AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture — AF25-0000-0000

B. SECONDARY: Soil fertility,fertilizers,and plant nutrition

2. TITLE AND SUBTITLE

The feasibility of shipping bulk fertilizer materials into developing countries

3. AUTHOR(S)

Kelso,T.M.; Waggoner,D.R.; Corrigan,P.A.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1971	88p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

TVA

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(In NFDC bul.Y-29)

9. ABSTRACT

10. CONTROL NUMBER

PN-RAA- 202

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Bagging
Bulk cargo
Transporation
Unloading
Urea

13. PROJECT NUMBER

14. CONTRACT NUMBER

PASA TA (QA) 6-69 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

10

July 1971

Bulletin Y-29

THE FEASIBILITY OF SHIPPING BULK FERTILIZER MATERIALS INTO DEVELOPING COUNTRIES

Tennessee Valley Authority

Prepared for the

AGENCY FOR INTERNATIONAL DEVELOPMENT

by

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THE FEASIBILITY OF SHIPPING BULK FERTILIZER MATERIALS INTO DEVELOPING COUNTRIES

SUMMARY

The first phase of studies by the Tennessee Valley Authority (TVA) of the feasibility of shipping bulk fertilizer materials into developing countries (DC's) has been completed. Shipment of urea was emphasized in the work because urea is becoming the most widely used nitrogen fertilizer (1) and because urea is one of the more difficult fertilizer materials to ship, handle, and store in humid areas. Also, for economic reasons, urea must be produced in conjunction with ammonia production. Thus, there will likely always be substantial long-distance movement of urea.

Three bulk urea ocean shipments, including one into a DC, were evaluated. The unloading operations were studied and documented. Costs were estimated and compared with costs of bag shipment. Problem areas were identified.

Bulk shipment of fertilizers, including urea, into DC's is feasible if suitable equipment is provided and is properly utilized. Cost studies showed that shipment of bulk fertilizer from the United States to India or Pakistan should cost about $20 per ton less than bagged shipment. If the bulk fertilizer is bagged at the receiving port, total costs should be about $10 to $12 per ton less than for materials bagged prior to shipping.

With the usual clamshell type of unloading equipment, loss of material due to spillage and degradation was substantial.

Some new concepts in shipping, such as self-unloading vessels and vessels that can be loaded with bulk material and bagged en route, were investigated. The Lykes and LASH (Lighter-Aboard-Ship) handling concepts of transporting barges inside a mother ship were studied. An investigation of the possible use of containerization for fertilizers was initiated. All of these concepts have special advantages that may be attractive for movement of bulk fertilizer materials to and within DC's.

THE FEASIBILITY OF SHIPPING BULK FERTILIZER MATERIALS INTO DEVELOPING COUNTRIES

INTRODUCTION

In many situations the shipping handling, and storing of fertilizers represent more than half the total cost of getting fertilizers to farmers in the DC's. Sometimes the total cost of moving fertilizers from the production location to the use area is $50 or more per ton of product for imported fertilizers.

In the past decade improvements in technology of fertilizer production have substantially lowered costs of production of most fertilizer products. In fact, further substantial cost reductions due to improvements in production technology are not likely. In contrast, comparatively little effort has been devoted to improving the efficiency of handling fertilizers--particularly fertilizers moving to and within DC's. Therefore, there is considerable potential for reducing fertilizer costs by increasing the efficiency of movement between the producer and the user. To investigate means for lowering these fertilizer handling and shipping costs, TVA and AID initiated two joint studies of the handling of bulk and of bagged fertilizers in fiscal year 1970. This study relates to bulk fertilizers.

Since, with the exception of anhydrous ammonia, practically all fertilizer materials imported into DC's are solids, it was agreed that handling of solids would be studied further. It was further agreed that bulk handling and shipment of urea should be emphasized. Urea was investigated because (1) it is becoming the leading nitrogen fertilizer in the world with increasing movement to and within DC's, (2) urea is one of the physically weaker and more hygroscopic of the fertilizer materials; so equipment and procedures that work well with urea should be suitable for most other solid fertilizer materials, and (3) urea must be produced in conjunction with ammonia production. Therefore, many countries that do not have suitable ammonia feedstock likely will rely on importation for their urea supply.

Objectives are to evaluate possible equipment and procedures for bulk movement of urea to DC's; to study costs, losses, and potential problems; and to suggest changes in hardware and procedures for avoiding these problems and to lower costs.

This report summarizes the work done. Studies of bulk handling of urea should be continued. Also, the study should be broadened to include bulk handling of fertilizer materials other than urea by all types of carriers. To derive the most practical and tangible benefits from these studies, it is proposed that TVA directly assist the Agency for International Development (AID) and select DC's in preparing for and in initiating test handling of some fertilizer materials in bulk where cost savings can likely be achieved.

Studies have been directed primarily toward river barges and ocean-going ships. Later studies should be broadened to include ocean-going barges and land transport--railways, trucks, etc.

TRANSPORTATION SYSTEMS

Water-Based Systems

A wide variety of carriers and handling systems for the bulk transportation of the various cargos is used. The capabilities of different types of vessels and of different ports sometimes assist and sometimes hamper cargo handling. A summary of the information obtained follows.

Loading and Discharge of Cargo

Both loading and unloading systems use similar equipment, such as clamshell buckets (grabs), cranes, receiving hoppers, and conveyor belts. These may be mounted on the vessel or the dock. If mounted on the vessel, it is called "self-unloading." If the dockside equipment is movable, such as a clamshell on a traveling gantry, it can load or unload without moving the ship; also, ship trim can be maintained during the operation without ballasting. If the unloading facilities are stationary, the vessel must be warped into a new position frequently or ballasted.

Cranes equipped with clamshell buckets (automatic grabs) are the most commonly used equipment. For some small-scale operations, crawler or truck-mounted cranes are used particularly in conjunction with barges. However, to handle large tonnages of materials most sophisticated equipment must be used. For example, during a special test at the Port of Santos, State of São Paulo, Brazil, 4500 tons of fertilizer was off-loaded in 24 hours. To unload at this rate, five gantry cranes were used and a complete crew of stevedores was assigned to each hold of the ship. The normal routine off-loading rate is much less, especially when manually filled gravity dump buckets are used as is shown in the tabulation below.

Handling procedure	Total tons unloaded	Average unloading rate, metric tons/operating hour
From ships to railway cars using automatic clamshells	452,400	34
From ships to railway cars using cranes and gravity dump buckets (manual fill and manual dump)	27,700	7
From ships to trucks using automatic clamshells	322,800	25
From ships to trucks using dump buckets (manual fill and manual dump)	4,950	7

These unloading rates are too low to be economical in most situations. To increase the annual tonnage of materials that can be off-loaded at Santos and similarly equipped ports, the hourly off-loading rate must be increased by methods other than utilizing additional manpower, i.e., mechanical means.

Loading

In many cases where ships are loaded from trucks and railroad cars, these vehicles discharge into a hopper feeding a conveyor belt loader which discharges through a telescoping chute into the hold of the ship. If discharge hoppers are not available, a clamshell crane transfers the material directly from the open truck or railroad car into the hold.

If the ship is loaded from a barge, a clamshell crane or a marine leg removes the material from the barge and transfers it to the ship loader. Self-unloading barges (and ships) will be discussed in detail later.

When a ship is loaded from dock storage, front-end loaders, bucket wheel reclaimers, and clamshell cranes are usually used to transfer the material from the bulk storage pile to a hopper which feeds the material to the shiploader through conveyor belts. If storage is in silos, the material feeds by gravity onto a conveyor belt to the shiploader.

During loading, the cargo must be evenly distributed throughout the hold (trimmed) to keep the ship on an even keel. This can be done manually or by using bulldozers to push the material under the wings of ship when a clamshell or a nontrimming shiploader is used, or the end of the chute on the shiploader can be equipped with mechanical trimmers which throw the material evenly throughout the entire hold.

Discharge of Cargo

Shore-Mounted Equipment: When unloading from ships to trucks, rail cars, or barges, shore-mounted clamshells are frequently used. The clamshell can be dumped directly into the vehicle or barge, often with considerable spillage, or in the case of trucks or rail cars the clamshell can dump into movable or stationary gantry hoppers over the vehicles. Also used are marine legs (Fig. 1) which discharge by conveyor belts directly to the vehicles or barges or to hoppers over the vehicles. When unloading directly to storage, the clamshells or marine legs discharge to the storage conveying system. Both clamshells and marine legs are unable to unload the cargo under the wings of the ship. Small bulldozers and manual labor are used to move the material to the hold opening where it can be picked up by clamshell or marine leg. Manual labor has to be used to shovel the cargo from the tween decks in ships so equipped.

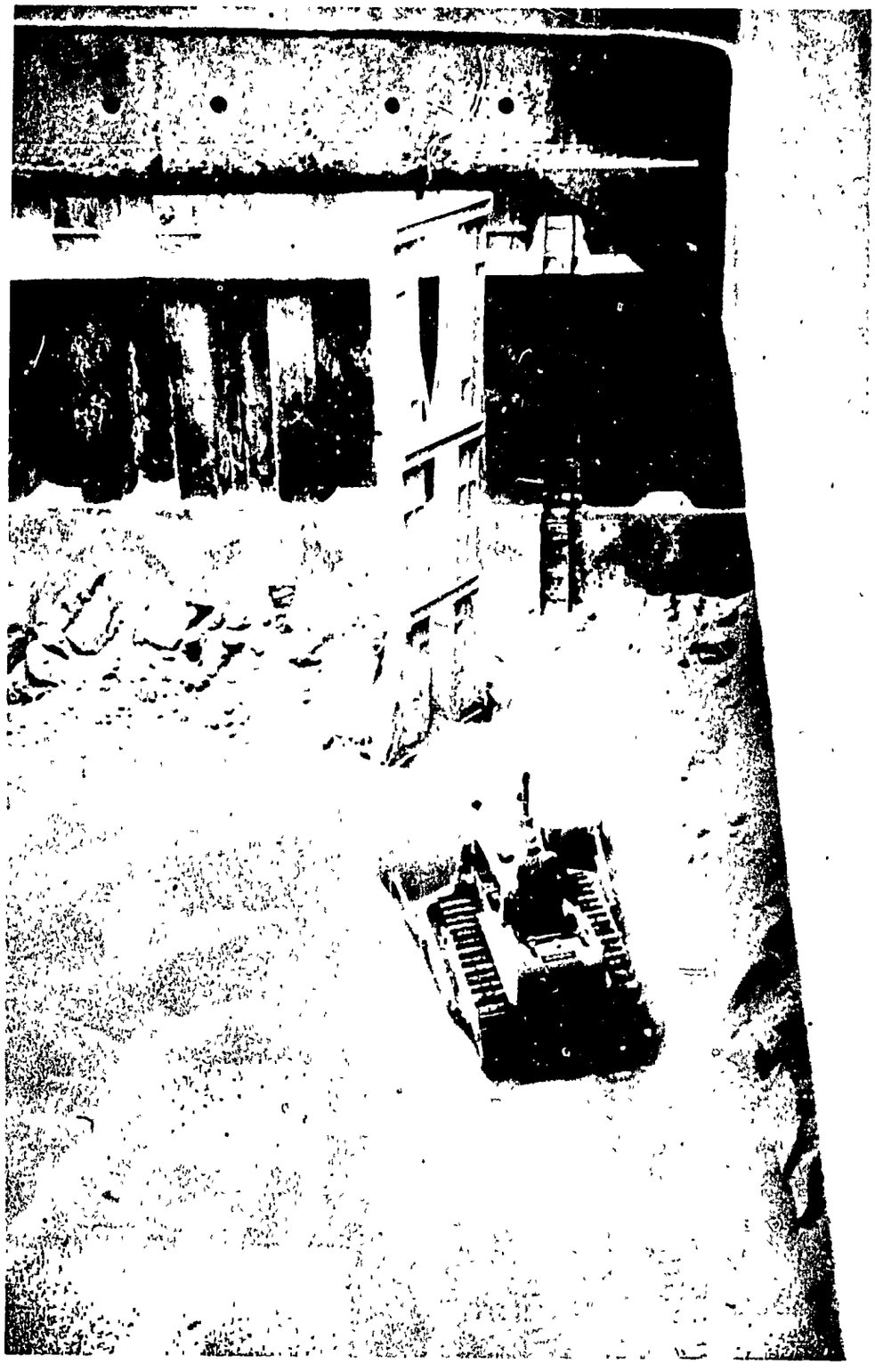


FIGURE 1

Marine Leg Unloading Potash

Clamshell buckets, even though well maintained, leak. Most of the material that spills from the clamshell is lost. When the losses are reported as a percentage of the total cargo, the losses may sound almost insignificant; however, an indicated 2% loss from a 10,000-ton urea cargo could be a loss of $12,000.

Also, fertilizer loading and unloading operations using conventional equipment have to be suspended during periods of bad weather. Delay time can easily cost $6,000 per day.

Not only does spillage of fertilizer represent a direct money loss but when the fertilizer is spilled on equipment such as railway cars, extensive corrosion can result. The Sorocabana Railway in Brazil assigned 400 cars to fertilizer movement at the Port of Santos. The cars used were either boxcars or gondola cars. Hopper cars were not used. Most of the cars were made of mild steel. During 1969, three hundred of the cars were removed from service because of damage by the fertilizer cargos. During the loading process at the docks, the cars are liberally coated with fertilizer materials. Consequently, corrosion may occur from the outside as well as the inside of the car.

Self-Unloading Vessels: To expedite the discharge of cargos and avoid the use of dockside gear and crews, self-unloading vessels have been developed. These vessels have usually been used on such commodities as coal, iron ore, and cement. Ultrafertil in Brazil has been using two self-unloading ships during the past year to transport phosphate rock, sulfur, and potash. One of the vessels (Fig. 2) supplied by Gearbulk of Bergen, Norway, has a deadweight of 24,900 tons and is equipped with two traveling deck cranes. Both cranes working at full capacity can unload a maximum of about 2500 tons per hour.

Self-unloading vessels are usually one of five types, depending upon the size of the vessels and the type of unloading equipment used.

1. Smaller vessels, usually barges, which have a relatively large number of small hopper bottom holds, usually two to a vessel, one port and one starboard. The bulk cargo is discharged by gravity through slide gates in the bottoms of the hoppers or through rotary paddle wheel feeders onto two longitudinal belt or screw conveyors one under each row of hoppers. These conveyors discharge either to inclined screws, bucket elevators, or to a pressure-pneumatic conveyor. The inclined screws and bucket elevators discharge to a topside belt conveying system which transfers the material to the dockside handling system. The pneumatic conveyor discharges directly to the dockside system.

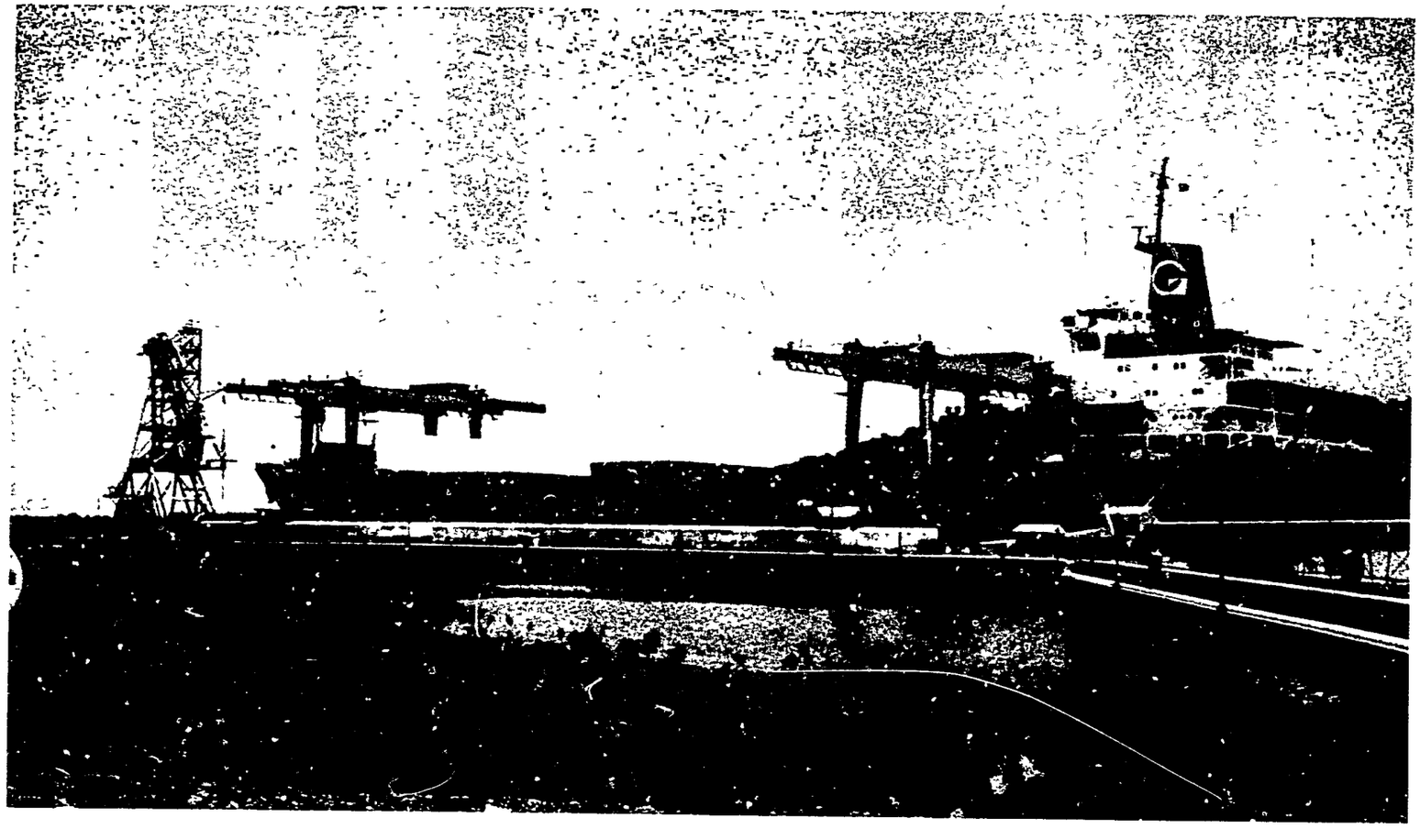


FIGURE 2

Ocean-going, Self-unloading Ship

2. Larger vessels, both barges and ships, which have a small number of larger holds, but these larger holds have several hopper bottoms in each hold. These vessels discharge cargo from the hopper-bottomed holds in the same manner as in (1) above.

3. Larger vessels with a small number of large, conventional (not equipped with hopper bottoms) holds with ship-mounted clamshell unloaders which discharge either directly to the dockside handling equipment or to an ondeck conveying system which unloads to the dockside equipment either through outboard shuttle conveyors or through telescoping unloading booms. This type of vessel can be anchored in sheltered waters where it can either unload to barges or simultaneously unload and take on different cargos from barges without using land-based facilities.

4. Vessels, either barges or ships, which have one continuous hold and can be unloaded using a ship-mounted drag scraper (a bucket without either top or bottom) which travels back and forth the length of the hold and drags the cargo to the boot of a bucket elevator. The elevator discharges either to a shuttle belt or to a positive pneumatic conveyor (cement pump if the cargo is cement). Both systems discharge from the hold to the dockside handling equipment.

5. Small vessels, such as converted LSM's (landing ship mediums) and ships, which have cargo doors in their sides can become bulk carriers when loaded and unloaded by front-end loaders. They can be self-loading and unloading if the front-end carriers are stowed aboard.

A self-unloading system that might be applicable to bulk fertilizer shipments was installed in the MV Cemento Ponce for the Puerto Rican Cement Company, Inc. (PRCC). (A detailed discussion of the Cemento Ponce will be given later.) Drag scrapers are used to unload cement from the holds of the ship.

Several persons experienced in building and operating self-unloading systems expressed the opinion that drag scrapers are the most economical equipment for small ships and barges (2, 3). Therefore, this type unloading system was investigated in some detail.

Marine consultants and designers have designed and installed a variety of self-unloading systems in vessels. Among those designed is the Sauerman drag system used in the MV Cemento Ponce.

Sauerman Bros., Inc., 620 South 28th Avenue, Bellwood, Illinois, has supplied brochures and data that we have on file dealing with their Sauerman drag scrapers. Films of the drag scraper in operation are available on a loan basis. The Sauerman system consists of a bucket with sides but no bottom which travels back and forth in the hold of a vessel and moves the material into the ship's discharging system. A drum-hoist system similar to that used on dragline cranes is used to move the bucket back and forth (Fig. 3).

A visit was made to the Decatur, Alabama, terminal of Missouri Portland Cement Company to observe a cement barge equipped with Sauerman drags to discharge cargo (4). This drag had been in service about 20 years. Terminal personnel expressed complete satisfaction with the drags. Ease of operation and low maintenance costs were stressed as particular advantages.

Self-unloading barges of up to 2500-ton capacity have been built by Ingalls Iron Works, Marine Division (3). The unloading systems they use are drag scrapers in conjunction with rotary plow feeders. Ingalls' personnel expressed satisfaction with this type system.

Unfortunately drag scrapers have never been used for unloading urea or other fertilizers. Therefore, data on particle degradation are not available. Sauerman Bros., Inc., has offered to cooperate with TVA in a test program with urea.

Pneumatic Systems: Self-unloading systems for grain using pneumatic conveyors are in use in many of the developing countries. Some types of pneumatic conveying equipment are reported to be more economical than conventional unloading gear. Pneumatic equipment is particularly adaptable to portable systems that can be easily moved from one location to another. They could also be the basis for all-weather unloading systems.

Pneumatic systems can generally be divided into those operating with "dilute-phase flow," and those with "dense-phase flow" or "plug flow" (5). In applications where material is conveyed by dilute-phase flow, a gas velocity as high as 90 miles per hour must be maintained to assure the conveyance of the particles. This high gas velocity causes severe abrasion of the conveyed material. Vacuum systems are always dilute-phase systems.

Abrasion of the material being handled is very small in plug (dense) flow because velocity of material is much lower. However, pneumatic plug flow can only be used if short pipes with few bends are used. A plug flow system must be fed and cannot lift material as a dilute-phase system does.

FIGURE 3

Sauerman Drag Scraper

During a trip to New Orleans (6) representatives of Dunbar Kapple Incorporated demonstrated the use of a vacuum (dilute phase) pneumatic system. The unit was set up in a warehouse at the Desire Street dock. For the demonstration, the unit was to convey conditioned urea from a storage pile approximately 100 feet to a bagging machine. During the brief test, the urea transported through the system was practically all pulverized. It was difficult to find a prill intact in the discharge from the unit. This particular type of pneumatic equipment obviously would not be suitable for handling urea for most uses.

Voigt-England Company of Birmingham, Alabama, was asked for data on a SEMCO system marketed by their firm. Following is a direct quotation from the letter received in answer to the request.

> Our factory noted that in handling urea prills, the degradation is severe by pneumatic methods and is not normally suitable if the customer is interested in coating the prills with diatomaceous earth or clay for marketing purposes.

Inquiries were also made of Halliburton Services of Duncan, Oklahoma, concerning Halliburton's pneumatic systems. Halliburton's vacuum system is not likely to be suitable for handling urea prills. They do have a dense-phase pressure system which might handle urea successfully. Halliburton is now testing urea and urea - ammonium sulfate supplied by TVA in their dense-phase equipment.

Tests should be continued with vendor's cooperation in an effort to develop pneumatic systems capable of successfully unloading urea and other fertilizers from the holds of ships.

Need for All-Weather Systems: Observations of the unloading of urea from the holds of vessels emphasized the need for totally enclosed all-weather systems. To obtain information pertaining to all-weather self-unloading systems for barges and ships, discussions were held with Hewitt-Robins, Inc., Totowa, New Jersey (7). Most of the self-unloading systems built by Hewitt-Robins are large units for handling such commodities as phosphate rock, bauxite, or iron ore. Systems available range from sophisticated ones like the rotary plow feeder to simple shipside clamshell cranes.

Vessels

The vessel type and size are usually dictated by the size of cargo, type of cargo, limiting draft, and loading and unloading ports. In this study, vessels were categorized as barges, small bulk carriers similar to C1-M-AV1 cargo ships (coasters and lighters of 3050 tons

deadweight or less) and ocean-going vessels of 5,000 to 15,000 tons deadweight class (victory class). Larger bulk carriers (up to 150,000 tons) are used in ore service and for specialized cargos. Such carriers were not considered in this report because of the very large cargo requirement and the scarcity of suitable deep water ports.

Barges

Barges may be built for practically any cargo capacity. The most common barge size for transport of materials on inland waterway in the United States is 200 feet long, 35 feet wide, and 12 feet high (Fig. 4). Capacity is 1500 tons at 9 feet of draft. With the emphasis on preventing stream and water pollution, future barges are likely to be almost entirely of double-skin construction.

Barges can be equipped with independent portable propulsion units. Barges so equipped can serve as a carrier plus a tub for other barges. These units could be used for moving cargos on inland waters with 5 to 6 feet of draft.

Two firms were found which manufacture portable propulsion systems: (1) Murray and Tregurtha, Division of Mathewson Corporation, Quincy, Massachusetts, who manufactures the Harbormaster, and (2) Schottel of America, Inc., 21 Northwest South River Drive, Miami, Florida 33125, who makes the Schottel Navigator. These units use an outboard screw for both propulsion and steering, and are available in models ranging from 50 to 2500 horsepower. Up to 1500 horsepower, the units can be readily mounted on the stern deck of barges with four holddown bolts. (About 1000 to 1200 hp is required to move a tow of six barges, or 5600 tons, at a rate of 6 miles/hr.) These units can be moved from barge to barge with relative ease.

Ocean-going barges (Fig. 5) have especially designed bows and a gimbal harness on the stern for the tub (Fig. 6). The barges are usually pushed in protected waterways. At sea, they are hawser-towed. The cost of an ocean-going barge and appropriate tug is usually less than a comparable ship.

Small Bulk Carriers

One example is the MV Komoku, a 210-foot, 800-ton-capacity vessel in service in the San Francisco Bay area (Fig. 7). The Komoku has twin screws and is equipped with two General Motors diesel engines, each rated at 1300-brake horsepower at 800 revolutions per minute. The vessel was designed as a high-speed, propelled container for palletized cargo. It is loaded with a forklift through a door in the side. It can also be adapted for use as a bulk carrier in conjunction with front-end loaders.

