bulk solids handling Volume 1, Number 2, May 1981

Bulk Materials Transportation in Western Europe in the 1980s

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Die Entwicklung des Massenguttransports in den Achtziger Jahren in West-Europa
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1980年代の西ヨーロッパにおけるバラ材料の輸送
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Die Entwicklung des Massenguttransportes in den Achtziger Jahren in West-Europa

Im zukünftigen Massenguttransport wird die Entwicklung steil ansteigen, besonders in der Hafenausrüstung und in der Berücksichtigung der Umwelt- und Sozialprobleme. Der Wunsch nach erhöhtem Materialfluß ist ein wesentlicher Faktor in der Entwicklung moderner Seefrachter, Binnenschiffe und Häfen, Umschlagsanlagen, Eisenbahn- und Pipeline-Transportnetzen. Wir müssen uns die Frage stellen, ob unsere Transportrouten und -anlagen hinsichtlich der ansteigenden Transportkapazität für die nächsten Jahrzehnte noch ausreichen. Der Aufstieg und der Untergang einer Nation hängt davon ab, inwieweit sie ein umfassendes Transportnetz geplant hat, um den Güterumschlag sicher abzuwickeln.

Le développement du transport de vrac dans les années 80 en Europe de l'Ouest

Le développement sera très intense dans le futur transport des matériaux en vrac, en particulier en ce qui concerne l'équipement portuaire et la prise en considération des problèmes écologiques et sociaux. Le souhait d'une manutention plus élevée est un facteur important dans le développement des cargos modernes, des péniches, des ports, des installations de transbordement, du réseau de transport par fer et par pipeline. Nous devons nous poser la question, si nos intinéraires et nos installations de transport suffisent encore pour les années prochaines face à la capacité de transport qui s'accroit. L'ascension et le déclin d'une nation dépendent de la façon dont a été prévu un réseau de transport étendu pour procéder en toute sécurité au transbordement des marchandises.

El desarrollo del transporte de materiales a granel en Europa de los años 80

En el transporte futuro de materiales a granel se presentará un desarrollo muy elevado, especialmente en el equipo portuario y en la consideración de problemas sociales y del medio ambiente. El deseo de un flujo de materiales mayor es un factor muy importante en el desarrollo de barcos de carga modernos, barcos para el interior, puertos, plantas de transbordo, redes de transporte ferroviarias y de tuberias. Nos debemos preguntar, si nuestras rutas de transporte y nuestras plantas son suficientes para satisfacer la más elevada demanda de transporte para las siguientes décadas. La ascensión y el ocaso de una nación depende, hasta a que punto ella ha planeado una extensa red de transportes para realizar, en forma segura, el transbordo de materiales a granel.

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Summary

A quiet revolution is taking place in bulk materials handling and transportation, more particularly in the development of modern port facilities and in methods for coping with growing social and environmental pressures. The demand for an efficient flow of freight traffic is an important factor in the development of sea-going freighters, inland navigation craft, harbours, freight handling systems, railways and pipeline networks. This being so, it is necessary to consider whether available transportation routes and facilities will be adequate to handle the increasing volume of traffic in the next few decades. The rise and fall of industrial nations will depend on how efficiently they plan comprehensive transportation networks in good time to ensure continuing and uninterrupted flow of goods and materials.

1. The Importance of Transportation in Raw Materials Supply

With the ever increasing world population there is a corresponding increase in the magnitude of food, raw materials and energy supply problems, which can be solved only by the development of new raw material resources and by bringing barren and hitherto uncultivated land under cultivation. To this end, new transportation routes and facilities will have to be planned, and port installations of adequate capacity developed. These problems, with which more particularly the industrialized nations are faced — world population is currently increasing at a rate of 80 million per year, so that it will be approximately doubled by the year 2015 — can be effectively dealt with only by a major effort on the part of all nations. By the year 2000 Africa alone will have about four times as many people to feed as now live in the Common Market countries.

The future interlinking of all transportation connections between the five continents, together with a world-wide integration of transportation and supply networks for maritime/transcontinental long-distance conveying of materials, such as already exists for oil and natural gas pipelines, will be the main task facing transportation technology in the 1980s.

2. Transportation Chains

Raw materials supply, more particularly those associated with primary energy resources, and the export of goods demand efficient *transportation chains* extending from the winning of the raw materials through shipment and sea/overland transportation to the transfer and distribution terminals on the sea coast and at inland locations and finally to the consumers. A wide variety of alternative means are available for the purpose, which, when linked together, can be formed into the optimum chain for coping with the tasks and problems concerned (Fig. 1).

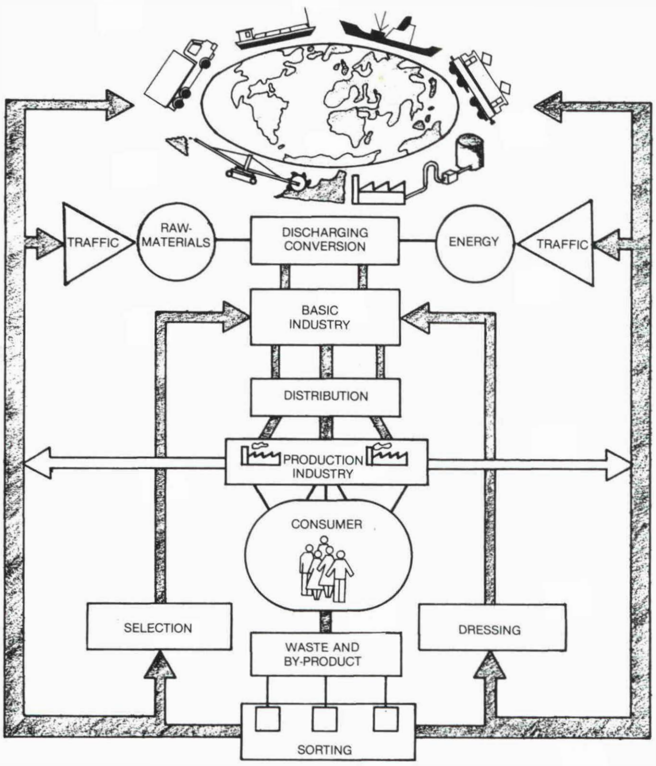


Fig. 1: Transportation chain

The world's continents can easily be interconnected by sea navigation, but the transportation chains run into trouble due to poorly developed port facilities, and overland transportation for the large-scale opening-up of often impassable country in order to gain access to raw material sources and populated regions is likely to present even greater difficulties. Hence it is necessary now already to plan additional and new systems to overcome these problems [1].

2.1 Maritime Cargo Transportation

The transportation of goods and materials by sea will, in the next decade, undergo a substantial change as a result of shifts in the pattern of primary energy supply from oil to coal. World coal trade, at present amounting to about 220 million t/year and mainly comprising coke for iron smelting, is expected to expand to around 1,000 million t/year around the turn of the century. These fuels and raw materials will be carried by combined cargo vessels which can convey oil, coal and ore. At the present time there are about 49 million tdw of such combined carrier vessels out of a total of 135 million tdw of bulk carrier capacity.

In the 1980s, world trade tonnage will undergo a further increase, and the existing bulk cargo fleet will no longer be sufficient to meet the needs. Already the ship-owning firms have placed orders for new bulk freighters comprising more than 30 vessels, and nearly 90 OBO ore/bulk/oil carriers with capacities of over 100,000 t are under construction in various parts of the world.

Because of the unstable world economic situation it is at present still uncertain when these special freighters will be used and on what routes and with what handling methods they will operate — dry bulk carriers for discharging with grabs or with continuous conveyor equipment, self-loaders and self-unloaders or slurry tankers (based on the Marconaflo system). The growth rate of dry bulk carrier and tanker capacity will increase to around 50 million tdw/year in the period from 1985 to 1990, corresponding to the full construction capacity of present-day shipbuilding facilities.

Crude oil transportation from the Persian Gulf to Europe, amounting to about 600 million t/year, will require 100 tankers of 1 million tdw each. The sea route around Africa is about 20,000 km in length. Assuming a period of 60 days for performing a round trip of 40,000 km, the *mass flow rate* attained by a 1 million t tanker can be estimated at 695 t/h.

Crude oil deliveries from the Persian Gulf to Europe total about 70,000 t/h, however. A direct pipeline to Europe would be more economic than using a hundred 1 million t tankers for conveying this oil. Taking account of the much shorter pipeline route (only about a quarter of the sea route), the tanker operation using vessels of 400,000 tdw will cost ten times, and the operation using 1 million tdw vessels will cost five times as much as transportation by pipeline.

As Fig. 2 shows, a 1 million tdw tanker transports oil at a cost of about 14.7 DM/t, equivalent to 0.00014 DM/MWh km. For transporting oil to the North German ports, France and the Benelux countries the use of 1 million tdw tankers costs about as much as conveying the oil by pipeline, because the flow rate to these consumer countries is no more than about 35,000 t/h.

