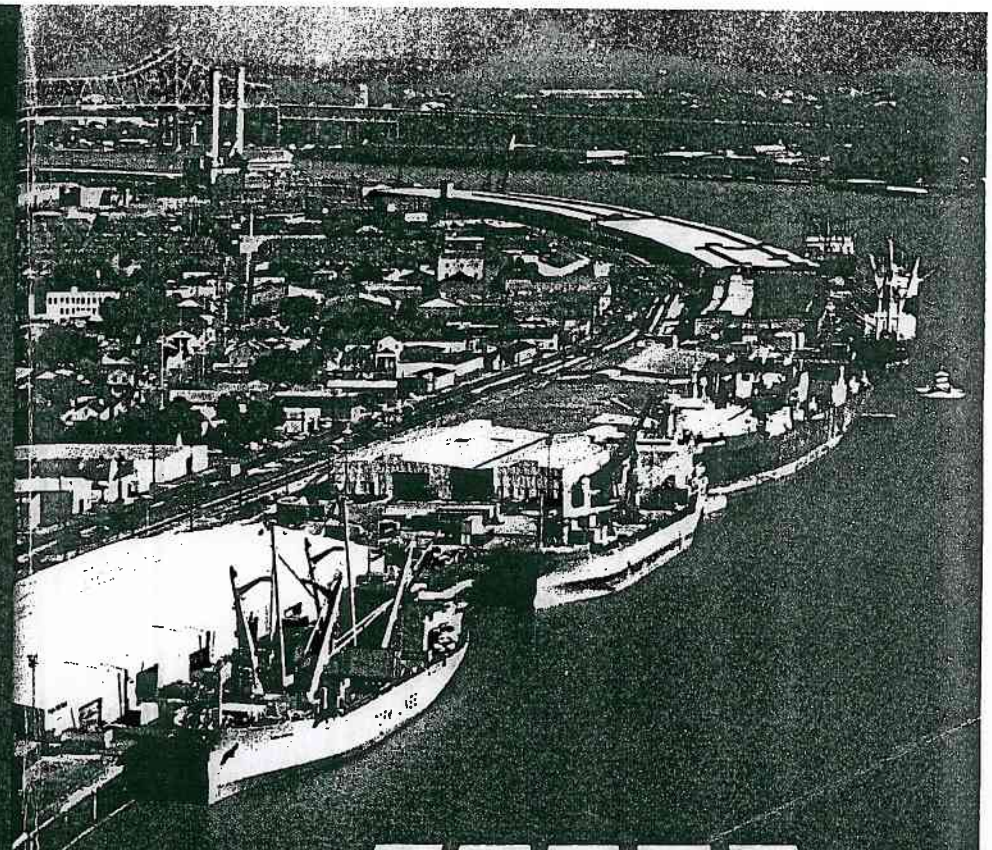

PORTS 83

Kong Wong, Editor

Midstream Mooring Facilities

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ABSTRACT

Since the inception of water borne commerce, man has strived to develop faster, less expensive methods of moving cargo between land and floating vessels. Recently, the use of midstream transfer operations has proved to be a relatively inexpensive, highly efficient method of loading bulk cargo on the lower Mississippi River. The low initial cost and the relatively short construction period associated with this type of system enables it to be used to supplement existing loading facilities or temporarily replace some facilities during periods of their renovation.

The midstream transfer system utilizes a floating loading vessel which transfers cargo between barges and a bulk carrier that is held in position by a mooring system. This mooring system consists of anchor piles, chains, buoys, and other structural elements.

This paper provides a brief introduction to the midstream mooring concept before it deals with the more specific aspects associated with facility utilization, site selection and, in particular, the design of the major structural elements that are employed by the system. The economic considerations related to the establishment of the mooring system will also be addressed.

WHAT

In essence, a midstream ship mooring is a system of several basic structural elements installed in a body of water for the purpose of holding a vessel in a relatively fixed position. The vessel is usually held in the mooring so that loading and or unloading operations can be conducted.

The basic structural components of a midstream mooring system are: anchor piles, chains, buoys and buoy mooring hooks (see Fig. No. 1, 2, & 3).