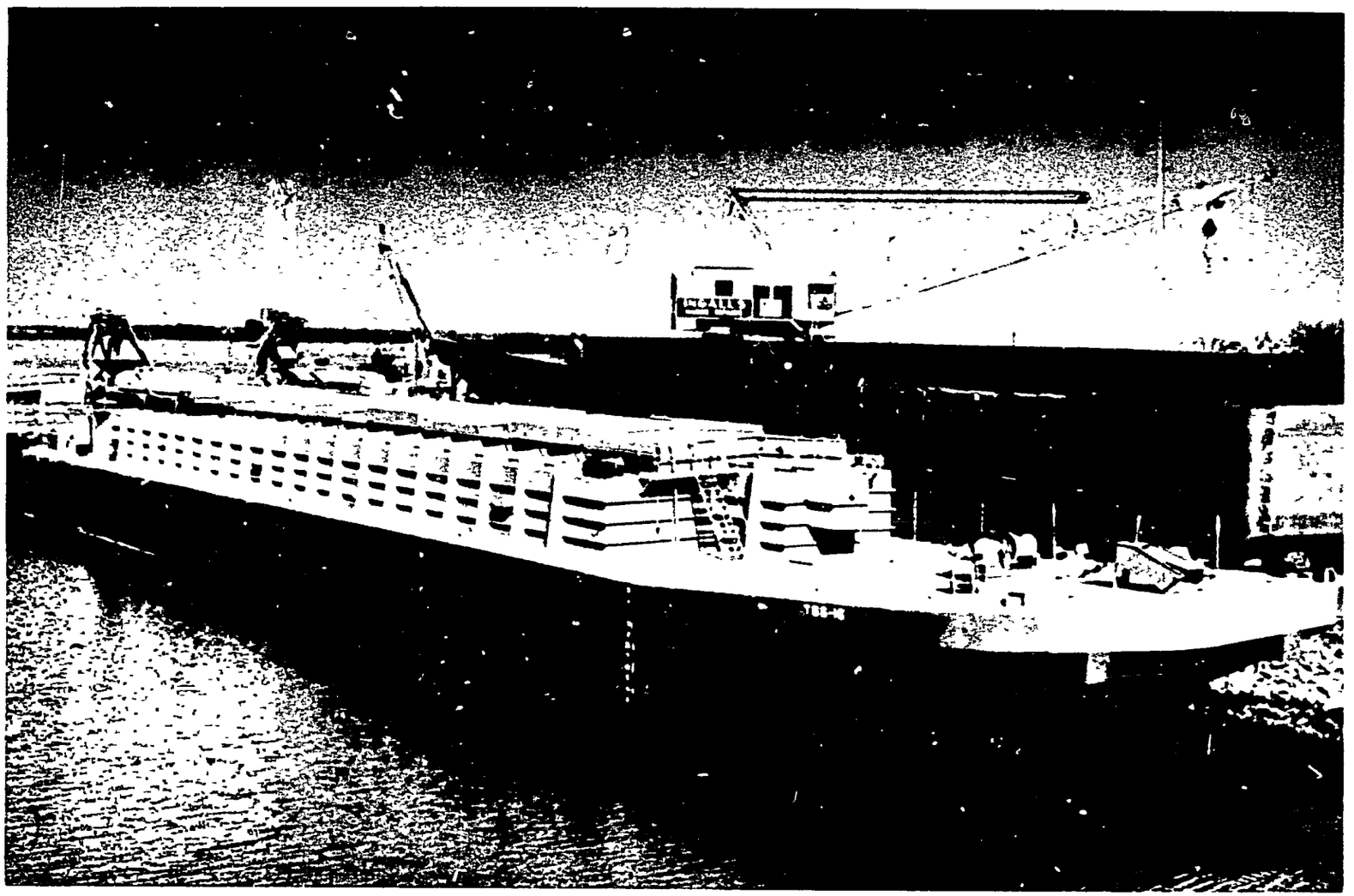


FIGURE 4

Barge for Use in Transporting Phosphate Rock on Inland Waterways in the United States

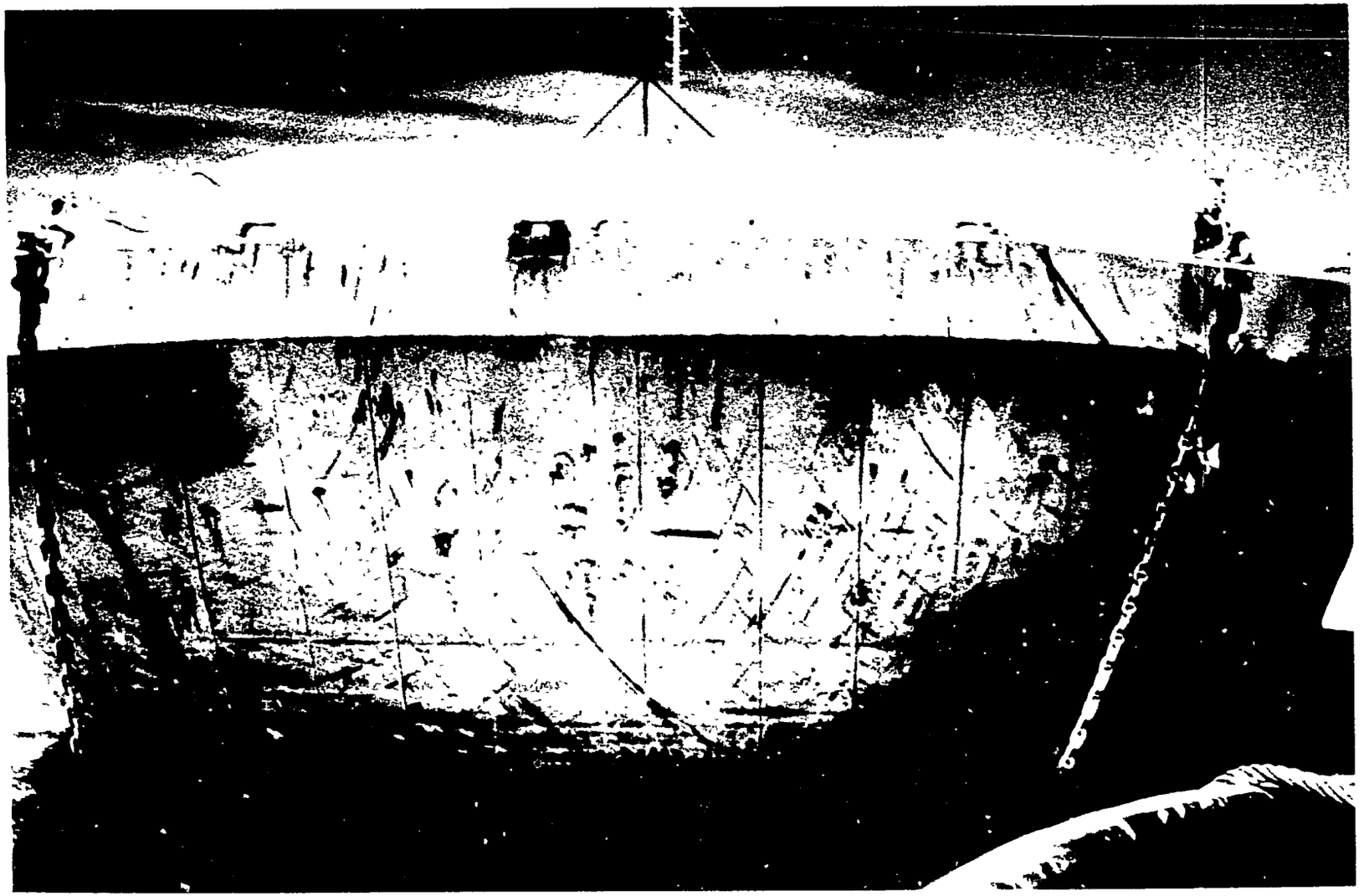


FIGURE 5

Ocean-going Barge for Transportation of Urea

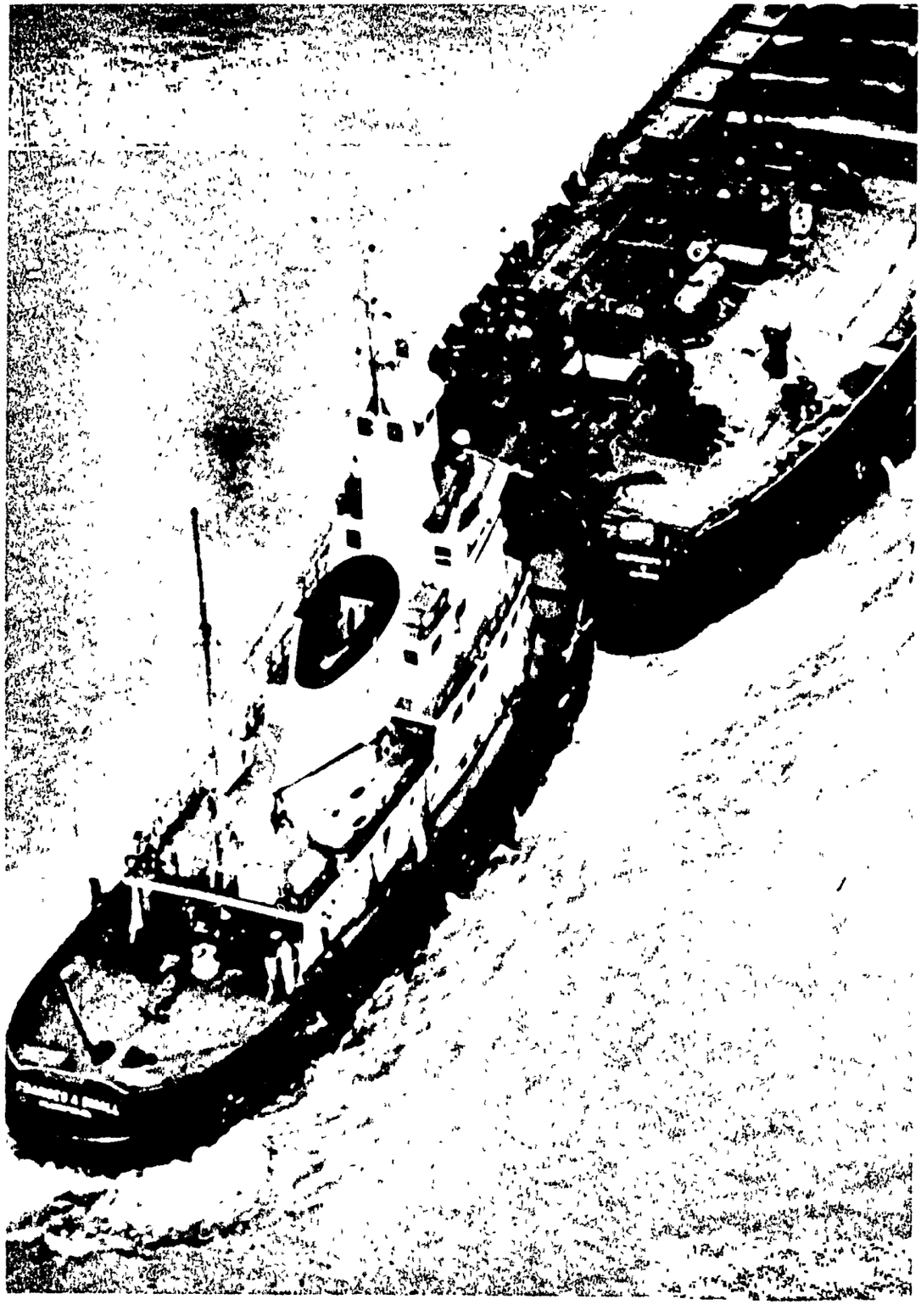


FIGURE 6

Ocean-going Barge and Tug

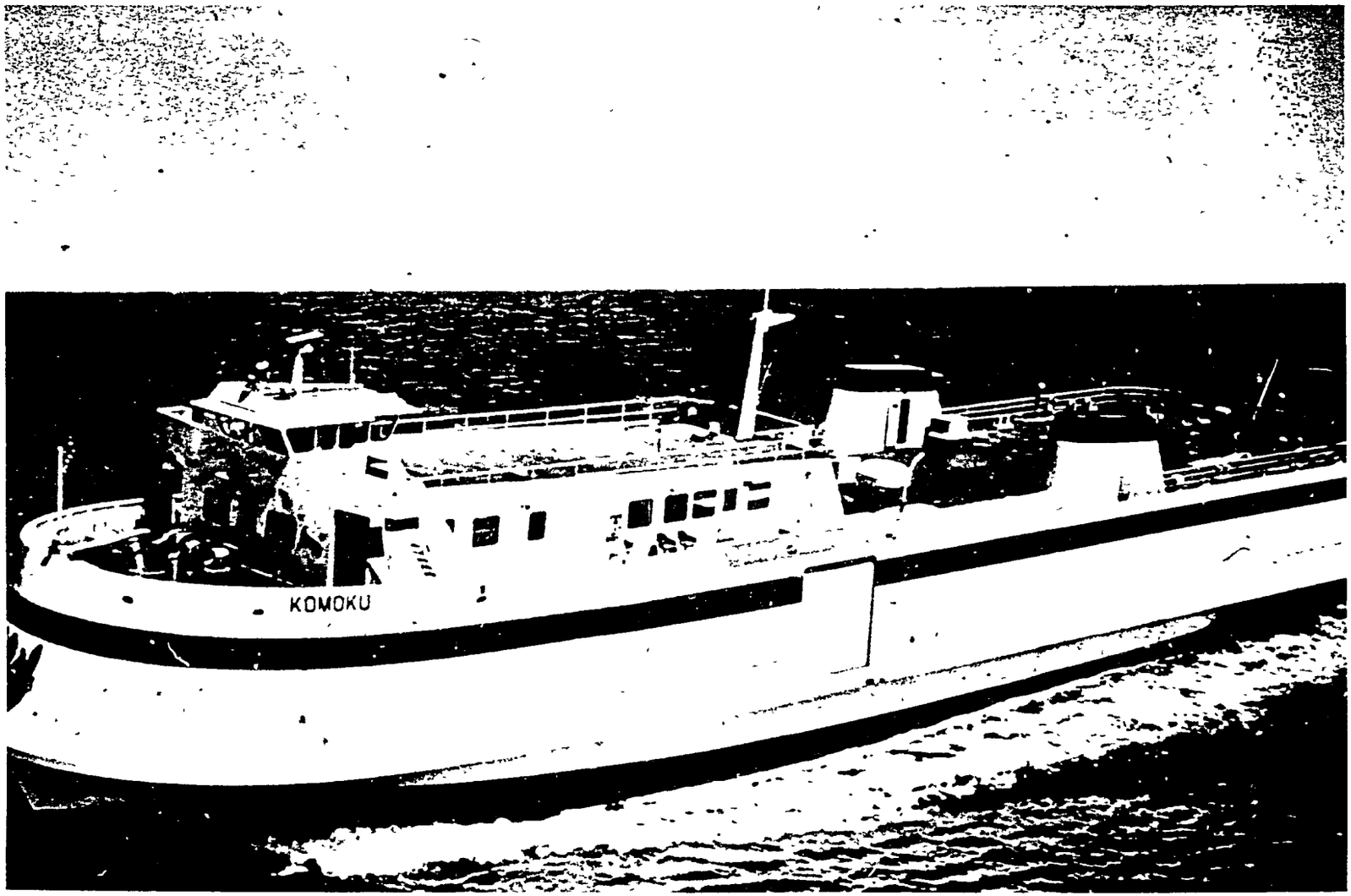


FIGURE 7

High-Speed, Small Bulk Carrier

LSM's can also be used as small cargo ships (Fig. 8). Either palletized or bulk material can be loaded and unloaded across a ramp using ship-carried forklifts for palletized cargo and front-end loaders for bulk material.

Ocean-going Vessels (5,000- to 15,000-Ton Category)

To evaluate the utility of larger vessels (about 5,000-15,000 tons deadweight), the loading and unloading operations of several such ships were observed.

Bulk Cement Carrier (Cemento Ponce): Visits were made to the facilities of the PRCC located in Ponce and San Juan, Puerto Rico, and the facilities of the Virgin Islands Cement Company in Charlotte Amalie, St. Thomas, Virgin Islands. The purpose of the visits was to observe and discuss the operation of the MV Cemento Ponce (Fig. 9) and evaluate the applicability of such a vessel to transporting fertilizer materials into DC's. Complete reports of the visits are available in TVA files (8, 9).

The holds of the MV Cemento Ponce are loaded with bulk cement at Ponce.

Empty bags are loaded into the forward part of the ship in the space that would not normally be utilized. Two bagging trains are installed aboard the ship. The cement cargo is distributed throughout the Caribbean area either in bags or bulk at the choice of the customer.

A schematic diagram of the Cemento Ponce before and after conversion to cement service is shown in Figure 10. Normal capacity is 5000 deadweight tons. The cargo hold is fitted with a 2-1/2-yard drag scraper. Only the scraper and cables are located inside the cargo hold. The two-drum drive and the positioning drive are located externally to the hold.

The scraper travels the length of the hold, up a ramp, and discharges through a grizzly. The cement discharges through the grizzly into three parallel steam-out hoppers mounted in the ship that feed an 18-inch reversible screw. If trucks are to be loaded, the cement from the screw conveyor discharges into a bucket elevator mounted on the starboard side of the ship. The bucket elevator discharges into a screw that can be swiveled through a horizontal arc of 180 degrees for positioning over the truck.

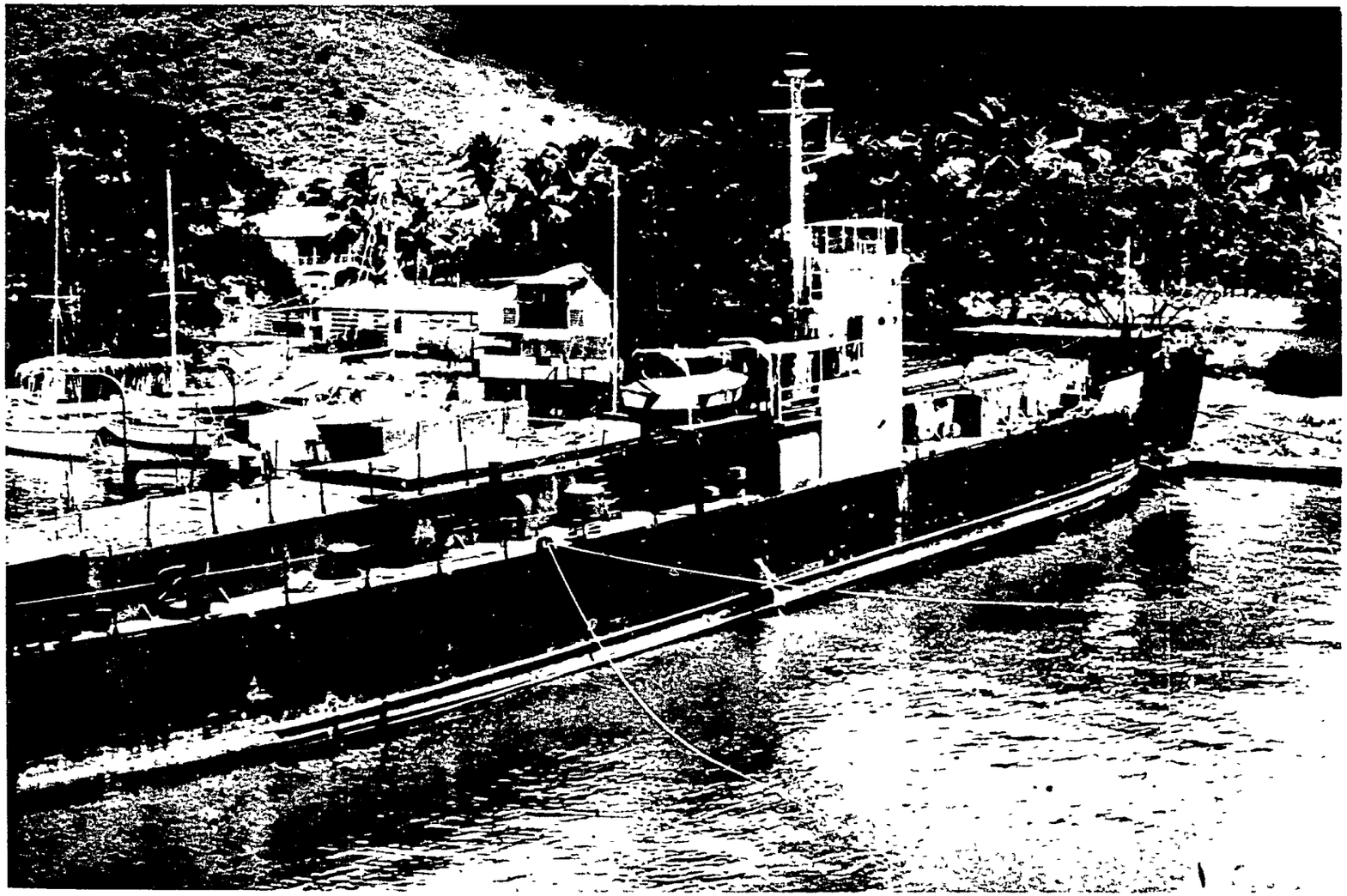


FIGURE 8

LSM-Type Bulk Carrier

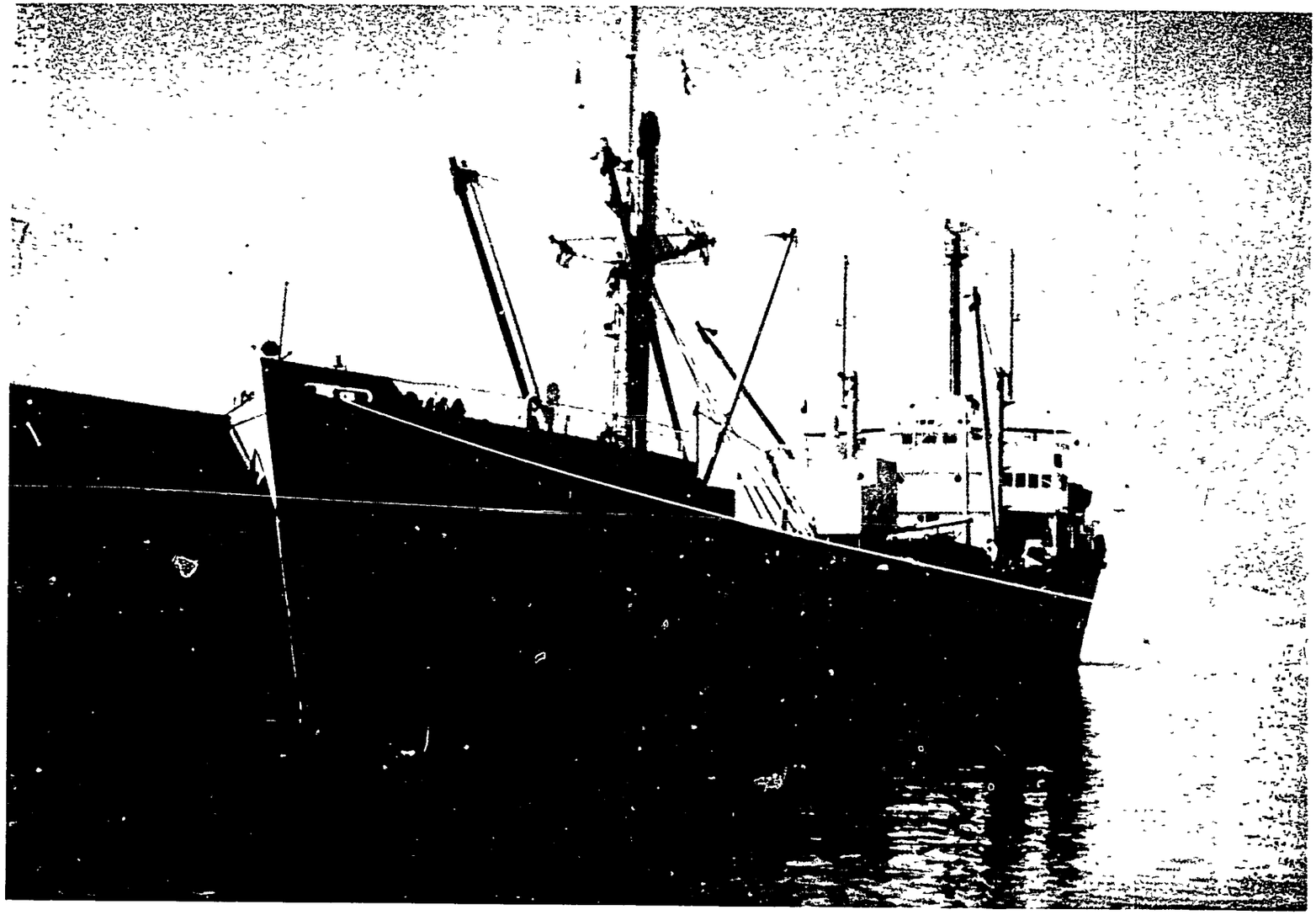


FIGURE 9

Bulk Cement Carrier MV Cemento Ponce

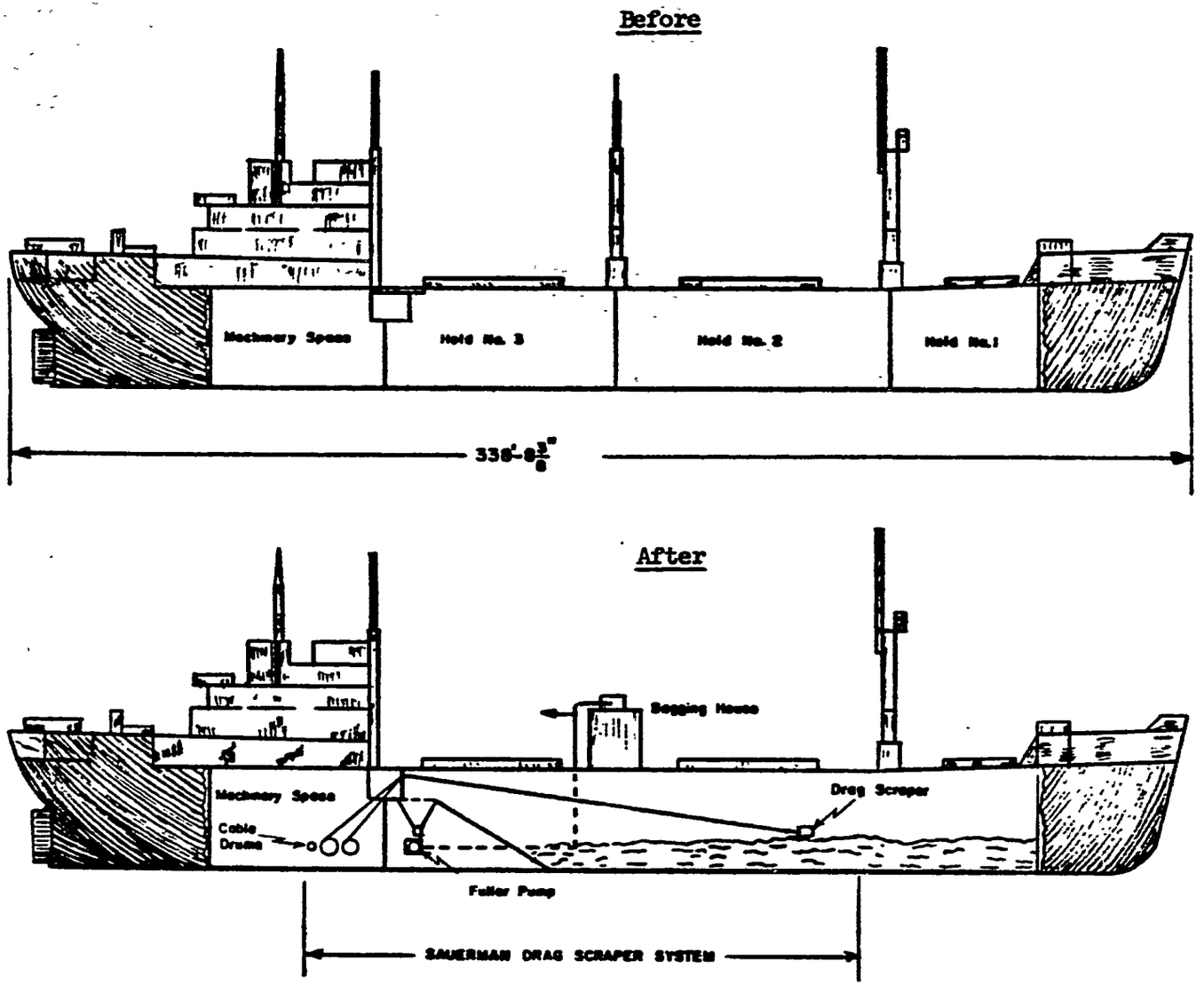


FIGURE 10

Schematic Diagram of the MV Cemento Ponce Before and After Conversion to Cement Service

If the cement is to be discharged bulk to silos or bagged on the ship, the screw conveyor under the steam-out hoppers is reversed. The screw then discharges into a cement pump which discharges either to silos on shore or to the bagging house topside. The bagging house contains two bagging machines with capacities each of about 1350 94-pound bags per hour. The bags drop onto a reversible belt that can be operated to discharge either port or starboard. From the reversible belt the bags drop onto another conveyor belt (one starboard, one port) that discharges onto the dock.