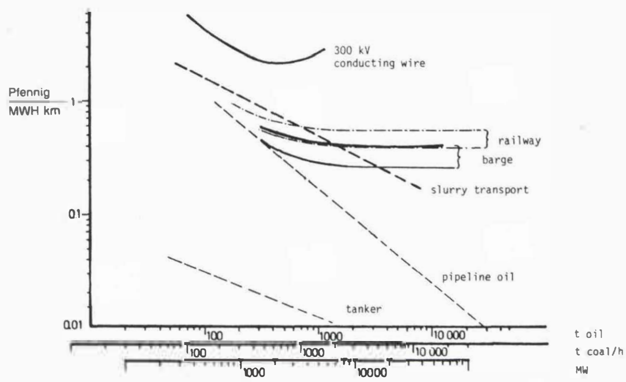


Fig. 2: Transportation costs of oil, coal and electric energy

2.2 Ship Dimensions and Harbours

The principal oil ports will be able to accommodate vessels of 24—25 m draught in the next few years. This would make possible the design of a very wide 1 million tdw tanker with a beam/draught ratio of about 3.5. The design of a 425,000 tdw tanker of limited draught is based on a value of 3.03 for this ratio. A conventional vessel, e.g., of 165,210 tdw, has a length of 300 m, a beam of 46.88 m and a draught of 17.49 m, i.e., its beam/draught ratio is 2.88. On the other hand, a wide shallow-draught vessel with a length of 240 m, a beam of 75 m and a draught of 14 m will, for equal tonnage, have a beam/draught ratio of 5.35.

It is a well known fact that the freight rate chargeable can be reduced according as the tonnage carrying capacity of a vessel is higher. If the capacity increase is achieved by increasing only the beam (instead of all the dimensions), while the draught is kept constant at 14 m, the freight rate is correspondingly reduced (Fig. 3) [2].

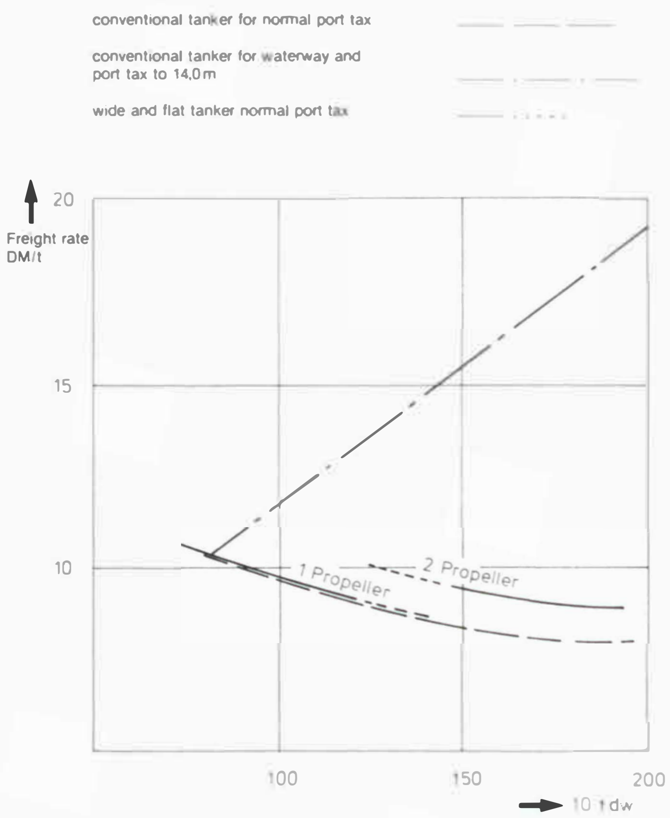


Fig. 3: Freight charges for crude oil transportation by tanker

For bulk materials the most economic method of transportation is by sea. Hence it is advisable to convey bulk cargoes by ship to a port located as close as possible to the consumers and to use rail, barge or pipeline only for the distribution of the materials to their final destinations. Broad-beam shallow-draught ships can use ports which had, on account of water depth limitations, previously been excluded from bulk material trade. Fig. 3 shows the freight rates (in DM/t) as a function of ship size (in tdw) for conventional freighters of 14 m and deeper draught and for broad-beam shallow-draught freighters drawing 14 m of water in all cases.

Although it is not yet normal practice to charge the actual cost of port and waterway development to the ships that use these facilities, it is an approach that will have to be given closer attention in the future. The waterway and port costs entailed by having to provide additional depth of water for ships of conventional design are taken to include the cost of dredging a 55 km long navigation channel to greater depth and of building a quay with wing walls, together with various ancillary installations. Maintenance charges per m³ of dredged spoil are assumed to be approximately 10 DM.

For building up flexible transportation systems suitable for a variety of liquid and solid cargoes and capable of serving a fairly large number of distribution or rendezvous points, even in shallow water, trains of towed shallow-draught vessels offer economic and technical advantages. Ships which operate in the North Sea have to allow for limited depths of water in certain areas, so that considerable navigational difficulties are encountered by big tankers or freighters.

The need to convey cargoes in larger ship units which are more economic and of shallower draught and which can split up their cargoes into smaller sub-units for unloading in special harbours or at quays with limited depth of water can be met by a newly developed conception of the towed train of barges: the so-called *bulk ship train* (Fig. 4).

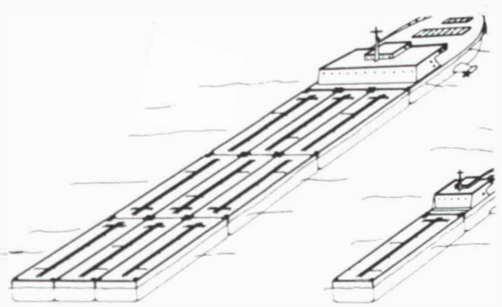


Fig. 4: Bulk Ship Train

In this system, the principle employed in pusher barge navigation on inland waterways is here applied to a number of large freight units (of 80,000 tdw each, for example) which are assembled into a *train* towed by a tug vessel connected to the bow end of the assembly. On each side (port and starboard) the tug vessel is equipped with outrigger stabilizers at the ends of which the propellers are mounted. The rotational speed and pitch of the propeller blades are controlled, through hydrostatic gearing, by an automatic steering system that keeps the vessel on course. Thanks to the reversibility of the direction of propeller rotation there is moreover excellent manoeuvrability of the ship train.

Nine freight units of 80,000 tdw each can, for example, be assembled into a sea-going ship train. If necessary, a larger or a smaller number of units may be employed, depending on the type and quantity of cargo to be carried, so that there is considerable adaptability to requirements. The draught is the same as that of the individual large bulk freight container, so that relatively shallow waters can be navigated. The freight units are assembled into the *bulk ship train* with the aid of a tug.

2.3 Inland Navigation

Inland navigation has hitherto mainly engaged in bulk materials transportation, namely to the extent of about 95 %, with general cargoes accounting for only 5 %. Sand, gravel, clay, coal and ore constitute the greater part of the bulk cargo carried.

The largest material flow in the Common Market is routed via the ports at the mouth of the Rhine, while the volume handled by the North German ports amounts to only a third of this. This large-scale movement of materials is concentrated on the Rhine/Ruhr/Main region, while the Rhine itself, as always, handles the main flow of bulk materials such as ore, coal, building materials and oil, so that this river surpasses all the other transportation routes in importance.

Another problem associated with inland navigation consists in the long turn-round times. According to the latest investigations the average time spent lying at berth is about 42 hours, of which only 7 hours can be rated as effective cargo loading or unloading time. The following is a breakdown of the turn-round time of a bulk carrier vessel operating on inland waterways:

waiting time before cargo handling	67.0 %
effective cargo handling time	10.0 %
loss of time during cargo handling	10.7 %
waiting time after cargo handling	12.3 %
total time at berth	100.0 %

From this it appears that 79.3 % of the total time spent in port is assignable to waiting. Hence it is necessary, first and foremost, to investigate the cargo handling (loading/unloading) operations in inland ports.

Future developments in inland navigation will be chiefly bound up with the growth in the size of the vessels and in reducing the turn-round times required. In addition, substantial rationalization can be achieved by limiting the number of types of inland craft and by standardization (Fig. 5a, b).

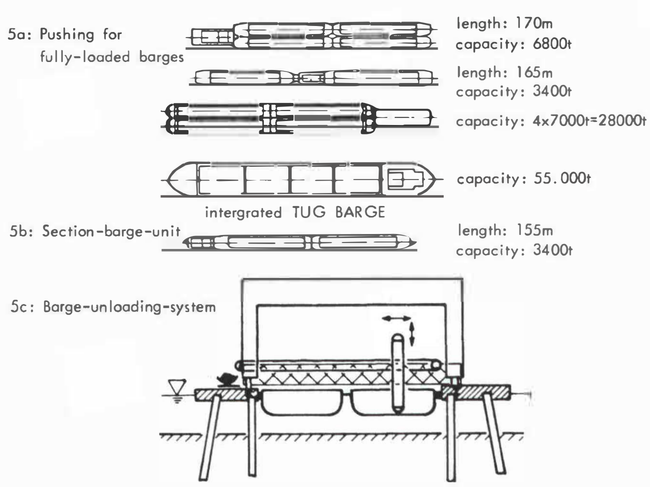


Fig. 5: Barges and barge unloading facilities

2.4 Continuous Handling Systems for Shortening Cargo Unloading Times

In order to shorten the times spent on discharging, new types of lighters and barges are built as *single hold* craft, i.e., without transverse bulkheads, enabling grabs for cargo unloading to operate more effectively and also making it possible to use small bucket wheel systems, bucket elevators and other continuous handling appliances economically. This new technology has resulted, for example, in the development of modern devices such as the portal-type unloading installation (Fig. 5c).

The last-mentioned device comprises a bridge-type portal frame which is mounted either on a floating pontoon or on finger piers and which can travel longitudinally over the barges straddled by it. A cross-girder mounted in the portal can be raised and lowered. It carries a bucket wheel which can be moved sideways with respect to the barges. The buckets scoop the bulk material out of the vessel being unloaded and deposit it on a reversible transverse belt conveyor which in turn discharges it onto a longitudinal belt conveyor for delivery to the stockpile.

