# WATERFRONT CONSTRUCTION

# IN

# NEW YORK HARBOR

BY

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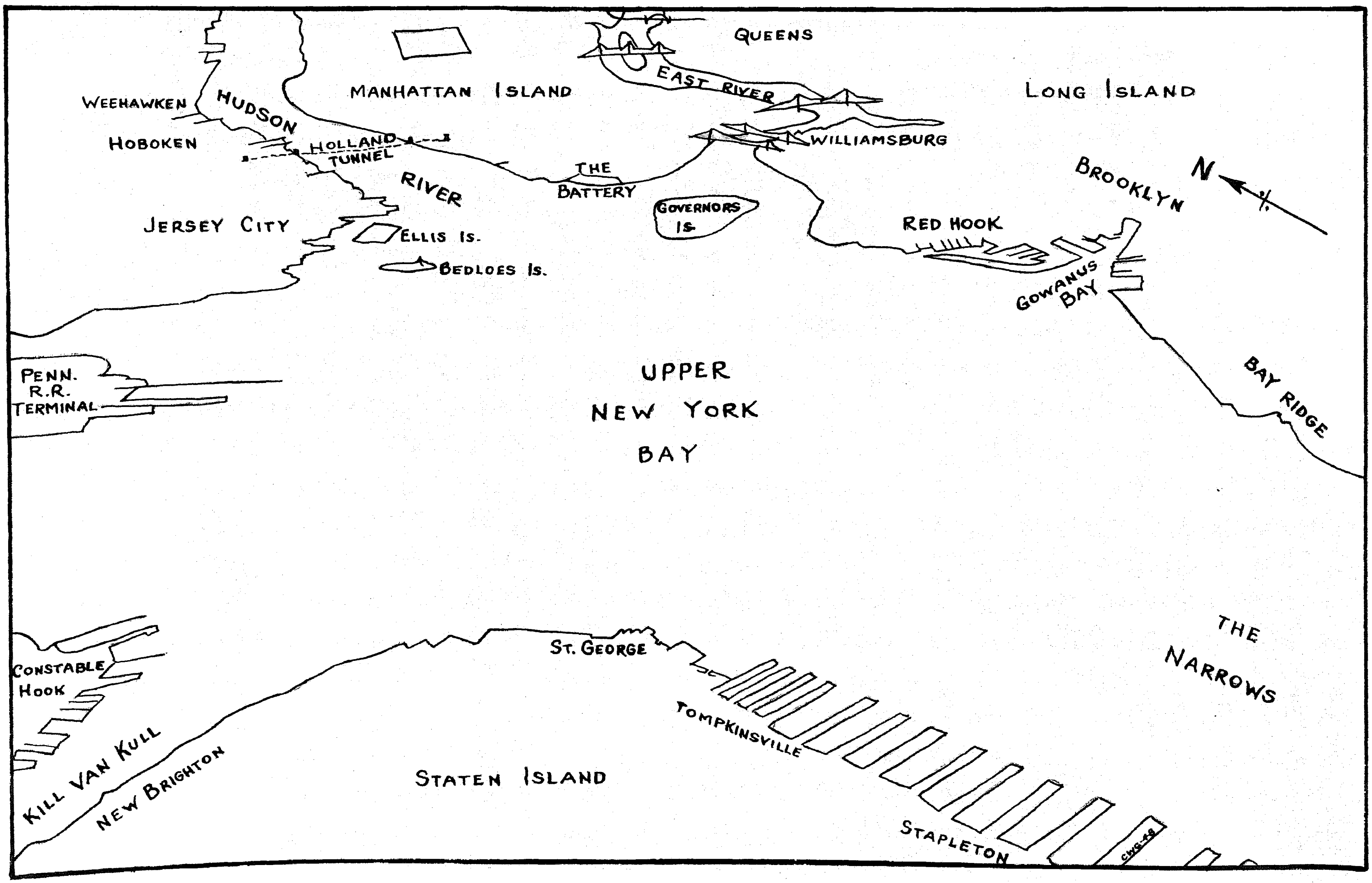
QUEENS
EAST RIVER
LONG ISLAND
MANHATTAN ISLAND
WEEHAWKEN
HUDSON
HOBOKEN
HOLLAND TUNNEL
WILLIAMSBURG
RIVER
THE BATTERY
BROOKLYN
N
JERSEY CITY
GOVERNORS IS.
RED HOOK
ELLIS IS.
BEDLOES IS.
GOWANUS BAY
PENN. R.R. TERMINAL
UPPER NEW YORK BAY
BAY RIDGE
THE NARROWS
ST. GEORGE
CONSTABLE HOOK
TOMPKINSVILLE
KILL VAN KULL
NEW BRIGHTON
STATEN ISLAND
STAPLETON
CWG-48

Aerial view of Upper New York Bay

# PREFACE

The following chapters are devoted to the various phases of that branch of construction which is followed from the offshore side of the waterfront. This branch, in the parlance of the building trades, is known as dockbuilding. Years ago all waterfront structures in New York Harbor were constructed almost entirely of timber and experience taught that the most economical approach for building docks and wharves was made by utilizing floating piledrivers and derricks. Thus it happened that dockbuilders became skilled both in the use of wood framing tools and in handling marine equipment. Modern dockbuilders must have, in addition to those skills, the ability to build forms for concrete construction, handle steel and concrete piling, and operate mechanical labor saving devices.

It is recognized that, in the construction of modern waterfront facilities, dockbuilding is not the only trade represented. The ironworkers, masons, metalsmiths, and so forth however, may ply their trades in any location, whereas dockbuilding is a specialty confined to the waterfront. Were it not for the fact that portions of it include such other operations as dredging, subaqueous pipe and cable laying, and diving, this text might have been appropriately entitled Dockbuilding rather than Waterfront Construction.

The problems that confront the promoters and designers of waterfront facilities have not been considered to any great extent and it has been attempted to describe in the chapters that follow only the various types and methods of construction peculiar to the waterfront, together with the materials, plant, and labor required for them. While the subject of waterfront construction is far from being exhausted in the following chapters, the more important kinds of facilities, types of construction, and varieties of plant prevalent in New York Harbor have, in varying degrees of detail, been described.

Chapter One may, at first, seem to digress considerably, but it is believed that the incidental information contained therein may prove of interest to someone unfamiliar with historical geology. The latter part of the chapter will be found to contain more pertinent information. In the second chapter, as in the first, there will be found paragraphs not closely pertaining to the subject of construction. They have nevertheless been included because a broader background for the chapters that follow is thus provided.

In gathering some of the material assembled herein the services provided by the Public Libraries of Newark, New Jersey, and New York City, the Engineering Societies Library, and the American Museum of Natural History were utilized. Some of the information, not to be found in books, and many of the photographs with which the text is illustrated, were generously contributed by a number of organizations whose representatives were considerate enough to give some of their own valuable time to be of assistance. Particularly helpful in this respect were:

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New York City Board of Transportation
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Merritt-Chapman & Scott Corporation
Atlantic, Gulf & Pacific Co.

Massey Concrete Products Company

National Association of River and
Harbor Contractors

McKiernan-Terry Corporation

Vulcan Iron Works

Bucyrus-Erie Company

Ellicott Machine Corporation

Superior-Lidgerwood-Mundy Corporation

United States Pipe and Foundry Company

Carnegie-Illinois Steel Corporation

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# CHAPTER ONE

## THE GEOGRAPHY OF NEW YORK HARBOR

Since all forms of building construction must begin with the establishment of a foundation, supported in some way by the materials which compose the crust of the Earth, it seems fitting that a description of construction should start from the ground up, so to speak, and include some information concerning that portion of the Earth's crust involved. In order to afford some degree of familiarity with the underlying conditions to be encountered beneath the surface of the water and the ground in the vicinity of New York Harbor a geological history will be recounted. First, however, it is considered appropriate to provide an introduction to some of the terms frequently used by geologists in connection with rock formations and geologic time intervals.

During the countless ages that elapsed before history was first recorded by man, an unwritten account of events and life on this planet was registered in the rocks that form the present crust of the earth. Through the efforts of those geologists who devoted themselves to the study of rocks and fossils, we are now able to interpret the records kept by the rocks and, to a certain extent, trace the evolution of the physical features of New York Harbor almost as accurately as though each phase had been witnessed and recorded by man himself. The history of the Earth, according to some estimates, dates back two billion years and has for convenience been divided into three major segments.

The first, the Cosmic Eon, includes the astronomical history of the Earth during which it was a mass of fiery gases torn, according to a popular theory, from the Sun. It includes also the time required for the gases to cool, for molten matter to appear, and for the first rocks to form by the solidification of the molten elements.

The second, the Cryptozoic Eon, derives its name from the fact that the evidence which is usually studied to determine the circumstances concerning the period is slight and for the most part obscure. As a result, knowledge of this period is rather vague. The Cosmic Eon and the Cryptozoic Eon combined constitute approximately three fourths of total geologic time.