The general configuration of the midstream mooring is usually formed by three anchor pile assemblies located at

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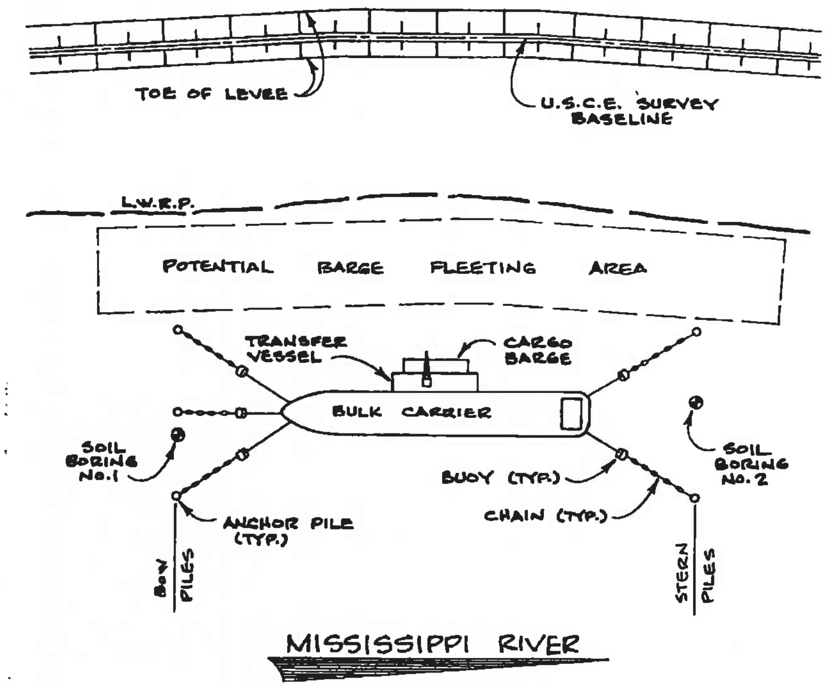
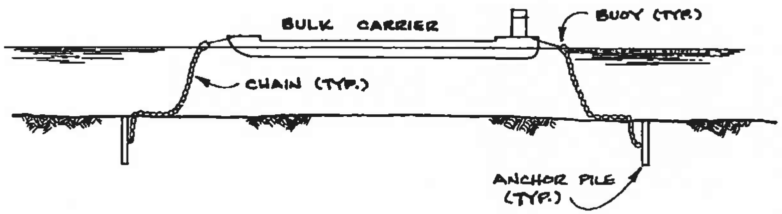


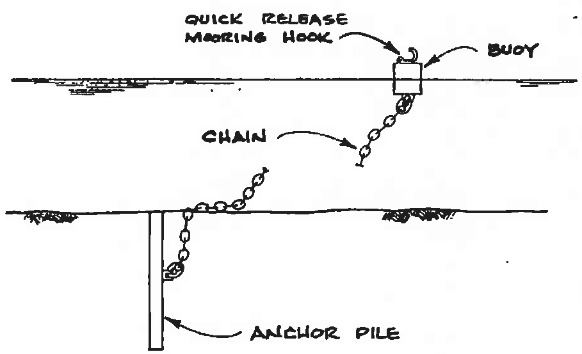
MIDSTREAM MOORING FACILITY

FIGURE NO. 1



MIDSTREAM MOORING ELEVATION

FIGURE NO. 2



ANCHOR PILE ASSEMBLY

FIGURE NO. 3

the upriver end of the mooring site and two assemblies at the downriver end (see Fig. No. 1). Variations on this concept include mooring patterns that employ as many as eight and as few as three anchor pile assemblies.

WHY

Like many things in life, midstream moorings are primarily used as a result of monetary considerations. Midstream moorings provide a highly efficient, low cost method of moving certain bulk commodities between barges and bulk carriers.

Grain products, coal, and to a limited extent, rice, salt, steel, ores, fertilizers and paper products are moved down the Mississippi in barges. Most of these products are destined for consumption outside of the U. S., so transfer of the product directly from the barges to the bulk carriers eliminates the double handling and additional costs associated with moving the goods through a conventional land based dock facility.

This movement of goods is performed by a "transfer rig" that is positioned between the moored bulk carrier and the cargo barges.