For dealing with wet bulk materials the possibility of hydraulic loading and unloading, as will be described in connection with the Marconaflo system, deserves consideration.

3. Evolution in Harbour Design

The devolopments that have taken place in the design of cargo vessels have not been without their effect upon the harbour works and port facilities that have to serve them, and they will in the future continue to make fresh demands in terms of materials handling technology. In recent years the loading and unloading installations for bulk materials have, with the growth in size of the vessels, increasingly been moved from harbours located relatively far inland on the mouths of rivers to deep-water coastal harbours. And already a world-wide race has started in building even deeper harbours for the giant tankers of the future and in planning outer harbours on offshore islands beside deep sea channels (Fig. 6).

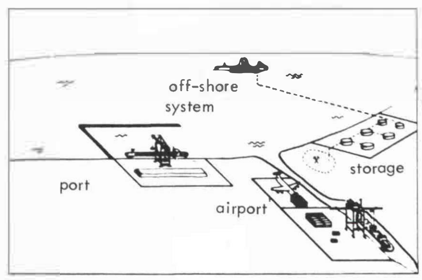


Fig. 6: Artificial offshore unloading island

For the design and development of appropriate shipping access lanes and vast harbour engineering projects it is not sufficient merely to base oneself on the evolution in the size of ships into the megaton range. Thus, it would not make good economic sense if the Common Market countries were to develop their present port facilities to receive ships which, in terms of anticipated size in the near future, will soon be obsolete. Accordingly, in the quest for future-oriented solutions it is necessary also to include other priorities, with their various associated influencing factors, in an overall review that duly takes their interaction into account and from which an optimum solution can be derived.

3.1 Cargo Handling Technologies

The evolution of a sea port is to a great extent influenced by the cargo handling methods and by the size of the vessels served. Both these parameters require new technological developments in shipbuilding as well as in cargo handling and organization of port working.

General cargo operations have already been rationalized to a great extent as a result of the introduction of the container. In this case the ideal solution is obtained with carefully timed ship departures and arrivals and with the loading and unloading operations likewise geared to a controlled cycle.

In so far as the discharging of bulk freighters is concerned, the trend, starting with fully automated grab operation, has increasingly been towards the introduction of continuous methods, including more particularly the use of continuous handling devices (bucket wheels, elevators, etc.) (Fig. 7) [3].

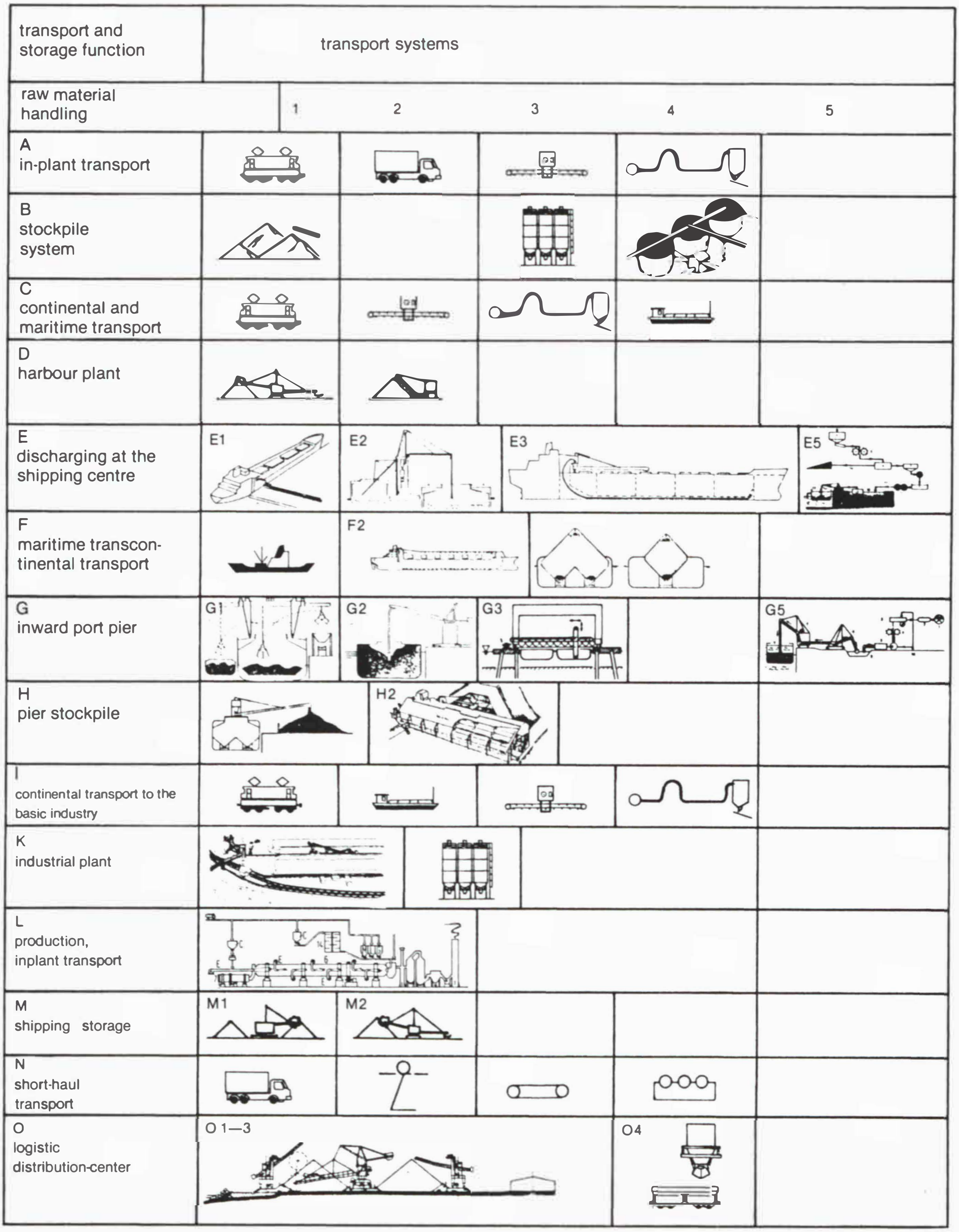


Fig. 7: Transportation chain for raw materials from the source to the final distribution centre

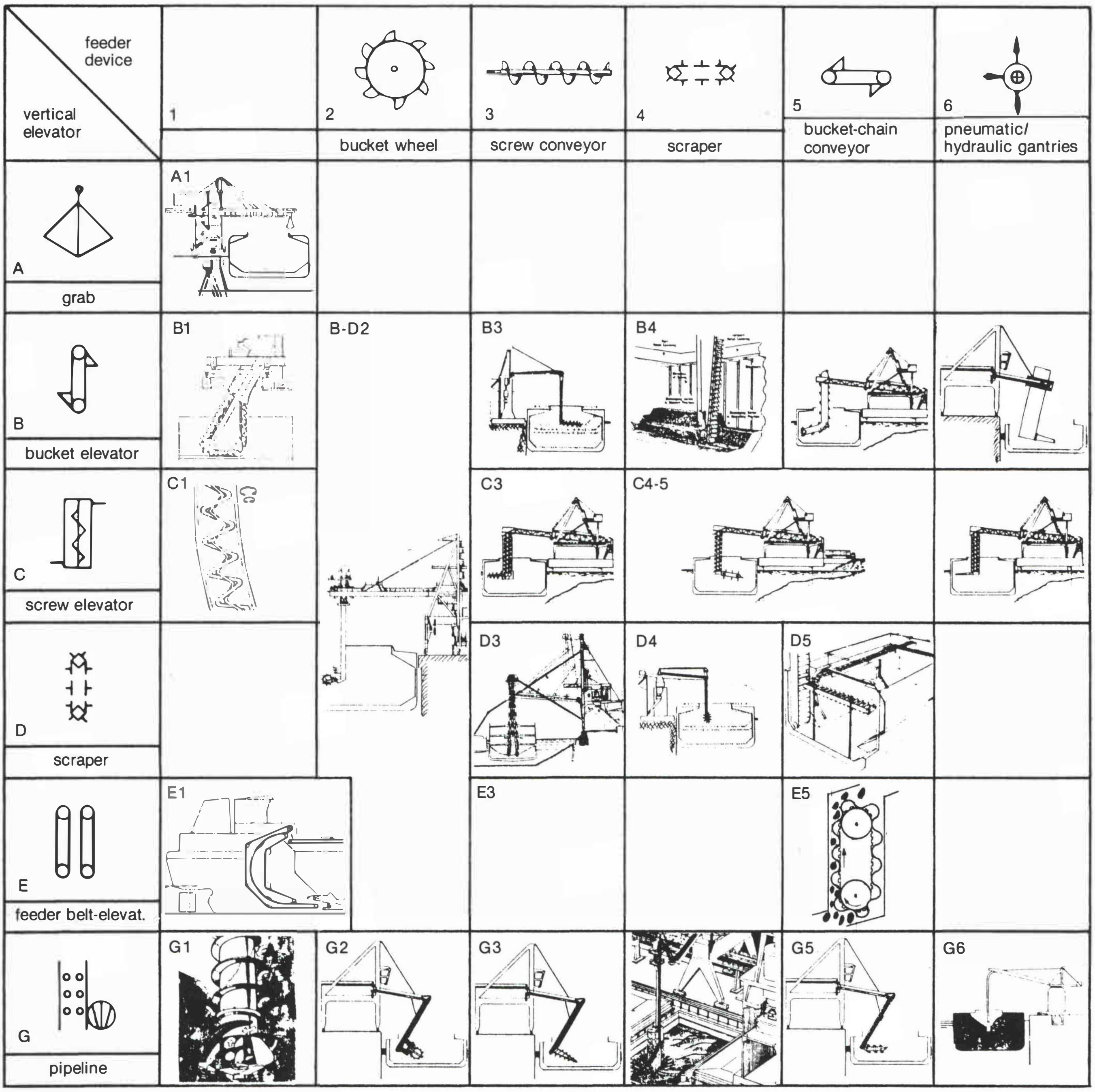


Fig. 9: Continuous ship unloading systems for bulk materials

3.2 Ship Unloaders for Bulk Materials

The two EUROPOORT gantry-type unloaders for ore and coal (Fig. 7/GI) each have a handling capacity of 3,000 t/h. The overall height is 74 m, the span between supports is 70 m and the overall length of the crab travel track is 114 m. The rope-drawn crab (trolley) travels at a speed of 240 m/min and is equipped with grab which can pick up a payload of 30 t. Each unloader, weighing about 2,000 t, is supported on 48 track wheels and can travel at a speed of 25 m/min. A personnel lift is installed in the fixed leg of the gantry.