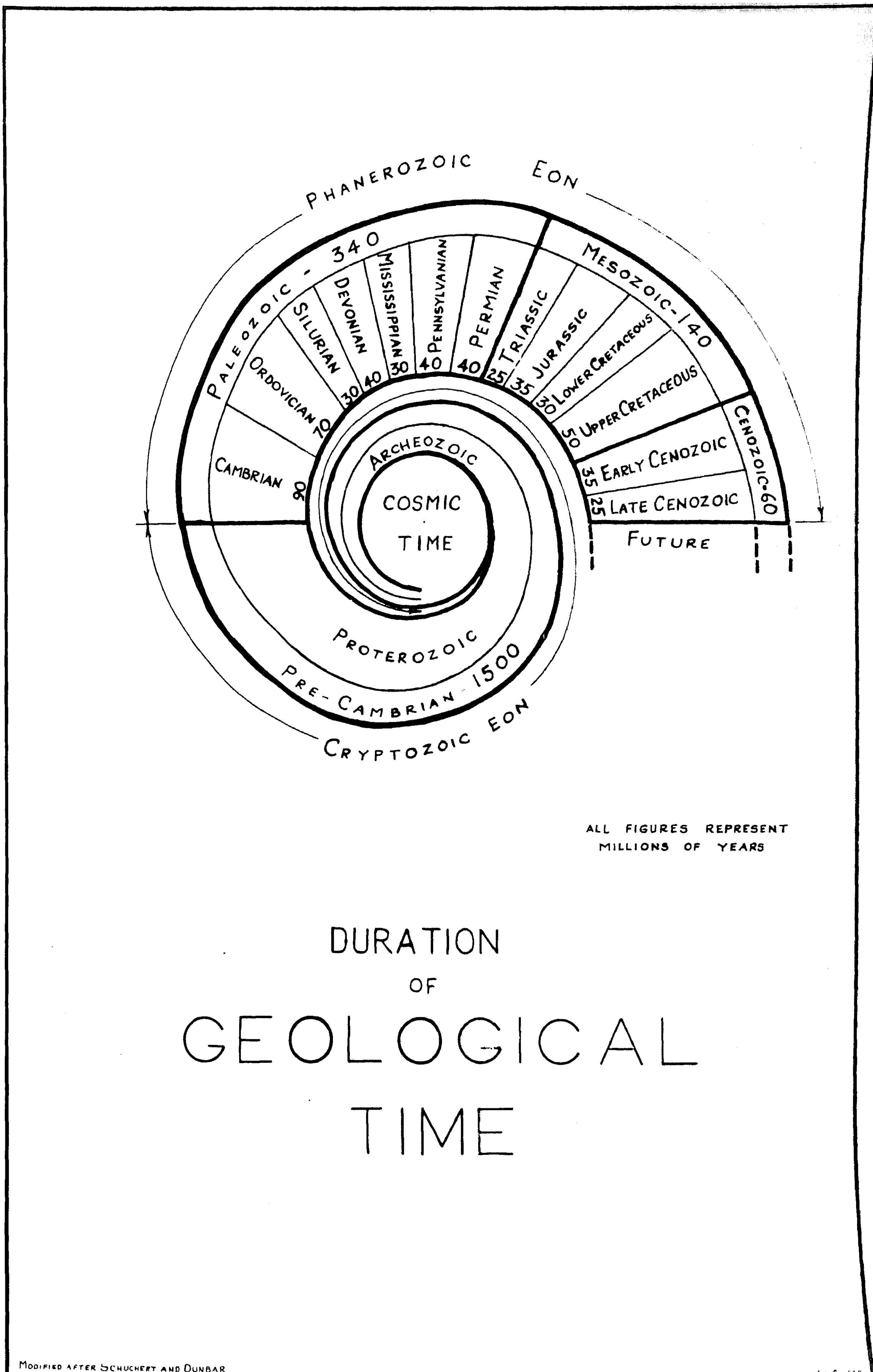


Fig. 1.- A graphic illustration of geologic time.

The third, the Phanerozoic Eon, includes the most recent quarter of geologic time in which evidence adequate to ascertain facts and to trace evolution is visible in the form of fossils and various types of rock.

The latter two eons have been broken further into subdivisions, the names, order, and characteristics of which are detailed in a Table of Geologic Time. The numerous subdivisions of the Phanerozoic Eon were made possible by the discovery of a wealth of fossils and rock formations originating during this period of time. They, figuratively speaking, comprise the reading matter from which geologists obtained their information and which is clearly punctuated by radical changes in the aspect of both animals and plants. Radical changes or breaks in the continuity of evolution have been attributed to continental uplift or submergence, volcanic eruption, drastic climatic change, and glaciation. Any occurrence which may have resulted in the acceleration of evolution or in the extinction of a species, as well as any of the foregoing, is as a punctuation mark and a basis for making the subdivisions. The term Pre-Cambrian is commonly applied to any geologic time, rock, or fossil that is

## TABLE OF GEOLOGIC TIME

### GEOLOGIC CHRONOLOGY OF NORTH AMERICA

| ERAS | SUB-ERAS | PERIODS AND EPOCHS | BIOLOGICAL AND CLIMATIC CHANGES | AGES | |
|---|---|---|---|---|---|
| Cenozoic or Modern Era | Late Cenozoic | Psychozoic | Mental Dominance | Age of modern seed floras | Age of man |
| | | Pleistocene<br>or<br>Glacial<br>Epoch | Periodic glaciations<br>Dawn of social life and industry among men<br>Extinction of large mammals | | |
| | | Pliocene<br>Epoch | Cooling of climate<br>Changing of man-ape into man | | Age of mammals |
| | | Miocene<br>Epoch | Culmination of mammals and land floras | | |
| | Early Cenozoic | Oligocene<br>Epoch | Rise of anthropoids<br>Last of archaic mammals | | |
| | | Eocene<br>Epoch | Spread of modernized mammals<br>Dawn of modern life<br>Rise of grasses, cereals and fruits | | |
| | | Paleocene<br>Epoch | Expansion of archaic mammals<br>Local alpine glaciation | | |
| Mesozoic or Medieval Era | Late Mesezoic (Cretaceous) | Upper<br>Cretaceous | Last of the ammonites<br>Extinction of dinosaurs<br>pterodactyls and toothed birds<br>Rise of archaic mammals and birds | | Age of reptiles and ammonites |
| | | Lower<br>Cretaceous | Spread of flowering plants and modern insects | | |
| | Early Mesezoic | Jurassic<br>Period | Rise of toothed birds and spread of pterodactyls<br>Spread of primitive mammals<br>Culmination of ammonites | Age of medieval seed floras | |
| | | Triassic<br>Period | Rise of dinosaurs, pterodactyls and primitive mammals<br>Spread of cycads and conifers | | |

Fig. 2a - Table of Geologic Time (Medieval and Modern Eras).

## TABLE OF GEOLOGIC TIME

### GEOLOGIC CHRONOLOGY OF NORTH AMERICA

<table>
<tr><th>ERAS</th><th>SUB-ERAS</th><th>PERIODS</th><th>BIOLOGIC AND CLIMATAC CHANGES</th><th colspan="2">AGES</th></tr>
<tr><td rowspan="7">Paleozoic or Ancient Era</td><td rowspan="3">Late Paleozoic</td><td>Permian</td><td>Periodic glaciations in southern hemisphere<br>Extinction of trilobites and Paleozoic corals<br>Spread of primitive insects and amphibians</td><td>Age of medieval seed floras</td><td rowspan="3">Age of amphibians</td></tr>
<tr><td>Pennsylvanian</td><td>Warm, humid climate with extensive coal making<br>Dominance of spore floras<br>Spread of reptiles</td><td rowspan="4">Age of spore-bearing floras</td></tr>
<tr><td>Mississippian</td><td>Spread of ancient sharks and culmination of crinoids</td></tr>
<tr><td rowspan="2">Middle Paleozoic</td><td>Devonian</td><td>Rise of amphibians, marine fishes and primitive ammonites<br>First spread of forests</td><td rowspan="2">Age of fishes</td></tr>
<tr><td>Silurian</td><td>Rise of air-breathing invertebrates<br>Spread of Paleozoic reef-corals<br>First known occurence of land plants</td></tr>
<tr><td rowspan="2">Early Paleozoic</td><td>Ordovician</td><td>Rise of fresh-water fishes and of corals<br>Spread of molluscs<br>Culmination of trilobites</td><td rowspan="4">Age of marine floras</td><td rowspan="3">Age of marine invertebrates</td></tr>
<tr><td>Cambrian</td><td>Rise of shell-bearing molluscs<br>Dominance of trilobites<br>First appearance of well-known marine faunas</td></tr>
<tr><td colspan="3">Proterozoic Era</td><td>Primitive marine life<br>An early and a late glacial period</td></tr>
<tr><td colspan="3">Archeozoic Era</td><td>Oldest known life<br>Geologic history very obscure</td><td>Age of larval life</td></tr>
</table>

Fig. 2b - Table of Geologic Time (Pre-Cambrian and Ancient Eras).

associated with the Cryptozoic Eon.

*   *   *

The rocks which form Manhattan Island and underlie the country to the north and east are among the oldest to be found on the North American continent. These ancient rocks are all metamorphic and were originally formed by sedimentation during the Archeozoic Era.