The majority of the transfer rigs found on the lower Mississippi resemble large flat deck barges that have been equipped with large rotating duty cycle cranes fitted with grab buckets that usually range in capacity from 10 to 35 cubic yards (7.6 to 27 cubic meters). One of these rigs can move approximately 800 to 1000 tons (725 to 900 metric tons) of dry bulk cargo per hour and usually has a new price tag that reads approximately "Four Million Dollars".

Currently in operation are a very limited number of highly sophisticated transfer rigs that utilize state-of-the-art weighing and conveying equipment. These units range in cost from $10 million to $25 million and are now principally employed to move grain products. Purchase of a transfer rig does not have to be the first step in establishing a midstream mooring operation. This stems from the fact that the services of a transfer rig can be obtained on a rental basis. Although rental prices are often negotiated, a cost of $400.00 per hour is usually not far from the mark when discussing conventional rigs with a capacity of 800 to 1000 TPH (725 to 900 MTPH).

WHERE

Currently, there are approximately fifteen midstream ship berths located on the lower Mississippi River. Several of these facilities are located at sites that could, for a host of reasons, not support a conventional land based cargo handling facility. The entire midstreaming operation generally takes place not in the middle of the river as the term "midstream" suggests, but, at a location between the middle of the river and the river bank.

In theory, a midstream mooring can be established at virtually any point along the lower Mississippi River. The most attractive locations are areas of the river that are relatively straight and have minimum utilizable water depths of 45 to 55 feet (14 to 17 meters). Large vessels entering a river bend have a tendency to "slide" to the outside of the bend. Smaller vessels including tugs and barge tows tend to hug the inside of a river bend. As a result of this, sites located in tight river bends are generally not considered to be the best locations for midstreaming operations.

Sites located in relatively shallow portions of the river are avoided because these areas often require periodic dredging which, besides being very expensive, usually produces very short lived results. Underestimation of the extent to which the river can "cut" or "build" a portion of the river bottom has in the past and will in the future prove to be a costly error. Analysis of old hydrographic data and current site specific hydrographic data provides a basis for evaluating the cutting and building capabilities of the river. This provides a basis for predicting the future adequacy of a given site.

The obvious limitations imposed by land availability and river safety also come into play. It should be remembered that the selected site must be capable of providing fleeting space for the loaded and empty cargo barges that are generated by the transfer operation. In general, fleeting for approximately 80 barges is required to sustain the operation of a midstream mooring that services a 130,000 DWT (132,000 DWMT) bulk carrier. Owing to the 37 to 40 foot (11.3 to 12.2 meter) water depth currently encountered at certain portions of the river, a 130,000 DWT bulk carrier which typically draws approximately 54 feet (16.5 meters) when fully loaded can only take on a maximum cargo of approximately 75,000 tons (76,000 metric tons) during its loading operations in the river. A minimum river depth of 55 feet (16.8 meters) would, of course, increase the barge fleeting space required to support transfer operations at all midstream facilities designed to accommodate large bulk carriers.

Once a general area of the river has been shown to be available and adequate, the questions of orientation and exact placement must be answered.

Orientation is a relatively easy problem to solve. The contours of the river bottom are closely related to the flow patterns of the river at that site. In most instances, installing the midstream mooring hardware such that it allows the moored vessels to align with the general orientation of the river bottom contours will assure the desired result of minimizing the current induced lateral loads on the vessel.

Determining the exact mooring location within a given area involves more of a give and take operation. In general, and up to a point, as the ship mooring is moved closer to the levee, the current loads, water depth, navigational objections and mooring system costs are decreased. As the mooring is moved closer toward the center of the river, the ease of facility access is increased, and the probability of utilizing the area between the ship mooring and the river bank as a barge fleeting area is increased. Given the economics that dictate the efficient use of river frontage, most midstream ship mooring facilities are positioned as close to the center of the river as navigational and monetary constraints will permit.

HOW AND HOW MUCH

The basic concepts related to the design of midstream mooring are, for the most part, uncomplicated. The current, wind and dynamic surge loads to which a moored bulk carrier is subjected must be transmitted to an acceptable soil medium via the midstream mooring hardware (see Fig. No. 1).