At the present time, the bagging facilities aboard the ship are not being used. Consumption of cement in the area now is greater than was forecast for 1975. Consequently, to transport cement to supply this market, the Cemento Ponce has been committed to bulk cargos only. If cement must be delivered to a customer in bags, the cement is bagged and palletized in Ponce. A ship similar to an LSM is leased from a Dominican firm. Palletized material is loaded and unloaded across a ramp with forklifts carried on board.

During the visit, the loading operation at Ponce was observed and unloading of the same cargo was observed at the Virgin Island Cement Company located at Charlotte Amalie, St. Thomas, Virgin Islands. During unloading, one crewman operated the drag scraper and one operated the diesel electric generator units, the compressor for the cement pump, the cement pump, and auxiliary compressors. The remainder of the crew built pallets to be used for shipping bagged cement from Ponce.

Unloading rate was limited to about 180 tons per hour by the cement pump capacity. The drag scraper was in operation less than 70% of the total unloading period.

All of the personnel at PRCC seemed well pleased with the performance of the Cemento Ponce. The system appears to be simple, rugged, and relatively maintenance free. If such a system were used for bulk urea, belt conveyors and elevators could easily be used rather than the screw conveyor which might result in excessive degradation. (The cement pump would not be suitable for unloading fertilizer materials.) Data on degradation of the urea that would occur because of the movement of the drag scraper system are needed to fully evaluate the system.

Vessels similar to the Cemento Ponce and the LSM-type vessel could readily be used to transport bulk fertilizers to DC's where demands are for small tonnages (5000 tons/trip). They would also fit into a system that delivers large tonnages of bulk into a central area for distribution into other areas, i.e., bulk to Singapore and bag or bulk to Indonesia.

Bulk Urea Carriers: Visits to observe loading and unloading of bulk fertilizer materials from larger vessels were limited to urea. Urea is the most fragile of the fertilizer materials normally moved into the DC's. It is as susceptible to moisture absorption as any other fertilizer. Therefore, systems that can handle urea successfully should readily handle other types of fertilizer materials. Three bulk urea shipments were observed. Detailed reports of the trips are in TVA files. Summaries of the trip reports follow.

The Federation Chemicals Limited (W. R. Grace and Company) routinely ships unconditioned urea in bulk from facilities at Pt. Lisas, Trinidad, to Wilmington, North Carolina, by the Savonetta (10, 11). While en route from Brazil, T. M. Kelso of TVA stopped in Trinidad to observe the urea loading operation. Unloading of a urea cargo in Wilmington, North Carolina, was also observed and documented.

Prilled urea produced at Trinidad is stored in bulk without conditioner in a shed of 6000-ton capacity. Humidity in the shed is controlled at about 65%; the temperature ranges from 90° to 100° F. The urea was said to be at a temperature of about 170° F. as it reaches the storage pile. It is recovered from storage with front-end loaders and dumped into a bucket elevator which discharges onto a covered belt conveyor 1700 feet in length to the ship. No screening is done. The temperature of the urea as loaded onto the ship was reported to be about 150° F.; loading temperature was not verified. About 1 to 2% of the urea is minus 20 mesh in size. The usual loading rate is approximately 100 tons per hour. Figure 11 is a schematic diagram of the urea-handling procedure both at Trinidad, West Indies, and Wilmington, North Carolina.

The same ship, the Savonetta (Fig. 12), is used for each shipment. The ship hauls about 4000 tons total in four cargo holds. Fully loaded it draws less than 20 feet. To protect against rain and wind storms, a plastic tent is erected over the open hold being filled. After the hatches are secured, canvas covers are lashed over them.

Transit time to Wilmington is about 5-1/2 days. At Wilmington, the ship is berthed at the North Carolina State Docks located on the Cape Fear River.

In the unloading operation the urea was removed from the holds with a gantry equipped with a 6-1/2-yard clamshell bucket. The urea had taken a light set in the hold but the lumps were readily broken up. During the early phases of the unloading, urea is removed from the center of each hold at a rate of about 250 tons per hour. During this unloading period, the material contains 3 to 5% minus 20 mesh. The gantry is unable to remove the material under the wings of the ship. Therefore, after about 2 or 3 hours of unloading, small bulldozers are lowered into the holds to push the urea from the wings and bulkheads to the center of the holds (Fig. 13).

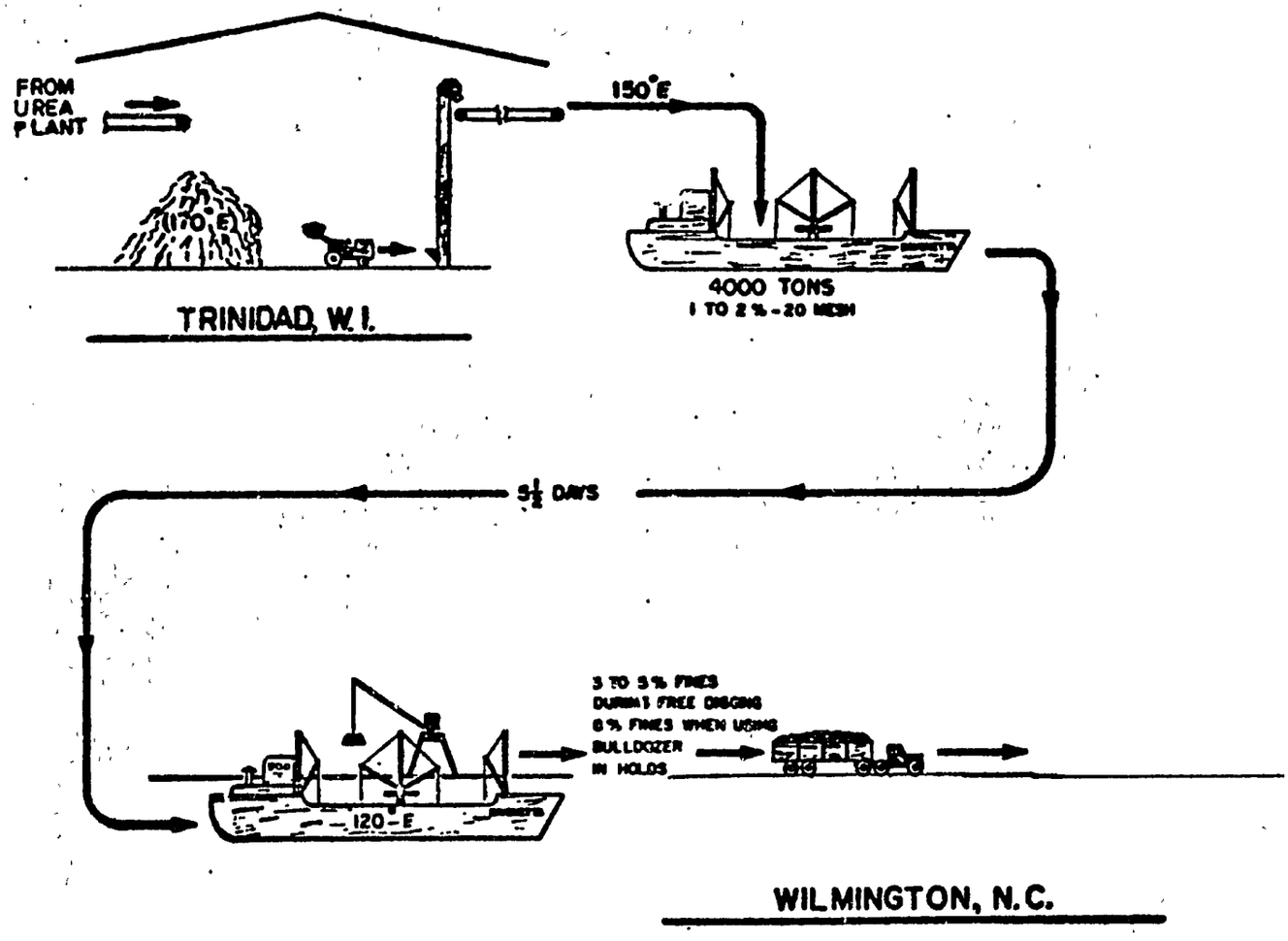
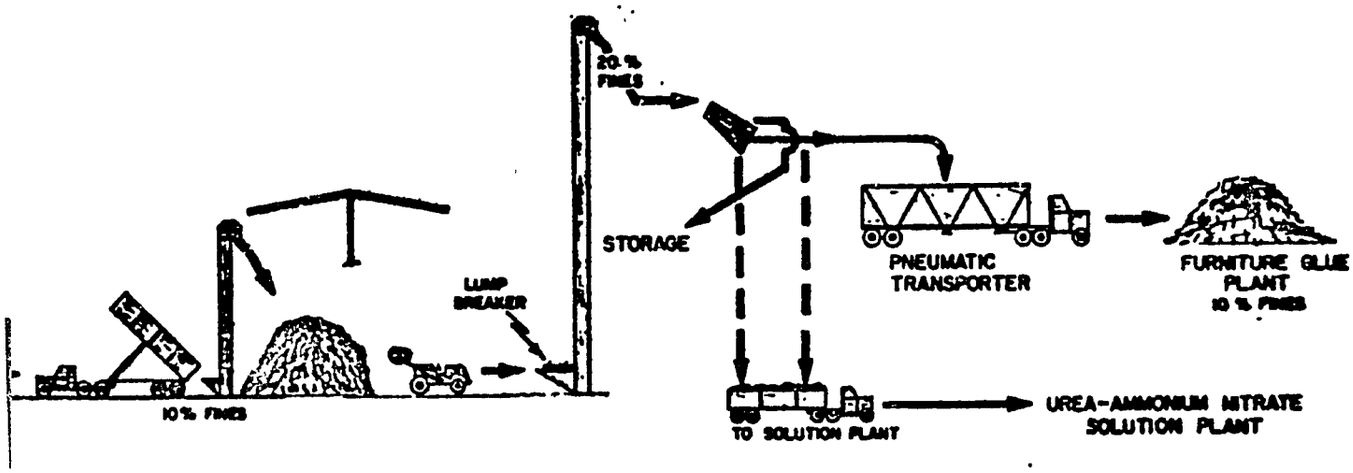


FIGURE 11

Flow of Bulk Shipment of Urea from Pt. Lisas, Trinidad, to Wilmington, North Carolina


20 % FINES
STORAGE
LUMP BREAKER
10 % FINES
PNEUMATIC TRANSPORTER
FURNITURE GLUE PLANT
10 % FINES
TO SOLUTION PLANT
UREA-AMMONIUM NITRATE SOLUTION PLANT

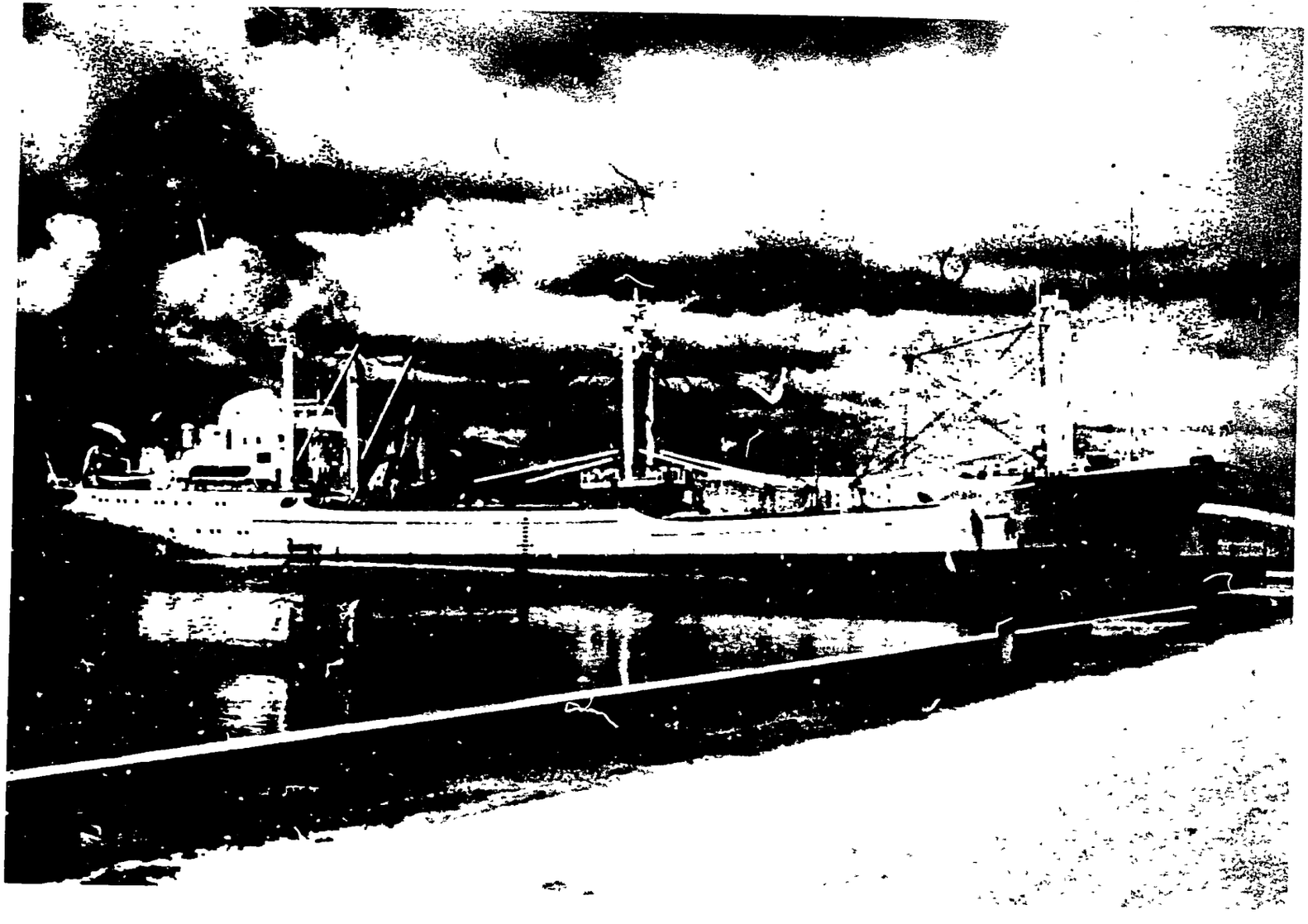


FIGURE 12

SS Savonetta Used for Bulk Transportation of Urea

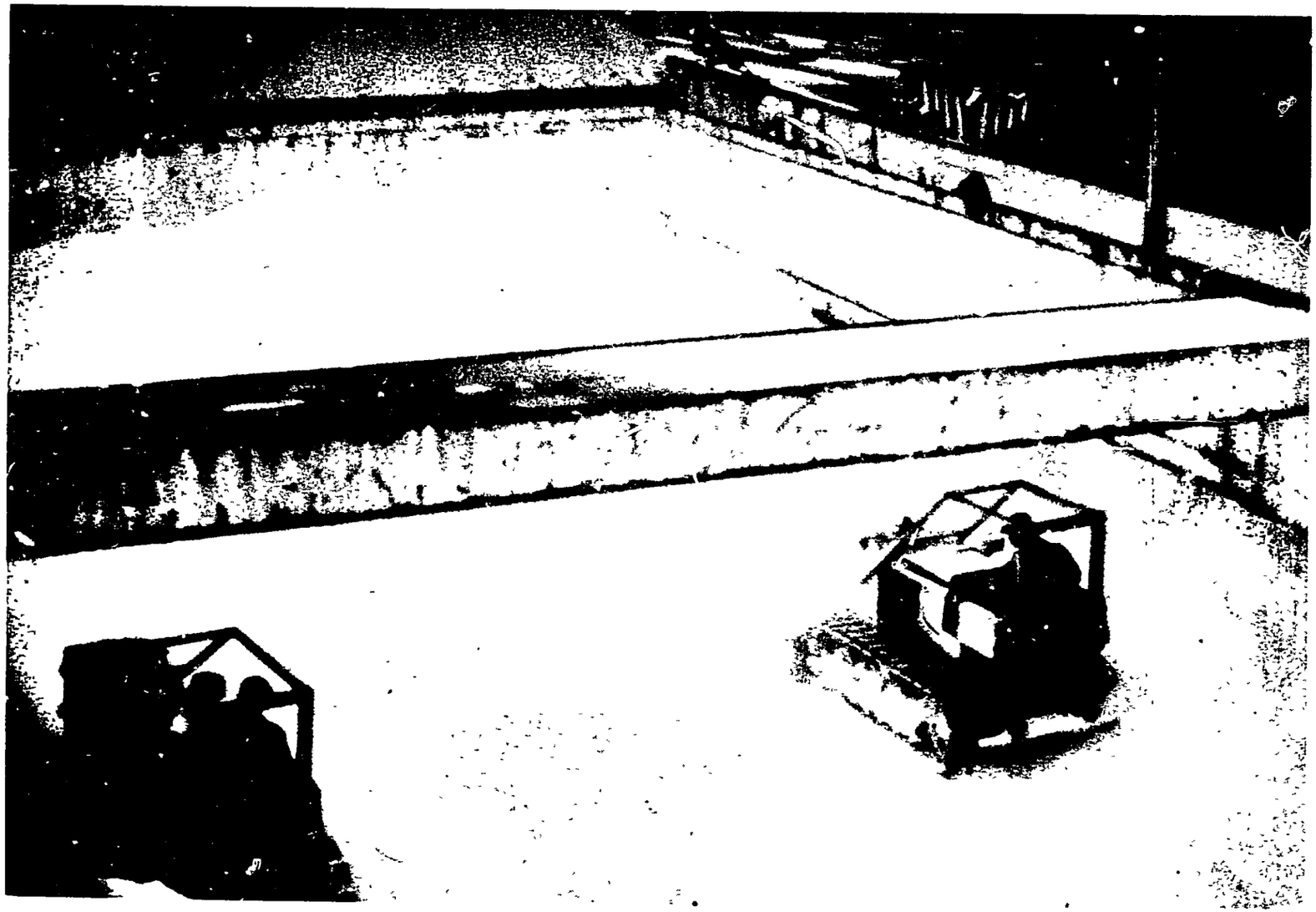


FIGURE 13

Small Bulldozers Moving Urea from Wings of SS Savonetta to Center of Hold

During periods when the bulldozers are used, the minus 20-mesh material increases to about 8%. The unloading rate is much slower during this period, as considerable maneuvering of the bucket is required.

The bucket on the crane was practically new and well maintained; yet there was appreciable spillage through the bucket lips. Also, urea was spilled over the top of the bucket as it was swung between the holds and the loading hopper. The results of these spillages are shown in Figure 14.

The gantry dumps into an elevated hopper which discharges intermittently into open dump trucks of about 25-ton capacity (Fig. 15). The urea is hauled from the dock to a nearby storage shed.

This technique of moving bulk urea is satisfactory in this system since the urea is used to prepare fertilizer solutions or furniture glue, and the moisture content or particle size of the urea is of no major importance. Urea losses from the storage shed in Trinidad to storage in Wilmington are said to be less than 1.5%.

The primary contaminant of the urea is rust from the ship. The holds were coated with epoxy; however, the lining did not last because of damage from the crane buckets and bulldozers. The discolored urea is used in solutions manufacture; the pure white urea is used in the manufacturing of glue.

The unloading operation is done by the Wilmington Shipping Company. A total of about 20 hours is required to unload the ship (3800-4000 tons). Unloading cost is usually $1.75 to $1.80 per ton, including trucking to the warehouse. Use of overtime, such as when rain stops scheduled unloading, increases the cost to about $2.20 per ton. A 40-cent-per-ton wharfage fee and berthing fees (undisclosed) are charged as part of transportation costs.

The Savonetta is used almost exclusively for urea transport. Consequently, the holds are carefully cleaned and maintained to minimize contamination. Using tramp ships, the hold conditions would likely be much worse. Most tramp ships are fitted with tween decks; the Savonetta is not. The between decks make unloading more difficult and time consuming. In Figure 16, a ship unloading in Brazil, urea is being shoveled from the tween deck into the center of the hold for unloading.

Dehumidification of a ship, such as the Savonetta, does not appear to be necessary. However, the hatch covers must be watertight. There was no evidence of any water leakage into the holds of the cargo observed unloading at Wilmington, even though rough seas had broken over the Nos. 1 and 2 hatches in transit.

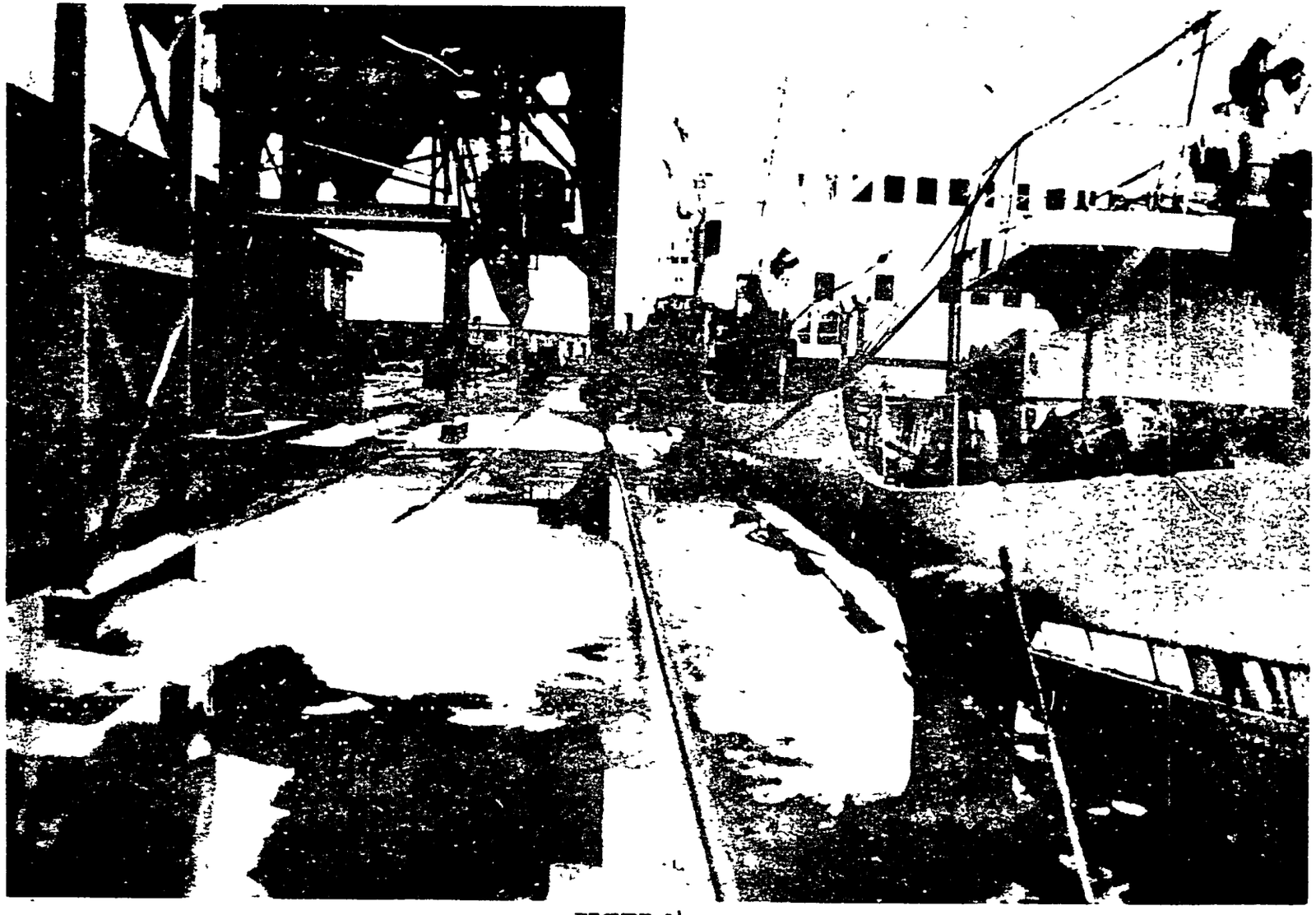


FIGURE 14

Urea Spilled on Wharf During Unloading of SS Savonetta

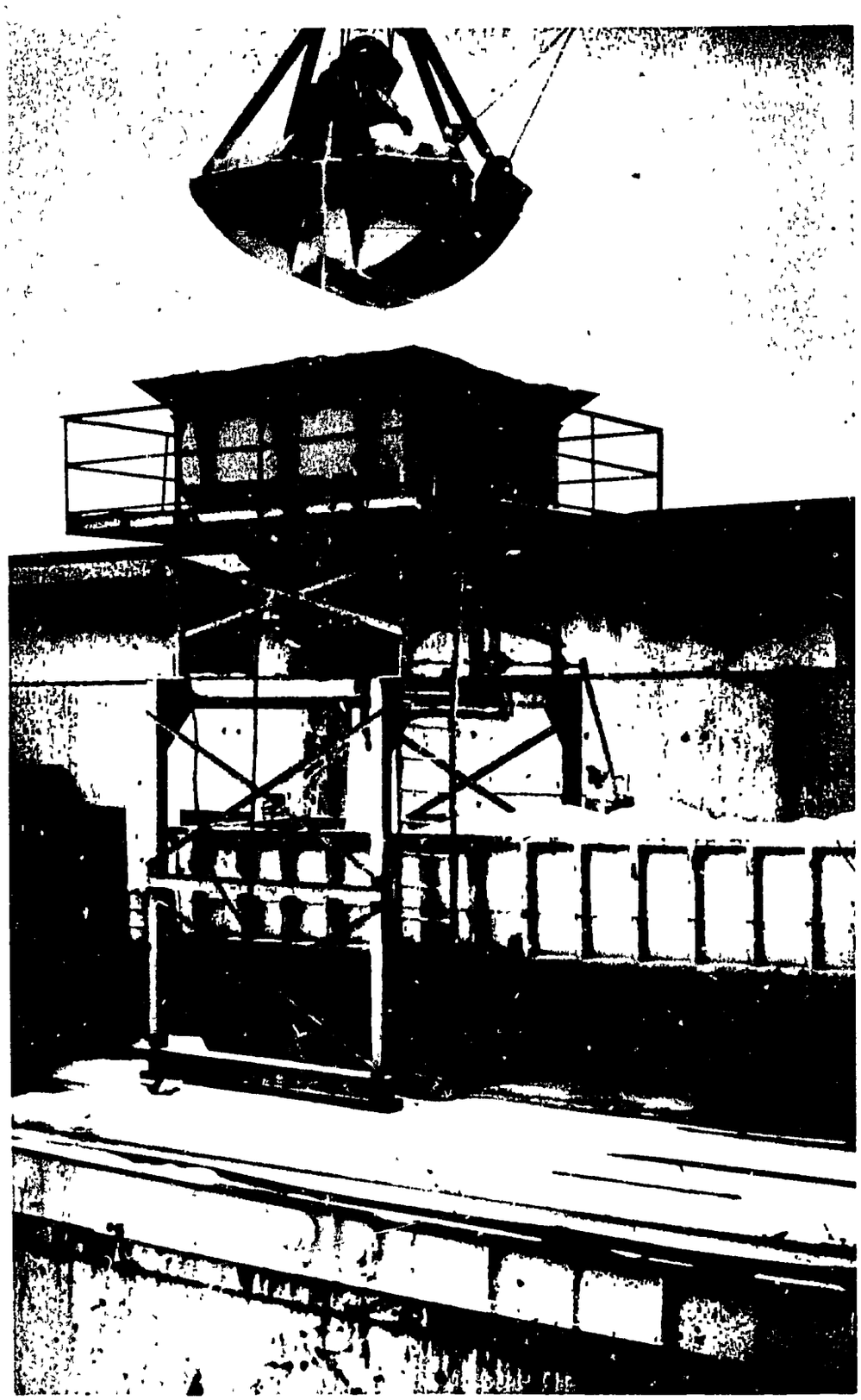


FIGURE 15

Elevated Hopper Used for Loading Trucks

FIGURE 16

Shoveling Urea from Tween Deck into Hold of Ship

This transportation system would not be completely satisfactory if a dry, granular material were required. To minimize losses, some type of salvage process, such as manufacturing of solutions from contaminated spillages, would be necessary.