The first in the series is a variety of rock known as Fordham Gneiss, named for its conspicuous outcropping at Fordham Heights. It has a complex structure consisting primarily of granite and quartzose black and white banded gneisses and schists. It is found principally in the Bronx where it forms a cliff overlooking the Harlem River and north of the Spuyten Duyvil paralleling the Hudson River. Other outcrops in the Bronx are located on the Harlem River near Randalls Island and on the upper East River opposite Lawrence Point and Rikers Island. One narrow band extends southward from the Bronx, crossing Wards Island, Blackwells Island and the tip of Hallets Point in Long Island. Very little is found on Manhattan Island, only two locations being known. The first, uptown on the Harlem River, is a continuation of one of the Bronx formations, the other is downtown, as a narrow band extending almost north and south from the East River near 23rd Street to the East River near the Battery, as a continuation of the Blackwells Island outcrop.

Next, in the order of age, is Lowerre Quartzite. This is a thin schistose quartzite occurring in layers which vary up to a hundred feet in thickness and is conformable to the Fordham Gneiss. Three small outcrops are found in the Bronx, only one of which is near the water, along the Harlem River.

Inwood Dolomite is a coarsely crystalline limestone found in layers of from 200 to 800 feet. In some localities it contains pegmatite, tremolite and mica. Exposures are found over small areas on Manhattan Island, the Bronx, and Long Island. The Long Island outcrop is on Hallets Point while in the Bronx a narrow band follows the Hudson and Harlem Rivers and divides one of the sections of Fordham Gneiss. Farther south in the Bronx it separates the Fordham Gneiss from the Manhattan Schist. In Manhattan it is found at the northern tip of the island at the Spuyten Duyvil and in the northeastern portion bordering the Harlem and East Rivers. In southern Manhattan two narrow strips are found parallel to and on each side of the Fordham Gneiss, while other outcrops exist on Wards and Randalls Islands.

In turn, the dolomite is overlaid conformably by Manhattan Schist. This is the most widely distributed variety of rock east of the Hudson River and the rock most frequently met in excavating for foundations in Manhattan Island. It is a coarsely crystalline mica schist, having marked foliation and occurring in pegmatitic layers which probably reach several thousand feet in thickness. It covers most of Manhattan Island and the eastern part of the Bronx, extending into Westchester along the upper East River and Long Island Sound. It is also found in a small area in lower Jersey City.

Since their original formation these rocks have been folded and crumpled, faulted and crushed, intruded and considerably altered by the process of recrystallization. In spite of all this they have retained their original relative positions and the characteristics of sedimentary rocks.

Before the metamorphosis of the foregoing rocks was completed a series of igneous rocks was formed. Some of them, in all probability, are of the

Proterozoic Era, but some date back to the earlier sedimentary periods. This group includes Yonkers Gneiss, Serpentine, and dikes and sills of granite and diorite.

The Yonkers Gneiss, which covers a sizable area in Westchester County, is intrusive into Fordham Gneiss and is composed of pink granite, granodiorite and diorite, but none of it reaches the waterfront.

The greatest exposure of serpentine is to be found on Staten Island where it constitutes a large portion of the island. Lesser outcroppings are located in Hoboken and on Manhattan Island, the latter being the smallest. It also is a metamorphic rock, being without cleavage and having a fibrous green appearance.

The granites and diorites are found locally in numerous places in the form of dikes and sills. Some intrusions of pegmatite penetrate the ancient beds of Inwood Dolomite and Manhattan Schist and have partaken of all the metamorphic changes undergone by the latter. In general all of the intrusive rocks have been subjected to varying degrees of metamorphosis which include folding, flowing, and recrystallization.

Ravenswood Granodiorite is the only sizable formation in this category, the remainder of the outcrops being comparatively small and widely separated. It is found mostly on Long Island in the area north of Newtown Creek bordering the East River to Lawrence Point and on Manhattan Island in the vicinity of Corlears Hook.

Thus are accounted for the rocks which were formed during the dark ages of the geologic past. Life on this planet during that period consisted of very low forms of marine animals, but none of their fossils have been found in the rocks near New York. If any ever existed in them, they must have since been destroyed in the process of metamorphosis.

* * *

During the Paleozoic Era large portions of the continent were overflowed by the sea on numerous occasions. Throughout the entire era however, one section consistently remained above sea level. It was the area extending in a northeast-southwest direction that is at present occupied by the ridge of rolling hills which terminates in the south with Manhattan Island.

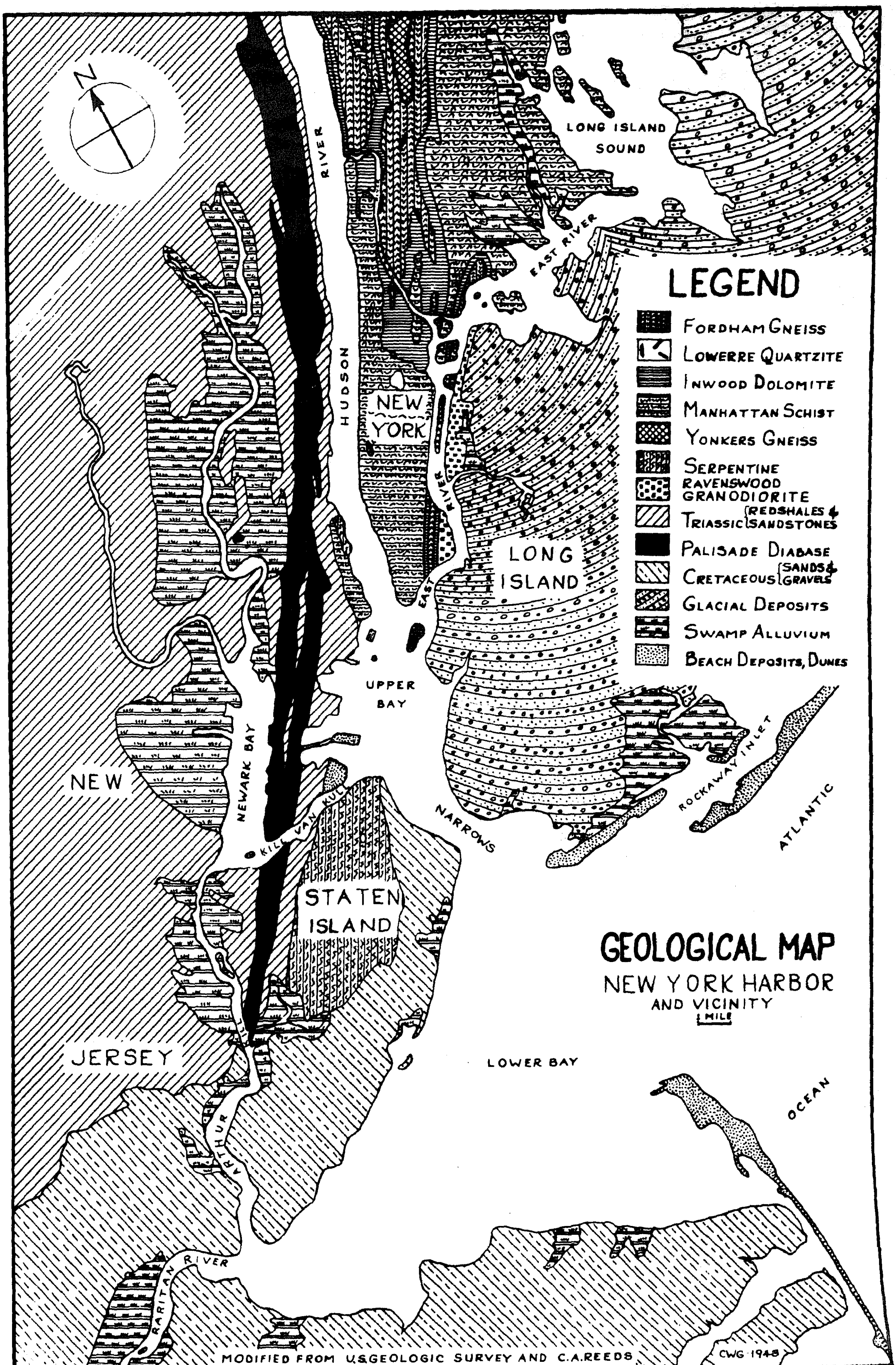


Fig. 3.- Geologic map of New York and vicinity.

The sediments deposited during the floods of the Cambrian Period later became the foundations of the Apallachian and Rocky Mountains, but the greatest inundations to be recorded occurred during the Ordovician Period. At one time one-half of North America was under water and, while in neighboring areas the dark shales of western New Jersey and eastern New York, and the slates of Pennsylvania, New Jersey, and Vermont were being deposited, the New York section experienced only erosion. Toward the end of this period the ancient sedimentary rocks of this section, together with their more recent igneous associates, were subjected to a slow process of elevation and folding until they became part of a mountain range which extended from Newfoundland to south Jersey. At the same time the southern Apallachian area commenced to rise slightly.

The Silurian and Devonian Periods both saw the level of the sea rise and subside several times. For the most part the continent remained flat, although the Apallachian highlands continued to rise.

The following periods, called the Mississippian and Pennsylvanian, are together known as the Carboniferous Age. All of New York, New Jersey, and Connecticut remained land areas during this time, but along the seacoast in Rhode Island and Massachusetts on the east and, as is better known, in Pennsylvania, Ohio, and Illinois on the west, great tracts of swamp developed. They were composed of half land and half water and supported luxuriant vegetation which formed the peat bogs destined to become the world's most extensive coal deposits. The Permian Period, the last of the Paleozoic Era, witnessed a pronounced elevation of the mountains of eastern North America and marked the end of extensive overflowing of the continent.