The first order of business in establishing a midstream mooring revolves around obtaining a permit to construct the facility. The U. S. Army Corps of Engineers views certain portions of a midstream mooring as a fixed permanent structure and, therefore, the permitting process associated with the mooring is similar to that of a conventional dock. The Corps document entitled, "U. S. Army Corps of Engineers Permit Program, A Guide for Applications (Pamphlet No.EP1145-2-1)" defines the steps that must be taken to obtain this permit.

After, or concurrent with, obtaining the permit, site specific geotechnic data must be collected. For most midstream moorings two (2) soil borings are adequate. One of these is commonly taken at the location of the bow piles and the other is taken at the stern pile location (see Figure No. 1). These borings are typically made by a mobile boring rig mounted on a flat deck barge. The cost for two borings complete with soils analysis typically ranges between $17,000.00 and $23,000.00 and is a function of the depth of both the borings and the water at the site.

Site specific hydrographic information is also required in order to accurately define river bottom contours. This information is commonly obtained by collecting and plotting fathometer readings that are taken at points defined by a grid established at the proposed project site.

The final bit of data collection concerns wind and current velocities. The National Oceanic and Atmospheric Administration - National Climatic Center based in Asheville, North Carolina, is an excellent source for all local climatological data. The maximum sustained wind should be considered in place of the maximum gust velocity since the response time of large bulk carriers will be governed by loadings that act for durations in excess of 30 to 60 seconds. These moorings are not usually designed for hurricane conditions, owing to the fact that under such circumstances the vessels move into the Gulf or adopt alternate berthing arrangements. In addition to this, the size and number of mooring lines required to secure a large carrier to a system of midstream mooring buoys during hurricane conditions could not be utilized in an efficient manner. Site specific current velocity data is usually obtained via direct measurement or by more general information published by the Corps of Engineers.

Once all of the environmental parameters have been established, the physical characteristics of the design vessels must be determined. Because the type and size of vessels that travel the lower Mississippi River vary so greatly, it is suggested that, whenever possible, a listing of the vessels or types of vessels expected to utilize a facility be obtained. Aided by this list, the characteristics of the design vessel can easily be obtained from the vessel's "data sheet" which can usually be provided by the vessel's owner, agent or designer. Recently, virtually all midstream mooring owners have opted for the flexibility provided by designing their facilities to accommodate 130,000 DWT bulk carriers. Smaller vessels, virtually any ship on the lower Mississippi, can then utilize the mooring and need only be concerned with providing enough mooring line to reach the bow and stern mooring buoys which, of course, are spaced to accommodate the longest design vessel. Attachment One provides some general information on the gross dimensions of tankers and bulk carriers found on the lower Mississippi.

The environmental information and ship characteristics are then merged within the confines of conventional wind and hydrodynamic loading theory to produce the magnitude of the total load to which the stationary vessel will be subjected. The components of the mooring system must be capable of transmitting these loads to the supporting soil medium at the bottom of the river. Owing to the geometry of the

ATTACHMENT NO. 1

TYPICAL VESSEL DIMENSIONS

DWT LONG TONS (MT)	LOA FT. (M)	BEAM FT. (M)	DRAFT LT. FT. (M)	DRAFT LD. FT. (M)
BULK CARRIERS				
19,000	600	67	6	24
(19,300)	(183)	(20)	(1.8)	(7.3)
24,000	590	78	9	34
(24,400)	(180)	(24)	(2.7)	(10.4)
34,000	680	88	8	35
(34,600)	(207)	(27)	(2.4)	(10.7)
47,000	745	100	9	38
(47,800)	(227)	(31)	(2.7)	(11.6)
60,000	795	116	10	39
(61,000)	(242)	(35)	(3.0)	(11.9)
130,000	950	125	14	54
(132,000)	(290)	(38)	(4.3)	(16.5)
150,000	1005	155	14	54
(153,000)	(306)	(47)	(4.2)	(16.5)
200,000	1120	165	16	57
(203,000)	(341)	(50)	(4.9)	(17.4)
TANKERS				
7,000	400	50	5	24
(7,100)	(122)	(15)	(1.5)	(7.3)
17,000	524	68	8	30
(17,300)	(160)	(21)	(2.4)	(9.1)
30,000	660	85	8	34
(30,500)	(201)	(26)	(2.4)	(10.4)
56,000	790	105	11	41
(57,000)	(241)	(32)	(3.4)	(12.5)
105,000	940	130	11	50
(107,000)	(287)	(40)	(3.4)	(15.2)
130,000	955	140	13	55
(132,000)	(291)	(43)	(4.0)	(16.8)

system, the most severe loading condition is often generated not by the current loads acting on a loaded vessel, but by the relatively light operational winds impacting the side of an unloaded vessel.

