Pneumatic Unloading Equipment for Bulk Cement Carriers

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Summary

During the last ten years the demand for cement terminals has grown considerably in the whole world. The challenge of the market is mainly related to transloading installations for bulk cement with capacities of 100 to 400 t/h. To a growing extent bulk cement is delivered by river barges or seagoing vessels.

The state of pneumatic conveying technology is described by three case studies from Europe and the Middle East. These state-of-the-art terminals are characterized by two principal criteria: they are designed as either land based or floating installations and the land based installations can be provided with either stationary or mobile conveying equipment.

1. Pneumatic Conveying Systems

1.1 Introduction

Pneumatic conveyors may be classified according to the systems used into:

— high- and low-pressure conveying through pipelines
— suction conveying through pipelines, and
— conveying through airslides.

The criteria for design of such systems, i.e., air pressure, air quantity, and specific energy consumption, depend on the characteristics of the material to be conveyed. A completely satisfactory choice in favour of one or the other conveying system cannot be made. In choosing the conveying pressure it has to be remembered that greater conveying rates can be achieved by high-pressure conveying; longer distances can also be traversed in comparison to other systems.

The question of whether to use suction- or pressure-conveying can only be answered after careful study of local conditions. The following is helpful in coming to a decision: the suction system is normally used when conveying bulk cement from one, or a multiplicity, of pickup points to a single delivery destination, the pressure system is suitable when conveying from one pickup point to a multiplicity of delivery points.

In a combination of suction- and pressure-conveying in a pneumatic transport line the specific advantages of each system can be optimally used with regard to the conveying rates and distances required. This technique of pneumatic conveying has been developed by and is available through Claudius Peters AG, Hamburg.

1.2 Unloading of River Barges in West Berlin, Germany

As early as 1969/70 a pneumatic suction-operated conveying system for unloading cement from barges (≦ 600 G.R.T.) with subsequent pneumatic pressure-conveying of the bulk cement into two flat bottom silos of a capacity of 2,000 tons each has been installed in a building material plant in Berlin. The equipment has been in service for about 10 years and operates successfully and reliably. Fig. 1 shows the initial layout from Dr. Poesch. In the final design the swivel crane (item 2) has been replaced by a derrick.

The average unloading capacity is 100 t/h with a capacity of ≧ 100,000 tons bulk cement per year. Fig. 2 shows the installed vertical suction nozzle with rotating feeding discs; the vacuum nozzle is here in the conveying position in the ship's hull. The cement particles are slung up in front of the nozzle by the feeding discs and thus already receive a certain initial impetus. The technique of pneumatic conveying and mixing shown in Figs. 1 and 2 is relatively complicated, in particular the intake of the powdered material and the air material separation. The optimal separation of the material being conveyed, from the conveying airstream, has been achieved by developing the so-called through-pass airlock, of type Claudius Peters. It operates without moving parts and the material column seals the vacuum from the atmosphere.

1.3 Technical Development

As far as the geographical situation of the exporter and importer allows adequate loading and unloading facilities for cement vessels, shipment by sea is preferred for the transport of building materials, i.e., bulk solids. Consequently, a number of conveying systems for loading and unloading of cement ships have been conceived. Cement ships, seagoing vessels, and river barges have been developed; they are equipped with their own facilities on board for loading and

