the processes used, the equipment and the procedures will require the risk assessment report to be modified. This may come about following any future testing work or through a natural continuous modernisation of the plant. A particular driving force for continual improvement is the reduce the hazardous zoning requirements to a less stringent classification. Lowering a zone from a 21 to a 22 area will result in a lower equipment category being required and hence a cost saving.

ACKNOWLEDGEMENTS

Figure 1 has been reproduced from the Proceedings of the Institution of Mechanical Engineers, 1970–71, Volume 185, page 65–71, Figure 4 from "Mechanical handling aspects of the Tilbury grain terminal" by JB Griffith and DWR Addicott by permission of the Council of the Institution of Mechanical Engineers.

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