In contrast with grab unloading, which starts at peak performance with optimum digging conditions and ends up at very low performance when trimming and cleaning the cargo out of the hold, the so-called self-unloaders discharge the material at a uniform high rate throughout (Fig. 7/EI). Thus the shore-based conveyor systems can operate at full capacity during the whole unloading period, so that the average rate of unloading attainable at existing terminals can be doubled. A bulk cargo elevator, the C-conveyor or loop belt, brings the cargo up to deck level, from where it is discharged ashore by a boom conveyor. Fig. 8 illustrates gravity-type self-unloaders. The main advantage of the deck crane self-unloader is its high degree of operational flexibility and versatility, enabling vessels with such equipment to cater very efficiently for trade combinations involving various cargoes. The gear-type self-unloader also offers major advantages on account of its cargo handling capabilities and because vessels equipped in this way are also able to carry non-bulk cargoes such as timber, steel and various industrial products.

For conventional unloading by means of grabs, stevedoring costs would normally range between $ 1.25 and $ 2.50 per t, depending on the type of commodity handled and on the standards of the unloading terminal concerned. Stevedoring costs for gravity-type self-unloaders would be substantially lower — hardly more than $ 0.40 to $ 0.60 per t.

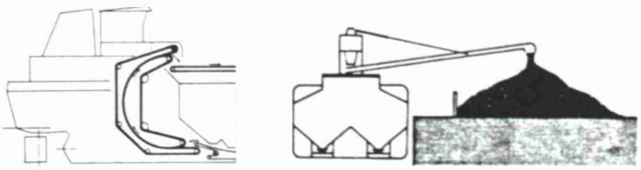


Fig. 8: Gravity-type self-unloaders (ship to shore): (a) C-conveyor, (b) boom conveyor

3.3 Prospects

Bulk shipping is not static, but continually evolving in order to keep pace with changes in basic factors such as growth and relative importance of trades, environment, new technology, new regulations etc. — changes which create new business opportunities at various levels in the service chain of bulk shipping.

The potential for further improvement of traditional dry bulk shipping systems, including economy of scale, has now almost been exhausted. Any significant further progress in this field will have to incorporate new thinking and innovation in the rationalization of ship/port functions and in the building-up of shipping systems with better operational flexibility and providing better environmental protection.

With the current development of industry in new areas of the world without the benefit of modern port facilities, in conjunction with a world-wide revival of coal as a major source of energy, the number of new ports for the import of bulk cargoes can be expected to increase substantially in the next decade. Most of them will, however, have considerably lower import volumes than the major bulk ports of Japan und Western Europe. In order to derive full benefit from the low freight costs offered by large ships in raw material trade involving only modest volumes of cargo, it will be imperative to employ shipping systems with simple ship/port functions and low requirements as to capital investment in port facilities.

3.4 Ship Unloading Equipment

Various types of modern ship unloading equipment are illustrated in Fig. 9. The vertical handling devices shown here are the grab, the bucket elevator, the screw elevator, the scraper, the feeder belt elevator and the pipeline. Associated with these are various feed devices, namely, the bucket wheel, the screw conveyor, the scraper, the bucket chain conveyor and the pneumatic or hydraulic gantry.

Fig. 9/B5 represents an unloader system comprising a bucket elevator fed by a bucket chain conveyor section. A bucket elevator unloader for iron ore, with a capacity of 3,000 t/h, is shown in Fig. 10. The elevator is the distinctive feature of this machine and is characterized more particularly by a feeding system of novel design. The boom, revolving frame and gantry are closely related to those used on conventional reclaimers and stackers. The feeding and elevating equipment comprises the bucket elevator, rotating distributor, slewing mechanism and cradle. The elevator

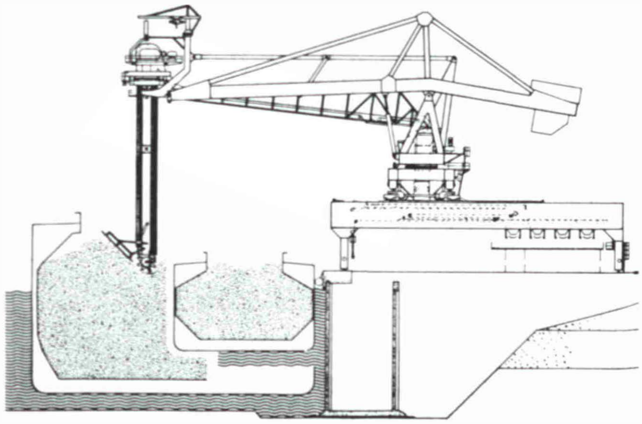


Fig. 10: Continuous unloader for coal and iron ore, 3000 t/h capacity (Delattre-Levier)

comprises two handling chains to which the buckets are attached, being bolted to the inner links in such a way as to give protection to the chains.

3.5 Reclaiming Scraper

An S-shaped reclaiming scraper is shown in Fig. 11. The handling path is fully enclosed from the point where it becomes vertical and all the way up to the head unit where the material is discharged onto a circular conveyor. The latter forms the transfer link between the scraper and the belt conveyor system which delivers the material to the stockpile. The bottom horizontal part of the scraper, which can be manoeuvred into the required position, can reach under the deck overhang of the ship's hold.

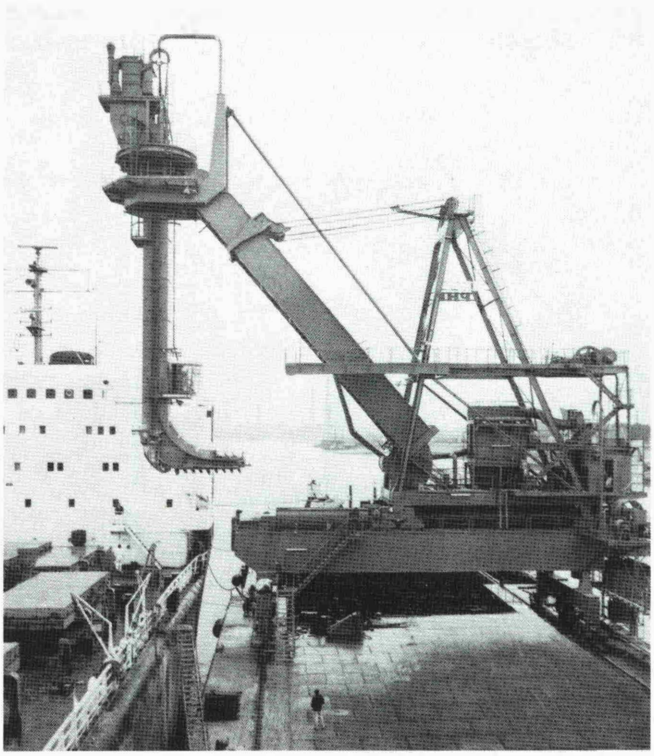
3.6 Feeding and Elevating System

Another feeding and elevating system is represented by Fig. 9/BD2, namely, the bucket wheel fed elevator, as is more particularly illustrated by the 1,700 m^3/h ship unloader, with twin bucket wheels, shown in Fig. 12. In this system the heavy bulk material is reclaimed by the bucket wheels and discharged onto a short feeder conveyor which in turn transfers it to the elevator. The wheels and conveyor are mounted on a steel frame pivotably attached to the bottom of the elevator and secured by means of inclined tie-rods to the elevator frame.

3.7 Cargo Scooper

The Kvaerner *Cargo Scooper* system (Fig. 9/D5 and Fig. 13) is basically built on the following components for each hold.

- One or more scraper conveyors working in the longitudinal direction.
- A scraper conveyor working in the athwartships direction.
- A bucket elevator working vertically in an enclosed shaft fitted with feeder flaps.
- A chute or hopper above deck level.
- A longitudinal collecting belt conveyor above deck level if there are three or more hatches.
- A slewing boom-type belt conveyor discharging over the side of the ship.