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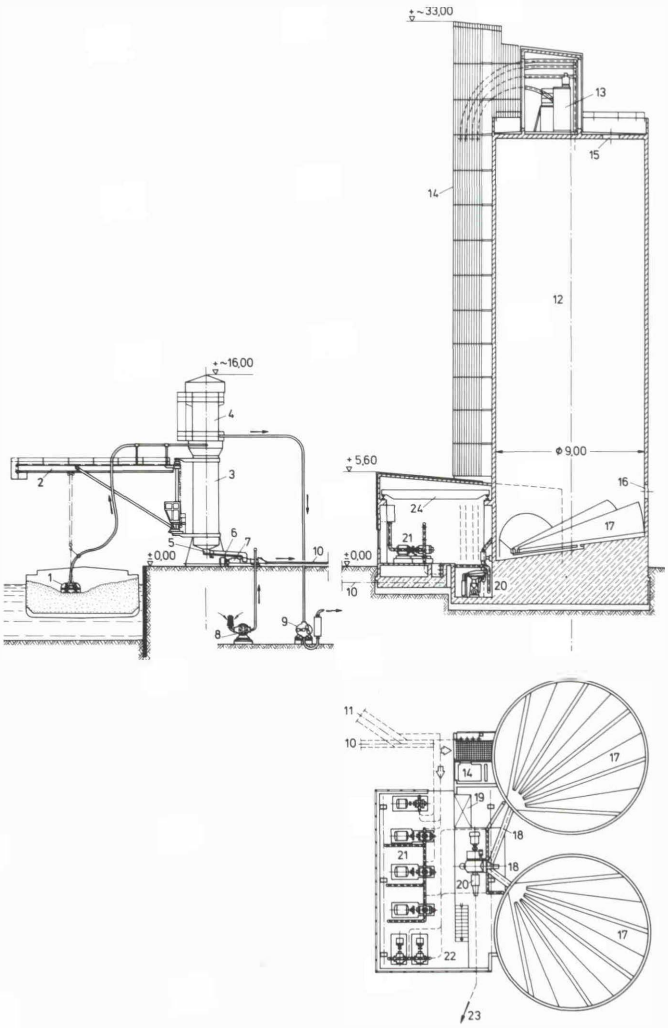

Fig. 1: Bulk cement terminal in West Berlin, Germany.
System for unloading of river barges.
(Layout: Dr. Poesch)
Storage capacity = 2 x 2,000 t

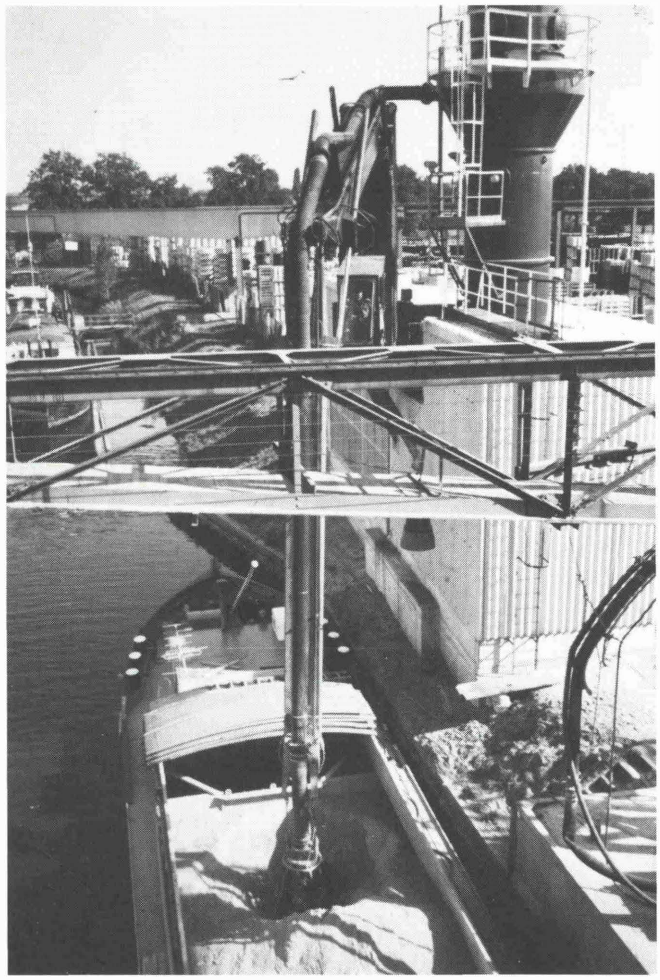

Fig. 2: The suction nozzle in conveying position; capacity ≤ 100 t/h

unloading of bulk soilds. They are thus self-unloading, e.g., pneumatically. Economic operation of these special ships is only possible at high turnround rates and return cargoes are of primary importance. A typical example is Japan. Because of the predominantly maritime location of the cement works, conveying and handling systems have been adapted for sea transport. This is significant for cement exports as well as domestic distribution. Motivated by the geographical situation of their country and the important export rates the Japanese shipyards have executed special ship constructions. They have also built floating factories operating for a limited period of time in countries of the Third World, stationed on the coast or in river estuaries.