On March 20, 1970, observations were made of the discharging of a bulk cargo of unconditioned urea from the ship Sally Stove at the New Orleans bulk terminal (6). The urea was produced in The Netherlands by Nederlandse Stikstof Maatschappij. Most of the cargo had been sold to Gulf Oil Corporation for conversion into nitrogen solutions.

The Sally Stove contained a total of 14,000 short tons of urea loaded at a dock near Amsterdam. The urea was at a temperature of about 70° F. and contained less than 0.2% moisture when loaded. A thin sheet of plastic had been placed over the urea in each hold. The material in each hold was in very good condition; it had taken a slight set but most of the lumps were fragile and easily broken. Transit time from The Netherlands to New Orleans was 16 days.

The urea was unloaded from the ship into barges with a dockside gantry clamshell. The unloading was hampered by frequent rainstorms. During the storms, the hatches on the ship and barges were closed and unloading was stopped. The clamshell buckets leaked some urea through the lips onto the ship's wings, barge covers, and into the canal. At times, the operator of the gantry opened the bucket from 25 to 30 feet above the barge allowing some of the smaller urea prills to be blown overboard (Fig. 17).

The Sally Stove is fitted with topside ballast tanks which limit the width of the hatch openings. Only 40 to 50% of the cargo in each hold can be discharged by free digging with the clamshell before bulldozers are lowered into the holds to move the materials from the wings into the hatch area. Also hand cleaning of urea from between the structural members in the holds is necessary (Fig. 18).

As mentioned before, this technique of unloading urea will be satisfactory if the urea spilled on the ship wings, docks, and barge covers can be reclaimed in nitrogen solutions or other processes that do not require a dry, sized product. However, improved techniques to decrease spillage would be desirable.

The technical aspects of a bulk shipment of 16,495 metric tons of urea fertilizers from Kenai, Alaska, to Jurong Wharves, Singapore, were documented by TVA. A complete report of the entire operation has been issued (12).

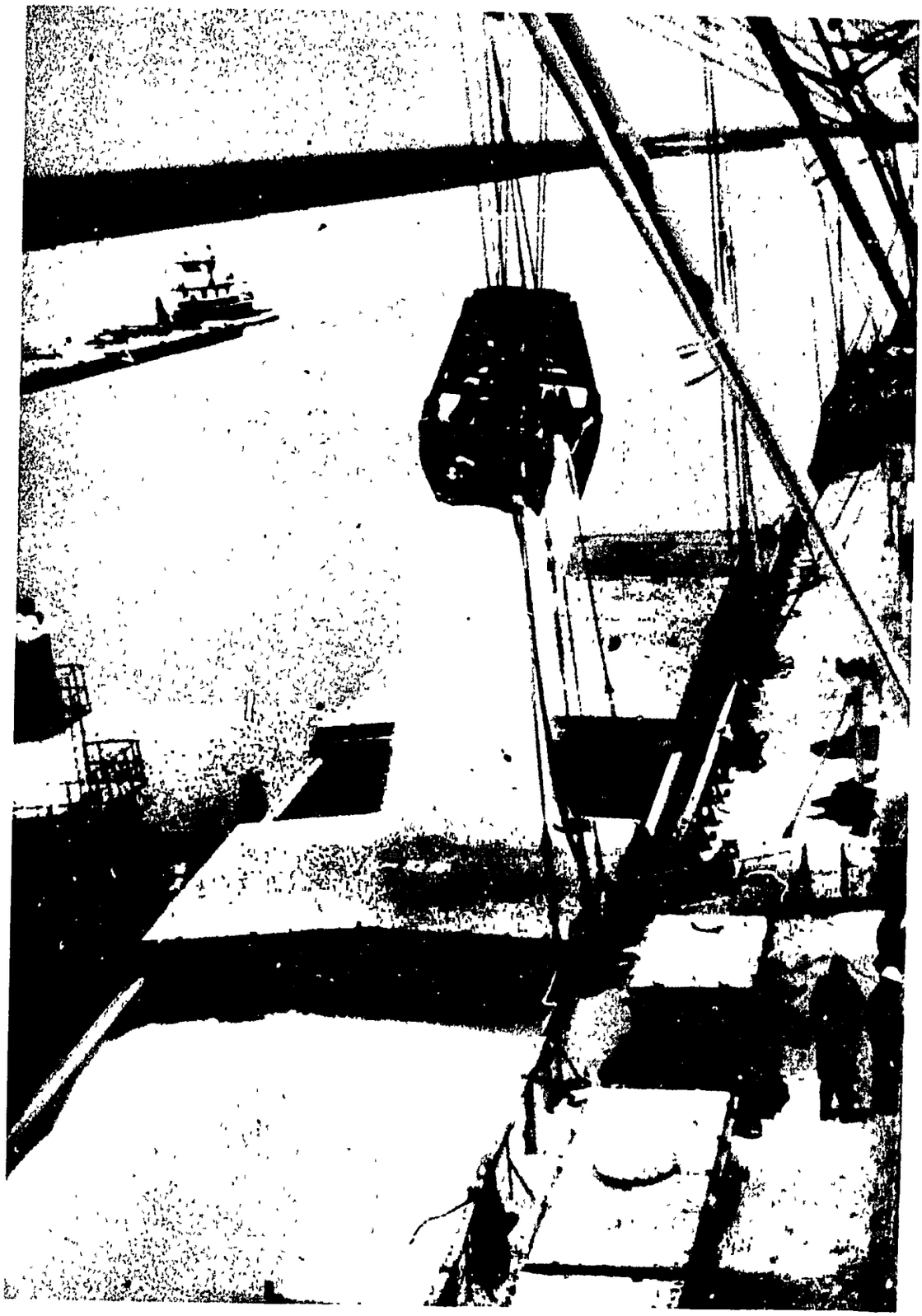


FIGURE 17

Loss of Urea During Loading of a Barge

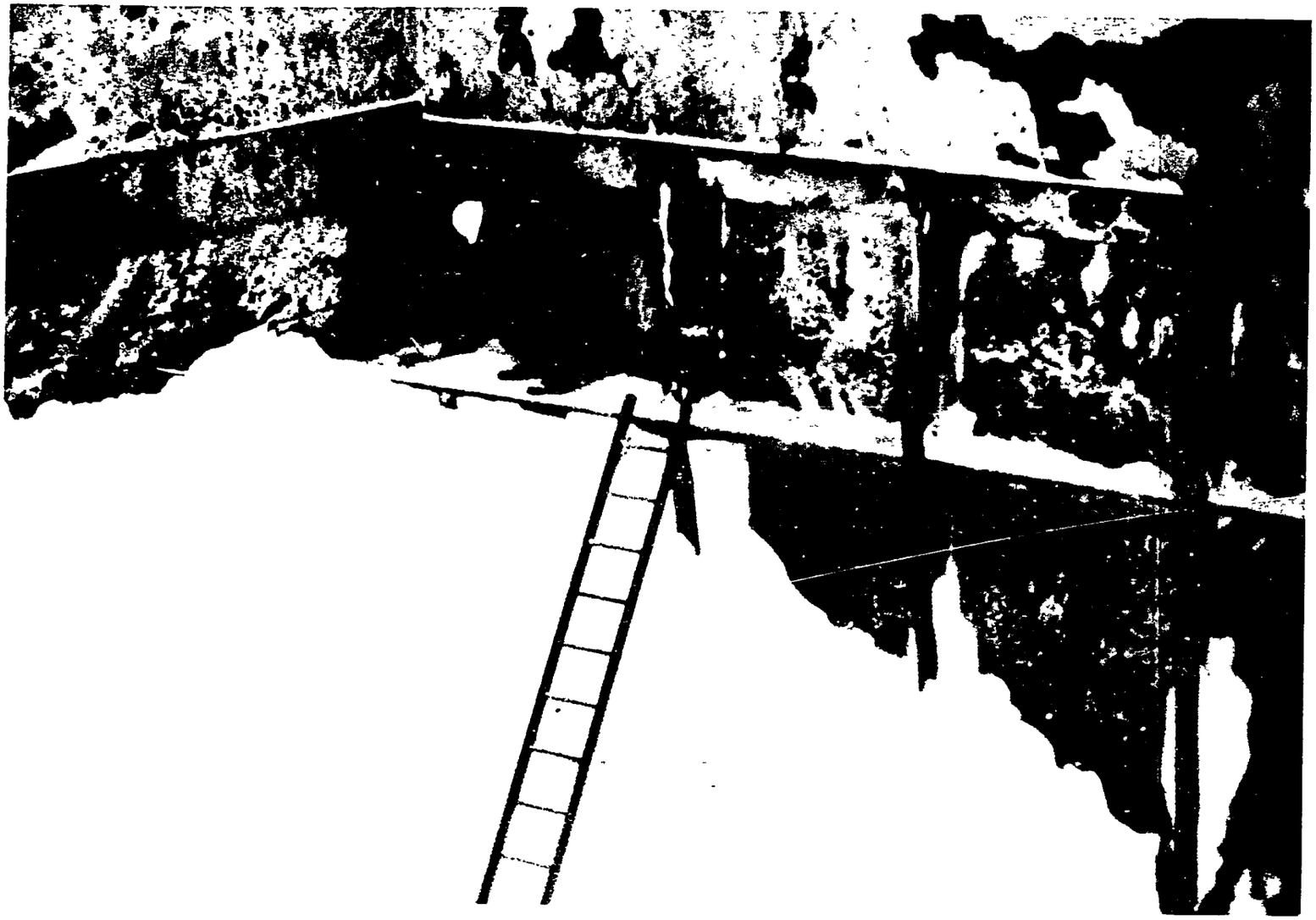


FIGURE 18

Hand-Cleaning Hold of SS Sally Stove

The urea was loaded aboard the Alain L.D. at the port of Nikiski, Alaska, beginning on September 7, 1970. The ship departed port on September 11 and was berthed and secured at Jurong Wharves, Singapore, on September 29, 1970.

The urea was manufactured at Collier Carbon and Chemical Company's ammonia-urea production complex at Kenai, Alaska. A total nitrogen content of 46% was guaranteed; the urea was chemically conditioned with a derivative of formaldehyde. Conditioner level varied from 0.08 to 0.2% by weight.

The Alain L.D. (Fig. 19) is a bulk carrier operated by Gearbulk, Ltd., Bergen, Norway. Each hatch is fitted with mechanically powered folding and roll-type covers which seal the cargo holds. The vessel is equipped with discharging gear--two moving clamshells. Bulk discharge capacity is 300 metric tons per hour. Vessel construction is double skin; thus the cargo does not touch the outer skin of the ship.

The urea was moved from the warehouse by a belt conveyor which was equipped with a Merrick belt scale. The urea was loaded into the holds of the vessel from a rotating boom which telescopes downward to 40 feet from belt level (Fig. 20). A belt slinger is attached to the bottom of the telescoping section for "throwing" the urea into all sections of the vessel's holds. Additional mechanical trimming of the vessel is not required.

Nineteen days after loading the urea at Kenai, Alaska, the Alain L.D. was berthed at Jurong Wharves, Singapore. The vessel encountered rain 11 of the 19 days at sea. On two occasions, the decks were awash due to rough weather.

The Nos. 5 and 3 holds were opened simultaneously and discharging began shortly thereafter. The upper startum of the urea was in good, free-flowing condition and appeared clean and dry.

Urea was discharged by the ship's gear (two clamshell buckets with 5-metric-ton capacity each) into four hoppers (each with 5-metric-ton capacity). The clamshells leaked (Figs. 21 and 22). The hoppers discharged into trucks. The trucks unloaded the urea into godowns (corrugated steel and concrete sheds) near the discharge area. The urea was hand bagged in the godown area. Lack of godown space slowed the discharge rate considerably.

The urea was easily discharged with no major problems, with the exception of some lumps. Pile set was apparent in the holds about one-third of the way down and the set increased with depth (Fig. 23).

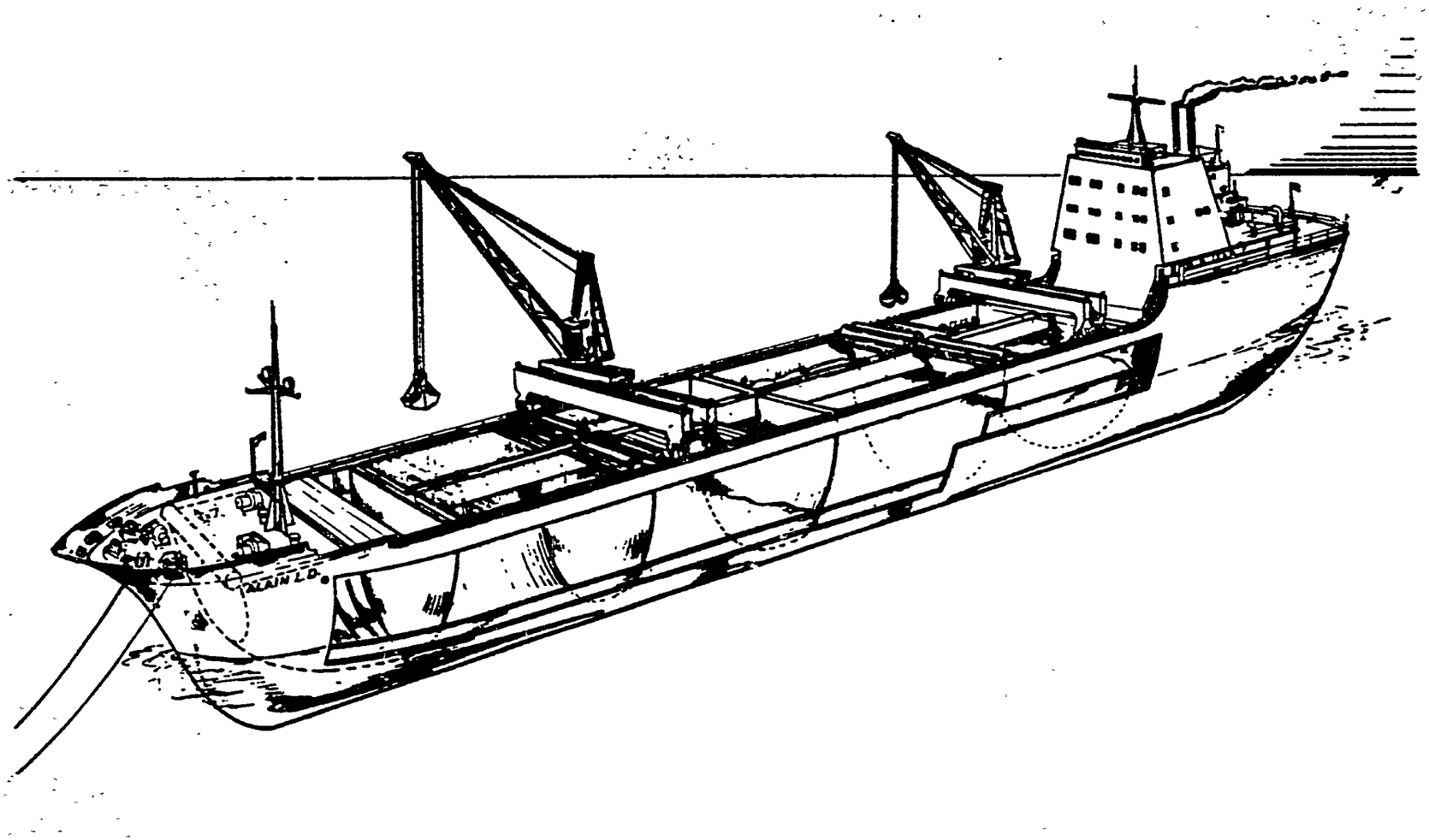


FIGURE 19

Alain L.D. Bulk Cargo Carrier

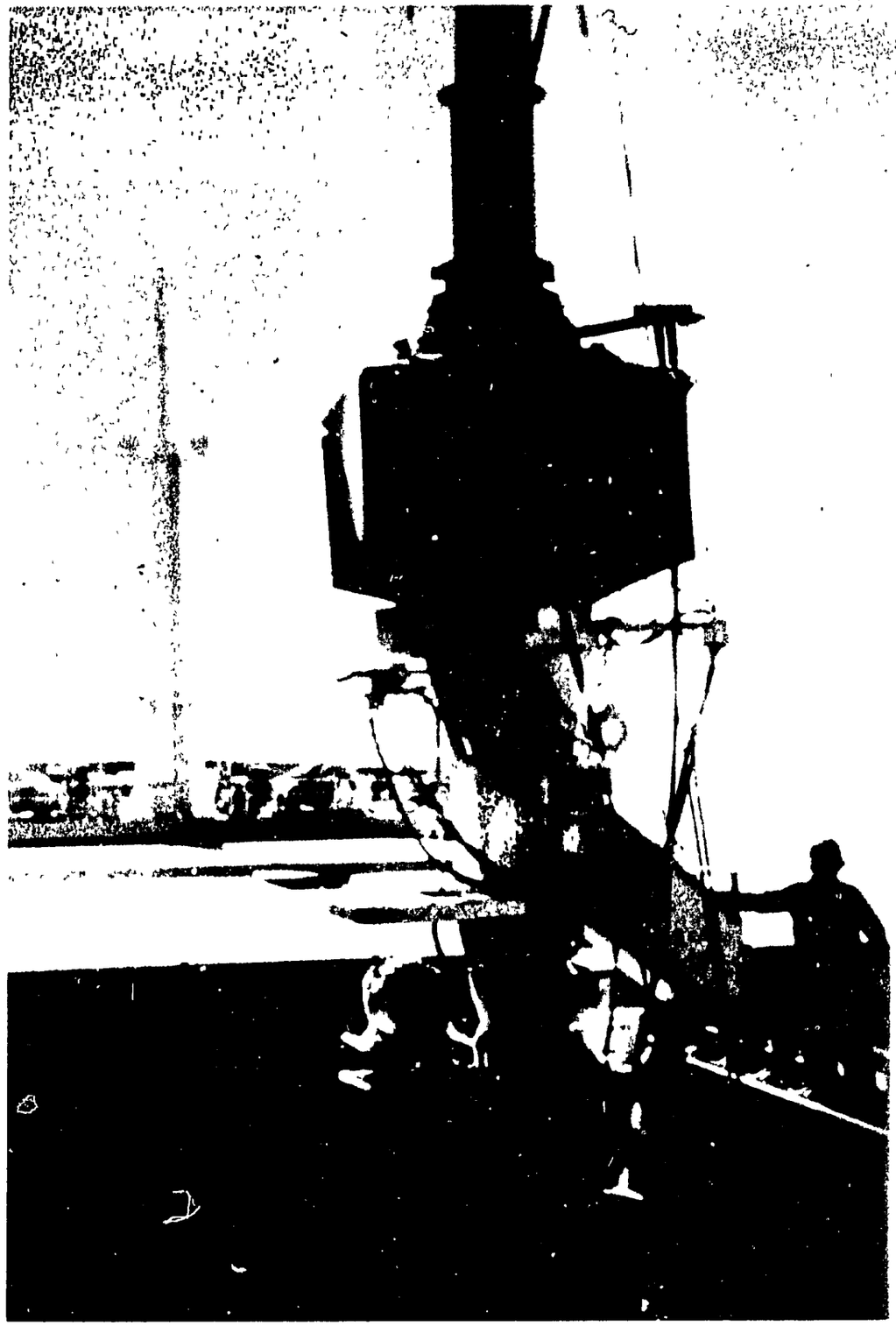


FIGURE 20

Automatic Trimmer Used in Loading Urea in SS Alain L.D.

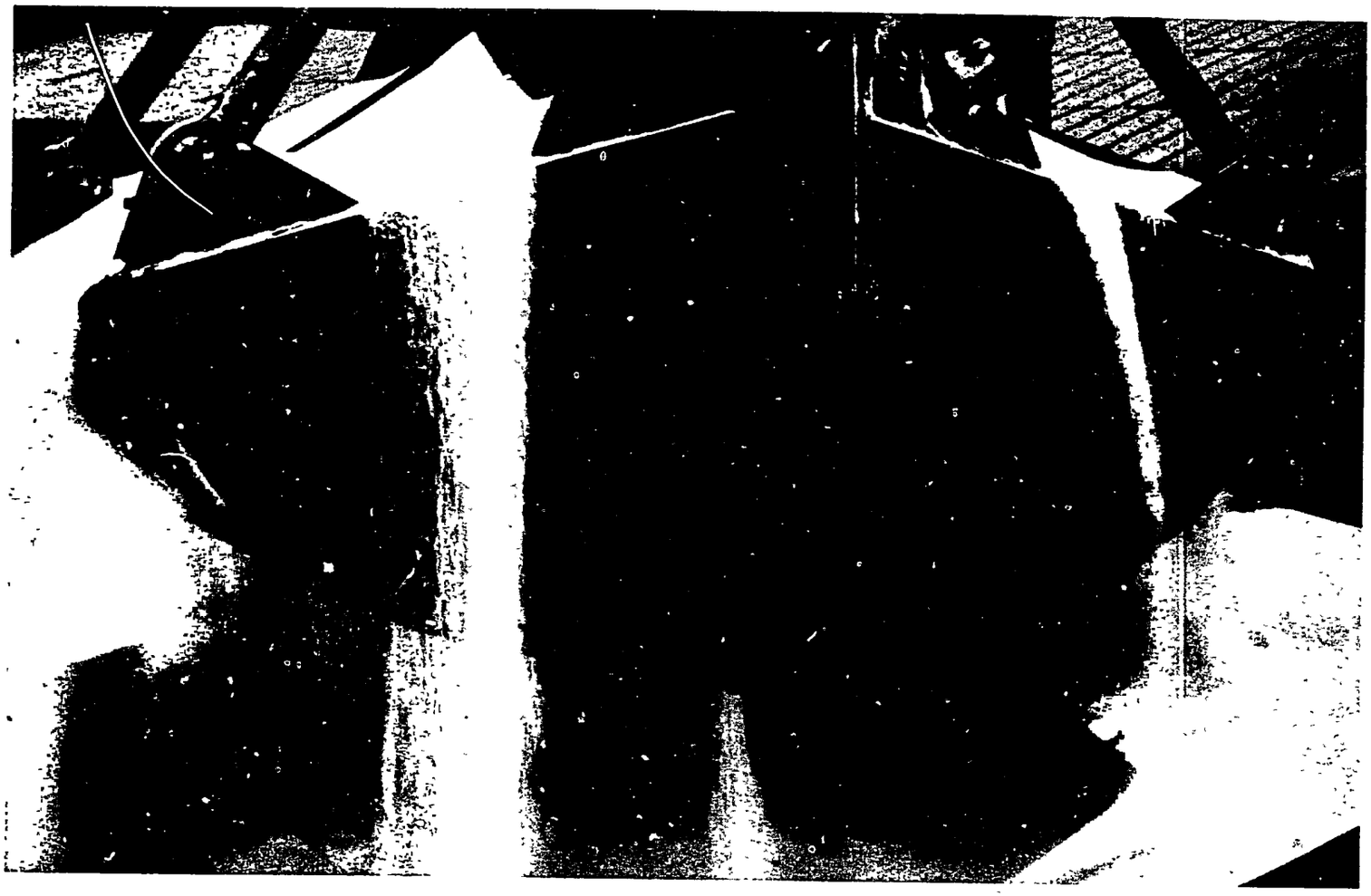


FIGURE 21

Urea Leaking from Clamshell Bucket

FIGURE 22

Urea Leaking from Clamshell Bucket

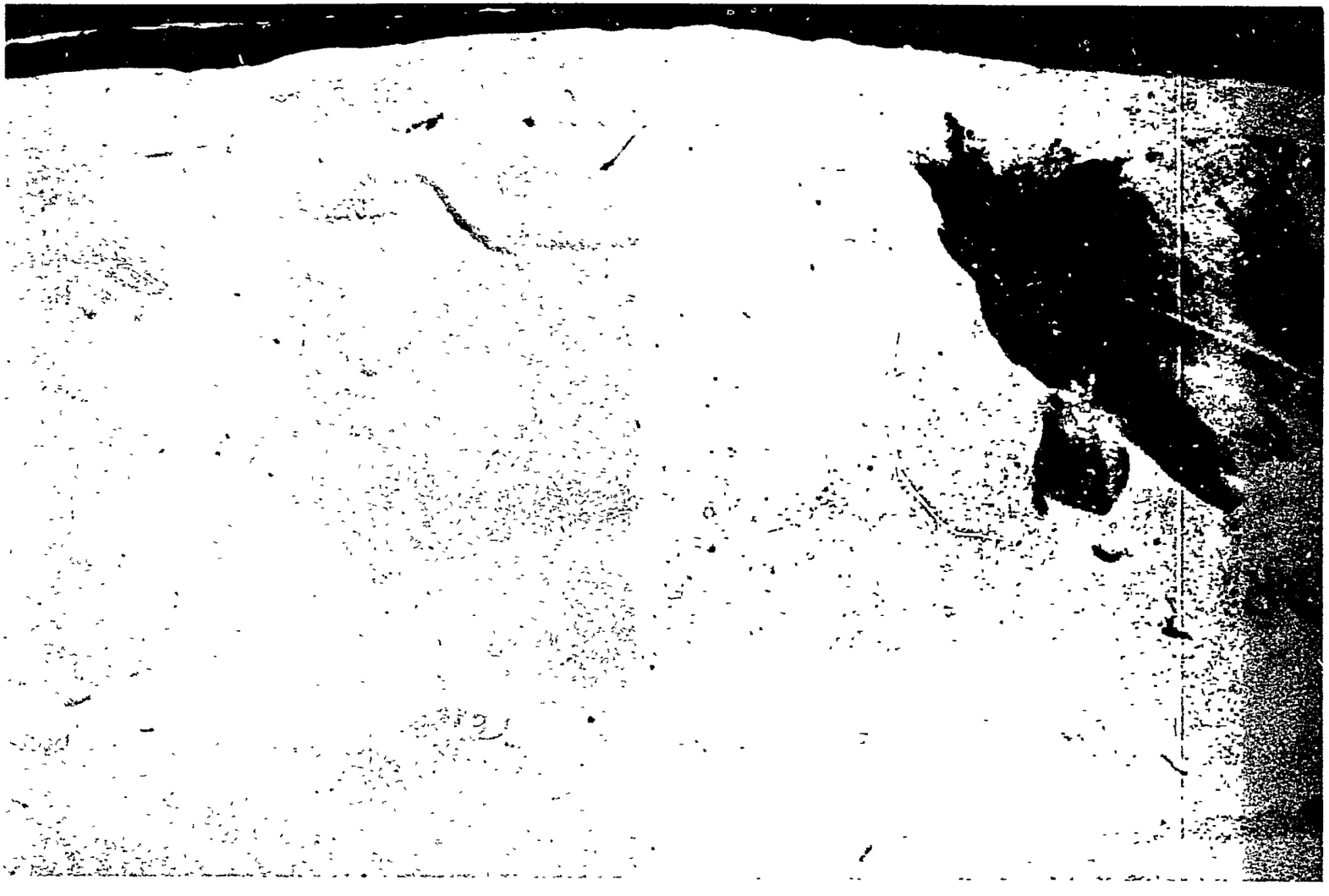


FIGURE 23

Pile Set of Urea in Hold of SS Alain L.D.