* * *

The Mesozoic of Medieval Era followed in the wake of the Permian mountain making. The first period, the Triassic, at first saw eastern North America remain emergent from the sea while erosion proceeded to reduce the mountain ranges. Then the forces which had previously caused the folding and elevation of the sedimentary rocks were removed causing the folds to relax and faulting to occur. This was followed by another incursion by the sea which overflowed one shallow trough between the Blue Ridge and the New York Ridge and another east of the New York Ridge where the Connecticut River valley now lies. Into these troughs were washed the materials eroded from the adjacent mountains. Throughout most of the Triassic Period the troughs continued to subside due to faulting as the sedimentary strata were deposited. The resulting sedimentary rocks consist of reddish brown sandstones, shales, and conglomerates which rest unconformably upon the ancient metamorphic rocks.

Apparently the forces of nature occasionally brought about drastic changes during this period. This is evidenced by the nature of some of the strata and by the fossil findings in them. For instance, the shales which are accumulated in quiet water, are found at various levels to contain the remains of the marine life that inhabited the lagoons where they were deposited. These fossils occur in great numbers confined to thin layers and consist of complete and mature specimens which indicates that they were killed by some unusual occurrence. Possibly there was a complete withdrawal of the water, the substitution of salt water for fresh water, or vica versa.

Moreover, these fish bearing shales are separated by beds of conglomerate that sometimes contain boulders. This suggests powerful hydraulic action which might have been caused either by violent waves or by torrential downpours over the highland areas.

Other conglomerates are found graded laterally into shales indicating the presence of alluvial fans. Some sandstones have ripple marks, sun cracks, and the imprints of the feet of contemporary animals plainly discernible in them. Long periods of drought were required for the preservation of such marks.

In the latter half of this period volcanic action again occurred in the vicinity. On three separate occasions lava welled up out of the earth to flow conformably over the Triassic beds. A fourth time the lava did not reach the surface, but intruded a sill between the lower strata.

During the course of their accumulation the sedimentary beds acquired a slight tilt, due to an uneven settlement in the area, and attained in New Jersey a thickness estimated to total approximately 20,000 feet. The area covered by these rocks is bounded on the east by the Hudson River and on the west by a series of fault lines which run from Stony Point, New York in a southwesterly direction across the state of New Jersey. The northwestern corner of Staten Island also lies within this area.

The close of the Triassic Period was marked by an uplift in the region that brought to an end for a while the deposition of sedimentary rocks. The uplift was accompanied by a steeper tilting of the beds and by the formation of numerous fault blocks.

Subsequent erosion, has worn down the rough edges of the tilted blocks and brought into conspicuous relief the more resistant igneous rocks. The outcroppings of those first three lava flows are known today as the First and Second Watchung Mountains and Hook Mountain. They are 600, 800, and 300 feet thick respectively. The intruded sill, which now outcrops from the vicinity of Haverstraw, New York well into Staten Island and forms the Palisades of New Jersey, varies in thickness from 350 to 1,000 feet. All of these igneous rocks are dark colored and are commonly referred to as traprock.

During the Jurassic Period which followed, the New York area remained wholly emergent, as did nearly the entire continent, and erosion was the only active agency. Not even alluvial deposits have been found on the eastern coast, which may indicate that they were carried out beyond the present limits of the continent, or that they were completely eroded away at a later date.

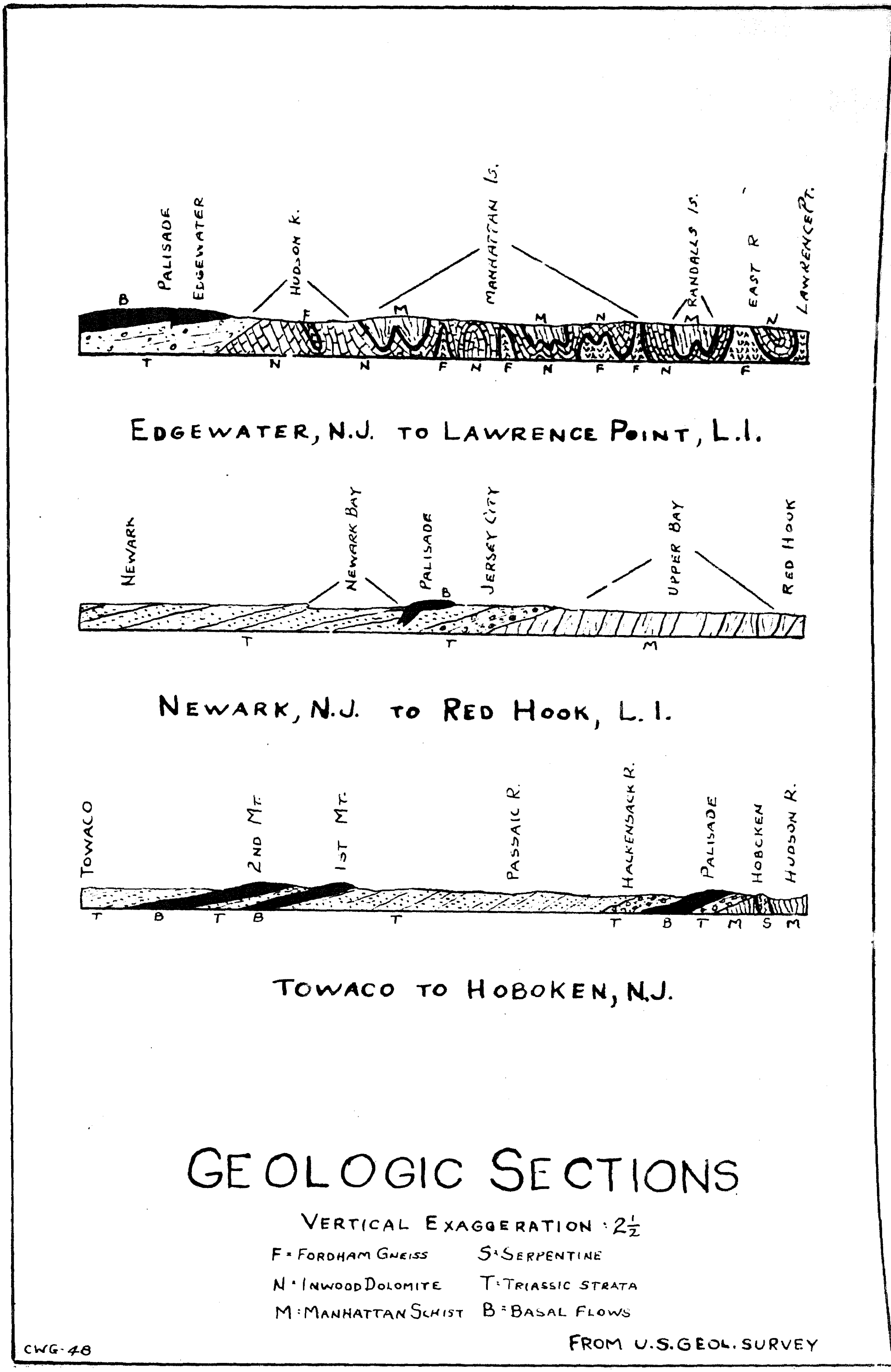


Fig. 4.- Geologic sections in the vicinity of New York.

The last extensive submergence of North America took place during the Cretaceous Period. The formations deposited during this period lie unconformably upon the Triassic Series in New Jersey and upon the ancient crystalline rocks in New York. They have, in general, become only slightly hardened, and only locally are they hard enough to be called rock.

They extend in a belt roughly parallel to and southeast of the Triassic formations in New Jersey, crossing the southeastern half of Staten Island, and continuing on in Long Island. Except for a section in the southwestern part, this series is buried on Staten Island under subsequent glacial till. On Long Island also the series is buried except for small exposures on the north shore and in the interior. Its existence under the remainder of the island is known from deep well drillings and only south of Raritan Bay are exposures extensive.

Throughout the Cretaceous Period the formations were mostly sands and clays having a slight dip toward the ocean. The earliest of the series were not all marine sediments and are not represented in the vicinity. There are however three later members of the series which are well defined in the New York area. They are the basal Raritan formation of plastic clays, the Matawan formation of clay marls, and the Monmouth formation of green sand and marl. Some of the later beds in Long Island have been deformed and even folded by the passage of a glacier in the next era.

* * *

Upon entering the era during which the final stages of development took place, North America had already attained approximately its present size and shape, and at no time thereafter did the sea overlap more than the coastal fringes of the continent. The New York Range stood at an elevation above the sea much higher than it is now and the Hudson River flowed through a gorge some 300 feet deep. These conditions persisted throughout the first five periods of the Cenozoic Era. Then came the Pleistocene Period during which, for reasons yet unknown, the subtropical climate which had prevailed at this latitude began to grow less temperate. The trend continued until such a severity of climate was attained that the area became covered with fields of snow and ice. As the cold increased sheets of ice developed in the north and began to spread southward over Labrador, New England

and New York. At the point of its greatest progress the glacier, as the ice sheet is called, reached to Trenton, Staten Island, and Long Island. All of the territory north of this line was buried under a moving mass of ice which in places was several thousand feet thick.

Of course there was no life in the area, and underneath the ice the topography of the land was being altered. Moving in a south southeasterly direction across the area where New York City now stands, the ice ground down and rounded off all projecting rock masses and, at the same time, filled up with the debris of rocks any valleys or depressions it passed.