With regard to such special equipment for unloading cement carriers, a floating terminal for bulk cement has been developed recently for Unicement, Dammam in cooperation with Claudius Peters. This special ship for bulk cement is in service in the Arabian Gulf namely in the region of Damman Port, Saudi Arabia. This new development will also be considered in the present article.

In the following the largest mobile suction-pressure conveyor constituting the main equipment of the Cement Terminal Shuwaikh Port, Kuwait is considered.

2. Cement Termimal in Shuwaikh Port, Kuwait

2.1 Cement Imports and Trade

Despite the remarkable cement production in Kuwait it has been necessary to meet the growing demand of the building market for cement by imports of bagged cement. The handling of bagged cement in the port of Shuwaikh, Kuwait was relatively unsuccessful. Ship unloading was too time consuming; furthermore, there were cement losses due to bag damage and significant environmental pollution by cement dust. With broad terms of reference including consideration of the ecological and economic problems, a project study was carried out to investigate whether the optimal solution was to be found in the erection of a Portland cement plant or alternatively, a cement distributing terminal for imported bulk cement delivered by ship. A number of idealised and practical solutions were discussed. At the end of 1977 the planning, construction, and commissioning of a cement terminal were agreed between Kuwait Cement Co. and Claudius Peters Industrieanlagen GmbH, Hamburg. A consortium was created including the company Müller Altvatter

Bauunternehmung GmbH & Co., Stuttgart, which provided construction planning and execution.

An unloading capacity of 500,000 t/year for the cement terminal was contracted. In the summer of 1979 the terminal started operations after an erection period of 1 1/2 years.

2.2 Technical Criteria and Plant Layout

The planning, construction, and installation of the cement terminal at the Gulf port Shuwaikh, Kuwait City were based on the following criteria (Fig. 3):

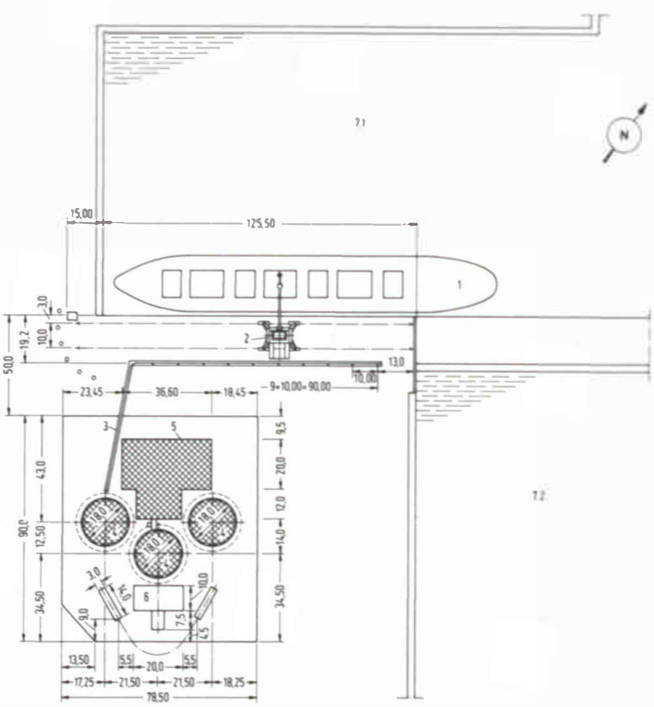

Fig. 3: Layout of the cement terminal equipped with suction-pressure conveyor for the discharge of seagoing vessels in Kuwait, Arabian Gulf; capacity ≦ 400 t/h