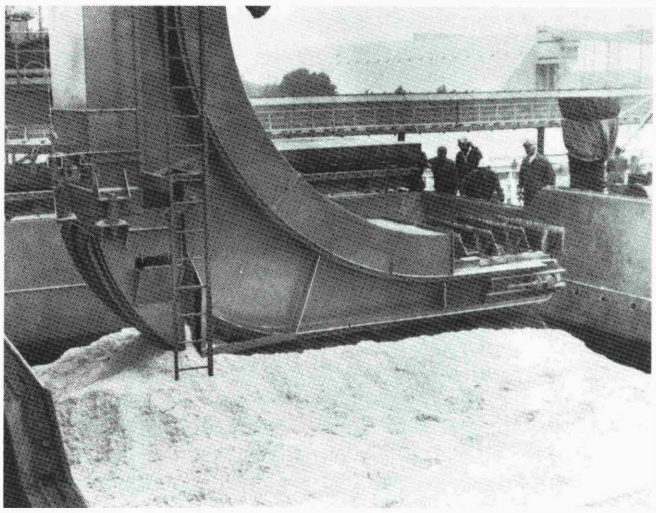


Fig. 11: S-shaped reclaimer, 350 t/h capacity (PHB Weserhütte, Cologne)

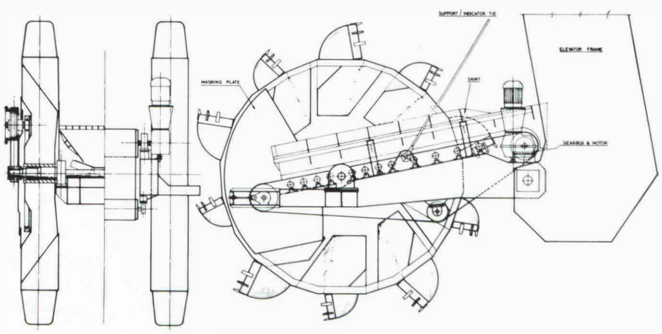


Fig. 12: Babcock-Moxey continuous ship unloader with bucket wheel feeder system, 1,700 m³/h capacity

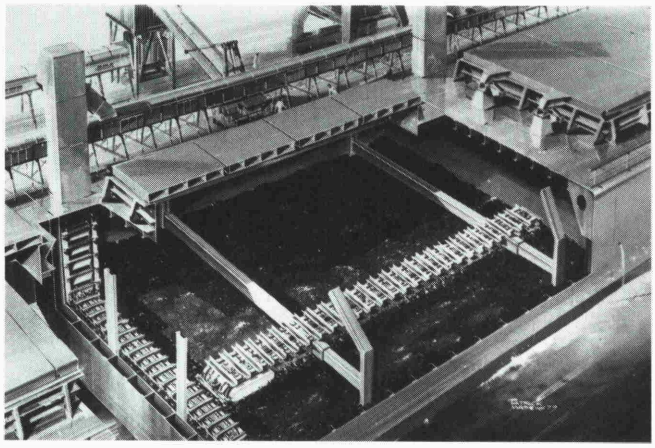


Fig. 13: *Cargo Scooper* self-unloading and trimming system for bulk cargoes (Kvaerner Brug A/S)

The longitudinal scraper conveyor shifts the cargo from its top level in a direction to feed the athwartships scraper conveyor.

The longitudinal scraper conveyor is supported on two athwartships telescoping beams on which the scraper conveyor automatically will travel from side to side of the hold. The setting of the scraping depth is adjustable.

The athwartships scraper conveyor is usually supported to the bulkhead in vertical sliding guides. Its operation is similar to the longitudinal one. It receives the cargo from the longitudinal scraper conveyor and delivers to the bucket elevator situated in the corner of the hold.

The bucket elevator is enclosed in a vertical shaft, the front side of which is fitted with a number of inlet doors or flaps acting as chutes which serve to feed the elevator. Below the cargo these flaps are closed and open automatically as the cargo level sinks.

Above deck level the bucket elevator discharges the cargo into a chute or a hopper which in turn will charge either a slewing boom type belt conveyor or fore and aft working belt conveyor.

Having brought the cargo above deck there are numerous possibilities for varying arrangements regarding the discharge over the side of the ship, for example: Two and two elevators placed against the same bulkhead can discharge into a common chute. Thus 4 hatches could have two slewing booms over the side, working simultaneously.

All movements during operation of the system are automatic and selfcontained. Manual selection of a movement is possible. To avoid pollution in the port area and onboard ship, the system can work with the hatches closed.

4. Pipeline Discharging Systems

4.1 Pneumatic Unloading of Bulk Cargoes

The pneumatic systems employed for the purpose are either of the suction or the pressure type. Major advantages offered by pneumatic handling are cleanliness, adaptability to awkward locations, and labour-saving operation. A pneumatic handling pipeline can be routed in virtually any direction — up, down, around corners — and can pass through restricted spaces in a way that would be impossible, or at any rate very expensive, with conventional mechanical handling equipment. All pneumatic handling systems for bulk cargoes operate on the same basic principles. For long conveying paths the designer will have to decide whether it is economically more advantageous to use a suction (vacuum) or a blowing (pressure) system. The limiting factors for a vacuum system are the size of the conveying pipes and the capacity of the exhauster. In order to keep the required vacuum (negative pressure) within acceptable limits, while obtaining the required handling rate, it is necessary to use fairly large pipe diameters and operate with high volumetric air flow rates. For conveying distances in excess of, say, about 200 m it is usually more advantageous to employ a pressure system in order to reduce the required pipe diameter and air flow rate and thus also reduce the size of all the components of the pneumatic conveying equipment.

If the bulk material to be handled has poor flowability, e.g., fodder, the difficulty consists in sufficiently loosening the packed or caked material to obtain favourable *pick-up* conditions at the intake nozzle. The pneumatic elevator shown in Fig. 14 is equipped with a special cutting device mounted so as to be rotatable round the nozzle of a suction system. With the aid of this loosening equipment a handling rate of 400 t/h can be attained even with poorly flowing materials.

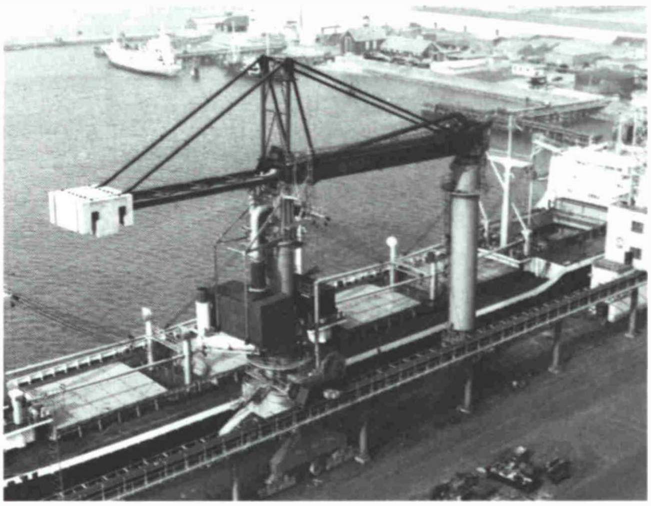


Fig. 14: Travelling gantry-type pneumatic elevator for poorly flowing materials, 400 t/h capacity (Fr. Kocks)

4.2 Slurry Transportation and Hydraulic Handling

The bulk materials currently transported in the largest quantities in ships are iron ore, coal, phosphate rock, bauxite, salt and grain. With the exception of grain, all these materials can be mixed with water to produce a pumpable slurry for handling purposes. Marcona has investigated the possibility of loading and/or unloading all these materials in the form of slurry [4]. In recent years, the handling of ore and coal as slurry has more particularly been in the focus of interest. In this connection the particle size of the material is the most important factor. Relatively large coal or ore particles can be efficiently dewatered, but require a very high power input to keep them suspended in the slurry during its passage through the pipeline. At the same time, the high flow velocities that this involves will cause correspondingly high rates of pipeline wear, necessitating early renewal of pipes. On the other hand, smaller particles require lower velocities (less power consumption) to keep them in suspension and would certainly be the better alternative except for the fact that they are difficult to dewater. This would not, however, be a major drawback if, for instance, the slurry could simply be pumped into a settling pond on shore and left for a sufficient length of time.

Fig. 15 schematically shows the transportation chain for ore from the mine (1) to the tanker (9). The ore is crushed and

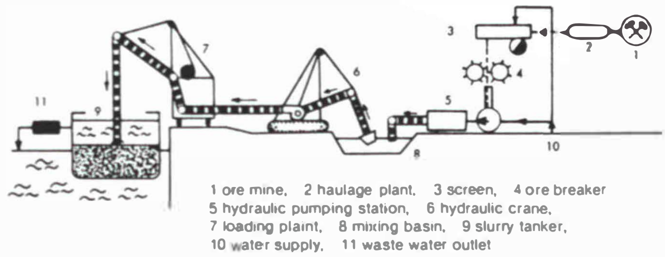


Fig. 15: Transportation chain for ore to the slurry tanker

ground (3, 4) to about 100 microns particle size and discharged into the slurry mixing basin or tank (8), from where the slurry is pumped to a slurry trough located on the landward side of the loading plants. The latter are of the rigid-leg gantry type. All auxiliary pipes and hoses for the capsules are contained within the capsule pipeline assembly. In the event of choking, flushout capability is available.