During the period of maximum glaciation the level of the sea was several hundred feet lower than it is at the present time and the mouth of the Hudson River, which emerged from under the ice, was about 100 miles southeast of the Narrows.

Eventually the glacier began to recede, and as it did so it left in its wake softer contours and moraines. The hardest rocks of northern Manhattan Island are striated or polished wherever they were exposed and the great terminal moraines, which define the southern reaches of the ice, cover the southeastern portion of Staten Island and comprise practically all of Long Island. The Hudson River, on its way to the sea, cut through this terminal moraine to form the Narrows.

As the glacier continued to melt and recede farther north the Great Lakes were formed, and for a while the Hudson River drained them by way of the Mohawk River valley. Later, with the formation of the St. Lawrence River valley, that drainage area was captured from the Hudson.

Incidentally it has been theorized that the Hudson River, in preglacial times, received two tributaries below Manhattan Island. The Housatanic River, and perhaps the Connecticut River also, may have flowed westward through the Hell Gate and into the East River to join the Hudson until the eastern end of Long Island Sound was opened by glaciation and the rising of the sea. From the west the runoff from the Passaic and Hackensack River valleys discharged through the Kill Van Kull gorge. The confluence of these streams, it is believed, may have produced the expansive valley which now contains New York Harbor.

The material with which the old valleys of the Hudson and East Rivers are filled consists of boulders, gravel, sand, clay, and glacial drift, all of which was scraped from the highlands in the north. In all probability they were at one time brim full, to be scoured out later by the rivers of melted ice.

Following the recession of the Pleistocene Glacier from the area, the level of the sea began to rise again. Eventually the littoral plain east of New Jersey and south of Long Island disappeared and at high tide seawater began to back up into the mouths of the rivers. Thus the waters of New York Harbor became deeper and the lower portion of the Hudson River became a tidal estuary. The velocity of the Hudson River was greatly reduced in the Harbor due to the greater width and depth of cross-section as well as the tides. As a result the glacial deposits have been covered with a thick layer of river silt. Southward along the coast, at Philadelphia and Norfolk, similar changes have effected the Delaware and Susquehanna, making them half-drowned rivers.

Even today changes are taking place. The coasts of New Jersey, Staten Island, and Long Island are apparently sinking. The great meadows of Newark and the Hackensack River valley contain the stumps of trees that have died within the last two centuries.

There are written records to the effect that the meadows between Newark and Jersey City were heavily forested during Revolutionary War days. The rate of subsidence may be slow, perhaps only several inches per century, but at sea level a change of several inches, if the land is flat, can cause large areas to be contaminated by salt water. This present trend may cease at any time or even reverse itself.

Into these areas that are gradually falling below sea level a so-called swamp alluvium is being deposited. It is thick black muck consisting of a mixture of decayed vegetation and the silt carried by the streams. These deposits are found to a great extent in the meadows of New Jersey, along the margins of the Staten Island Kills, and adjacent to Jamaica and Flushing Bays, Long Island.

Lastly there are the beach deposits and sand dunes that are constantly changing both in size and location. These sandy formations are found primarily along the margins of Lower New York Bay. The majority of the dunes are located along the New Jersey and Long Island shores, outside the limits of the inner harbor while Sandy Hook and Rockaway Point are the best examples of changing beach deposits.

* * *

The present harbor of New York consists of a number of rivers, bays, and straits connected with one another, thus forming an intercommunicating system of tidal waterways. In this respect New York differs from other port cities most of which are situated on a bay or a tidal river of which the harbor itself is a part. New York Harbor is different also in that it has two widely separated passages to the sea, namely the Narrows and Long Island Sound.

The Lower Bay is a triangular body of water extending from the Narrows to the junction of Arthur Kill and the Raritan River, thence to the south end of Sandy Hook, and thence to Coney Island. It includes Raritan Bay, Sandy Hook Bay and Gravesend Bay and has a total area of 118 square miles. The entrance to Lower Bay, between Coney Island and Sandy Hook is 7 miles wide, across which stretches a sand bar. Seaward from the bar the water rapidly reaches depths in excess of 40 feet while to the west it shoals considerably except for the channels leading into the Narrows where the water naturally attains depths of 50 to 60 feet. Taken as a whole, Lower Bay has an average depth of 20 feet reckoned from mean sea level.

The Narrows is a short passage, about 3 miles long, between the Upper and Lower Bays. At its least width, in the vicinity of Fort Hamilton, where it measures one mile there are depths of 100 feet. As the channel widens to the north and south however, the depths decrease to 60 feet. It has an area of about 5 square miles with an average depth of about 50 feet.

The Upper Bay is a body of water approximately $3\frac{1}{2}$ x 4 miles. The natural channel through it, which follows a more or less direct line from the Hudson River to the Narrows, is about one half mile wide with depths up to 60 feet. Extensive mud banks occupy the western portion where the water measures 8 feet or less deep, bringing the average depth to approximately 25 feet. Within the Upper Bay there are three islands. The largest, Governor's Island, is located close to the Brooklyn shore at the entrance to the East River. Ellis and Bedloes Islands are located in the flats on the western side roughly opposite Governor's Island.

The Hudson River, the most important on the Atlantic coast, is a tidal estuary for 150 miles above Upper Bay. For as far north as the limits of

New York City, 16 miles above the Battery, it is nearly a mile wide. There has always been a deep water channel in the river but prior to improvements shoals existed along either side. It has been estimated that the Hudson River discharges 2 billion cubic feet of fresh river water per day.

The East River extends from the southern tip of Manhattan Island to Long Island Sound. It is divided just about in halves by the Hell Gate. Southwest of the Hell Gate the river is comparatively narrow with an average depth of nearly 40 feet, while to the east the shores diverge and the depth averages only 25 feet. Several islands are located in the East River, the largest of which are Blackwells (Welfare), Wards, Randalls and Rikers Islands. The stretch of water known as the Hell Gate lies between Wards Island and Long Island. These islands tend to constrict the waterway and as a result the currents running through become very swift. Prior to improvement the eastern portion was studded with rock reefs which made the channel narrow and tortuous. Strictly speaking the East River is not a river but is a tidal strait, connecting Long Island Sound with Upper Bay, into which the tide enters not only northeastward from the bay but also southwestward from the sound.

The Harlem River, like the East River, is actually a tidal strait connecting the Hudson and East Rivers. Its junction with the East River is through three channels, the largest of which runs between Manhattan and Wards Islands. Its outlet to the Hudson River was originally a narrow winding passage through a tidal marsh called the Spuyten Duyvil. The present channel of the river is about 7 miles long with a depth of about 18 feet.

Newark Bay which is separated from Upper Bay by Jersey City and Bayonne covers an area of 8 square miles. The Passaic and Hackensack, two sizable rivers, empty into its upper end. Most of this bay is shoal, averaging about 9 feet, so that it must be dredged to admit ships of any consequence.

The Kills is the name applied to the narrow and winding straits which separate Staten Island from New Jersey. Arthur Kill, about 18 miles long, lies on the west side of the island while Kill Van Kull, bordering Newark Bay and Bayonne, is about 5 miles long. Their average depths are 18 feet and 28 feet respectively.

The waterways just described have given New York a natural advantage over other ports that is difficult to beat. From the earliest times the area has been served with a large expanse of navigable water opening to the sea through narrow passages and thus having shelter from storms and wave action. At first the only problem in harbor development was to build the docks and slips with sufficient water at their sides, since for many years the natural channels were deep enough to pass the world's largest ships.

* * *

The phenomenon of the alternating rise and fall of the level of the sea, which occurs twice daily, is known as the tide. The gravitational forces exerted by the moon are responsible for the tides and, during differant lunar phases spring tides and neap tides occur. The spring tides, which occur at new and full moons, exceed the mean tidal range at both high and low water, while neap tides, at the first and third quarters, fall short of the mean range. The averages of the monthly highest and lowest marks reached are called the extreme tides. Occasionally a combination of circumstances, such as an extreme tide together with stormy weather, cause even the so-called extreme tides to be exceeded. A strong east wind will cause a flood tide to rise above normal, while a west wind will cause an ebb tide to fall lower than normal.

The following figures are the result of observations at Fort Hamilton, L. I. over a period of years:

| | |
|---|---|
| Mean high water above mean sea level | 2.33 ft. |
| Mean low water below mean sea level | 2.42 ft. |
| Mean tidal range | 4.75 ft. |
| Spring high tide above mean sea level | 2.77 ft. |
| Neap high tide above mean sea level | 1.86 ft. |
| Extreme high tide above mean sea level | 4.13 ft. |
| Highest tide recorded above mean sea level | 6.3 ft. |
| Spring low tide below mean sea level | 2.88 ft. |
| Neap low tide below mean sea level | 1.90 ft. |
| Extreme low tide below mean sea level | 3.93 ft. |
| Lowest tide recorded below mean sea level | 6.5 ft. |

In different parts of New York Harbor the limits between which the mean tide oscillates vary and the spring, neap, and extreme tides in these different parts vary correspondingly. For several localities the mean tide ranges are as follows:

| | |
|---|---|
| Spuyten Duyvil | 3.8 ft. |
| Newtown Creek, Long Island | 4.1 ft. |
| St. George, Staten Island | 4.4 ft. |

| | |
|---|---|
| The Battery | 4.5 ft. |
| Fort Hamilton, Long Island | 4.7 ft. |
| Port Newark, New Jersey | 4.7 ft. |
| Astoria, Long Island | 4.8 ft. |
| Elizabethport, New Jersey | 5.0 ft. |
| Perth Amboy, New Jersey | 5.2 ft. |
| Rikers Island | 6.7 ft. |
| Throgs Neck, Bronx, N.Y. | 7.1 ft. |

To say that the tide rises and falls twice each day is only approximately true. Actually the tidal day, like the lunar day, is 24 hours and 50 minutes long. Consequently both the passage of the moon and the event of high and low water, at any given meridian, occur 50 minutes later on each succeeding day.