Men and women (trimmers) with long poles, forks, and shovels dislodged the urea that hung to the walls of the holds (Fig. 24).

Material discharged from the lower parts of the holds contained lumps larger than 12 inches in diameter (Fig. 25).

The lumps were easily broken, but some difficulty was encountered when large lumps lodged in the hopper discharge chutes and had to be rodded. Some spillage occurred when operators forgot to close the discharge chutes (Fig. 26).

Samples were taken at various locations and intervals during the unloading operation. Results of analyses of these samples as well as samples taken during loading are shown in Table I.

The laboratory and screen analyses indicate no serious physical problems. Moisture levels were well within tolerance, prill hardness was not appreciably affected, and nitrogen content remained consistent throughout the bulk-handling operation.

During the discharge of the Alain L.D. transshipment of the bagged urea to Indonesia was being carried out by two Chinese flag coastal ships. This is the first cropping season that Collier urea has been available to Indonesian farmers. Consequently, farmer reaction and experiences are not available.

Experiences with the handling and transshipment of the urea were discussed with the consignees in Indonesia. Complaints were limited to problems with bags; i.e., bags too small, weights inconsistent, etc.

These complaints point to the necessity of installing adequate bagging and closing equipment at Singapore.

Conclusions

Careful consideration must be given to the equipment available at the port receiving material. The facilities at the port should govern the type of ship chosen to haul the cargo. For example, ships without self-unloading bulk gear should never be dispatched to ports without adequate bulk unloading gear.

The type of equipment available for transporting material inland from the port is also of prime importance. As mentioned before, a recent study in Brazil has shown that 300 rail cars on one line have been taken out of service because of extreme corrosion from hauling fertilizer materials (Fig. 27). Some of the corrosion was caused by material on the outside of the car; i.e., the corrosion started on the outside and proceeded inward. This corrosion was probably caused by fertilizer materials being spilled on the outside of the cars and becoming wet. The spillage could have originated from leaking clamshell buckets.

FIGURE 24

Dislodging Urea from Sides of Hold of SS Alain L.D.

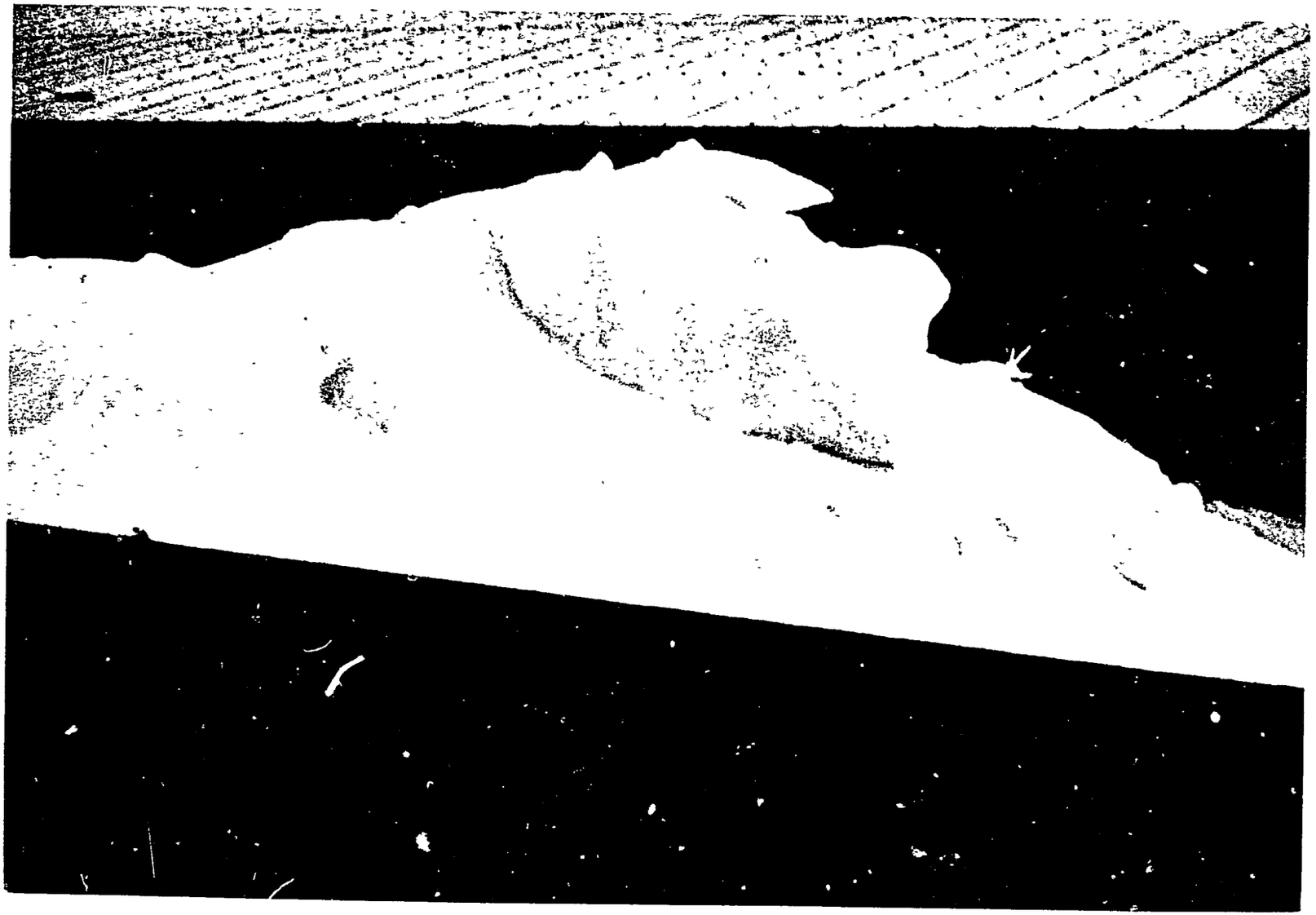


FIGURE 25

Lumps of Urea Unloaded from SS Alain L.D.

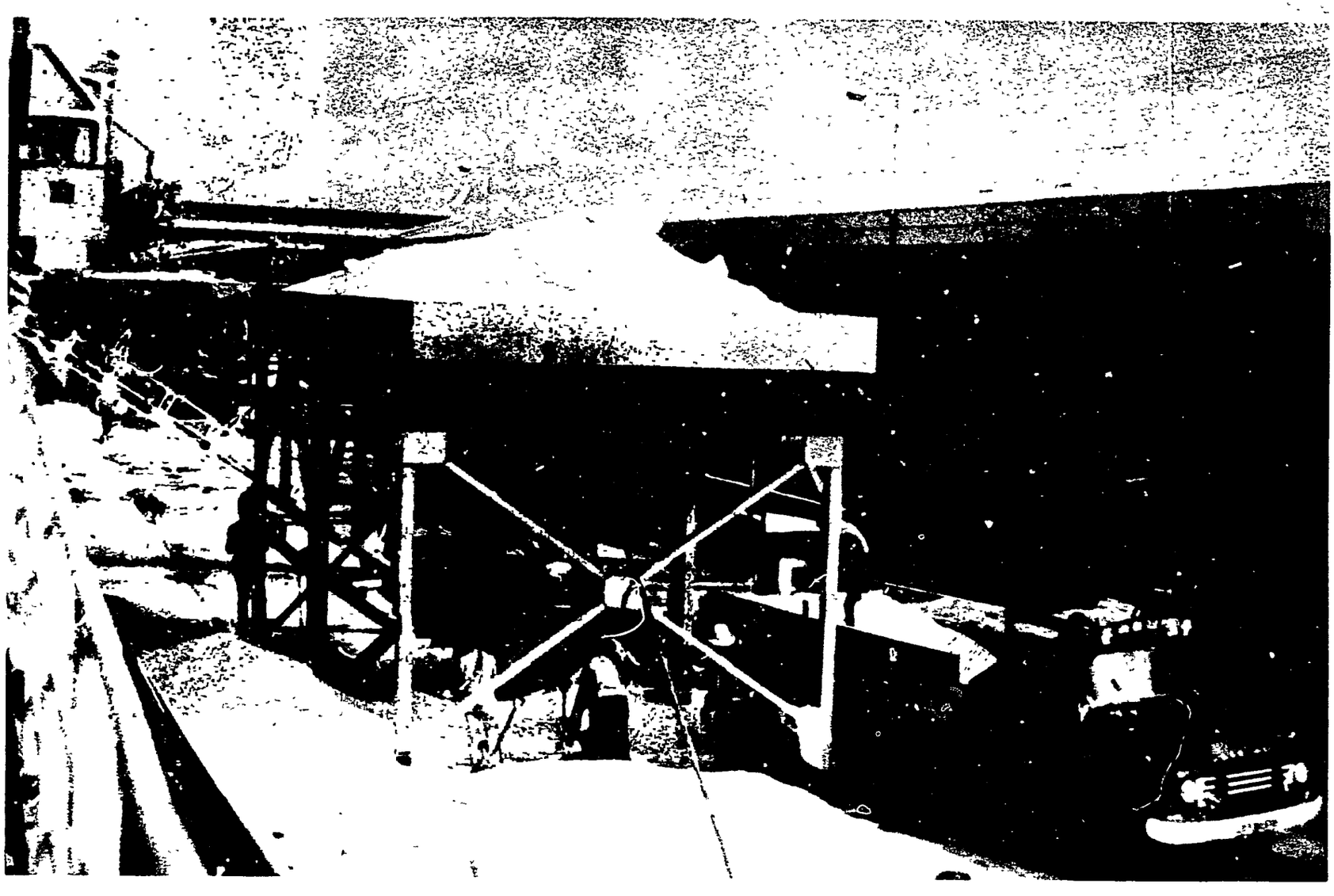


FIGURE 26. Accidental Spillage from Discharge Chutes

TABLE I

TVA Laboratory Chemical and Screen Analyses of Samples

Taken From a Bulk Shipment of Urea[a]

Sample	Chemical analysis, % Total N	H_2O	Biuret	Crushing strength, lb[b]	Apparent density, g/cm^3	Bulk density, lb/ft^3	Angle of repose, °	Screen analysis, % Tyler mesh +6	−6 +8	−8 +10	−10 +14	−14 +16	−16
No. 1 hold													
Loading	46.6	0.14	0.3	2.4	1.32	–	–	0	1.5	36.9	52.1	5.2	4.2
Discharge													
Center	46.5	0.19	–	1.7	–	–	31	–	1.1	48.4	41.6	3.0	5.9
Bottom	–	0.11	–	2.3	–	–	–	0	4.8	57.5	34.0	1.9	1.8
No. 2 hold													
Loading	46.7	0.09	–	2.7	–	45	–	–	–	–	–	–	–
Discharge													
Center	–	0.10	–	2.1	–	–	–	–	–	–	–	–	–
No. 3 hold													
Loading	46.6	0.10	–	2.3	1.32	–	–	–	–	–	–	–	–
Discharge													
Top	46.6	0.13	–	–	–	–	30	–	1.7	53.8	39.9	2.5	2.2
Center	–	0.20	–	1.9	–	–	31	–	0.7	46.9	46.0	2.9	3.4
No. 4 hold													
Loading	46.7	0.09	0.2	2.4	–	47	–	0	3.0	49.5	43.2	3.0	1.3
Discharge													
Center	46.6	0.14	–	2.0	–	–	–	0	2.7	41.2	40.8	5.0	10.3
No. 5 hold													
Discharge													
Center	–	0.14	–	–	–	–	–	–	–	–	–	–	–
Bottom	46.6	0.25	–	–	–	–	–	–	–	–	–	–	–
Hopper No. 2 hold	–	0.12	–	–	–	–	–	0	1.4	48.8	42.2	2.7	4.8
Warehouse pile	–	0.11	–	–	–	–	–	0	2.2	46.5	38.6	2.9	9.8
Warehouse bagging line	–	0.16	–	–	–	–	–	0	6.6	44.3	38.5	4.4	6.2

[a]Produced at Collier Carbon and Chemical Corp.'s Kenai, Alaska, plant; samples were taken during ship loading at the Collier dock and unloading at Singapore.

[b]Force required to crush −8 +9 mesh prills (average of 15).

FIGURE 27

Corrosion of Railroad Car Caused by Spilled Fertilizer

Conventional ship loading and unloading techniques frequently result in substantial degradation and spillage of urea. Also, considerable time is lost when handling operations have to be suspended because of rain. All-weather handling systems which minimize or eliminate degradation and spillage are needed if the full economic potential of bulk shipments of fertilizers is to be realized. Studies to this end should be initiated. These studies would include evaluation of pneumatic unloading equipment for fertilizer uses.

Equipment of the Future

SEABEE and LASH Systems

The Lykes Steamship Company is currently developing the novel transportation concept SEABEE. The SEABEE concept represents the development of a highly versatile shipping system using barge-carrying cargo ships called SEABEE clippers, Figure 28. Each ship contains a self-unloading system which utilizes an electrohydraulic stern elevator of 2000-ton capacity, Figure 29. Although the clippers will be used primarily to transport barges, the ships can also be used to carry standard containers or roll-on roll-off freight. The system is scheduled to be in operation some time in 1971.

The SEABEE clippers will initially be placed in liner service carrying high unit-price commodities. After the system has been proved, barges will be available for lower priced commodities, such as fertilizers on a nonliner schedule.

The SEABEE concept differs from operational LASH system primarily in size of the barges carried and the method of launching and retrieving barges. The LASH barges are somewhat smaller and are launched using topside ship gear (Fig. 3); the SEABEE barges will be launched and retrieved from a stern elevator.

The ship LASH Italia is now in service between the United States and Europe and has been well received.

Containerization

Future sophisticated transportation systems will rely heavily on the containerization concept including SEABEE and LASH systems, roll-on roll-off systems, and standard containerization systems. Two annual technical meetings of the Containerization Institute, Inc., were attended to obtain basic background information on currently used transport and handling equipment and on concepts that might conceivably be suitable for fertilizers in the future (13).

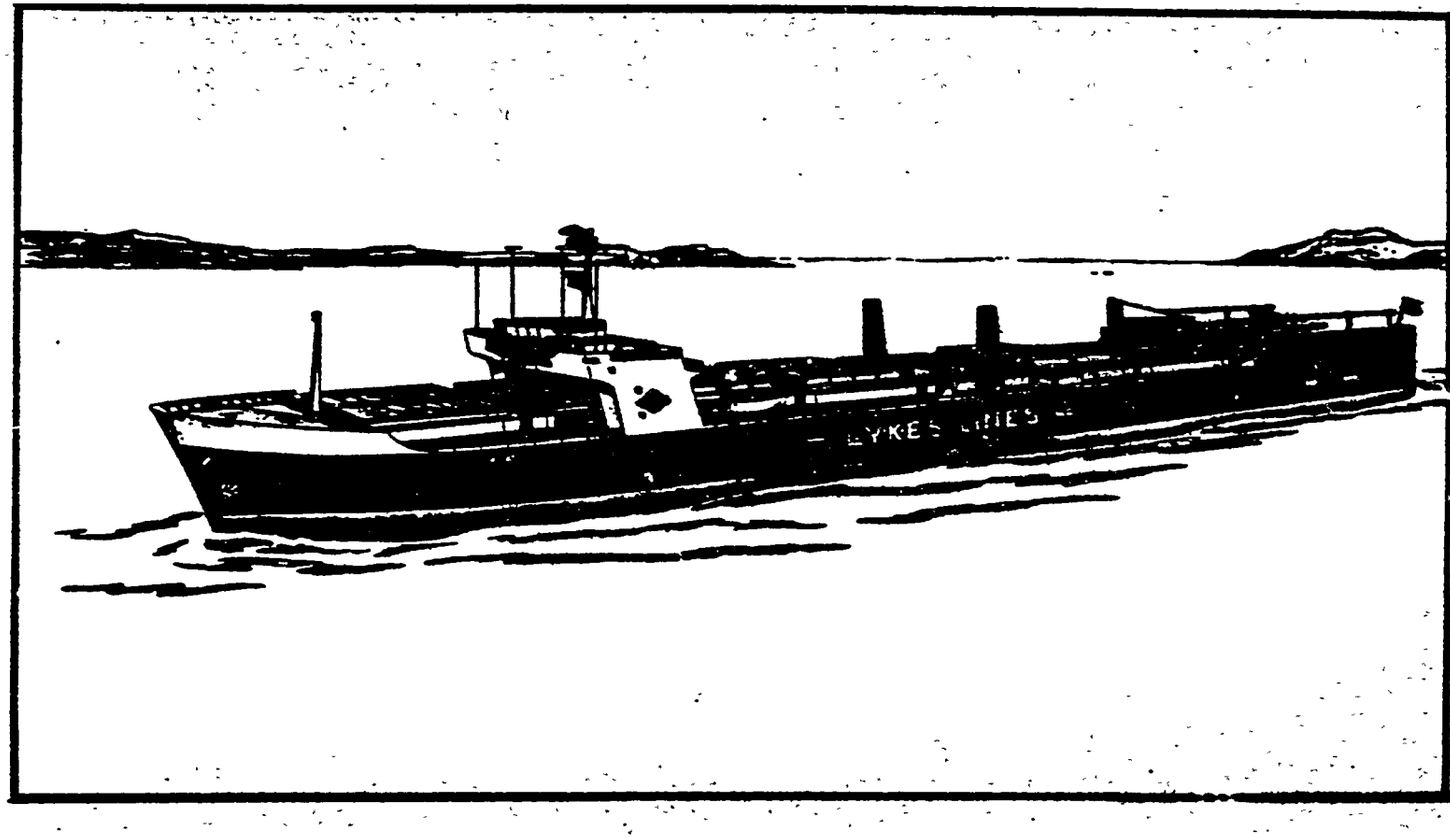


FIGURE 28

Typical SEABEE Clipper

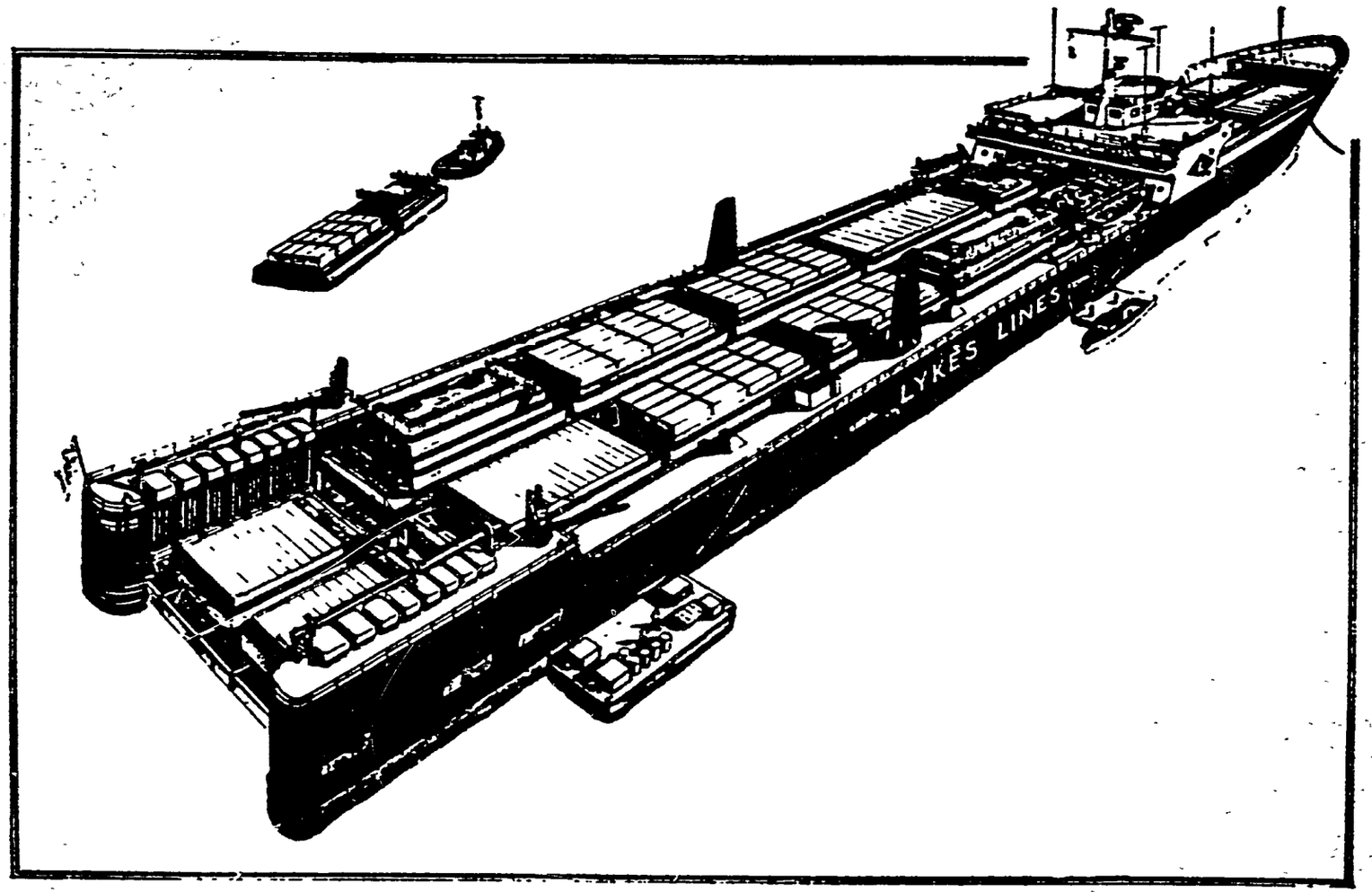


FIGURE 29

View of Typical SEABEE Clipper Showing Stern Elevator

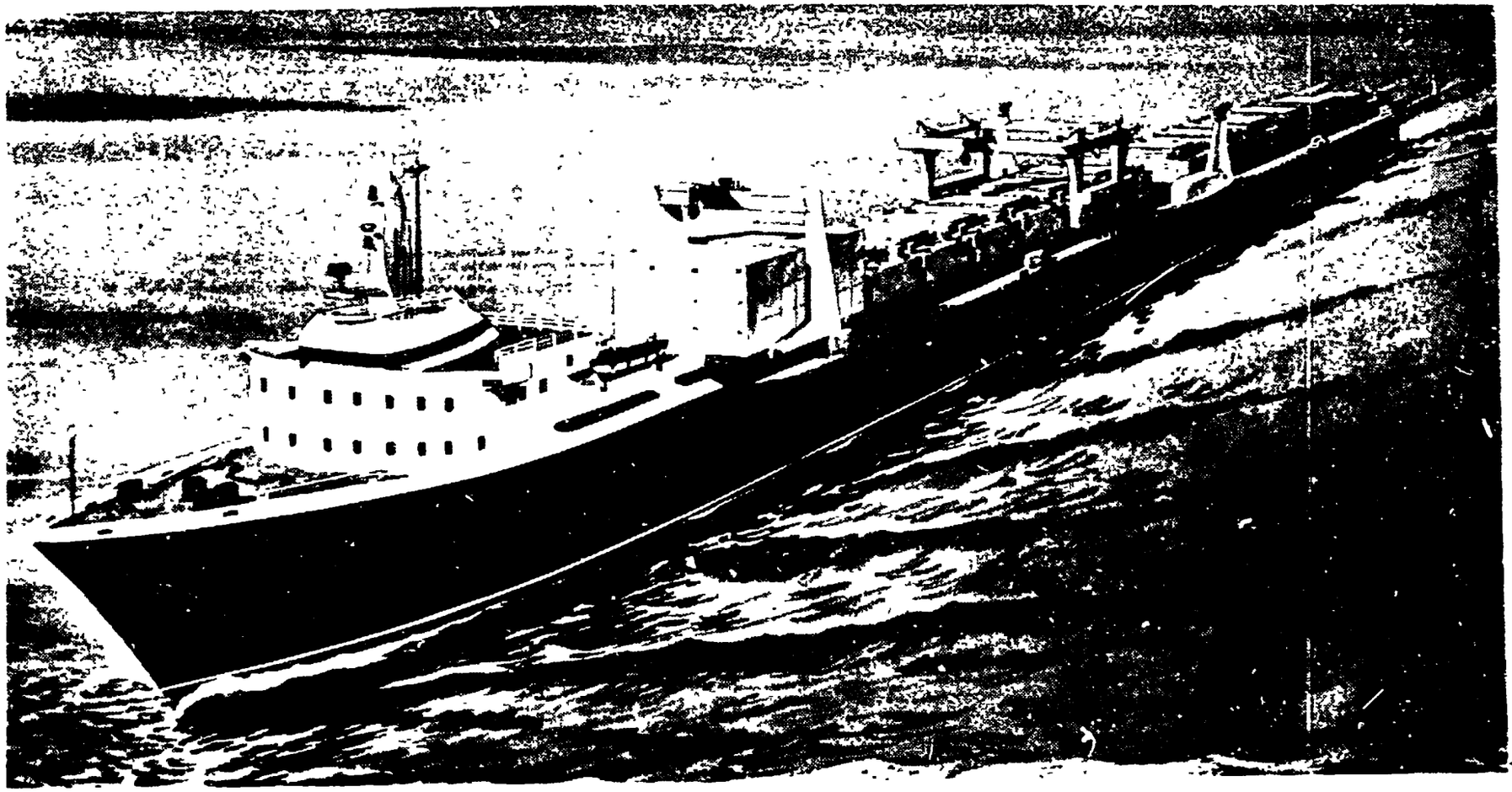


FIGURE 30

Barge Carrying Cargo Ship (LASH)

At the present time, it appears that the full benefits of containerization have not been realized because of problems in custom clearances, conflicts between the regulations of the several federal agencies involved, and lack of efficient port handling methods and equipment for containerization.

A substantial amount of information about these new concepts in shipping has been obtained and is on file at TVA.

Land-Based Systems

The study of land transport of fertilizers was limited by time and personnel available. Descriptions and illustrations of various rail and truck vehicles were obtained. Information on the protection of these vehicles from the corrosive effects of fertilizers was collected. Basic data were gathered on reclaiming fertilizers from storage. The results of this work are presented below.

Description of Vehicles--Railroad

Tank Cars

The cars are used to transport various fertilizer liquids. Figure 31 shows a "jumbo" tank car used to transport liquid anhydrous ammonia; it is made of carbon steel and holds 75 tons of ammonia at a pressure of 225 pounds per square inch gage. Figure 32 is a carrier for superphosphoric acid. The tank is made of Type 316L stainless steel and contains panel-type heating coils of Type 304 stainless steel. It is insulated with 4 inches of plastic foam and has a capacity of 12,200 gallons or 100 tons of acid.