4.3 Conveying Capsules

Alternatively, dry bulk freighters can be discharged by the slurry technique, as illustrated in Fig. 16. The shore receiving

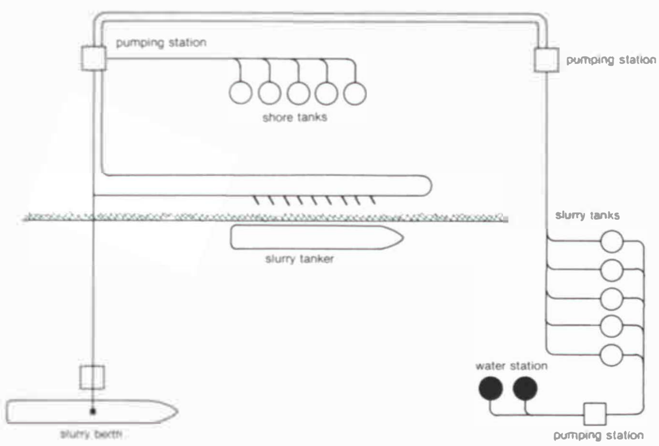


Fig. 16: Installation for the hydraulic discharge of dry bulk freighters by means of the slurry technique

facilities in this example are designed to operate with several conveying capsules. Water from tanks to supply the capsules is fed to the freighter, where the dry solids are mixed with it to form a slurry, which is then pumped from the ship to the slurry storage pond on shore. This system dispenses with the need for shipboard equipment and, instead, relies entirely on shore-bases installations. As the pipelines can be laid on the sea bed or be supported on

conventional transportation of ore from mine to smeltingplant	railway 210 km		freighter 50000 tdw		Eurobarge 5400 t		
transportation distance	mine port	ship loading-systems	maritime trans-continental transport	ship unloading system	waterway transport	discharging in the port	
cost tax	13 3,8	9,2 2,7	51,5 15,0	9,2 2,7	13,7 4,0	3,4 1,0	total 100 29,20
hydraulic ore pipeline	160 km		2 Slurry Tanker 250 000 tdw				
transportation method	mine to shipping port	ship loading system	maritime transport	port of destination	overland transport	discharging to smelting plant or power station	
cost tax	12,5 1,8	11,0 1,6	50,0 7,2	11,0 1,6	12,5 1,8	3,0 0,5	100 14,50
transport cost advantage in %	6,2	5,5	24,8	5,5	6,2	1,8	50

Fig. 17: Comparison of conventional and slurry transportation chains for ore from mine to smelting plant

floating pontoons, an offshore mooring island will suffice as berthing accomodation for the ships. More particularly, this can provide an economically attractive method of unloading large vessels in coastal waters where there are no suitable deep-water harbours to accommodate them. In such an arrangement one set of pumps would supply the suspension water to the ship, while another set would pump the slurry ashore to storage or filtration units. It is calculated that discharge rates of up to 2,000 t/h could be attained through just one pipeline.

A comparison between conventional and slurry transport chains is presented in Fig. 17.

The example highlights the advantage of hydraulic handling and conveying. It also shows that, for an economic solution, the whole transportation chain from mine to smelting plant must be studied. More particularly, the example considers a plant receiving 5 million t of iron ore (reduced to 100 microns particle size) per year from an overseas source of supply 8,000 km away. The first part of the example shows the conventional transportation chain. For the purpose of comparison the cost of this procedure (in DM/t) can be put at 100 %. An average vessel size of 50,000 tdw is assumed.

Over relatively short distances, hydraulic conveying has the advantage over carrying the material by rail. If, furthermore, hydraulic loading and unloading methods at ports are used instead of conventional cranes, considerable savings in cost can be effected.

With slurry tankers of 250,000 tdw capacity further substantial savings in transportation costs are possible. Thus, with the slurry method of handling and conveying, an overall saving of about 50 % can be obtained.

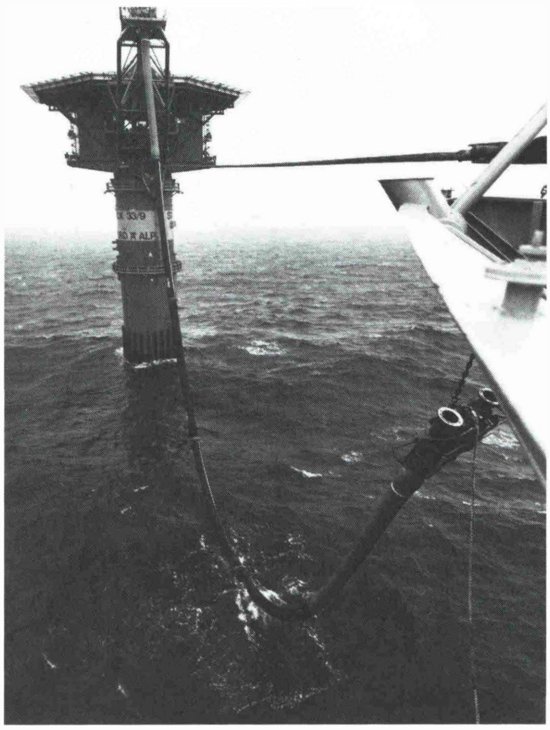


Fig. 18: *Statoil* distributing column for unloading oil from tankers

Freight rates between Brazil and Western Europe are in the range of about 15 to 20 DM/t. A 50 % saving would cut the freight charges in respect of this trade by something like 50 to 70 million DM per year.

In view of such figures there is a strong case for planning and transportation engineers to devote more attention to the possibilities of hydraulic handling and conveying of bulk materials.

With this new system of hydraulic bulk transportation it moreover becomes possible to use larger ships. The relatively simple procedure for discharging a tanker is not tied to any particular port facilities. All that is needed is an unloading jetty or an offshore artificial island situated in deep water or beside a suitably deep navigation channel, together with pipelines linking the jetty head or the island to the shore and the existing transportation and storage installations.

4.4 Distributing Column

Alternatively, a so-called *distributing column* in the sea (Fig. 18) may be employed — such as was, for example, installed in the North Sea at a distance of about 200 km west of the Norwegian mainland in the autumn of 1979. Besides oil tankers, slurry tankers could discharge their cargoes at such an offshore column, the material being conveyed to the shore through pipelines at rates of up to 10,000 m^3/h, corresponding to those attained in the pipelines of the Statfjord oilfield.

5. Cargo Terminals — Loading and Unloading Ports

On considering the many and varied developments that have occurred, and are occurring, in ships and in cargo handling methods, the effects of which partly overlap one another, but partly also diverge, the question that confronts us is: are our sea ports still sufficiently up to date or is the whole evolution in this sphere moving in the direction of entirely new forms of terminal facilities?

As a result of experience gained in the technical design of some of the world's largest bulk cargo ports in recent decades, new technologies have emerged in the field of cargo handling (loading and unloading operations) which in turn open up fresh design possibilities for cargo terminals.

The North Sea ports of the Benelux countries (Antwerp, Rotterdam, Amsterdam) and Northern Germany (Emden, Wilhelmshaven, Bremerhaven, Hamburg) are continually having to be dredged so as to maintain 20 m depth to accomodate big freighters and tankers. Apart from the effort and cost that this involves, there is the drawback of difficult manoeuvrability and collision hazard in the frequently quite narrow navigation channels maintained in this way. Also, the time it takes for a vessel to proceed from the harbour mouth to its berth at the quay, and vice versa, the waiting time until berthing and cargo handling installations are available, the time required by the actual handling operations, as well as the storage or warehousing and the overland transportation facilities linking up with the port, are important factors affecting the cost of cargo transfer operations in major ports.

In these ports the goods and materials brought in by the intermittently arriving means of transport — ships, barges, railway waggons — have to be kept, properly sorted and ready for despatch when called for, in appropriately large storage yards or warehouses, from where they are then fed continuously to other such means of transport which depart likewise intermittently, but at different times from the incoming ones.

In this context the so-called slewing-type ship loader (Fig. 19) is of interest. This handling machine has a telescopically extendable boom which can slew in a circular segmental path and can thus reach any of the ship's hatches to be served by it. The loader can be supported on piles.

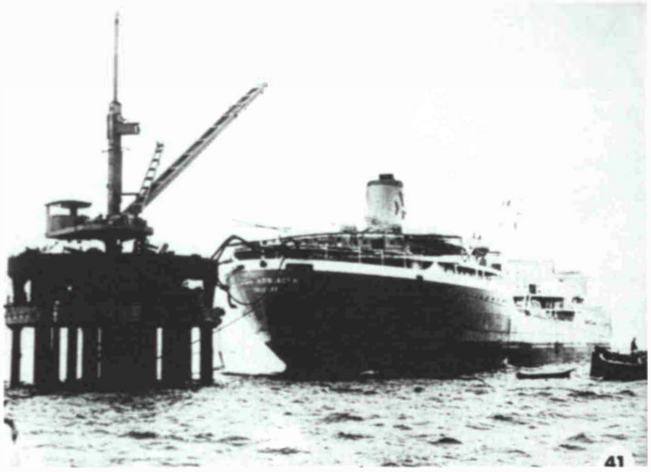


Fig. 19: Slewing-type ship loader

5.1 Deepwater Berthing Pier

There are plans to build a ship loading terminal in deep water at some distance from the coast at Cape Santa Clara in the Atlantic Ocean, near the mouth of the Gaboon estuary, 25 km north of the city of Libreville. In this scheme a bulk loading installation is to be constructed at a distance of 7.5 km from the coast, in 21 m depth of water. Initially, ore freighters of 150,000 tdw will be loaded at a rate of 10,000 t/h.