- max. unloading capacity: 400 t/h minimal berth times
- average unloading capacity: 300 t/h
- yearly capacity of the terminal: 500,000 t bulk cement
- storage capacity: approximately 42,000 t
- number of silos: 3
- The site available was limited; a compact installation was therefore required.
- Integration of the existing quay installation; Quay 8 has also to be available for other ship loadings and unloadings. Therefore, only mobile conveying equipment, running parallel to the quay, had to be installed. The number of berths at the port is constantly being increased (at present about 50). The tonnage discharged at Shuwaikh, excluding oil, amounted to about 4.72 million tons in 1976 (according to the Annual Statistical Abstract 1978). The annual tonnage totalled about 9.38 million tons; that means that approximately 50 % of the imported tonnage, arriving with 1,800 ships was re-exported, mainly to Saudi Arabia and Iraq.
- Mobile conveying installation for ship unloading. No warping of ships.
- Delivery of bulk cement in general by conventional bulk carriers (without special equipment) of ≦ 25,000 G.R.T.
- Dust-free discharging of the cement ships and minimal residual layer in the ship's hull.
- Low wear of the conveying elements and minimal maintenance.
- Low personnel requirement and ease of operation of the installation.
- Desert climate prevails in Kuwait with temperatures up to 55 °C, in direct sunlight up to 80 °C; for short periods the atmospheric humidity reaches 100 % at temperatures of about 30 °C.

These criteria resulted in the decision to equip the Cement Terminal with a mobile suction-pressure conveying installation (Fig. 4).

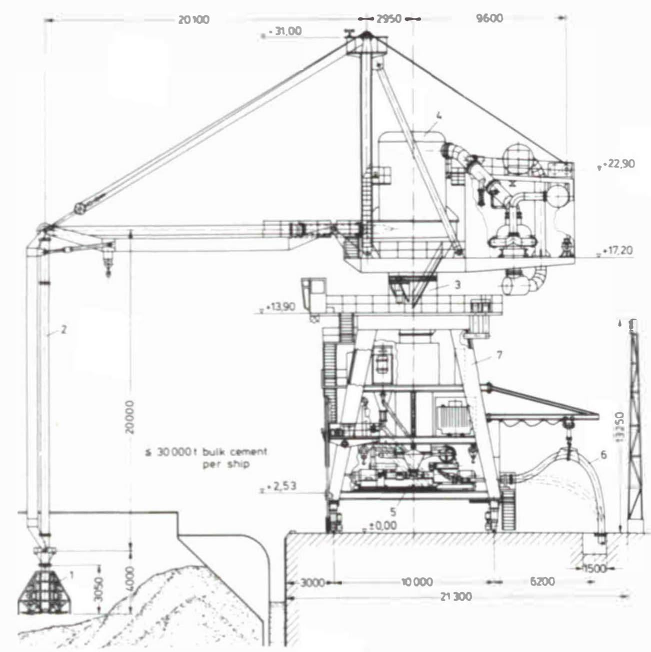

Fig. 4: Design of the conveying installation; capacity ≦ 400 t/h cement.
1 suction nozzle
2 suction conveying pipeline
3 through pass airlock
4 vacuum filter
5 pressure conveyor with screw feeding
6 pressure conveying pipeline to silos
7 swivel crane on rails

2.3 Techniques of Handling, Storage and Dispatch

Fig. 5 gives a view of the three cement silos. In the foreground the packing and loading station is perceptible. The total installation comprises two main groups:

- mobile swivel crane travelling on rails with suction-pressure conveying equipment (see Fig. 4)
- silos, packing and loading installation (see Figs. 5 and 6)

The mobile swivel crane travelling on rails serves to suspend the suction unloader, with subsequent pressure conveying to the silos. Such rotary cranes are equipped with a swivel

Fig. 5: The three silos of the cement terminal with a storage capacity of 10,000 m³ each (view from the north)

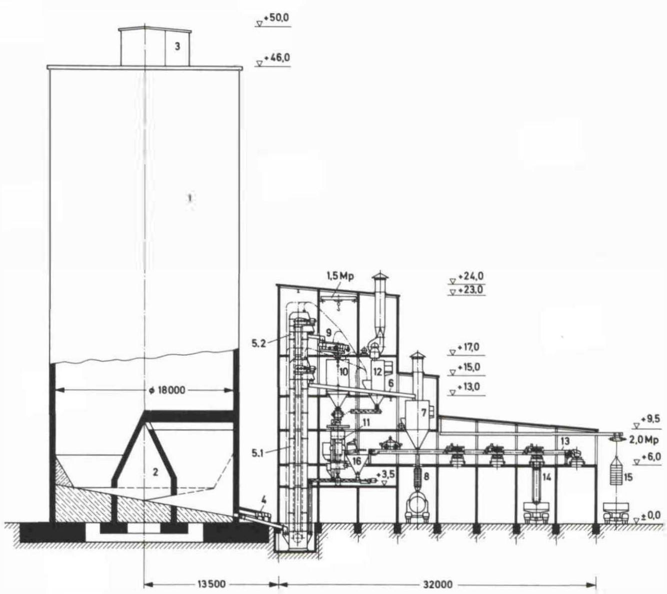

Fig. 6: Schematic representation of the silos and the packing and loading station