Covered Hopper Cars

These cars are used to transport bulk fertilizers. In Figure 33 a 100-ton conventional hopper bottom car is shown. This car has full length center draft sill which makes it necessary to have hoppers on each side of the draft sill for a total of six hoppers per car.

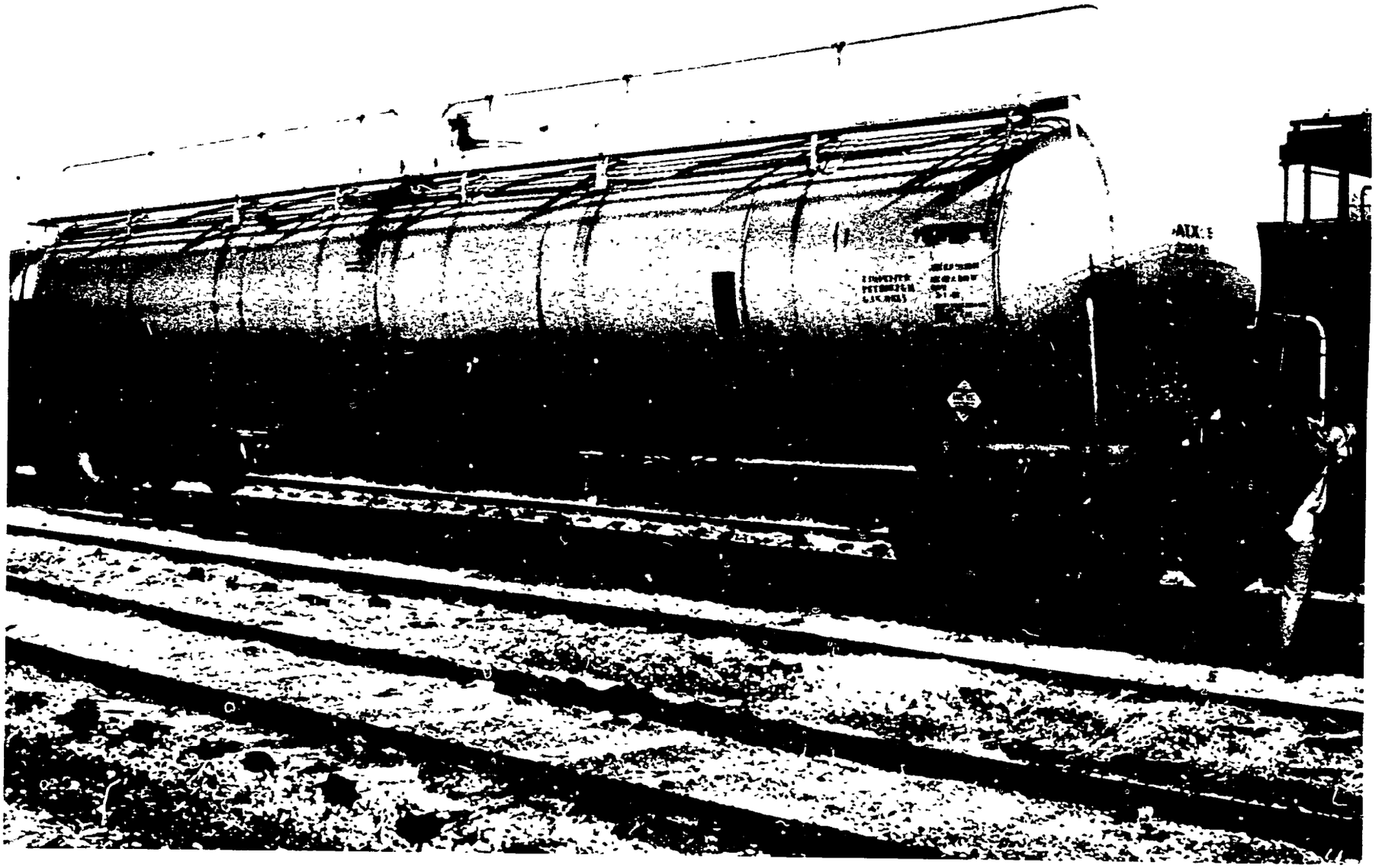


FIGURE 31

Tank Car for Transporting Liquid Anhydrous Ammonia

FIGURE 32

Tank Car for Superphosphoric Acid Service

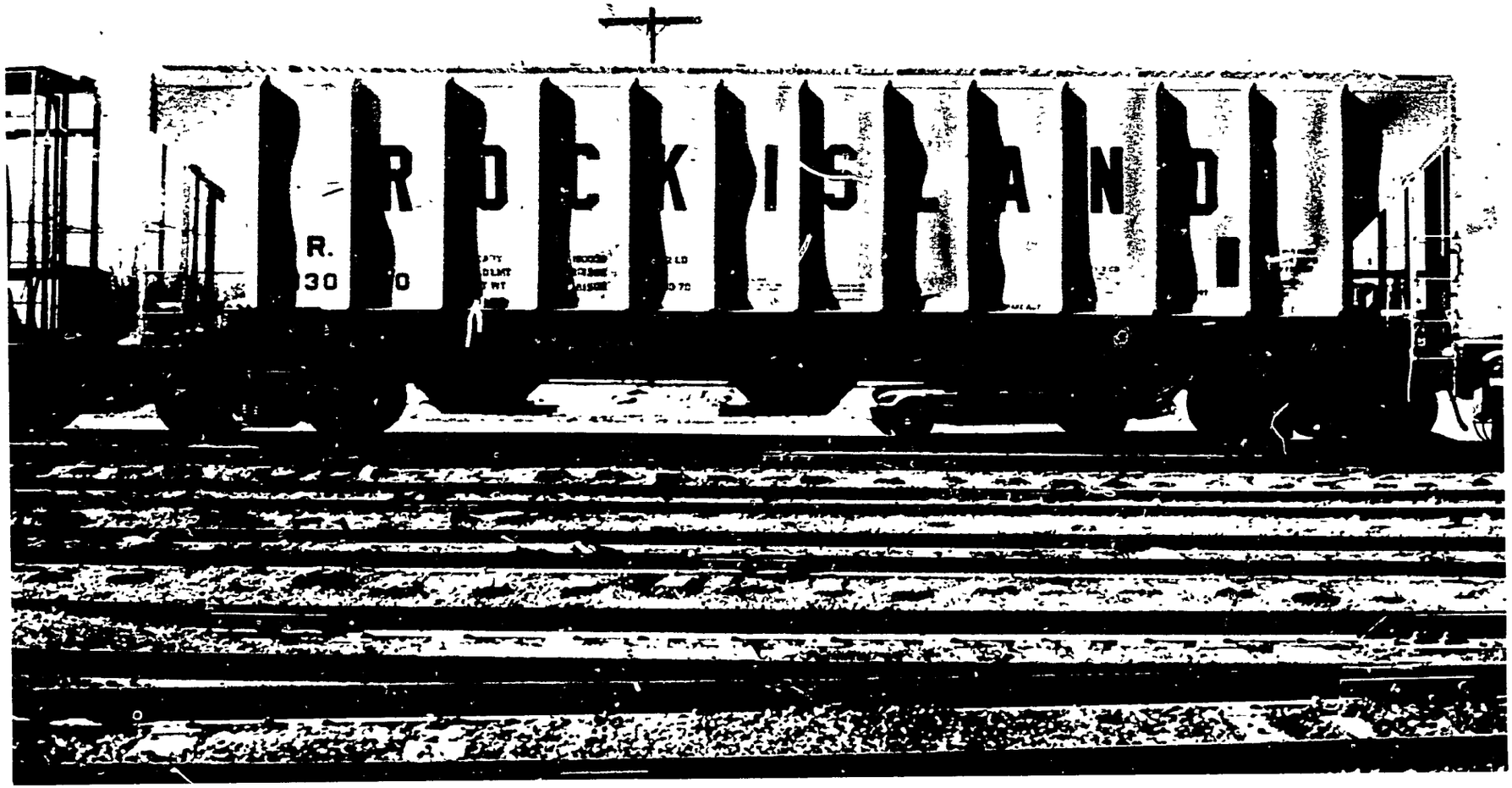


FIGURE 33

Conventional Covered Hopper-Bottom Car

Figure 34 shows a center-flow hopper car, a uniquely designed car built in the United States only by ACF Industries. The center-flow car utilizes only stub-draft sills which allow the three (instead of six) continuous outlet hoppers from side to side under the car body. Since the car body does not straddle a draft sill, the effective center of gravity of the car is lowered. The car also has one continuous rectangular loading hatch running the length of the car instead of the many small circular hatches on the conventional hopper car. The continuous hatch makes it possible to load the car without stopping the flow of material to change hatches. The continuous hatch and the quick-dump gravity outlets on the hoppers are shown in Figure 35.

Description of Vehicles--Trucks

Tank Trailers

These vehicles, depending upon construction, can transport fertilizer liquids under pressures up to 225 pounds per square inch gage. Figure 36 shows an insulated tank trailer made of stainless steel used to transport liquids at pressures up to 125 pounds per square inch gage. Figure 37 is a typical nonpressure (atmosphere) tank trailer made of stainless steel.

Figure 38 is a trailer for transporting anhydrous liquid ammonia at a pressure of 225 pounds per square inch gage. It is made of carbon steel.

Covered Hopper Trailers

These are used to transport bulk fertilizers. Figure 39 shows a hopper bottom trailer which discharges cargo by way of a belt conveyor running the length of the trailer along the bottom of the hopper. This conveyor discharges to a short movable auxiliary belt conveyor also mounted on the trailer. Both conveyors are powered by a trailer-mounted gasoline engine.

Combination Solids and Liquid Trailer

This trailer, shown in Figure 40, can transport either solids or noncorrosive liquids at atmospheric pressure. It is made of carbon steel and carries a gasoline-driven air compressor which is used to pressurize the tank for discharging either the solids or the liquids.

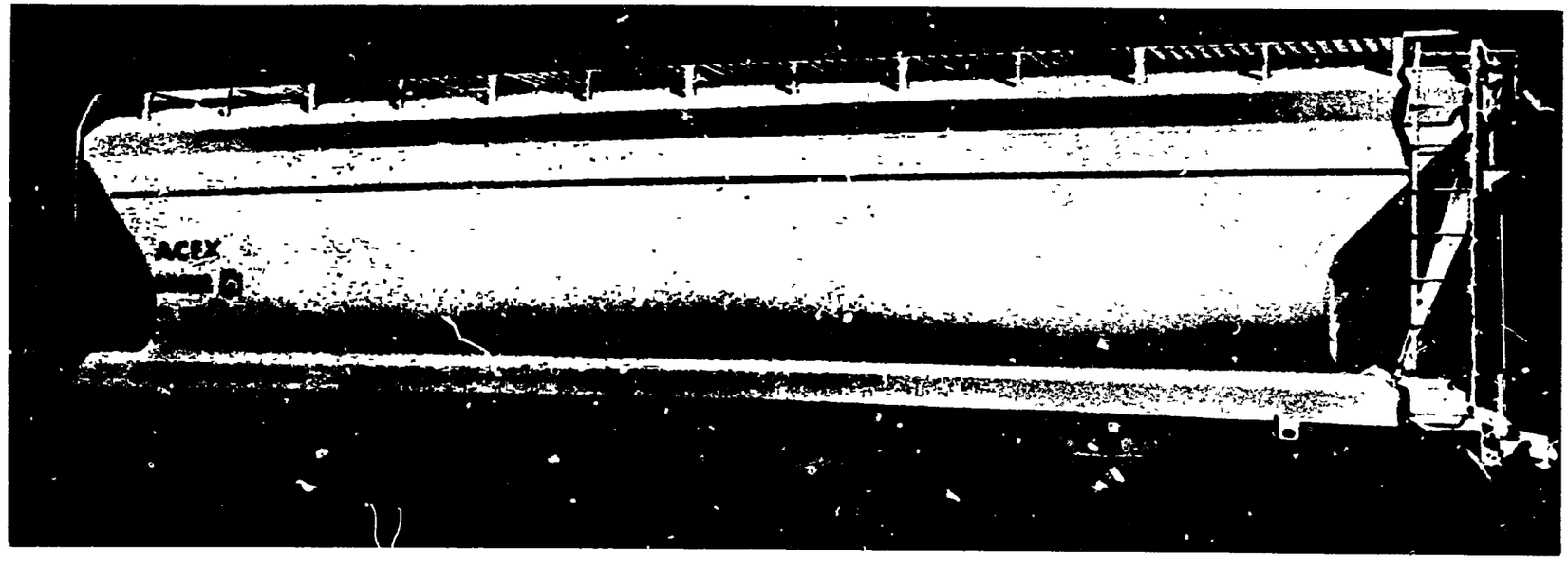
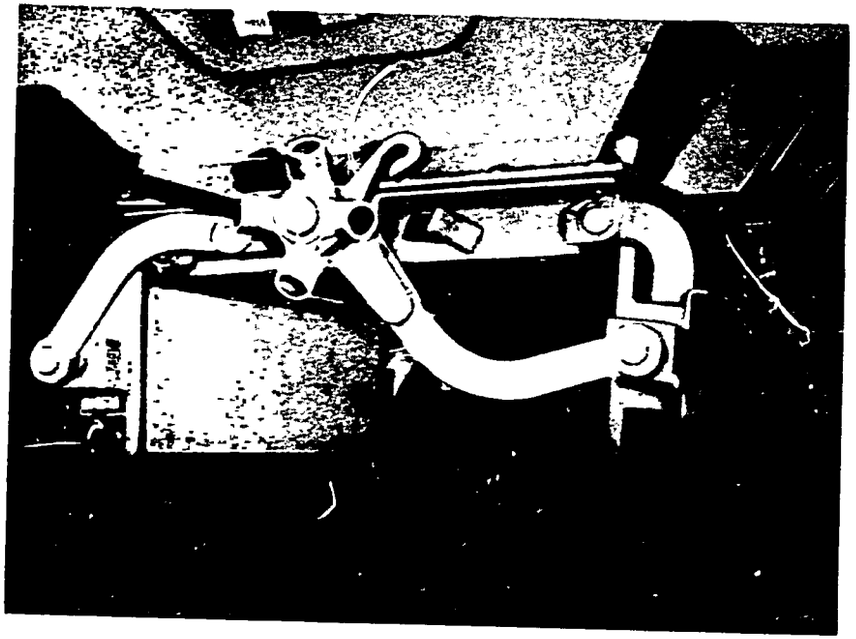
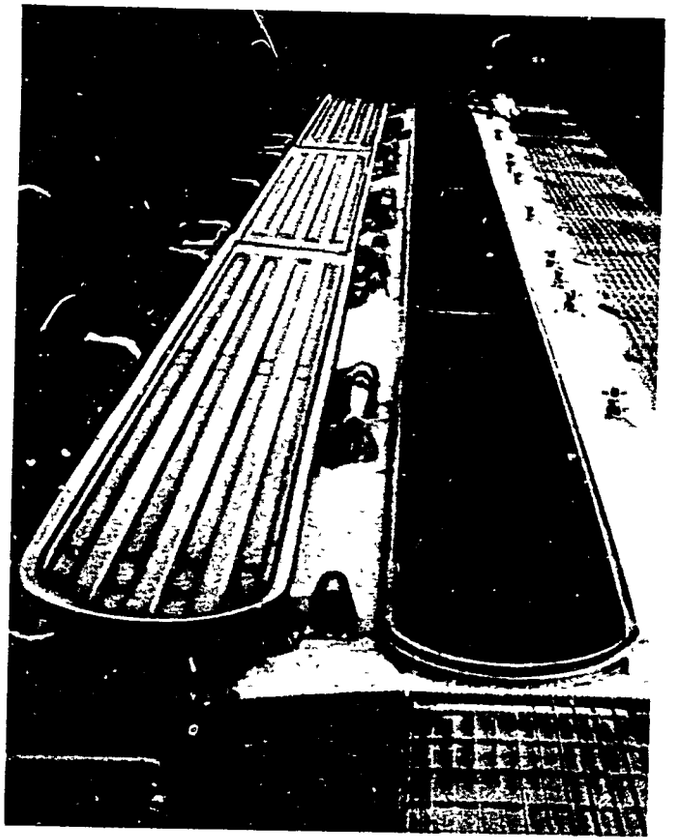