The first system component to be designed is the anchor pile. By vector manipulation, the loads to which the moored ship is subjected can be resolved into anchor pile loads that act: (1) vertically, (2) parallel to the centerline of the river, and (3) perpendicular to the river centerline. The latter two loads can be added vectorally to produce a single load that is perpendicular to the longitudinal axis of the anchor pile. The pile is then simply acted upon by a vertical load and a lateral load.

Given the soils information obtained at the project site, the length and size of the pile can be determined through the utilization of computer programs that simulate and analyze piles subjected to lateral loads. Several manual methods of assessing the passive soil pressures have also been found to yield favorable results. A description of the computerized and manual method of lateral pile analysis is very lengthy and is, therefore, beyond the scope of this report. It should, however, be noted that, in general, the length of the anchor pile is determined by the vertical load to which the pile is subjected. The lateral load principally governs the required flexural capacity and thus the size of the pile. Of course, the realized soil strength is the most dominant factor in establishing both pile length and size. While it does not affect the required pile length, the attachment of the mooring chain near the midpoint of the pile, instead of at the pile top, does reduce the pile's bending moment and this in turn permits the use of a smaller size pile.

The location, orientation and configuration of the high capacity lug, or padeye, that links the mooring chain to the pile must be carefully established. The padeye must be sized to transmit the previously discussed loads in addition to the loads that are produced when a vessel is positioned in the berth in a manner that does not properly align the vessel with the flow patterns of the river. Undesirable padeye lateral loads also can result from slight unanticipated rotations of the pile that may occur during the driving sequence. Because of this, it is advisable to monitor padeye orientation throughout the entire pile installation phase.

The cost to purchase material, fabricate, transport and install each anchor pile for a typical 130,000 DWT mooring is approximately $20,000.00.

The length of the chain that extends from the pile to the surface buoy is, of course, a function of the mooring system's geometry. Consideration should be given to the fact that most chain is stored and sold in "shots", 90 foot (27.4 meter) lengths. Whole and half shots can usually be otained with little difficulty. For midstream mooring, the chain link diameter commonly ranges from 1-1/2 inches to 3 inches (38 mm to 76 mm) and weighs from 22 to 90 pounds per foot (33 to 134 kg/m).

In many cases, used chain that has been inspected and certified to be in good condition is used in place of new chain. A substantial cost savings can be realized by implementing this practice of utilizing chain that at one time served in the oilfield or on a U. S. Navy vessel. Good used chain can be obtained for approximately $0.30 per pound ($0.66/kg) while new imported and new domestic chain costs $0.60 per pound and $1.00 per pound ($1.32 & $2.20/kg) respectively. For a mooring that utilizes five 270 foot (82.3 meter) chains, the use of used chain provides a savings of approximately $30,000.00 over new imported and $60,000.00 over new domestic chain.

One end of this chain is connected to the pile padeye and the other chain end is connected to the mooring buoy that floats on the surface of the water.

The surface buoy performs the task of supporting the mooring hook to which the ship's lines are attached. The buoy is generally fabricated from steel shells that have been rolled to a circular configuration. Buoy diameters typically range from 6 to 16 feet (1.8 to 4.9 meters) while their depth is usually 5 to 8 feet (1.5 to 2.4 meters). In general, the stability and the cost of a buoy increase rapidly as the diameter of the buoy increases.

A system of internal rods stiffen the buoy's shell which is usually filled with rigid closed cell urethane foam. This flotation foam occupies a volume that can not be filled with water even if the buoy is punctured by river traffic. Studies have shown that the foam will deteriorate after exposure to the chemicals that are carried in the river. The foam usually keeps the buoy afloat for several weeks. This is a sufficient length of time to detect and repair the puncture.

Concerning cost, one 8 foot diameter by 8 foot deep (2.4 m x 2.4 m) buoy complete with mooring hook and flotation foam will cost approximately $17,000.00 in place.