boom projecting out beyond the crane base to pick up the load. Apart from these swivel cranes, travelling on rails, stationary swivel cranes may be used, depending on local conditions.

Unloading of ships is accomplished by the suction nozzle; it is connected to the cyclone separator by the pneumatic pipeline. Two motor driven feeding discs are fitted to the suction nozzle, introducing the bulk cement into the conveying pipe. The equipment is designed for a maximum conveying rate of 400 t/h, and a maximum conveying distance of 30 m (minimum conveying distance is 15m). The suction nozzle, suspended on the jib, can be swivelled by up to 180°, the maximum crane range ex centre being 30 m; the minimum range ex centre is 15 m. The wheel base is 12 m and the gauge 10 m. The travelling range on rails is approximately 130 m.

The through pass airlock serves as recipient for the sucked bulk cement. The vacuum filter and the pre-separator are mounted on top of the through pass airlock, resulting in an overall construction height of approximately 31 m. By means of a suitable control technique the cement is kept at a constant level in the through pass airlock. Depending on the material filling level a pneumatic feeder is opened or closed, thus controlling the cement flow to the stationary screw pump. The bottom of the through pass airlock is aerated by means of a high-pressure blower. This aeration causes the cement to flow.

Through airslides the cement is conveyed to the screw pumps, mounted on the swivel crane. The pump installation of 2 x 200 t/h achieves a performance of 400 t/h in total at a conveying distance of 255 m between swivel crane and silo installation (maximum conveying height is 46 m). Pressure conveyors with screw feeding are air activated conveyors that have proved their worth over many years in the continuous transport of fluidised solids. The cement is continuously conveyed through the pipeline by an airstream, at a relatively high speed.

The most common pressure conveyors are classified according to the method of feeding the solid particles and according to the static admission pressure. The transfer of the material being conveyed from the non-pressurised chamber into the pressure chamber of the continuous high pressure conveyor is effected by a screw, rotating at high speed. The conveying chamber, being under pressure, is sealed-off from the silo by the screw, the cement in the screw, and by a shuttle gate valve. The performances that may be obtained with screw pumps depend on the specific characteristics of the goods to be conveyed and on the operating conditions (conveying distance, conveying height, etc.).

For the screw pumps, a pressure pipeline with a large number of underground pipe connections is laid in a channel, parallel to the rails. Extra strong, flexible conveying hoses are used as couplings.

The electric power for the mobile conveying system is supplied by a 11 kV-cable and a cable drum, leading directly into a medium voltage installation with 5 sections consisting of: input section, measurement section, two outgoing sections to the transformer, and a motor switch section for the 800 kW induced-draught blower motor. The voltage of the other motors is 415 V; this is produced by 2 transformers 11 kV/415 V. The control-system is designed using relay switching and centrally arranged in an air-conditioned control room.

Operation and control of the suction-pressure conveying installation are effected either from the central control cabin or from a portable control panel on the deck of the ship to be unloaded. The installed capacity of the suction conveyor together with the pressure conveyor is 2,800 kW comprising about 30 motors.

The cement is fed to the three silos and distributed through pipelines and pipe branches without any additional conveying effort. Depending on the cement quality and the silo control, a particular silo is fed. The conveying air is cleaned by a filter system; the filter chambers are erected on the roofs of the silos.

The three cylindrical silos of reinforced concrete construction have been erected in a slipform system. They were designed and reinforced as cylindrical shells. Each silo has a diameter of 18 m and an overall height of approximately 46 m. The storage capacity totals 42,000 t.