FIGURE 34

Center-Flow Covered Hopper-Bottom Car



Quick-Dump Outlet



Continuous Hatch

FIGURE 35

Quick-Dump Outlet and Continuous Hatch on Center-Flow Hopper Car

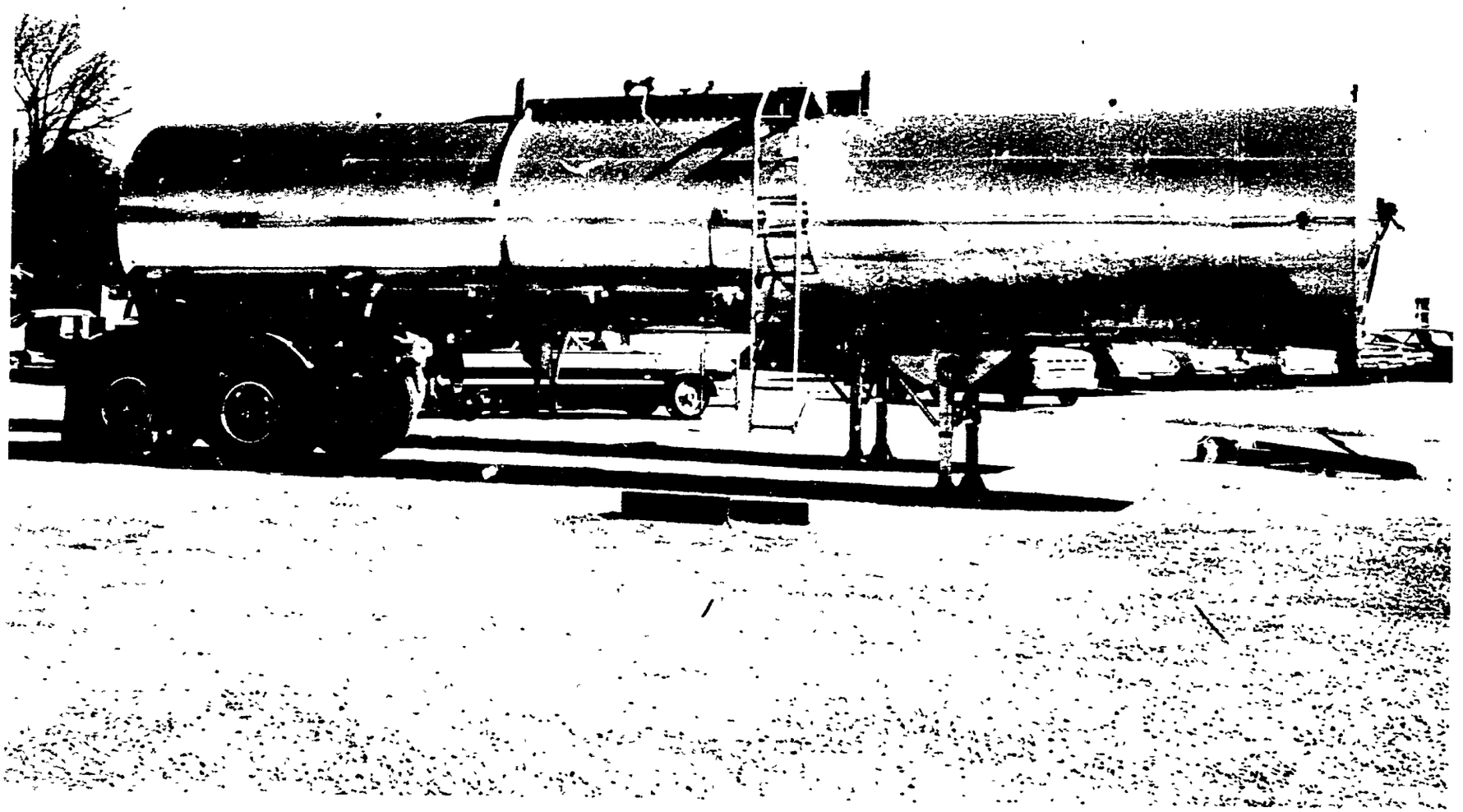


FIGURE 36

Insulated Tank Trailer

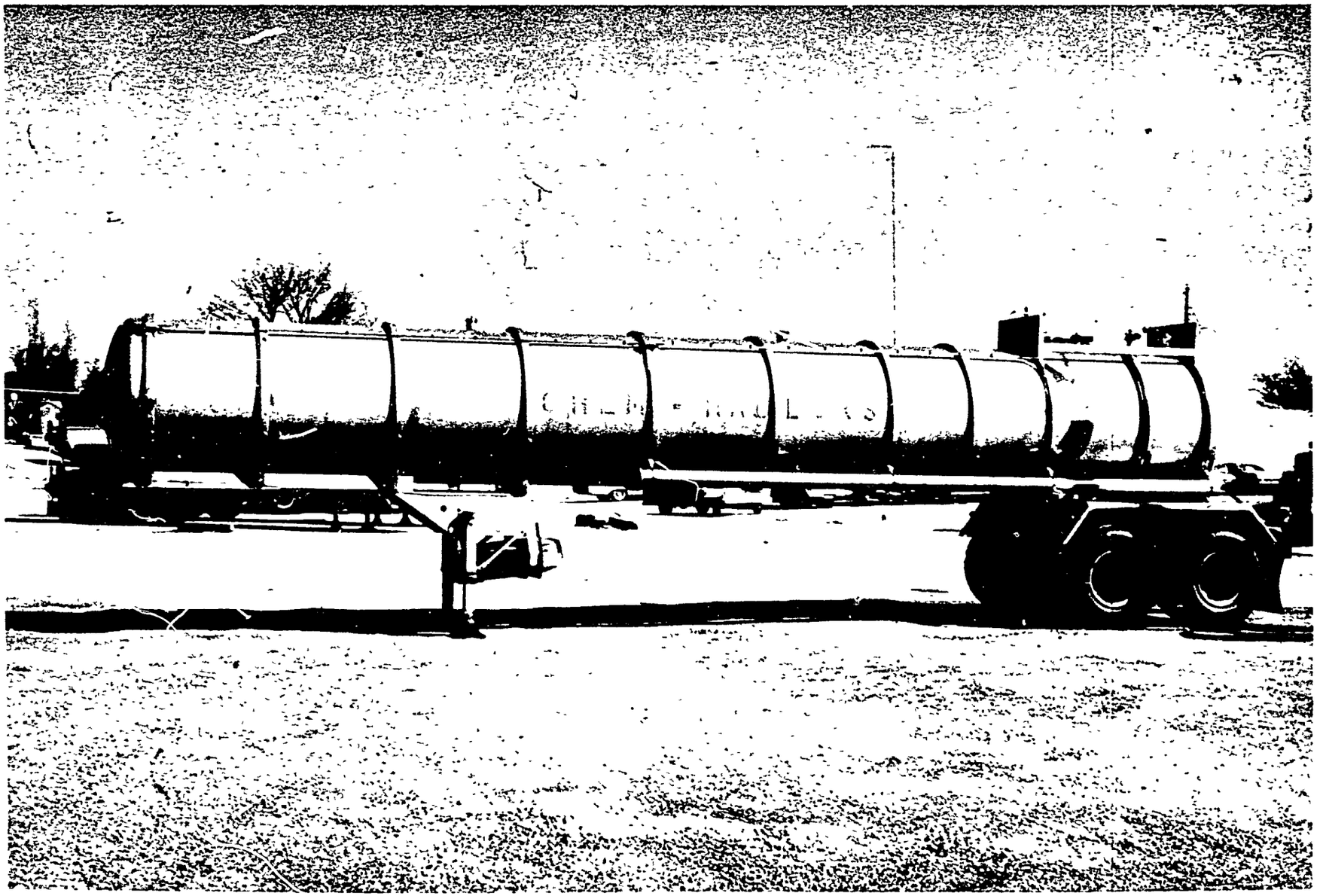


FIGURE 37

Typical Nonpressure Tank Trailer

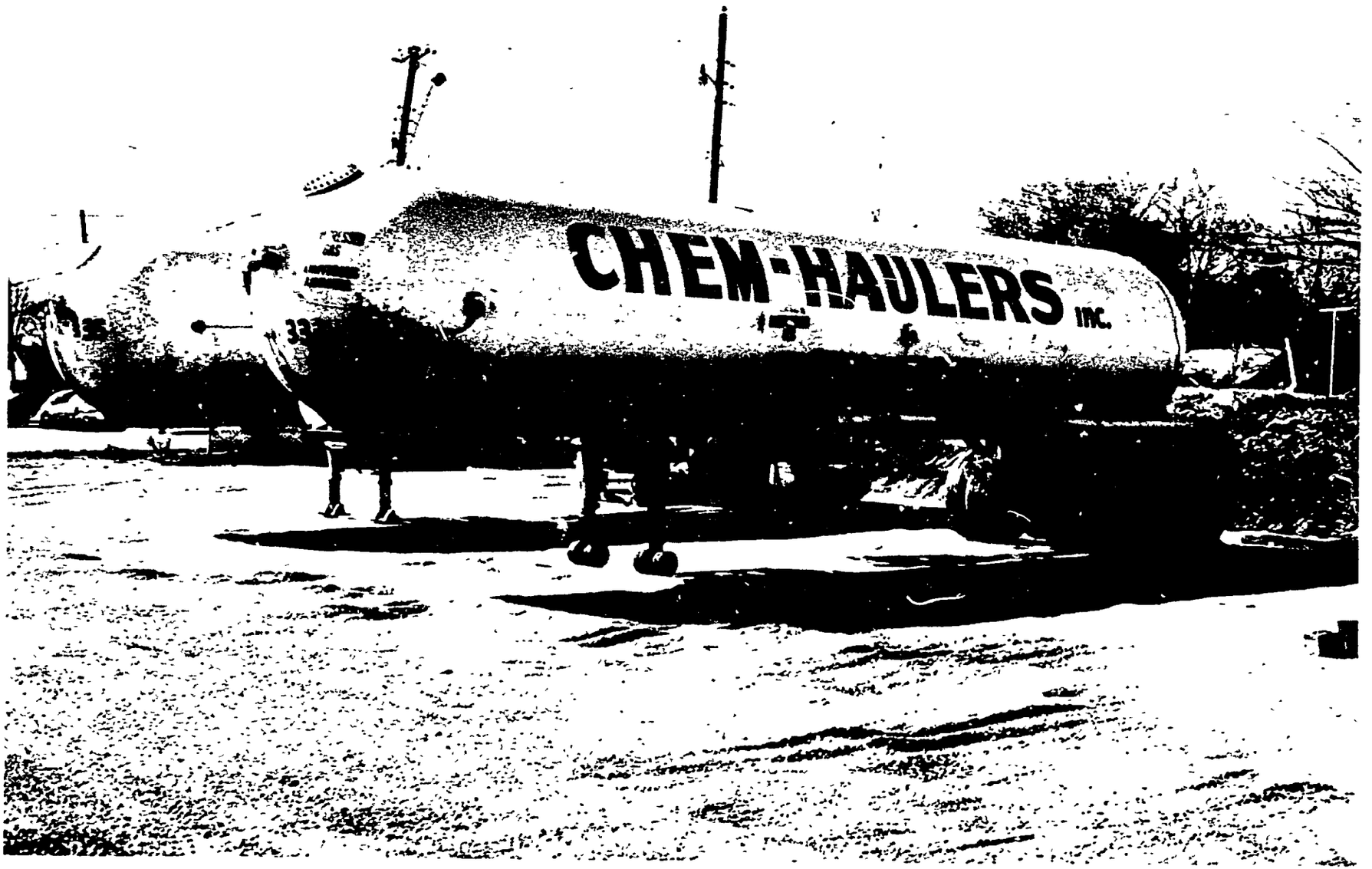


FIGURE 38

Tank Trailer for Transporting Liquid Anhydrous Ammonia

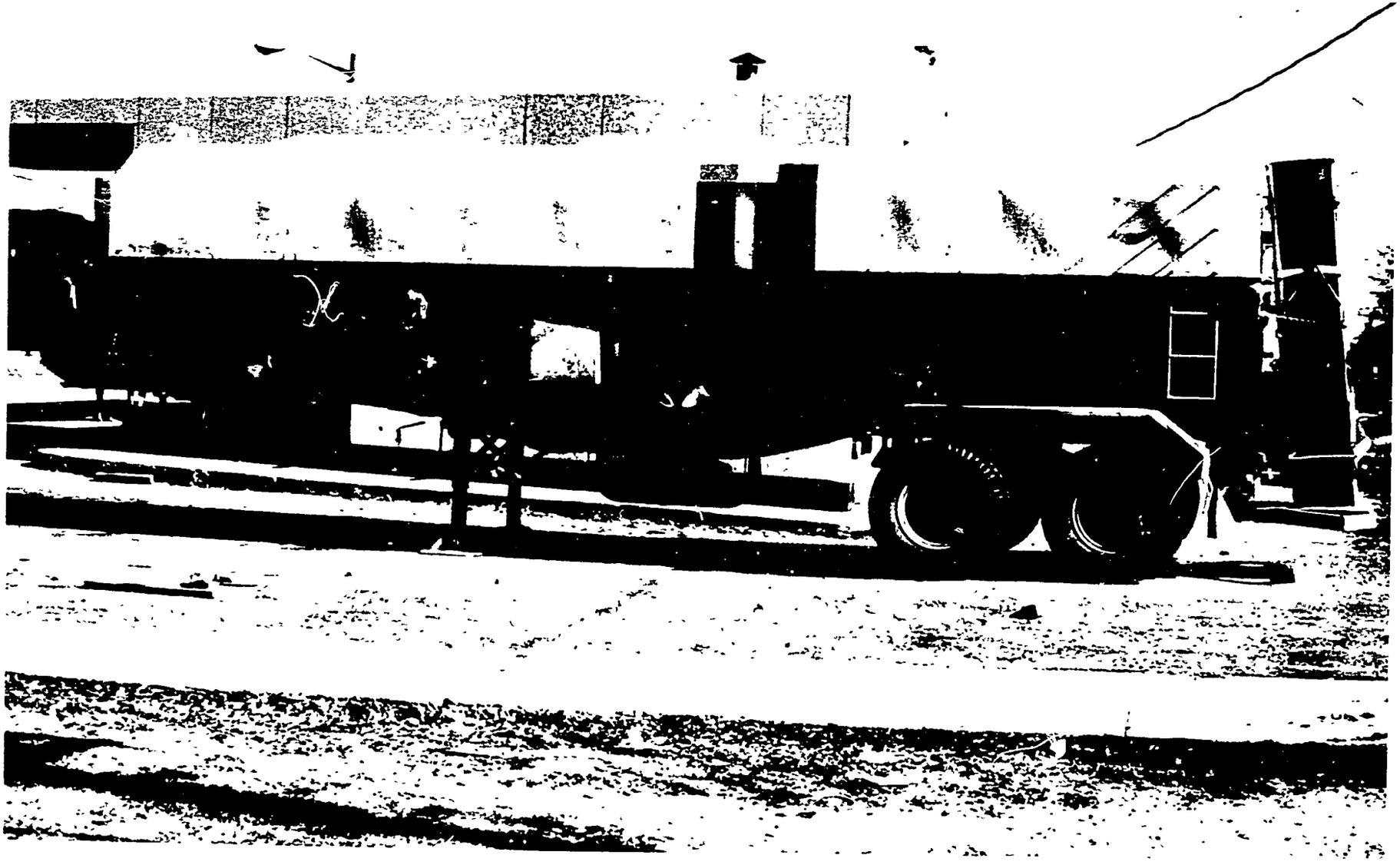


FIGURE 39

Covered Hopper-Bottom Trailer--Conveyor Belt Discharge

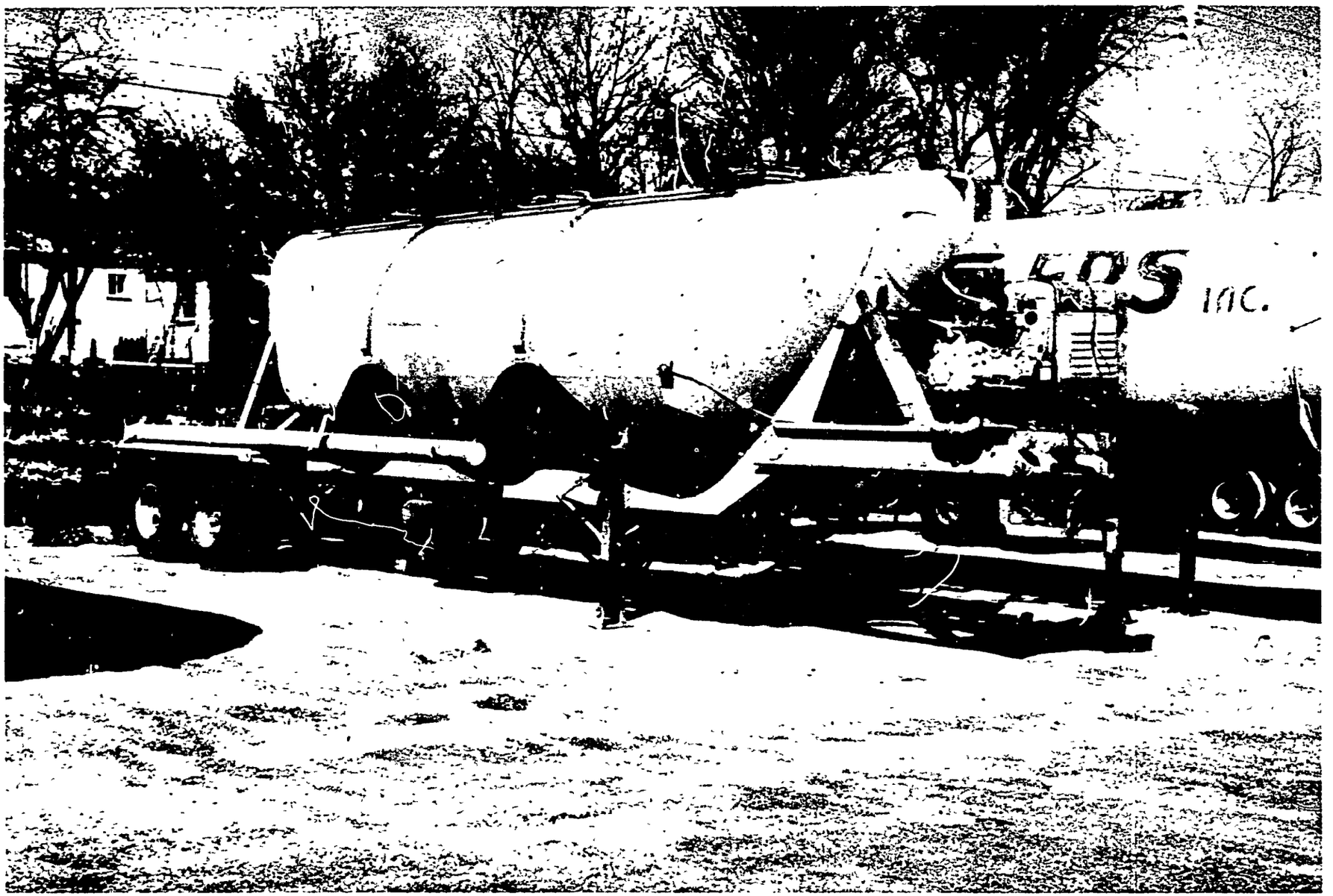


FIGURE 40

Trailer for Transporting Solids or Liquids

Protection of Vehicles From Corrosion

Because of the severe corrosion of the railway cars used to transport fertilizers in Brazil, two employees of the Sorocabana railway (São Paulo, Brazil) visited railroads, railway car builders, and shippers in the United States in December 1970 in an effort to find a solution to the problem. T. M. Kelso of TVA accompanied these visitors. As a result of the visit, information concerning protective coatings and their application was accumulated for transmittal to Brazil. Also, preliminary contacts have been made to establish direct communication between railway car builders in Brazil and the Pullman-Standard Corporation in the United States to develop a satisfactory hopper car design.

Reclaiming Bulk Materials

Since most fertilizer shipments begin with reclaiming the material from storage, basic data have been gathered on several concepts of reclaiming bulk materials from storage. This information is in the TVA files.

ECONOMICS OF BULK VERSUS BAGGED SHIPMENTS

Shipment of fertilizers in bulk is more economical than shipment in bags. The savings for bulk shipment of fertilizers versus bagged shipment from U. S. ports to India and Pakistan is about $20 per ton on a cost plus freight basis. In most DC's the lack of facilities for storing and shipping bulk fertilizers inland often necessitates bagging of bulk material at the receiving port. This negates some of the economics inherent in bulk movement. However, costs of bagging and sometimes also the costs of bags are in local currency, and foreign exchange is not expended. The cost comparisons indicate that savings in foreign exchange should be in the range of about $20 per ton for shipment of bagged fertilizers from the U. S. If the material is bagged at the receiving port, total cost savings are about $10 to $12 per ton for bulk import versus bagged. A breakdown of these cost comparisons is given in Tables II and III. Included is a breakdown of costs of movement from the U. S. to India, Pakistan, Vietnam, and Indonesia in either U. S. or foreign flag vessels.

Because of small size and/or lack of facilities, some ports are not capable of receiving bulk fertilizers. However, some of the economics of bulk shipment of imported fertilizers may be realized by (1) shipping in bulk to a nearby port, such as Singapore, where the product can be unloaded, bagged, and then moved to a final destination or (2) loading bulk fertilizer onto a carrier, such as the Cemento Ponce, and bagging en route to the final destination. (The Cemento Ponce is described in a previous section of this report.)

TABLE II

Estimated Comparative Costs Per Metric Ton of Shipping Bulk and Bagged Urea from U.S. Ports to East and West Coasts of India and West and East Pakistan

(Not Including Cost of Urea)

Coast of embarkation	Port destination: West Coast India/Karachi Vessel U.S.	West Coast India/Karachi Vessel Foreign	East Coast India/Chittagong Vessel U.S.	East Coast India/Chittagong Vessel Foreign
U.S. Gulf				
Bagged				
1. Stevedoring and bagging in U.S. port[a]	19.50	19.50	19.50	19.50
2. Freight cost[b]	42.00	20.00	45.00	23.00
3. Stevedoring and handling in receiving port[c]	0.75	0.75	0.75	0.75
4. Landed cost (excluding cost of urea)	62.25	40.25	65.25	43.25
Bulk				
1. Stevedoring and bagging in foreign port[a]	9.50	9.50	9.50	9.50
2. Freight[b]	39.00	17.00	42.00	20.00
3. Stevedoring and handling in U.S. port[c]	2.00	2.00	2.00	2.00
4. Landed cost (excluding cost of urea)	50.50	28.50	53.50	31.50
5. Cost differential[d]	11.75	11.75	11.75	11.75
6. Foreign exchange savings[e]	20.50	20.50	20.50	20.50
U.S. West Coast				
Bagged				
1. Stevedoring and bagging in U.S. port[a]	22.50	22.50	22.50	22.50
2. Freight[b]	37.00	18.00	40.00	20.00
3. Stevedoring and handling in foreign port[c]	0.75	0.75	0.75	0.75
4. Landed cost (excluding cost of urea)	60.25	41.25	63.25	43.25
Bulk				
1. Stevedoring and bagging in foreign port[a]	9.50	9.50	9.50	9.50
2. Freight[b]	33.00	14.00	36.00	16.00
3. Stevedoring and handling in U.S. port[c]	3.00	3.00	3.00	3.00
4. Landed cost (excluding cost of urea)	45.50	26.50	48.50	28.50
5. Cost differential[d]	14.75	14.75	14.75	14.75
6. Foreign exchange savings[e]	22.50	22.50	22.50	22.50

[a] Includes costs of bags, pallet rentals, service charges, wharfage, storage if any, custom clearance, and other incidental charges.

[b] Freight costs are averages based on categories 1, 3, and 4 ships and include a $5 Cape of Good Hope diversion. Freight rates do not include adjustments for demurrage or dispatch incurred as a result of shipping bulk or bagged urea.

[c] Includes cost of labor and incidental charges.

[d] Difference between landed cost for bagged and bulk urea.

[e] Calculated on the basis of item 1 minus item 4 plus adjustment factor for bulk stowage and lower freight rate for bulk cargo.

TABLE III

Estimated Comparative Costs Per Metric Ton for Shipping Bulk and Bagged Urea from U.S. Ports to Saigon, Vietnam, and Djakarta, Indonesia

(Not Including Cost of Urea)

Coast of embarkation	Port destination: Saigon, Vietnam, Vessel: U.S.	Saigon, Vietnam, Vessel: Foreign	Djakarta, Indonesia, Vessel: U.S.	Djakarta, Indonesia, Vessel: Foreign
U.S. Gulf				
Bagged				
1. Stevedoring and bagging in U.S. port[a]	19.50	19.50	19.50	19.50
2. Freight cost[b]	45.00	19.00	47.00	20.00
3. Stevedoring and handling in receiving port[c]	1.50	1.50	1.75	1.75
4. Landed cost (excluding cost of urea)	66.00	40.00	68.25	41.25
Bulk				
1. Stevedoring and bagging in foreign port[a]	10.50	10.50	11.50	11.50
2. Freight cost[b]	42.00	16.00	44.00	17.00
3. Stevedoring and handling in U.S. port[c]	2.00	2.00	2.00	2.00
4. Landed cost (excluding cost of urea)	54.50	28.50	57.50	30.50
5. Cost differential[d]	11.50	11.50	10.75	10.75
6. Foreign exchange savings[e]	20.50	20.50	20.50	20.50
U.S. West Coast				
Bagged				
1. Stevedoring and bagging in U.S. port[a]	22.50	22.50	22.50	22.50
2. Freight cost[b]	34.00	17.00	34.00	15.00
3. Stevedoring and handling in receiving port[c]	1.50	1.50	1.75	1.75
4. Landed cost (excluding cost of urea)	58.00	41.00	58.25	39.25
Bulk				
1. Stevedoring and bagging in foreign port[a]	10.50	10.50	11.50	11.50
2. Freight cost[b]	32.00	15.00	32.00	13.00
3. Stevedoring and handling in U.S. port[c]	3.00	3.00	3.00	3.00
4. Landed cost (excluding cost of urea)	45.50	28.50	46.50	27.50
5. Cost differential[d]	12.50	12.50	11.75	11.75
6. Foreign exchange savings[e]	22.50	22.50	22.50	22.50

[a] Includes costs of bags, pallet rentals, service charges, wharfage, storage if any, custom clearance, and other incidental charges.

[b] Freight costs are averages based on categories 1, 3, and 4 ships. Freight rates do not include adjustments for demurrage or dispatch incurred as a result of shipping bulk or bagged urea.

[c] Includes cost of labor and incidental charges.

[d] Difference between landed cost for bagged and bulk urea.

[e] Calculated on the basis of item 1 minus item 4 plus adjustment factor for bulk stowage and lower freight rate for bulk cargo.

In Figure 41 shipping and handling costs for shipment of urea from the United States Gulf Coast to either Saigon or Djakarta are compared for bulk and bagged urea, including the alternative of shipment in bulk to Singapore, bagging the urea in Singapore, and then shipping the bagged urea on to the final destination. The total handling, bagging, and shipping costs of alternatives for moving urea from the United States Gulf Coast to Saigon are tabulated below.

Total Cost $/Ton for Shipment of Urea

from U.S. Gulf Coast to Saigon Using

	Bagged shipment to Saigon	Bulk shipment to Singapore and then bagged and shipped to Saigon	Bulk shipment to Saigon
U.S. flag	64.5	57 (7.5)[a]	45 (19.5)[a]
Foreign flag	41.5	36 (5.5)[a]	22 (19.5)[a]

[a] Cost differential compared with bagged shipment.

In addition to the costs of bags and bagging, there are other economics for ocean shipments of bulk fertilizers which are listed below.

Higher Unloading Rates

Bulk fertilizer can be loaded and discharged at higher rates than bagged fertilizer. Thus, freight rates for bulk shipments are normally lower because of the lesser vessel time (lay time) in port. Also, payment of demurrage is avoided.

Lower Labor Costs

Less labor is required for loading and unloading bulk fertilizer. Therefore, stevedoring costs are lower.

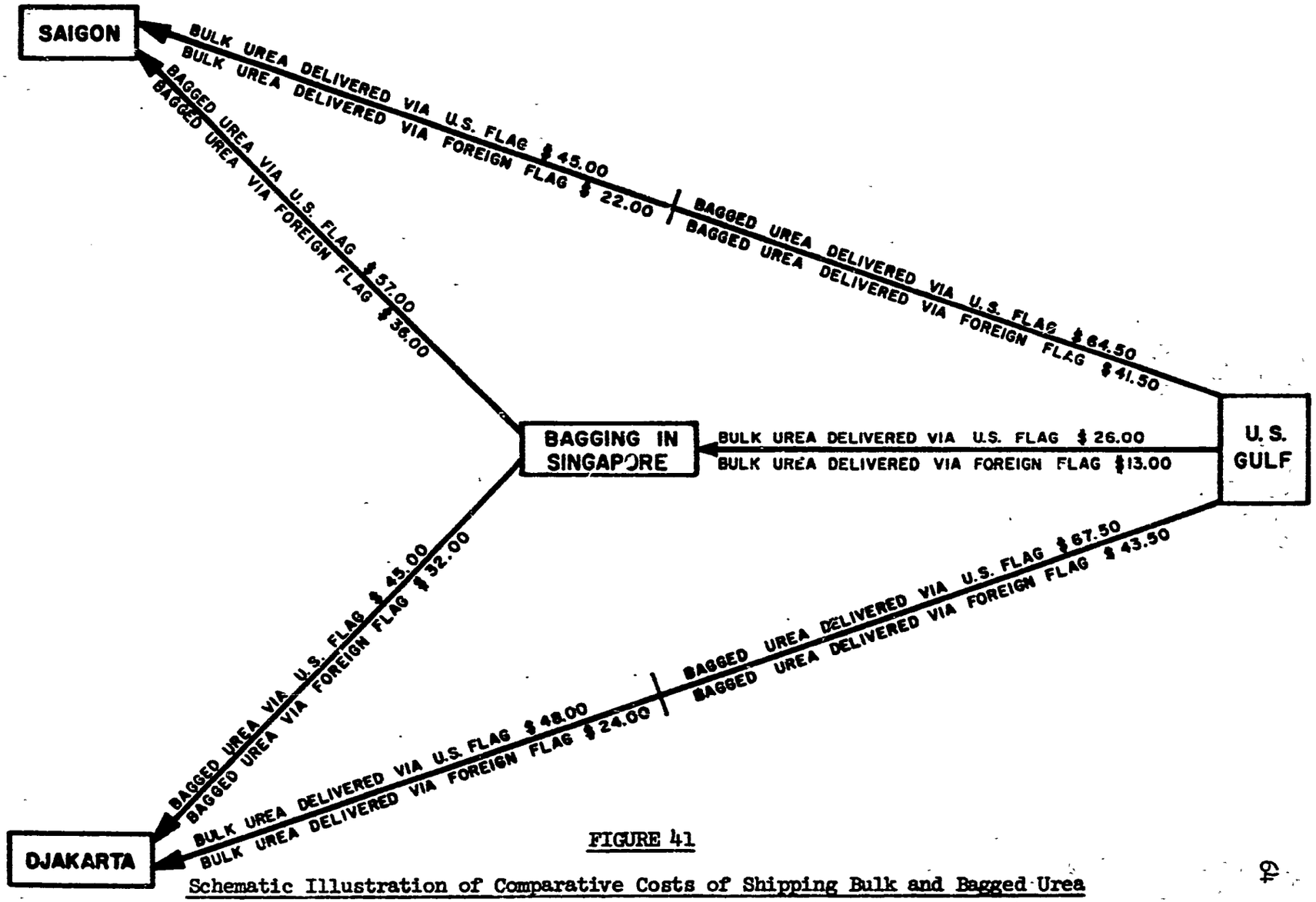


FIGURE 41

Schematic Illustration of Comparative Costs of Shipping Bulk and Bagged Urea From U.S. Gulf to Southeast Asia Via U.S. and Foreign Flag Vessels With Singapore as an Alternative Bagging Site, Costs/Metric Ton (Not Including Cost of Urea)

More Efficient Utilization of Shipping Space

Hauling fertilizers in bulk permits more efficient utilization of shipping space. For example, about 48 cubic feet is required to store a ton of bulk urea as compared with about 60 cubic feet for bagged urea.

Larger Ships Used

Ships used to transport bulk fertilizers are usually larger than ships used for bagged fertilizers. Bulk fertilizers are usually moved in ships carrying about 15,000 (category No. 3) to about 20,000 (category No. 4) metric tons of cargo, while bagged fertilizers are normally moved in ships carrying about 10,000 tons or less (category No. 1). Bagged fertilizer usually moves in the smaller ships because ports in the United States have difficulty supplying storage for more than 10,000 tons of bagged fertilizer and also because bagged fertilizer usually is carried in tween-deck ships to minimize the pressure exerted on bottom bags. (The usual size of a tween-deck ship is about 10,000 tons.)

Direct Loading at Manufacturing Plant

Several of the large plants producing fertilizer in the United States are located on waterways that can accommodate ocean-going ships.

Usually these plants are built with facilities for loading ships with bulk fertilizer, but facilities for loading bagged fertilizers onto ships are not normally available. Thus, when bagged fertilizers are to be shipped overseas, it is usually necessary to move bulk fertilizer from the plant to a nearby port where it is unloaded, bagged, and put in storage. Then the bagged fertilizer is loaded onto the ocean carrier. In contrast, bulk fertilizers can be loaded directly onto ocean carriers at many plants. These differences in handling are illustrated in Figure 42.

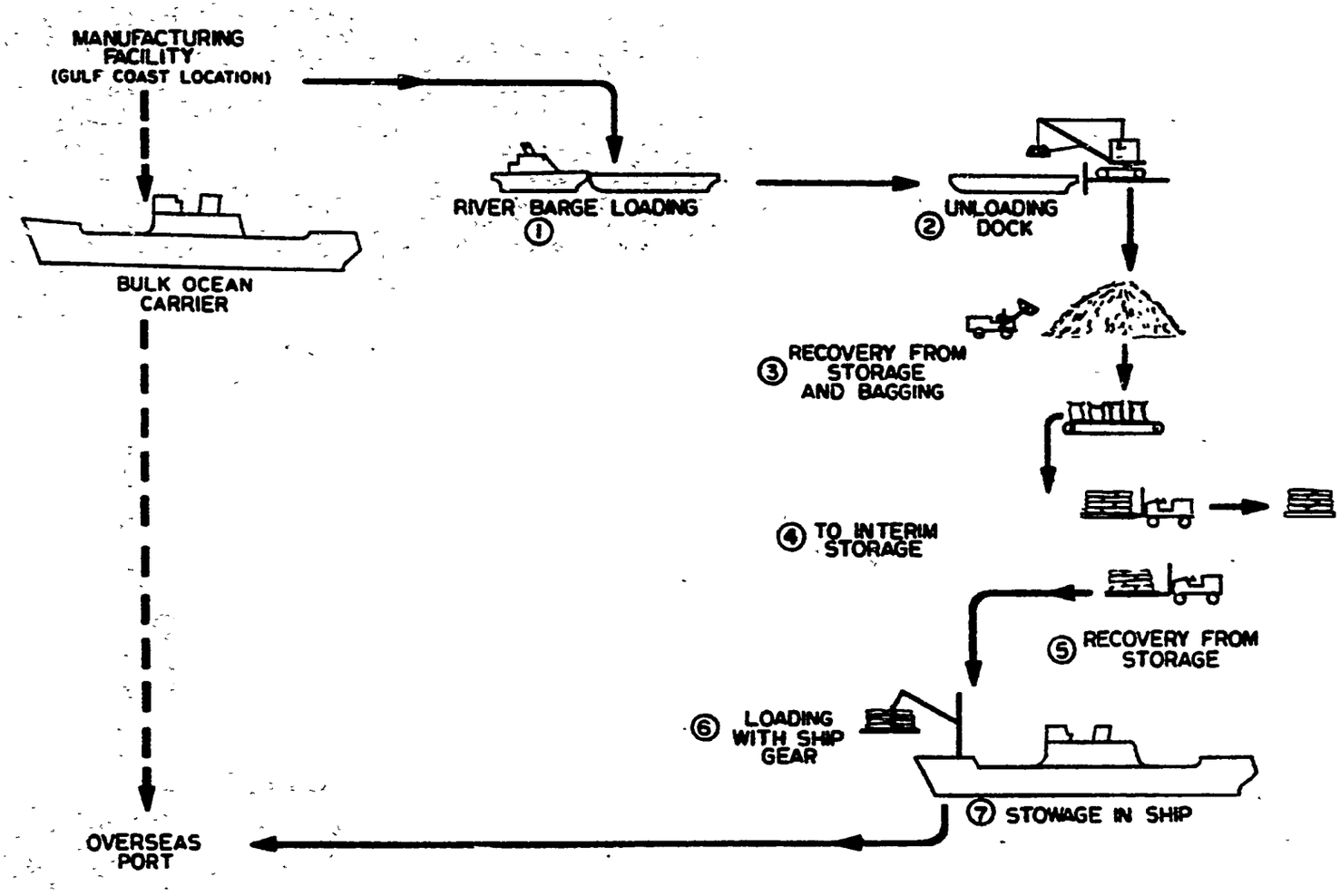


FIGURE 42

Differences in Handling Overseas Shipments of Bulk and Bagged Fertilizers

DESCRIPTION OF FERTILIZER MATERIALS HANDLED IN BULK

This section of the report describes some of the fertilizer materials that are currently being handled in bulk on a domestic and international scale. Some chemical and physical properties of the materials are given to serve as a guide for persons intersted in bulk movement. Almost all of the common fertilizer products, intermediates, and raw materials are now handled in bulk satisfactorily. Table IV shows United States exports of fertilizer materials during fertilizer year 1969-70.

Ammonium Sulfate

Ammonium sulfate has made up a major portion of the nitrogenous fertilizer exports from the United States in the period of 1959 to 1969. However, the trend is to an increasing proportion of urea, with less ammonium sulfate. India has been the largest importer of United States fertilizer materials with about 85 to 90% of these materials handled under AID assistance programs, including some bulk material. Brazil has also been a large importer with most shipments consisting of bulk materials.

The properties of ammonium sulfate depend on the process and raw materials used in production. It may be produced directly from the reaction of synthetic ammonia and sulfuric acid; with relatively pure materials, the product is high grade. It may also be produced from calcium sulfate (anhydrite or gypsum) through a double-decomposition reaction with ammonium carbonate. The calcium sulfate may be derived from natural or byproduct sources. Byproduct ammonium sulfate is also produced from various processes, such as from the chemical and steel industries. At the present, practically all the ammonium sulfate produced in the United States comes from byproduct sources. Generally, all of these methods produce an ammonium sulfate of sufficient purity for use as fertilizer. However, the physical characteristics may vary significantly, and in some cases can adversely affect its utility for some purposes. Therefore, it is sometimes helpful to know the end use of the material in order to adequately specify its physical properties. For example, if the material is to be used in production of compound fertilizers, a fairly wide range of particle sizes can be utilized. If the end use is for bulk blending, the size must be closely specified to ensure compatibility with other materials.