A high capacity mooring hook is located on top of each buoy. The lines of a ship entering the mooring pattern are carried to and placed on these specially designed hooks by trained crews who operate small highly powered "line handling" boats. The services of these crews are commonly obtained on an hourly rental basis. A large bulk carrier can be secured in a midstream berth by these special crews in approximately 45 minutes at a cost of about $350.00. The vessel can be detached from the mooring system slightly faster and at a slightly smaller cost.

The total cost to purchase, fabricate, transport and install the five anchor piles, chains, links, buoys and hooks required for one 130,000 DWT midstream mooring is estimated to be $225,000.00. An estimated cost summary of the total facility development is shown in Attachment No. 2.

It must be noted that the costs associated with the fabrication and installation of the ship mooring hardware are not the only cost incurred during the creation of a midstream mooring operation. In addition to the purchase or rental of a transfer rig, a site office must be established and a levee crossing/batture road must be constructed to provide access to the river's edge. Once at the edge of the river, a crew boat is required to transport men and material to the waiting transfer vessel and bulk carrier. Finally, a fleeting area for the barges must be established. One or, in most cases, two tugs must be rented or purchased to move the barges between the barge fleeting area and the bulk carrier.

The scale and thus also the cost of these facilities that support the ship mooring facility are highly dependent upon facility complexity, utilization and throughput. These costs, therefore, vary greatly from one facility to another. A detailed examination of these support facilities and their associated costs is too lengthy to include in this presentation; but, a typical range of approximate costs have been listed in Attachment No. 3 for general information.

WHEN

The length of time between the instant that it is decided to develop a midstream facility and the instant that the first ship is moored is usually about 9 to 10 months. The fact that the Corps of Engineers requires 4 to 5 months to process a permit application plays a large part in the establishment of this estimate.

ATTACHMENT NO. 2

SHIP MOORING FACILITY COSTS

ITEM	APPROXIMATE COST
---SHIP MOORING FACILITY ONLY---	
Hydrographic Survey, Permit Drawings & Coordination, Facility Design, Drawings/Specification Preparation, Bid Solicitation - Evaluation - Award....................	$ 17,000
Soil Borings (2) & Analysis............	20,000
Mooring Fabrication & Installation.....	225,000
Construction Inspection................	8,000
TOTAL...........	$270,000

ATTACHMENT NO. 3

RANGE OF COSTS
MOORING SUPPORT FACILITY

ITEM	RENTAL COST	NEW PURCHASE COST MIN	MAX
Site Office...........	-------	$ 20,000	Varies
Levee Crossing/Access Roads.............	-------	15,000	Varies
Crew Boat.............	$30/Hr.	40,000	90,000
Barge Mooring Facility for 80 Barges.....	$35/Day/Barge	140,000	1,000,000
Barge Facility Tugs for Two (2) Tugs..	$160/Hr.	600,000	1,000,000
Transfer Rig (900 TPH)	$400/Hr.	2,500,000	25,000,000
Land Acquisition......	Varies*	Varies	Varies
Labor Costs...........	Varies	---------	----------

*Currently, rental of river frontage can vary from $20.00 to $60.00/foot/year depending on location.

The initial site selection, topographic survey, hydrographic survey and permit drawing preparation can usually be performed by an experienced consulting firm in less than a month. The Corps will then spend 4 to 5 months evaluating the project and obtaining favorable responses from all involved parties. After the Corps permit has been issued, the soil boring program will be started. The boring program can be performed in approximately 3 days and information required for design should be available in 2 to 3 weeks. The design, drafting, specification preparation and bid solicitation can usually be prepared in a 3 week period. The bid process requires an additional 3 weeks. At a point 7 to 8 months into the project a successful contractor is selected. The fabrication and installation effort can usually be completed in 2 to 3 months.

Time saving measures such as conducting the soil boring and design efforts concurrent with the permitting process are usually very effective. Such practices could, however, be costly if the permit application is not approved.

CONCLUSION

The midstream mooring concept has in certain applications been proved to be a viable alternative to fixed land based transfer facilities. The capital investment and the length of time required to establish this type of facility is very attractive. As the number of river sites capable of supporting conventional barge/bulk carrier transfer operations dwindles, the use of midstream operations is destined to increase.