The silos have flat bottoms and are provided with an aerating system with expansion chamber, of the type Claudius Peters, Hamburg. The cement outlet is arranged at the side. Each silo has three discharge gates with metering devices. The individual outlets are connected by airslides. Thus, only three airslides lead to the packing installation. As two packing lines and one bulk loading line are to be fed, it is possible to convey the cement from each silo to each of the three lines.

In airslides the air conveying the bulk material flows through the mesh floor into the closed top slide, this having a slight slope of about 4°. The material to be conveyed is thus aerated and fluidized. It runs down the slide under its own gravity, this being the sole motive force; the air introduced serves in this way primarily to reduce the conveying friction. The hollow square framework design is most common for pneumatic airslides (Fig. 7).

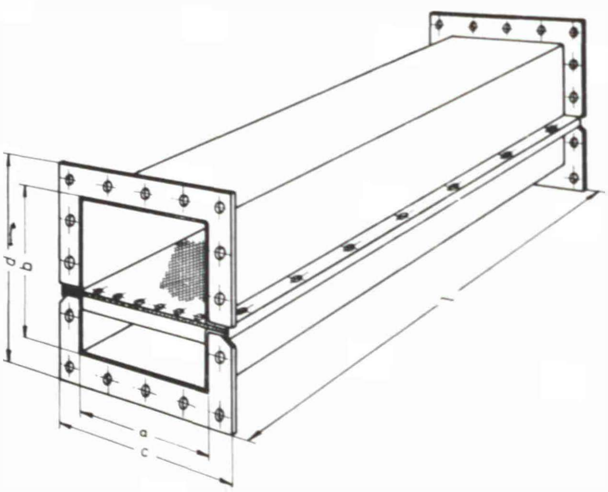

Fig. 7: Design of an airslide; capacity: 5 t/h to 3,000 t/h

The cement is conveyed through the airslides to the enclosed bucket elevators. Two of the vertical bucket elevators transport the cement mechanically to the height of the packing station (approximately + 20 m); the third, a short bucket elevator transports the cement for bulk loading of trucks to the delivery point at a height of approximately 13 m. Each of the three bucket elevators delivers the cement into intermediate storage bins with a capacity of 25 m³. From here the Turbopackers and the bulk loading device for trucks are charged. The trucks are loaded with bulk cement from a fixed loading point with a throughput of 120 t/h.

The Peters Turbopackers used are rotary packers and reach a packing speed of 2,200 bags/h. The predominant feature of this packer is the horizontally arranged turbine wheel allowing a precise filling technique. The slim construction is the result of a relatively simple design with a single central turbine wheel from which all the filler caps are supplied. Furthermore, the concept of this machine construction permits a linear material flow, vertically from above, into the silo of the packing station. The result is a short material flow through the packing machine. The Turbopackers discharge the cement bags via transfer belt conveyors onto four bag loaders for trucks (rearloaders).

The loading installation with four bag loading stations for trucks and one bulk loading station for trucks ensures continuous loading with a minimum of idle or waiting time. The packing station is not blocked by the necessary change of trucks. The packing and the bulk loading station are kept free of dust by separate filter systems; an optimal dust free operation is guaranteed.

To record the cement loads, two vehicle weighing devices are provided at the main gate of the Cement Terminal. Gross and net weighing is carried out to determine the cement quantity loaded.

A separate office building has been erected at the entrance of the Cement Terminal. The ground floor can be used as an empty bag storage. The required offices are located on the first and second floor. The office block is of concrete frame construction with concrete block walls.

3. Floating Terminal in Dammam Harbour, Saudi Arabia

3.1 Dammam, Capital of the Eastern Province and Harbour for Imported Building Materials

Dammam is the capital of the Eastern Province, one of the main arteries of the Kingdom of Saudi Arabia and its access to the Arabian Gulf. It is connected with Riyadh by a railway which was opened in 1951. The railway has brought new life to Dammam and indeed to the shores of the Arabian Gulf and is now the scene of incessant activity. The port of Dammam is of international importance. It has a jetty stretching 12 km out to sea with a railway line running to the end so that ships can unload their cargo directly into the trains.

Saudi Arabia, the most important crude oil producer in the Middle East, satisfies its cement requirements partly by local production and partly by imports from all over the world.