Even as the range of the tide varies between different locations in the harbor, so does the time of high and low water. Generally speaking, the farther inland from the sea that a point is located, the later will be the time of the tide.

With reference to the Battery, the time of high water at several other points is obtained as follows:

| | | | |
|---|---|---|---|
| South Amboy, New Jersey | subtract | | 25 min. |
| The Narrows | subtract | | 30 min. |
| Sandy Hook, New Jersey | subtract | | 45 min. |
| Weehawken, New Jersey | add | | 20 min. |
| Spuyten Duyvil | add | | 45 min. |
| Yonkers, New York | add | 1 hr. | 0 min. |
| Ossining, New York | add | 2 hrs. | 0 min. |
| Elizabethport, New Jersey | add | | 30 min. |
| Port Newark, New Jersey | add | 1 hr. | 5 min. |
| Brooklyn Navy Yard | add | | 40 min. |
| Hell Gate | add | 2 hrs. | 0 min. |
| Lawrence Point, Long Island | add | 2 hrs. | 45 min. |
| Rikers Island | add | 3 hrs. | 15 min. |
| Throgs Neck, Bronx | add | 3 hrs. | 0 min. |

The range of the tides often has a considerable effect upon the design and construction of waterfront structures. In the case of such facilities as the terminals for ferries and railroad carfloats the land approaches, the bridges, and the operating mechanisms must be built so that landings can be made at any extreme of tide.

Frequently where concrete foundations are built upon timber piles, plans call for the piles to be cut off at or near mean low water, and for concrete to be poured at this elevation. In such cases, when the work is scheduled, the fact that low enough water lasts only for a short time each day must be taken into account.

* * *

Those currents which depend upon the fluctuation of the water level for their movement, in contrast with ocean currents and those caused by the flow of rivers and by the winds, are termed tidal currents. Both tidal and non-tidal currents are active together in both the open sea and inland waterways. At any time and place the current encountered is the resultant of them all. In general, tidal currents attain appreciable velocities in the narrow entrances to bays and in the narrow openings between large bodies of water. When tides cause a reversal of current the period during which the velocity equals zero or less than one-tenth knot is called slack water.

In New York Harbor the flow of currents follows a fixed pattern dependent upon the stage of the tide. At the time of low water at Sandy Hook the tide is falling all over the harbor except in Lower Bay. The current in Upper Bay flows toward the Narrows and the flow of the Hudson River is about at full

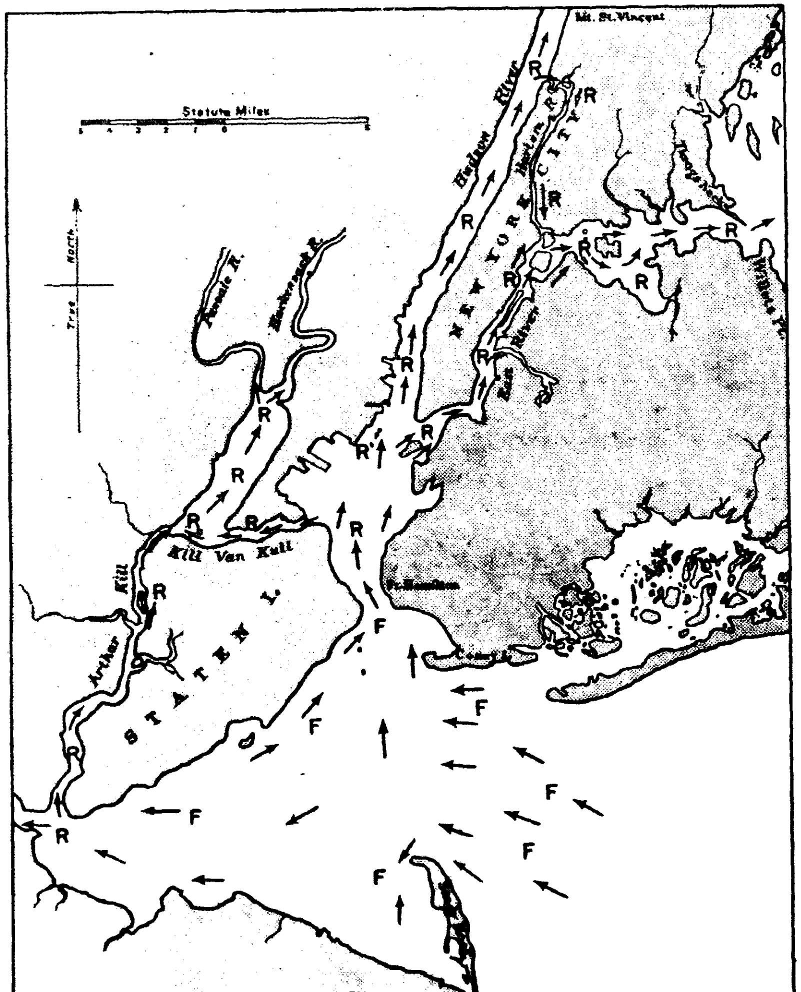


Fig. 5a.- Tidal currents at time of high water at Sandy Hook.

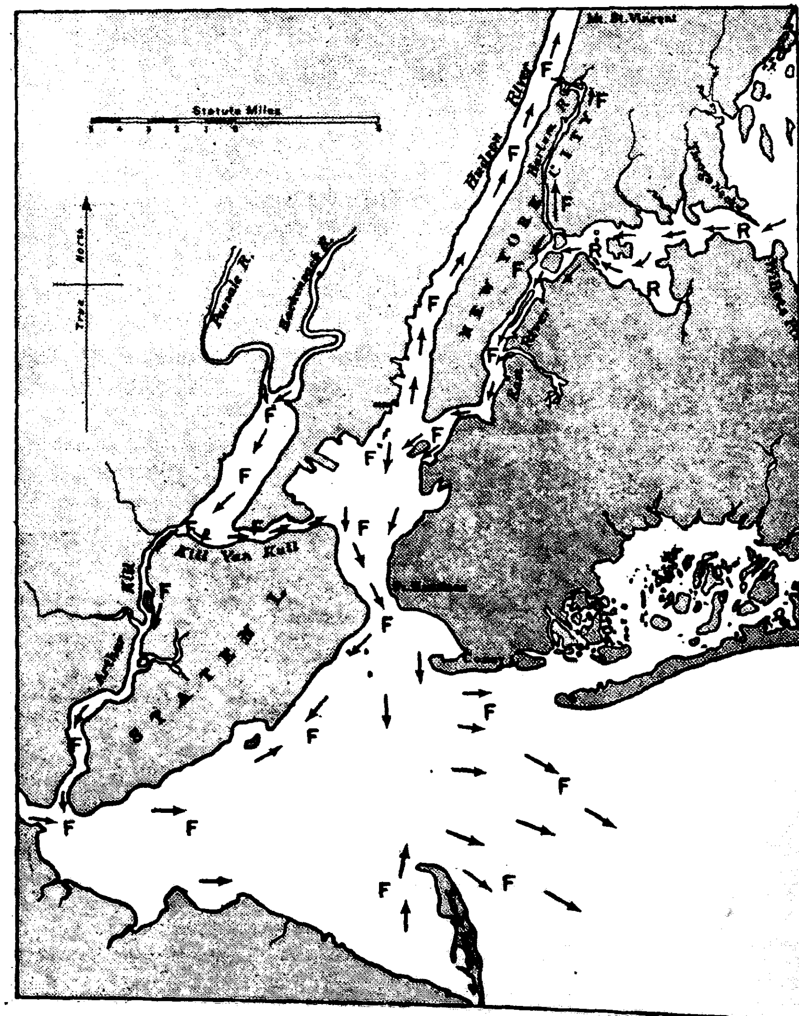


Fig. 5b.- Tidal currents three hours after high water at Sandy Hook.