A summary of chemical and physical properties of ammonium sulfate is tabulated below.

TABLE IV

U.S. Exports of Selected Fertilizer Materials by Country of Destination, Fertilizer Year 1969-70 1/

Country of destination	Ammonium sulfate	Anhydrous ammonia	Ammonium nitrate	Urea	Phosphate rock (all)	Normal super-phosphate	Concentrated super-phosphate	Potassium chloride	Ammonium phosphate	Mixed fertilizers
	Short tons									
Canada	18,653	356	262	777	2,024,664	2,666	23,681	454	54,703	27,908
Mexico	486	23,366	3,245	12,417	932,963	166	12,871	43,101	22,729	3,752
Guatemala 2/	16	---	65	---	---	---	---	36	12,520	2,004
El Salvador 2/	15,177	---	20	35	21,156	---	399	3,816	21,728	9,987
Costa Rica 2/	1,266	1,996	4,077	---	1,[illegible]	521	5,726	14,451	8,939	150
Bahamas (British)	2,860	9	887	104	94	475	20	---	159	10,025
Jamaica 2/	3,381	16	1,024	---	28	---	3,053	14,088	4,787	322
Dominican Republic 2/	28,727	17	336	---	161	134	4,485	5,555	11,490	875
Trinidad and Tobago	---	16,976	---	---	---	---	251	---	405	8
North America, Other 2/	2,228	123	174	1,798	29	2,987	243	1,533	5,438	12,337
Colombia 2/	3,568	---	14	---	19,51[illegible]	13	33,604	20,844	17,564	1,543
Venezuela 2/	6,282	---	3,669	32	1,632	---	3,134	14,281	1,425	13
Peru 2/	11,087	---	17,196	---	14,606	---	66	2,481	4,693	146
Chile 2/	10	63	5,122	---	---	---	163,951	13,207	19,571	---
Brazil 2/	91,426	13,905	1,826	69	372,370	---	177,940	172,848	239,242	5,944
Uruguay 2/	7,765	---	10	---	13,734	---	---	---	4,143	32
Argentina 2/	---	---	6	---	---	---	9,208	3,086	21,325	468
South America, Other 2/	---	58	652	3,067	4,663	304	7,133	3,508	8,063	3,042
Sweden	---	---	---	---	194	---	---	13,353	---	1
Norway	---	59,035	---	---	107,520	---	---	---	---	5
Finland	---	60,632	---	---	---	---	---	---	---	---
Denmark	---	76,427	---	---	24	---	6,604	---	2,201	---
United Kingdom	---	143,784	---	---	69,689	---	---	569	2,931	53
Netherlands	---	82,690	14	191	408,204	---	37,484	12,322	28,681	16
Belgium and Luxembourg	---	137,373	---	---	395,181	---	1,543	72	19,263	3
France	---	---	---	3,850	327,450	---	2,425	---	23,587	14
West Germany	---	---	107	12	1,355,320	---	8,777	---	516	2,359
Austria	---	---	---	---	99,428	---	---	---	---	---
Poland and Danzig	---	7,559	---	---	---	---	52,150	---	---	---
Spain	12	63,540	---	200	235,801	---	3,307	---	69,412	225
Italy	5,875	---	6	314	1,305,543	---	13,872	---	48,279	4
Yugoslavia	---	9	---	---	---	---	10,648	---	63,752	---
Turkey 2/	---	---	---	49	7	---	15,792	---	3,472	---
Europe, Other	91	---	---	187	922	14	---	---	---	541
Iran 2/	---	16,180	---	---	33,331	---	374	---	18,021	2,205
India 2/	281,827	---	25,607	227,306	364,440	---	---	---	101,102	75,217
Pakistan 2/	---	36	---	358,292	---	---	38,684	---	35,871	5,000
Ceylon 2/	34,369	---	---	---	---	---	---	---	---	9
Thailand 2/	---	17	260	---	6	---	13	72	13,234	2,671
South Vietnam 2/	12,134	---	---	---	---	---	16,994	12,125	42,860	191,346
Indonesia 2/	---	---	---	61,664	---	---	25,496	3,024	130	33,220
Philippines 2/	14	8,188	---	---	148,334	---	---	25,759	2,756	18
Korea, Rep. of 2/	7	---	---	---	609,324	---	---	14,336	8,566	3
Taiwan 2/	---	---	---	---	70,562	---	---	45,363	---	---
Japan	---	10,764	13,982	---	2,014,913	29,740	30,533	281,803	27,463	128
Asia, Other 2/	25	2,197	---	400	8	---	---	---	555	34
Australia	5	10,746	2,622	---	20,699	---	---	87,929	8,232	76
New Zealand and Western Samoa	60	---	---	---	13,443	---	---	92,379	5,303	11,858
Oceania, Other	---	---	28	---	---	---	---	---	---	109
Algeria 2/	---	26,963	---	---	---	---	---	---	---	---
Africa, Other 2/	91	1,624	---	77	5,627	139	---	13	940	110
Total	528,444	764,649	81,211	670,841	10,972,968	36,359	710,461	902,408	986,051	403,981
Amount to AID countries	500,400	71,383	60,058	652,789	1,680,916	3,29[illegible]	506,295	370,426	608,435	346,896
Percent to AID countries	95	9	74	97	15	9	71	41	62	86

1/ Other exports: 585 tons sodium nitrate; 32,482 tons nitrogenous fertilizers, n.e.c.; 186,138 tons potassium chemical fertilizers, n.e.c.; and 50,314 tons organic materials.
2/ Countries with active AID programs, all quantities not necessarily financed by AID.

Nitrogen content, % N	
Theoretical	21.1
Typical	20-21
Specified minimum	20.5
Sulfur content, % S	
Theoretical	24.3
Typical	22-24
Critical relative humidity (30° C; 86° F.), %	79
Particle size, recommended	90% -6 +16 mesh
	95% -4 +28 mesh
Moisture content, recommended, % by wt.	1.0 max.

Regardless of the end use of ammonium sulfate, the material should be free flowing. To achieve a free-flowing material, the moisture content should be limited to about 1%.

Due to the popularity of ammonium sulfate in many DC's and its general availability from byproduct sources at attractive prices, the commodity will likely continue to be handled in large quantities. To achieve economy in transport, bulk shipments are a necessity.

Ammonium Nitrate

Due to several factors, such as explosive characteristics, low critical humidity, and less favorable effectiveness for fertilization of rice, ammonium nitrate has not reached a high level of importance in international transport. Bulk material is moved in the United States, however, by rail and truck with a good proportion of the solid material used in bulk blending. Ammonium nitrate transforms into different crystalline phases as the temperature changes. Studies have been directed toward stabilization of phases of ammonium nitrate to increase its attractiveness for bulk handling. This is expected to improve its handling qualities for domestic uses, but probably will not have much impact for international shipments due to the other factors mentioned above.

Physical and chemical properties of fertilizer-grade ammonium nitrate are given below.

Nitrogen content, % N	
Theoretical	35.0
Typical	33.5
Minimum	33.5
Critical relative humidity (30° C., 86° F.), %	59
Particle size, recommended	90% -6 +16 mesh
	95% -4 +28 mesh
Moisture content, recommended, % by wt.	0.5 max.

Organic materials, such as waxes or resins, should not be allowed to contact ammonium nitrate, since its explosive sensitivity is increased. Therefore, organic matter is generally limited to a maximum of about 0.1%.

Ammonium nitrate is produced by reaction of nitric acid with ammonia. It is usually produced as prills, but there is also substantial production of granular ammonium nitrate, especially as a product cogranulated with limestone to reduce its explosibility.

Urea

Urea is gaining in popularity in some of the DC's. New plants are steadily coming on stream for urea production. Tests of the bulk shipment of urea are being made to DC's and to humid areas. It is generally agreed now that bulk shipment of urea is feasible to humid, tropical regions provided that necessary precautions are taken and that adequate facilities are available and are properly utilized. In addition, tests are being made by TVA in cooperation with AID and by others to determine better methods of conditioning and coating of urea to reduce its rate of moisture absorption and to increase its handling strength. Achievement of an improvement of these characteristics for urea would do much to ensure the trouble-free handling and shipment of urea.

Ammonia and carbon dioxide are reacted under pressure and elevated temperature to form the intermediate ammonium carbamate; dehydration of the carbamate yields urea in solution. The urea solution may be used in liquid form, or the urea solution may be processed into a solid form. Solid urea may be in the form of crystals, granules, flakes, or prills. For fertilizer use, most material is in the form of prills, but it is likely that the granular form will gain in popularity. Urea also has a tendency toward hygroscopicity so that most material shipped in international trade has a conditioning agent. A coating agent, such as clay, or a chemical conditioner, such as paraformaldehyde, is often used.

A summary of physical and chemical properties of urea is given in the tabulation below.

Nitrogen content, % N	
Theoretical	46.6
Typical	45-46
Specified minimum	45
Critical relative humidity (30° C., 86° F.), %	75
Particle size, suggested (Tyler)	90% -6 +16 mesh 95% -4 +28 mesh
Moisture content, suggested, % by wt.	0.1-0.5
Biuret content, % specified	1.5 max.

Ocean shipment of urea has been increasing rapidly since 1968. At the present time, however, a large portion of the material is moving internationally in bagged form. Urea has been shipped in bulk to Singapore and to Brazil. Material imported into Brazil is heavily coated, usually with clay, to about 45% nitrogen content since urea containing over 45% nitrogen is classed as a nonfertilizer material.

Tests are also being made at TVA in cooperation with AID for the production of urea - ammonium sulfate. This is a homogeneous mixture of the two materials to give such grades as 34-0-0-10S and 40-0-0-5S. This material may help to eliminate some of the problems in handling and transport ng of straight urea. The mixed prilled product is two to three times harder than urea alone. The product may make the shipment of ammonium sulfate more feasible in areas where sulfur is needed, and where urea alone is not popular with farmers.

Ammonium Phosphates

Of the various ammonium phosphates, solid diammonium phosphate is now the most important in regard to bulk transport and handling. The material contains both nitrogen and phosphate in a form suitable for use in direct application, bulk blends, and granulation processes. The material can be made from ammoniated wet-process acid to yield an 18-46-0 (containing impurities) or 21-53-0 when electric-furnace acid is used. Almost all fertilizer diammonium phosphate is derived from ammoniating wet-process acid.

Two basic methods are used in manufacture of diammonium phosphate: granulation and crystallization. Almost all fertilizer-grade diammonium phosphate is now produced in granular form.

Physical and chemical characteristics are given below for diammonium phosphate produced from wet-process phosphoric acid.

Nitrogen content, minimum, % N	18
Phosphate content, minimum, % available P_2O_5	46
Water-soluble phosphate, % of total P_2O_5	85
Critical relative humidity (30° C., 86° F.), %	82
Particle size, recommended	90% -6 +16 mesh 95% -4 +28 mesh
Moisture content, % by wt.	2 max.

No particular problems are encountered in bulk transport and handling of diammonium phosphate, especially that made from impure wet-process acid. (Some caking tendency has been noted with high-grade diammonium phosphate made from electric-furnace acid.) Apparently, impurities, such as iron and aluminum in impure diammonium phosphate, served to inhibit crystal growth and decrease caking. Generally, diammonium phosphate is not conditioned.

A relatively new addition to the ammonium phosphate supply of fertilizers is nongranular monoammonium phosphate; the material is also referred to as a powdered monoammonium phosphate and is now being produced worldwide in more than 20 plants. The material can be used in granulation plants instead of or to supplement ammonia and phosphoric acid. It is said that the use of powdered monoammonium phosphate will allow production of high-analysis materials at high production rates. Also, it is claimed that the material can be stored and shipped at lower cost than the equivalent amounts of wet-process acid and ammonia.

Some chemical and physical properties of powdered monoammonium phosphate are given below.

Nitrogen content, actual (wet process), % N	11
Phosphate content, actual (wet process), % P_2O_5	54
Moisture content, % by wt.	1
Particle size (Tyler)	98% through a 12-mesh screen with 66% through a 35-mesh screen

The status or ease of handling of powdered monoammonium phosphate for bulk shipments has not been thoroughly defined. Some producers claim that no unusual problems in bulk shipment in hopper-bottom cars or in bulk ocean shipment have been encountered, while a few instances of difficulty have been reported. Materials received at TVA in bags were in very good condition after several months of storage.

Triple Superphosphate

Triple superphosphate (0-46-0) provides a more concentrated form of phosphate as compared with single superphosphate (0-20-0) and can be more economically transported due to its higher analysis. The material can be used for direct application, bulk blending, or for granulation depending upon its particle size. A granular triple is used for direct application and blending, while run-of-pile (nongranular) material is used in granulation. Due to these factors, triple superphosphate is shipped in bulk to several DC's.

Triple superphosphate is made by the reaction of fine-ground phosphate rock (60-70% through 200 mesh) with phosphoric acid (54% P_2O_5); reaction product is allowed to cure to complete the reaction to produce the run-of-pile product. In the production of granular triple superphosphate the run-of-pile material is sized by screening and is granulated in a rotary drum through the use of steam, or the slurry from the acid-rock reaction can be granulated directly. Granules are dried and sized for the intended end use.

Physical and chemical properties of triple superphosphate (granular) are given in the tabulation below. The analysis is based on material made from Flor'da rock.

Phosphate content, % total P_2O_5	47-48
Available P_2O_5, %	46
Water-soluble P_2O_5, %	39
CaO, %	20
Al_2O_3, %	1.9
Fe_2O_3, %	1.4
F, %	1.6
Critical relative humidity (30° C., 86° F.), %	94
Particle size, recommended	90% -6 +16 mesh 95% -4 +28 mesh
Moisture content, %	4.0 max.

No particular problems are encountered in handling granular triple superphosphate in bulk. The material is not appreciably hygroscopic, and a relatively high moisture content can be tolerated in triple superphosphate granules.

Compound Fertilizer

A large proportion of bulk materials now being shipped internationally contains more than one of the primary fertilizer nutrients and is classed as compound fertilizer, such as 16-16-8, 15-15-15, 12-8-8, 10-26-26, 12-32-16, and 14-36-12. Much of the compound fertilizer financed under AID programs is currently shipped to Vietnam and India.

Essentially all compound fertilizer is shipped in the form of granules that have been produced in either a pug mill or drum ammoniator-granulator. The process normally includes facilities for sizing the material to a range of about minus 6 plus 12 mesh.

Due to the wide range of materials that are used to formulate numerous grades of mixed fertilizers, there are no standard chemical properties that can be assigned. Specifications should be adjusted to suit the grade of product and the raw materials to be used. Most of the products shipped in international commerce are based on combinations of ammonium phosphates, ammonium sulfate, and potash. There is an increasing tendency to include some urea in these products.

Raw Materials

Phosphate Rock

Phosphate rock-producing areas in the United States are mainly in Florida, with other producing areas in North Carolina, Tennessee, Missouri, and Rocky Mountain region that includes Montana, Idaho, and Utah. Accessibility to water-oriented transportation has helped to put Florida in a strong competitive position for phosphate production. A significant quantity of phosphate rock exports to DC's originates in Florida.

Rock is mined by surface methods in most locations. Overburden is removed followed by reclamation of the ore and transfer to the ore processing site. At the plant, the ore is sized and graded for the appropriate process and end use. Shipments are made principally of unground Florida land pebble with fine grinding being done at the point of production. Fine-ground rock suitable for reaction would be extremely dusty and difficult to handle in bulk.

In international trade, the rock containing about 30 to 33% P_2O_5 and 45 to 47% CaO from Florida accounts for the most significant tonnage. The rock is usually shipped as flotation concentrate and the particle size is usually about 99% between 10 and 100 mesh. The moisture content is normally about 1 to 1.5%.

As shown in Table IV, Canada, West Germany, Spain, and Japan are prime consumers of phosphate rock from the United States. Rock is used in the production of such fertilizer materials as superphosphates, wet-process phosphoric acid, nitric phosphates, electric-furnace acid, and in some areas for direct application to the soil. Phosphate rock is insoluble in water and can be stored in the open without damage or spoilage.

Sulfur

Another material handled in large quantities in bulk is elemental sulfur. Bulk shipments are made domestically and in international trade. Sulfur deposits of economic importance are found in the Gulf Coast regions of southern United States and Mexico. For fertilizer production, either bright or dark sulfur can be used. Bright sulfur is 99.5% pure, while dark sulfur may contain up to 1% carbon. Both grades are free of arsenic, selenium, and tellurium.

Sulfur in the United States is obtained from native sources and by recovery processes. For example, sulfur is recovered from sour natural gas and crude oil. The native production of sulfur accounts for about 78% of the total production. Exports of sulfur from the United States for the period January through September 1969 and 1970 indicated that Western Europe and Latin America were prime importers of sulfur from the United States. Data are given in the tabulation below.

Sulfur Shipments from the United States[a]

Countries	Quantity, tons 1969	1970
Western Europe	710	638
Asia	18	23
Latin America	81	145
Africa	13	-
Oceania	18	-
Total	840	806

[a] Sulphur No. 91, November/December 1970, p. 12.

Anhydrous Ammonia

Anhydrous ammonia continues to be a large export item from the United States. About 765,000 tons was exported in fertilizer year 1969-70. The United Kingdom, Belgium, Luxembourg, Norway, Finland, Denmark, Spain, and The Netherlands accounted for much of this material.

Some of the more important physical and chemical properties for ammonia are tabulated below.

Nitrogen content, theoretical, % N	82.2
Boiling point, °C.	-33.4
Vapor pressure at 30° C., atm.	10
Density, gm./ml. at 30° C.	0.6
Solubility in water at 30° C., % by wt.	27

Since ammonia is a gas at atmospheric pressure, the storage vessels must either be built to withstand the pressure (10 atm., 147 psi at 30° C.) or it must be refrigerated to permit operation at atmospheric pressure. The present tendency for international shipment of anhydrous ammonia is to build refrigerated atmospheric storage terminals that can take the full output of the ammonia tanker (usually about 10,000 tons).

Some of the factors which impede the flow of anhydrous ammonia to DC's have been the lack of equipment to accept, store, transport, and apply or upgrade the material. Importation of ammonia into DC's is expected to increase substantially during the next several years.

Potassium Sources

Most fertilizer requirements for potassium are supplied by potassium chloride (KCl). Other sources of potassium include potassium sulfate and potassium nitrate. A summary of the potash minerals and the equivalent K_2O content is given below.

Mineral	Composition	Formula	K_2O, %
Sylvite	Potassium chloride (muriate of potash)	KCl	63.1
Carnallite	Potassium chloride - magnesium chloride	$KCl \cdot MgCl_2 \cdot 6H_2O$	17.0
Kainite	Potassium chloride - magnesium sulfate	$KCl \cdot MgSO_4 \cdot 3H_2O$	18.9
Polyhalite	Potassium sulfate - magnesium sulfate - calcium sulfate	$K_2SO_4 \cdot MgSO_4$	15.5
Langbeinite	Potassium sulfate - magnesium sulfate	$K_2SO_4 \cdot 2MgSO_4$	22.6
Nitre	Potassium nitrate	KNO_3	46.5

Fertilizer-grade potassium chloride contains impurities which limit the K_2O content to 60 to 62%; pure KCl contains 63.1% K_2O. This material derived by mining and from brines accounts for 90 to 94% of the potassium used in fertilizer.

Chemical and physical properties for potassium chloride are given below.

Fertilizer-grade KCl	
KCl, %	95-96
K_2O, %	60-62
Particle size, recommended	
Standard	80% -10 +200 mesh
Coarse	95% -8 +35 mesh
Granular	90% -6 +20 mesh
Moisture content, %	0.5
Critical relative humidity (30° C., 86° F.), %	84

No particular problems have been encountered in bulk transport of potassium chloride. Much of the North American potash is moved by rail. There has been substantial movement of potassium chloride in bulk to DC's.

The data in Table IV show that United States export of potassium chloride was significant to Brazil, Mexico, Taiwan, Japan, Australia, New Zealand, and Western Samoa.

Phosphoric Acid

The primary intermediate material used for the production of solid ammonium phosphate fertilizers is wet-process phosphoric acid. This material is often used near the point of production, but recently it has increased in international trade. Mexico, Israel, and the United States have exported wet-process acid, and other countries are said to be planning export of this commodity.

Sulfuric acid is reacted with finely ground phosphate rock (90+ -100 mesh, 60% -200 mesh). Dilute acid is separated from byproduct calcium sulfate by filtration. The dilute acid containing about 30% P_2O_5 is concentrated to 54% P_2O_5 by evaporation, and this composition is commonly referred to as merchant-grade phosphoric acid. The type and quantity of impurities in the acid depend primarily on the type of phosphate rock used in production.

Typical analyses of wet-process phosphoric acid being shipped in bulk by water in international trade are given below.

Analysis	Weight, %
P_2O_5	53.5
Water	18.0
CaO	0.1
Al	1.4
Fe	1.5
SO_4	3.9
F	0.8
Suspended solids	1.5
Specific gravity at 15.5° C.	1.7

PLANS FOR FUTURE WORK

Onsite Assistance in Carrying Out Projects in DC's

Assistance should be provided in initiating the movement of bulk fertilizers into DC's. This assistance should be carefully coordinated with USAID. Assistance should be restricted to situations where economics are favorable and where there is also interest and initiative on the part of the receiving country.

Potential ports in DC's for receiving bulk shipment should be carefully screened to determine their capabilities and limitations for receiving bulk fertilizers. This screening would include evaluation of available port unloading equipment and storage capabilities. Then the type and quantity of fertilizer material and the size and type of ship can be matched to the capabilities of the port.

In most situations it will probably be necessary to construct additional facilities for receiving bulk fertilizers. Such additional equipment would likely include hoppers for receiving bulk material and also weighing and bagging equipment. (Most DC's probably will not have adequate facilities for storing bulk fertilizer and for moving bulk material inland.)

It should be possible for a TVA engineer to assist AID and local personnel in all phases of the planning and preparation for receipt of bulk fertilizers as outlined above. Then the TVA representative should observe, document, and evaluate the unloading (and probably bagging) and handling operation. Onsite assistance would be provided. Then with this experience TVA can better assist AID in initiating bulk handling into other DC's.

Studies of All-Weather Handling Systems

Pneumatic Conveyors

Pneumatic conveyors offer attractive possibilities for use in all-weather unloading systems. Many ports in DC's already have pneumatic facilities for unloading grain which probably could be converted to all-weather systems with little difficulty. In addition, some types of pneumatic conveying equipment are less expensive than more conventional bulk unloading equipment. Pneumatic handling equipment can be more portable than the usual types of permanently mounted handling facilities. However, there has been little movement of fertilizer products pneumatically, with practically no utilization for unloading bulk fertilizer in the United States.

In the usual types of pneumatic equipment that are used for grain, breakdown or degradation of fertilizer particles may be excessive. Also, in some types of equipment hygroscopic fertilizer dust could cause problems of corrosion and caking.

Pilot-scale tests should be made to better determine the degree of degradation that can be expected with different types of pneumatic unloaders, and to investigate the feasibility of modifying the equipment to make it more suitable for fertilizers. For example, lower air velocities should be tested to reduce the degradation of particles. The use of softer, more resilient conveying tubes without sharp bends should be evaluated.

Tests could be made either at TVA laboratories or in laboratories of vendors. Whenever vendors already have test facilities available, testing there would likely be more economical.

Since urea is structually weaker than the other fertilizer products shipped in large quantities to DC's, it should be prominently included in test programs. Urea treated with other materials (such as ammonium sulfate) to improve its physical strength should also be evaluated and compared with untreated material.

Tests of Drag Scrapers and Unloading Equipment

Drag scrapers in covered holds also offer promise for use in all-weather handling systems. In addition, they may not degrade or spill fertilizer as much as systems using clamshells, bulldozers, etc., where as much as 8 to 10% of the material shipped has been broken up. Losses of fractured material as dust are sometimes excessive.

The Sauerman-type scraper, which was observed in operation on the Cemento Ponce, should be suitable for unloading urea because its operation apparently results in relatively little abrasion on particles unloaded. The bucket that moves material to the unloading equipment in the ship has only sides, without any bottom. Thus, any abrasion by scraping of material between the bucket bottom and ship is minimized. Also, the Sauerman can be mounted so that there is little or no need for "trimming" of material that clings to the sides of the vessel, provided the hull is of suitable design. There is no need to use any bulldozer or other mechanical equipment to move material in the hold of the vessel.

Since the Sauerman system has characteristics that should give reduced urea breakdown as compared with other systems, it seems feasible to test it with urea. Such a test should be made under carefully controlled and realistic conditions so that operation of equipment can be evaluated and physical condition of unloaded urea can be determined. Test shipment of urea in a barge equipped with Sauerman equipment would be appropriate.

Study of Land Transport

The study of land transport of fertilizers will be continued to the extent that time and budget permit. This will include a description of various rail and truck hardware and procedures for handling in bulk. Relative costs will be detailed to the extent that is practicable.

Continue to Evaluate New Developments and Concepts in Shipping and Handling That May Be Used for Fertilizers

The procedures and equipment for shipping and handling bulk materials are always changing as new and improved concepts and equipment evolve. Examples are containerization, and the Lykes and LASH concepts of transporting small vessels on large vessels. Recently shipments of wet-process phosphoric acid and of liquefied natural gas in bulk have been initiated.

There is a need for continual monitoring of new developments and their applicability to bulk movement of fertilizer materials. This should include studying the literature, maintaining contacts with shipping brokers, bulk-handling equipment and ship manufacturers, shipping corporations, and railroads. This would include trips to observe and discuss new equipment in operation, attendance at technical meetings related to bulk shipments, and meetings with other interested and knowledgeable groups and individuals to exchange information.

Reports

A continual series of detailed reports will be made on visits and other items of interest. Periodically, all information will be summarized and updated.

CONCLUSIONS AND RECOMMENDATIONS

Although this is considered to be a progress report on bulk handling with emphasis on urea, some generalized conclusions can be stated from work to date. It is evident that urea can be shipped in bulk from the United States to DC's, provided that suitable facilities are available for off-loading and handling at the receiving port and that reasonable precautions are taken in the choice and preparation of the shipping vessel. Potential cost savings as compared with shipments of bagged material should be in the range of $10 to $20 per ton.

Many of the common bulk carriers can be utilized to ship urea and other bulk fertilizers. However, facilities at the receiving port must be considered in choosing the carrier. For example, if bulk urea is to be moved into ports which lack mechanical equipment for bulk off-loading, some type of geared carrier should be utilized.

Clamshells are the most commonly used equipment for unloading bulk fertilizer ships. However, TVA studies and observations indicate that the losses due to spillage and mechanical breakdown are usually high with clamshells, and use of more efficient equipment should be considered. Studies indicate that pneumatic equipment of the type used to unload grain will likely give excessive breakage of urea. Other types of pneumatic equipment may be usable, but should be tested for verification.

Lack of bulk storage equipment and lack of facilities for moving fertilizers in bulk within DC's will often necessitate bagging of bulk material at the receiving ports. This negates some of the economic potential for bulk shipments, but costs of bagging and sometimes bags also are in domestic currency rather than foreign exchange.

Lack of all-weather handling systems for such fertilizers as urea in also a major disadvantage.

Studies to develop and utilize more efficient unloading equipment should be continued and intensified. Modern bulk carriers developed and utilized for other bulk materials, such as cement and petroleum products, should be considered for fertilizers.

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