In 1980 Saudi Arabia's cement requirement amounted to nine million tons, of which approximately 55 % was produced locally, the remainder imported mainly by sea.

A considerable volume of the imported cement was bagged cement. Turnround time for vessels laden with bagged cement is usually long. Furthermore considerable losses can occur with bags splitting open — as much as 25 %, often also causing environmental pollution. The storage conditions of bagged cement in Dammam harbour, in the years 1978/79 are shown in Fig. 8. During this period the author

Fig. 8: Bagged cement stored in the harbour of Dammam (open air store; 1978/79)

acted as consultant in Saudi Arabia, in the region of Dammam, Dharan and Al Khobar, in the design of comminuting machinery for the Government. This machinery, stationary or mobile, was proposed for the recovery of Portland Cement which partly set and/or hardened in Dammam harbour (recycling of Portland Cement). This long-term project has been replaced by the improvement of the transshipment and storage installations in the harbour at Dammam, including the floating terminal described below.

Various cement importers and sales organisations also investigated the problem of the cement imports. Investments in new cement works, clinker grinding plants, stationary cement terminals of various sizes and technical variants as well as floating terminals were considered closely.

At the end of 1979 Unicement of Dammam, Saudi Arabia and Mitsubishi Heavy Industries of Hiroshima signed a contract for the design and construction of a complete cement barge with a carrying capacity of 25,000 DWT, in fact, a floating terminal.

Unicement asked Hamburg based Claudius Peters to supply the design and arrange for the delivery of the complete transloading plant for the barge with a capacity of 10^6 t/year. Deutsche Afrika Linien, Hamburg, were called in as consultants and to supervise and inspect the work in progress.

3.2 The Floating Terminal for Bulk Cement

The floating terminal is a system with special features. It combines all the facilities of a traditional terminal in one floating unit:

- ship unloading
- storage
- intermediate transport
- packing station, and if so desired
- transloading facilities, onshore or offshore.

Owing to its own supply facilities and accommodation for the operating personnel it is totally self-sufficient. For short-term projects it is not bound to any particular location. It is adaptable to various quay and port conditions. It is independent of the weather: Operation and loading of bulk material as well as bagged material take place in any but the worst weather. It is completely assembled at the shipyard and is ready for operation as soon as it has reached its location.

3.3 Design Criteria for Floating Terminals

The floating terminal in the King Abdul Aziz Harbour Dammam, on the Arabian Gulf, Saudi Arabia is an example of state-of-the-art technology (Fig. 9).

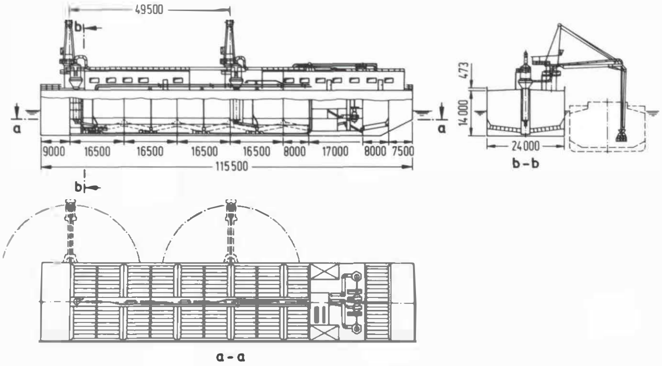

Fig. 9: Schematic representation of the floating terminal Dammam with two suction levers. Carrying capacity ≦ 25,000 DWT bulk cement

Two pneumatic ship unloaders shown in Fig. 10 have been installed on the floating material handling plant with a carrying capacity of 25,000 DWT for the purpose of unloading bulk carriers. The cement is distributed into the storage facilities of the terminal via a pipe system and screw pumps. From there the cement is conveyed via the same facilities either to onshore transloading silos for bulk transloading onto truck tankers or rail tankers or it is conveyed to the packing plant on board. This packing plant consists of two Turbopackers with electronic weighing systems. The filled bags are then transferred via a conveyor belt installation to four rear loaders of an onshore truck bag-loading station.