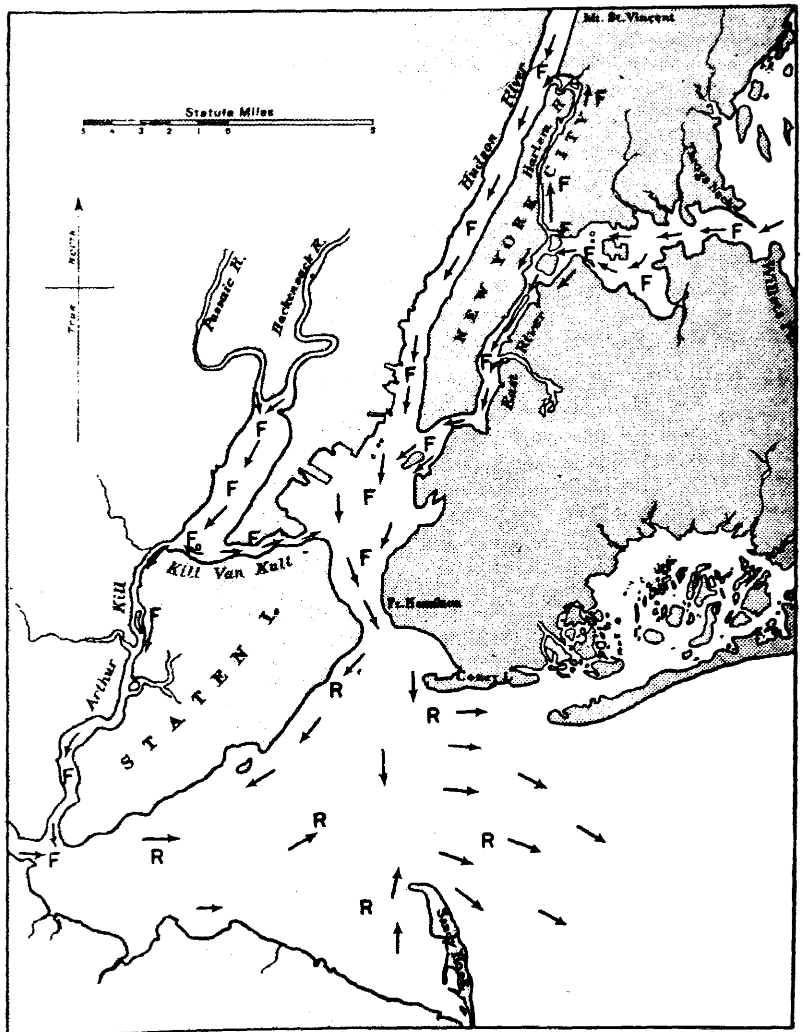


Fig. 5c.- Tidal currents at time of low water at Sandy Hook.

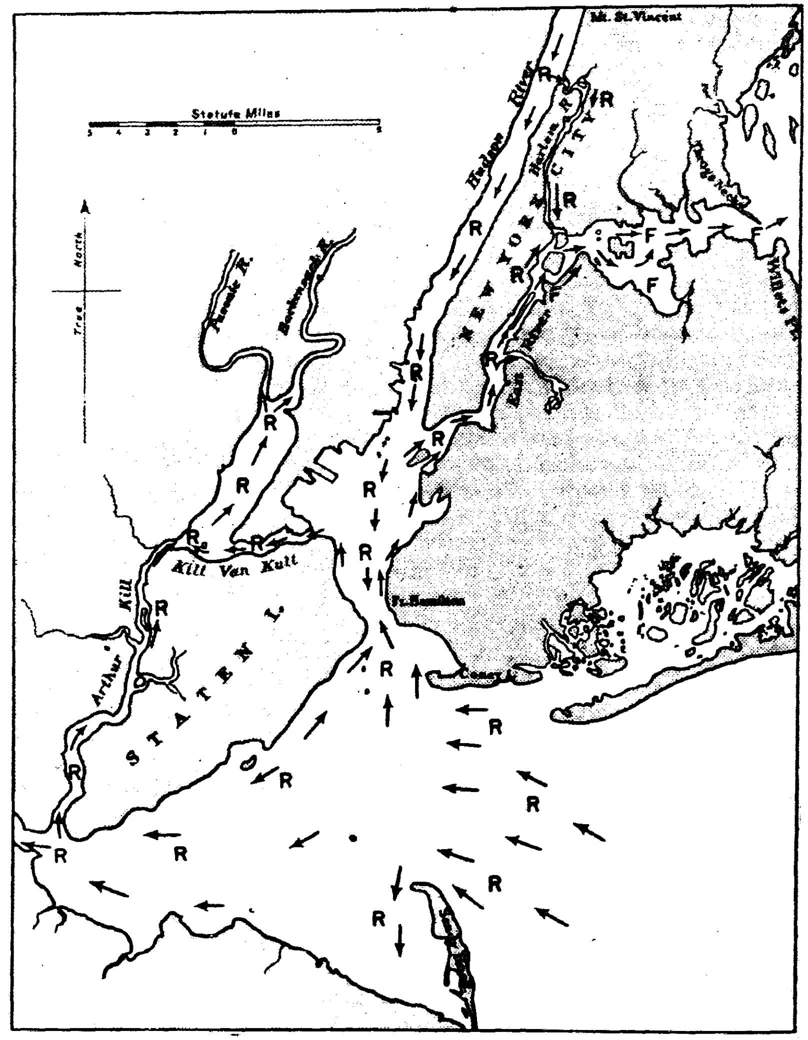


Fig. 5d.- Tidal currents three hours after low water at Sandy Hook.

strength, low tide still being one hour away. The Harlem River flows north into the Hudson River while the upper East River carries water from Long Island Sound toward Hell Gate, where low water is two hours away. The lower East River flows nearly at full strength while the water level drops rapidly. In Newark Bay the current flows south, pouring principally into Kill Van Kull but also into Arthur Kill. The current through the Narrows reaches its maximum velocity one hour before low water at Sandy Hook and continues to flow for 40 minutes after the water starts to rise again. In Arthur Kill, flowing toward Lower Bay, the water is falling, but in Lower Bay the water has begun to rise slightly because low water there occurred 3 minutes before this time.

Three hours after low water at Sandy Hook the currents have changed. The tide in the Hudson and Harlem Rivers is rising, but the currents in both flow southward. The entire East River is flowing toward Long Island Sound but in the lower section the water is rising while in the upper section it is still falling. In Upper Bay, the Narrows, Kill Van Kull, Newark Bay, Arthur Kill and Lower Bay the tide is rising and in all of these except Upper Bay and the Narrows the current is flooding. In the Upper Bay channel and the Narrows the current is still dominated by the flow from the Hudson but in the shoals along the shores the current has started to flood.

At the time of high water at Sandy Hook the current throughout the harbor is flooding and except for Lower Bay the tide is rising. The Narrows and Upper Bay are running at full strength, while in Arthur Kill full strength was one and a half hours before and in Kill Van Kull the flow is westward at about one half strength. The Hudson River is at full strength while in the Harlem River the current is toward the East River. The East River current runs toward Long Island Sound, its full strength having occurred one hour before. Throughout its length the tide is rising with high water 2 hours away in the lower section and 3 hours away in the upper section. The water of Lower Bay is falling slowly while in the Narrows and Upper Bay it is still rising, high water coming 15 minutes later. In Newark Bay and the Kills the water is likewise rising, high water having not yet arrived.

Three hours after high water at Sandy Hook the tides are falling and the currents are ebbing throughout the harbor except for the Hudson and upper East River. In the Hudson the current is flooding slightly, slack water before ebb being an hour away.

In addition to being of general interest the behavior of the currents in the harbor effects the movement of ships and smaller craft, Large ships are usually scheduled to enter and leave on the tides although they can easily make headway against them. To towboats however, the matter of tides is of great importance. Both plant and material for waterfront construction are moved by water. The plant, such as piledrivers and derricks, is large and ungainly compared to the towboats commonly employed to move them. Deck scows and catamarans represent the opposites of difficulty in handling. Deck scows ride in the water with small draft and high free board and, with any amount of wind they act like a sail. Catamarans, in contrast, when loaded with piles or timbers, sink deeply into the water and create a heavy drag. As a result, in making long tows, adverse tides represent not only an inconvenience but a great loss of time and a considerable additional expense.

* * *

Of interest to waterfront constructors is the nature of the soil at the bottom of the various waterways, especially along their margins. In most cases the shore lines of the harbor are formed by gravel, sand, clay, and river muck.

The muck, being the most recent deposit, is the first layer to be encountered at the bottom. It varies from a soft fluid to a sticky black clay-like substance and is composed of a mixture of silt carried by the river, the sinkable refuse dropped from ships, piers and bulkheads, oil, and the sediment from the numerous sewers that discharge directly into the harbor. The thick, clayey muck is capable of supporting piles by skin friction, but usually piling is driven entirely through it to hardpan.

The clay, sand, and gravel of glacial origin occurs in beds of irregular shape and thickness. The banks of sand and gravel were deposited from the under side of the glacier while its retreat was in progress and some of them are the sand bars of streams that once flowed under the glacier.