One such loading pier is thus able to handle about 15 million tons per year, corresponding to some 230 shiploads, assuming a tonnage range of vessels from 10,000 to 150,000 tdw served by it. The average ship turn-round time will thus be 34 hours, comprising a waiting period of 14 hours and 20 hours actual loading time. These berthing piers are to be equipped with so-called linear loaders. A machine of this kind (Fig. 20)

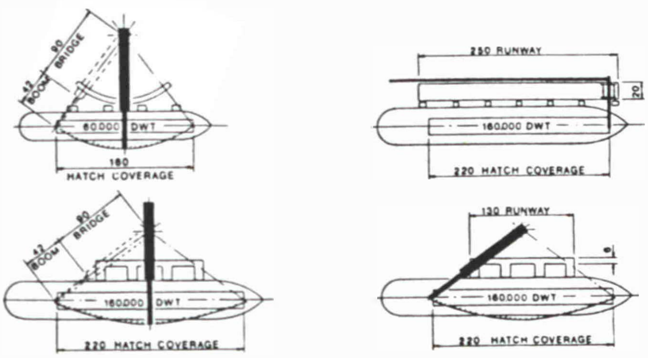


Fig. 20: Radial loader (top left), travelling loader (top right) and linear loaders (bottom left and right)

comprises an extendable loading boom attached to a bridge which can slew and slide on a rear supporting structure, while its front part moves on a straight track running parallel to the edge of the quay [5]. The boom projects out over the ship and can serve all the hatches. In comparison with other ship loading systems this type of loader entails lower pier construction costs.

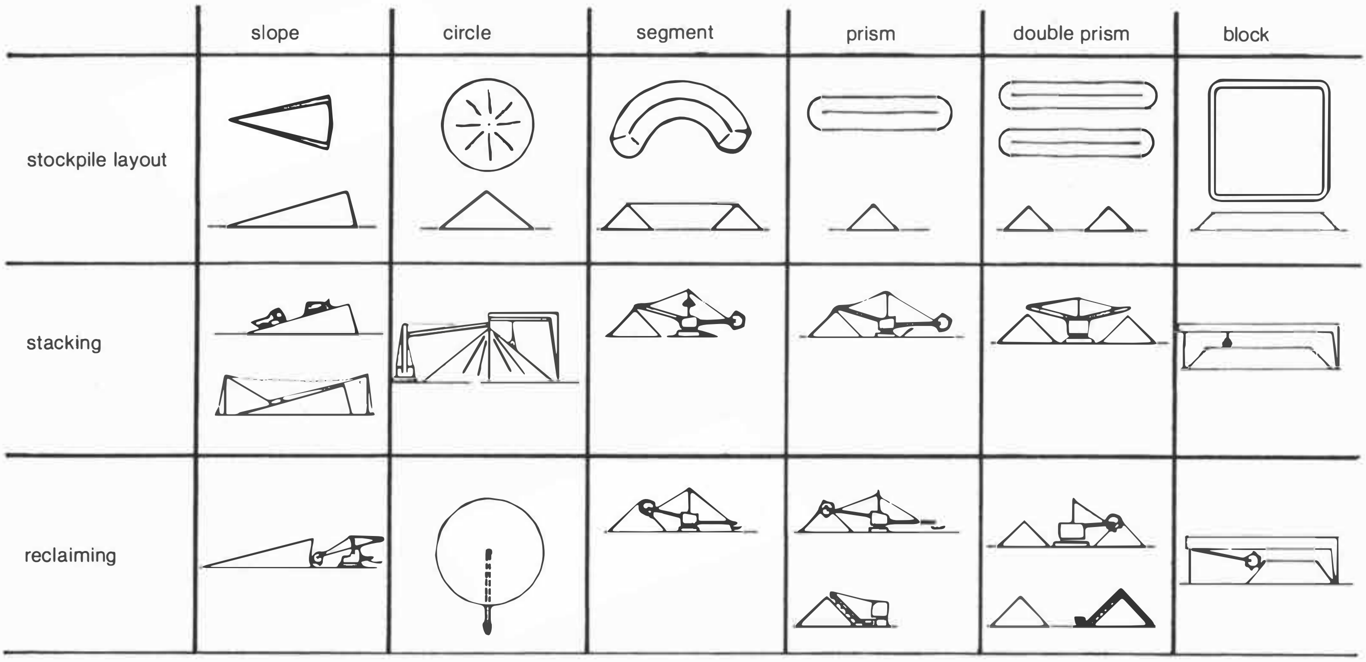


Fig. 21: Various types of stockpile with stacking and reclaiming equipment

A quay equipped with a linear loader and offering berthing accommodation for vessels of 400,000 tdw has been commissioned at Narvik. The whole substructure consists merely of five concrete caissons of 14 m diameter and four vertical intermediate supports. The equipment includes a bucket wheel reclaimer of 10,000 t/h capacity which, in combination with an intermediate hopper, can feed either or both of the storage yard conveyors.

In these modern cargo handling ports in future the problems of environmental protection, higher operational reliability and full automation of operations are bound to play a major part. Bulk material transfer projects with capacities of 20 million t/year are now by no means unusual.

The functional relationships between the bulk material to be handled and the storage yard (Fig. 21) show that, for smaller particle size and reduced storage quantities, the stockpiles need no longer be on or near the quay [6]. The distance at which the stockpile can be located away from the quay will depend on the type and capacity of the means of transport connecting them. Therefore, if less expensive methods of foundation construction are devised, the ship loaders and, even more important, the unloaders can be installed on pier-type substructures, thus dispensing with the need for building quays and providing expensive areas of land adjacent to them.

5.2 Offshore Facilities

The next step in this evolution would be the transition from the deep-water berthing pier to the truly offshore loading and unloading installation as illustrated in Fig. 22 and as actually built at Port Latta with two groups of four anchorage buoys. Besides some South American installations in this category, the offshore loading installation at El Aaiun and the projected new double pier structure at Narvik call for mention.

Such cargo transfer systems can be built far out at sea, thus dispensing with the high cost of dredging the navigation channel for superfreighters and also reducing the ship turn-

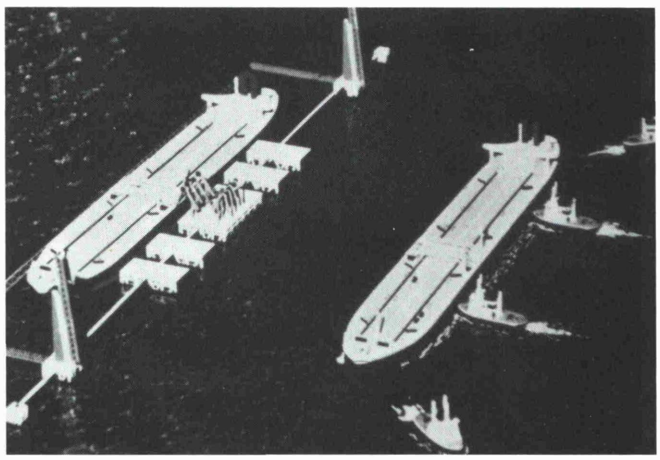


Fig. 22: Offshore loading and unloading installations

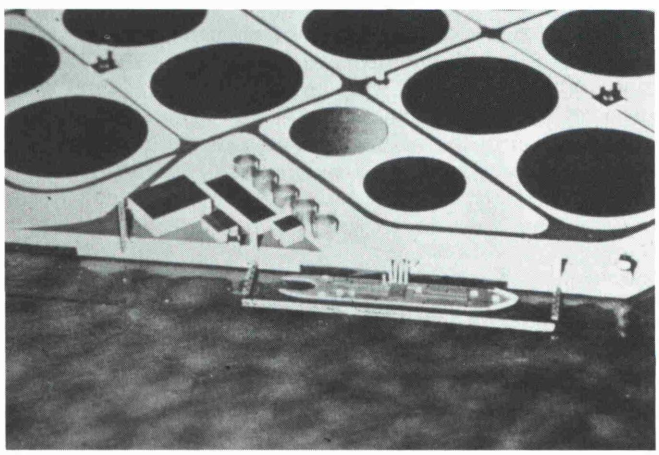


Fig. 23: Offshore floating tank installation

round times. With such solutions the main problem is that of conveying the material to and from the shore. For this purpose, belt conveyors or pipelines carried on supporting structures above sea level may be employed. Alternatively, pipelines can be laid under water, as has already been done with the Ekofisk pipeline.

These offshore loading/unloading installations, equipped for dealing with oil and slurry tankers, together with the pipeline system, form an optimum overall system in the linkage of overland and sea transportation facilities. In calm coastal waters it would moreover be possible to use floating tanks for storage at the transfer terminal. Fig. 23 shows a floating tank installation of this kind, equipped with loading and unloading gear to serve tankers berthing alongside.

5.3 Container Handling with Amphibious Craft

Cargoes can be shipped in special lighters stowed in a carrier vessel. On arrival at the destination, the lighters are lowered into the water by means of shipboard cranes. Alternatively, containers loaded in amphibious craft can be used. Fig. 24 shows the *Amphitruck AT400*, developed by Krupp, which can convey a 20 ft container from the ship to the shore, where it can continue its journey by road (on public highways) to the final destination, and vice versa. It can be used as the central linking feature of an alternative transportation system in cases where the usual loading and unloading methods for seagoing vessels are unavailable. On land the Amphitruck can travel up to 300 km on one fuel tank filling, at speeds of up to 40 km/h. On the sea it can, fully laden, travel a distance of 80 km without refuelling, attaining a speed of 10 km/h. With its payload of 20 t this craft can operate under conditions up to "sea 3".

Fig. 24: *Amphitruck* (Krupp)

5.4 Floating Cargo Handling Installation

Under circumstances where large freighters cannot be berthed in ports lacking in suitable deep-water facilities, a floating platform equipped with loading/unloading gear may be provided instead of a fixed deep-water installation some distance from the shore, where the cargo can be transferred from the large vessels into lighters, and vice versa, as exemplified by the system illustrated in Fig. 25. Grab cranes remove the material from lighters and deposit it into hoppers from where it is delivered by a continuous handling plant, comprising an inclined belt conveyor and a boom carrying a belt conveyor which discharges the material into the hatchways of the ship. With these arrangements the floating cargo handling installation can serve a number of ships in close succession.