Fig. 10: The two suction unloaders capable of sucking ≦ 300 t bulk cement per hour out of the vessel

The onshore loading plant is part of the floating terminal. It consists of a steel construction which can be rapidly dismantled, capable of taking two loading silos of 80 t capacity each, 2 truck bulk loading installations with a capacity of 120 t/h each, 2 waggon bulk loading installations with a capacity of 120 t/h each, 4 bag loading installations including 4 rear loaders with a capacity of 100 t/h (two of these four rear loaders can operate simultaneously at any time) as well as a control panel for loading.

Dust-free truck waggon loading of bulk cement is accomplished by the loading equipment. For this purpose suitable filter installations have been provided for use on the loading silo units. Suitable weighbridges have been installed to take care of gross-net weighing.

The operation of this terminal has been highly automated by means of a control system specially designed by Claudius Peters to minimize manpower requirements. This control system combined with an optimum plant layout and coordination of all machinery results in a material handling operation of the highest economic efficiency.

The main performance data of the floating terminal are as follows:

Floating Terminal	
— Transloading capacity	1,000,000 t/year
— Carrying capacity	25,000 DWT
Main Dimensions	
— Length	115,500 mm
— Width	24,000 mm
— Lateral height	14,000 mm
— Draft	7,000 mm
— Number of holds	7
Suction lever	
— Max. capacity	150 t/h each
— Number of levers	2
— Lift of suction nozzle	
above deck level	+ 6.0 m
below deck level	— 21.5 m
Max. tonnage of vessel to be discharged	35,000 DWT
4 screw pump installations (2 operating simultaneously)	4 x 150 t/h
Packing plant	
— 2 Turbopackers with electronic weighing system	2,000 bags/h each
Onshore Loading	
— Bulk truck loading via 2 stationary loading points with loading equipment	120 t/h each
— Bulk waggon loading via 2 stationary loading points with loading equipment	120 t/h each
— Truck bag loading via 4 rear loaders (2 operating simultaneously)	100 t/h each
Installed capacity for cement plant	
— Floating terminal	3,600 kW
— Onshore loading	120 kW

The three case studies have the following in common:

— Economy of operation through efficient installations and optimum design.

— Short turnround times for vessels by high unloading capacities (100 t/h to 400 t/h) and desired silo capacity.

— Compact plants for better utilization of the port area.

— Absolutely dust-free handling in compliance with existing and future pollution control regulations.

— Low operating costs, including minimum personnel requirement for operating, servicing and maintenance.

References

[1] Stoess, H.A., "Pneumatic Conveying", Materials Handling and Packaging Series, Wiley-Interscience, John Wiley & Sons, New York, London, Sydney, Toronto, 1970

[2] Poesch, H., "Erfahrungen mit pneumatischen Förderanlagen für losen Zement", Zement-Kalk-Gips, Vol. 27 (1974), No. 11, pp. 525—531

[3] Poesch, H., "Ausweitung der Zementindustrie im Iran", Zement-Kalk-Gips, Vol. 28, (1975), No. 5, pp. 177—188

[4] Poesch, H., "The Japanese Cement Industry Today", Technische Universität Berlin, 1976, 34 pp., 12 figs., 7 tables

[5] Poesch, H., "Fördertechnik — Ausgewählte Kapitel aus der Steine-und-Erden-Industrie (nach Vorlesungen)", Technische Universität Berlin, 1980, Second Edition, 91 pp.

[6] Middle East Annual Review, 1981, World of Information, Essex, England, "KUWAIT", pages 199—214, and "SAUDI ARABIA", pages 275—290

[7] Poesch, H., "Planung und Einrichtung von Baustoff-Fabriken (Vorlesungen)", Technische Universität Berlin, 1981, 8th Edition, 300 pp. (Part I)

[8] Poesch, H., "Cement Terminal in Kuwait/Arabian Gulf. — Unloading of seagoing ships by suction-pressure conveyor", First published in German in Zentralblatt für Industriebau 2 (1981), pp. 64—69

[9] Informational material and Fig. 10 from Claudius Peters AG, Hamburg

[10] Kuwait Times, The Leading Independent Daily in Arabian Gulf, Kuwait

[11] Gulf Daily News; Gulf Weekly Mirror, Northern Gulf Edition, Bahrain