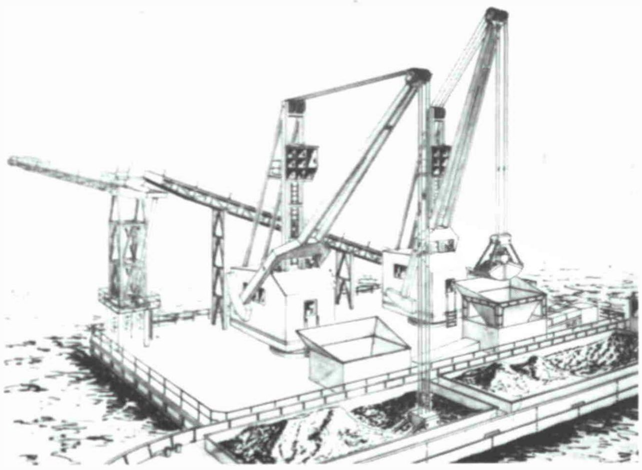


Fig. 25: Pontoon bulk cargo handling installation

6. Transportation Cost Comparison

The determining factor in a comparison is the specific cost of transport expressed in, for example, DM/tkm for the total annual quantity handled (t/year).

While for sea transportation the ship is the optimum means, for overland transportation there are a number of systems to choose from, such as inland navigation (barges, etc.), rail, pipeline, long-distance belt conveyor, etc.

A distinction must be drawn between operating expenses and capital cost. Whereas the former increases from year to year with inflation, the latter will remain substantially constant, apart from adjustments in interest rate, which are hardly very significant. The cost of transportation by rail comprises 15% capital expenditure and 85% operating expenses. For pipeline transportation the corresponding figures are 60% and 40% respectively, so that this system is less affected by cost increases due to inflation (1.5%/year) than the railway is (7%/year), as Fig. 26 shows [7].

In terms of energy consumption the pipeline is a little less favourable than the railway. In both systems, electric energy generated by coal firing is assumed to be used, so that in the long term the dependence on oil imports will be reduced. In America most locomotives are of the diesel-electric type, however, so that there the balance is not so favourable to rail transportation.

It is to be expected that future developments in unloader systems will diverge from the line they have hitherto followed. The new factors in the equation will be: stricter environmental control requirements and the increasing difficulty and delay in obtaining permits for carrying out constructional work on new sites in industrialized countries. Under these circumstances there is likely to be development of very high-capacity unloader systems on existing cargo

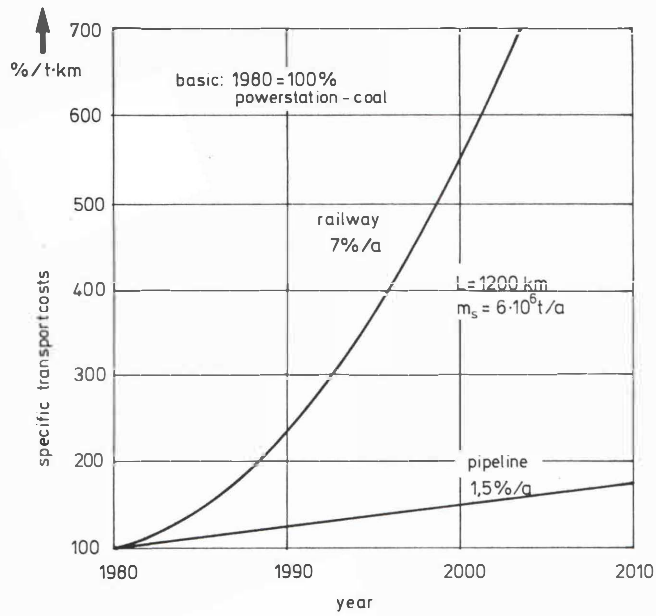


Fig. 26: Effect of inflation on the specific cost of transportation by rail and by pipeline

handling sites and the increased use of covered storage and covered protection for activities that now generally still take place in the open [8].

7. Reliability and Safety of Pipeline Conveying

The competitiveness of transportation systems is primarily measured in economic terms, with cost as the significant criterion. On the other hand, a comparison which includes non-quantifiable factors associated with safety, reliability and environmental requirements is possible only on the basis of a cost-benefit analysis. Thus, in choosing a system, the aspects to be considered besides purely economic ones are: operational reliability or availability, environmental acceptability (freedom from nuisance or pollution), and safety (absence of hazard to persons or property). As the hitherto available experience in the operation of solids conveying by pipeline is very limited, so that it is difficult to make a precise assessment of the reliability and safety of such systems, it is appropriate to turn to the statistics for the instances and causes of damage affecting oil and gas pipelines.

With the materials suitable for conveying by pipeline — such as ore, coal or red mud (Bayer aluminium process residue), i.e., materials which do not present a toxic contamination hazard to ground-water — the problem of environmental pollution hardly arises. Since the pipelines are laid underground, no significant harm or damage is likely to occur even in the event of fracture.

The experience that has been gained with oil pipelines provides sufficient guidance for the operationally reliable design of solids conveying pipelines, so that shutdowns due to technical trouble can largely be obviated.

7.1 Transportation Accidents

Fig. 27 presents a breakdown of the fatal accidents which occurred with various transportation systems in the USA in 1977. It emerges that the pipeline, with only 43 deaths, is the safest system in comparison with combined road/rail transportation with 1000 deaths (100 %), railway with 653 deaths (65 %) and economic sea navigation with 216 deaths (22 %).

In oil transportation by sea there have been serious accidents which, though not claiming so many human lives, caused major environmental pollution. Up to the present time some 160 oil tankers have been lost at sea. Off the North German coast alone an estimated 10,000 to 20,000 t of oil has accidentally escaped to pollute the beaches and tidal mud-flats.

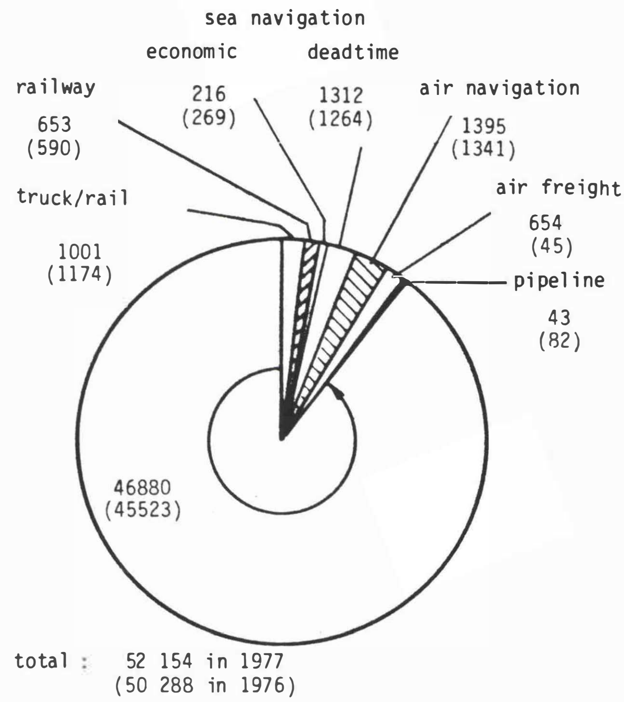


Fig. 27: Fatal accidents associated with transportation in the USA

A risk study undertaken by the Canadian atomic energy supervisory authority compares a number of energy systems with one another. For this purpose all the average accident and sickness cases assignable to these various systems have been taken into consideration — from winning, transportation and transfer handling of the materials through processing and firing of the fuels to the construction and operation of the power generating plants concerned. For the sake of valid comparability the respective hazard ratings have been expressed with reference to a relative energy output of 1 MW x year (MWa) (8,176 MWh). For comparison with working days lost due to illness, each case of death has been rated as equivalent to 6,000 days (Fig. 28) [9, 10]. Per million persons the annual death rate comprises 300 traffic accidents, 3 deaths in fossil-fuel-fired power stations (SO_2 poisoning), and a mere 0.01 in nuclear power stations (leukaemia and cancer).

8. Conclusion

The European Community will have to come to terms with the social, political and economic changes that have taken, and are still taking place in the wake of the world oil crisis

energy	working days lost	cases of death per annum and per 1 MW/a	cases of invalidity
generation of electrical energy from natural gas	6	$1.24 \cdot 10^{-3}$	$11.6 \cdot 10^{-3}$
from oil	2000	$1.66—87 \cdot 10^{-3}$	$81.3—156.7 \cdot 10^{-3}$
from coal	2800	$11.6—20.7 \cdot 10^{-3}$	$174—232 \cdot 10^{-3}$
from nuclear energy	2—10	$0.83—1.7 \cdot 10^{-3}$	$4.64—17.4 \cdot 10^{-3}$

Fig. 28: Canadian study of risks (in terms of working days lost, deaths and invalidity) associated with the use of oil, coal, conventional electric energy and nuclear energy

and will have to adjust itself to the unforeseen shift in raw material supply patterns that has resulted from this. The scarcity of resources demands long-term efforts to make the best use of available raw material deposits and reserves and to promote the development of trade routes and transportation facilities.

Trade routes have traditionally brought people and nations into closer contact with one another. Indeed, without these trading links, mankind would hardly have made much progress on the road to civilization. Whether considered from the cultural, the economic, the historic, the geographic or the world political point of view, trade routes have always been a very important factor in human affairs and will continue to fulfil this major role in the political and economic future of an integrated Europe.

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