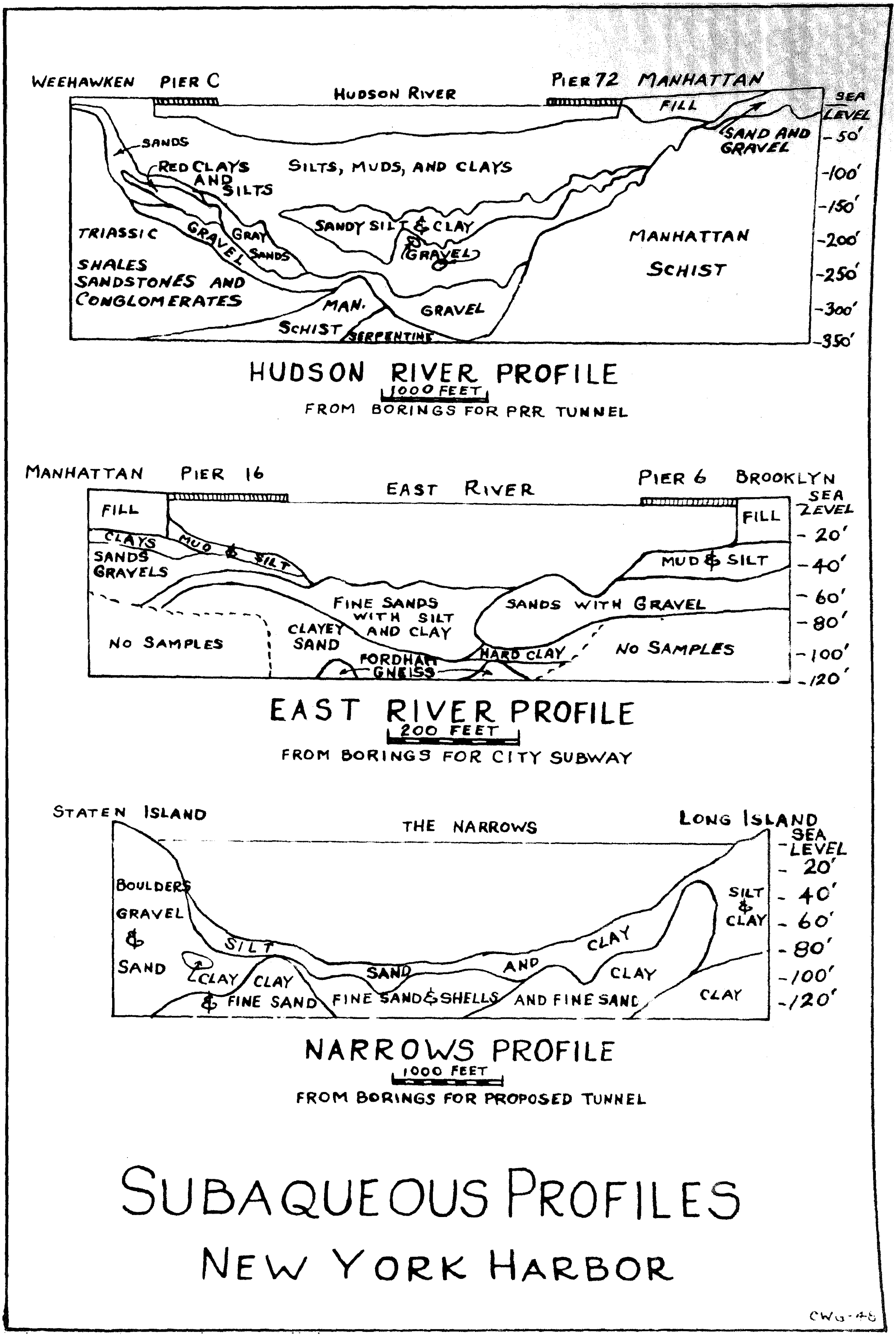


Fig. 6.- Subaqueous profiles in New York Harbor.

The fine material required to make the clays were carried and deposited by these same sub-glacial streams and often samples from the bottom are found to be an even mixture of sand and clay.

Boulders are encountered in some localities and bedrock occurs close to the surface in places. For the most part the boulders are found on Long Island and Staten Island where they were dropped by the glacier. Bedrock can be found at no great depth at almost any point on the perimeter on Manhattan Island. In many cases pier and bulkhead wall foundations have been carried to it. On Long Island the bedrock is too deep to be encountered in most places, but from Newtown Creek northward to Astoria rock is not beyond reach. In Kill Van Kull the continuation of the Palisades occurs close enough to the surface to require its drilling and blasting in order to dredge the channel to the desired depth.

There are places where quicksand is found, usually under strata of sand and clay at the sites of former streams that have been covered over in the past and forgotten. Many such pockets, colloquially called bull's-liver, have been encountered along the waterfront of Manhattan Island where the bulkhead line has progressively been moved outward to reclaim the water lands along the rivers. Some of the streams buried in this process continue to flow at the present time and sometimes present unexpected difficulties in the sinking of caissons and irregularities in the hardpan where firm footing is sought for piling.

All things considered, New York has been fortunate in the nature of its harbor subsoil. The clays, sands, and gravels provide an excellent medium for the various types of pile foundations which support the great majority of all waterfront structures. The soft clays and thin laminated strata of sand can in most places be penetrated to hardpan without the necessity of excessively long piles and hard driving. At the same time the strata penetrated affords the necessary lateral support at the lower ends of the piles. In addition to the fact that driving piles through the soft strata to hardpan provides a satisfactory cheap method of building foundations, these same soft deposits enable the channels, together with the slips between piers and berths along bulkheads, to be dredged with comparative ease. Very few projects in the harbor have required extensive rock excavation.

* * *

Being in a temperate zone as it is, New York has a climate which affords weather favorable for construction during the greatest part of the year. In an average year the area receives about 42 inches of rain, of which 10 per cent usually falls as snow. The sun shines about 60 per cent of the possible time and about 25 days out of the year are expected to be foggy. Temperatures vary from an average of 31 degrees Fahr. during February to 74 degrees Fahr. in July. Normally in several days per year the temperature goes above 90 degrees and during about 25 days per year it drops below freezing. The average relative humidity varies from 74 per cent in the mornings to 60 per cent at noon. The prevailing winds are north and northwest with an average velocity of from 10 miles per hour in the summer to 15 miles per hour in the winter. Velocities reaching 60 to 70 miles per hour, while not common, have been known to occur at any time of the year.

Rain is the primary cause of lost work days during the course of the year although, during the winter months, heavy snow and extreme cold may cause jobs to be knocked off.

# CHAPTER TWO

## THE DEVELOPMENT OF THE PORT OF NEW YORK

In order to appropriately close the gap left between the geological history and the present developed state of New York Harbor it is necessary to trace the sequence of events which resulted in the rapid growth and expansion of New York as a seaport.

Three hundred and forty years ago neither the Island of Manhattan nor the lands adjacent to it had yet been subjected to the first of the radical changes which were destined to so greatly alter their aspect in the course of only a few centuries. On the southern portion of the island were a group of wood covered hills surrounded by valleys which contained grass lands, marshes, streams, and a large pond. In the northern portion the land was higher, rocky, and densely forested. The forests abounded with game as did the streams with fish. The name of the island was taken from the aboriginal inhabitants, a tribe of Indians known as the Manhattans and belonging to the Lenni Lenape Nation. The land across the water in all directions from Manhattan Island has changed but little in contour, and as on the island, the one great change in appearance has been the replacement of forests by buildings and paving.

In their own primitive way the Indians were the first to use the waterways and beaches of New York Harbor. The size of their craft, however, never exceeded that of a canoe, and their landing places never amounted to more than a flat rock or a sandy cove. For how long the harbor was thus utilized by them is not known and the probable duration of the conditions existing then, without the advent of modern civilization, is speculative. At any rate nothing was done during that time to alter the natural appearance of the vicinity as it was left by the retreat of the last glacier.

In 1524 Verrazani, a Florentine navigator employed by the French, set out to explore the coast of North America. Reaching the coast somewhere near Delaware Bay, he proceeded northward until he found an inlet which, from his description, can be recognized to be the Narrows. Anchoring his ship outside, he entered the inlet in a small boat and found what he termed a lake. After a very brief inspection an unfavorable wind necessitated his prompt return to the ship, soon after which he departed northward. Thus Verrazani was the first white man to view New York Harbor and Manhattan Island, and while he never even went ashore, his visit formed the basis for the claim by France to this portion of the new world.

The next contact between the old world and New York Harbor was made in 1609. The Dutch East India Company, desirous of finding a route to the Far East via the polar seas, employed Henry Hudson, an Englishman, to investigate the possibilities. Stormy weather and an ice filled sea caused Hudson to give up his objective and, contrary to orders, he sailed for America. After reaching the southern part of the coast he cruised northward, passing the entrances of Chesapeake and Delaware Bays, and arrived at Lower New York Bay. In a small boat he sounded the Narrows, explored Kill Van Kull, and discovered Newark Bay. Later he proceeded up the Hudson River as far as the present site of Albany. This represented the head of ship navigation on the Hudson River and the end of Hudson's search, on that voyage, for a northern passage.

* * *

While the Dutch had not accomplished what they had set out to do, namely discover a new route to the Orient, they did not fail to recognize in the description of the newly explored land an opportunity to profit in another way. Accordingly, during the following year, a fur trading post was set up on Manhattan Island and the first structure of a permanent nature was erected in New York. This, consisting of a small fort which stood on the site of present 39 Broadway, was named New Amsterdam.

The venture was a success and the traders there enjoyed a monopoly in the fur business for many years. By 1623 Holland had become interested in colonizing New Netherland, as the land was called, as well as exploiting it. As a result other settlements were established, principally at Wallabout, Long Island (Walla-bogt or Walloon's Bay), and on the Hudson River near Albany. Once the colonies were established the Dutch set up a provincial government and in 1626 they formally purchased the Island of Manhattan from the Indians for sixty guilders ($24 in American money). As the years passed the colony at New Amsterdam prospered and grew.


Fig. 7.- Nieuw Nederlandt, 1650.

England, meanwhile, basing its claim on the discovery of North America in 1497 by John Cabot, an Italian navigator in the service of King Henry VII, considered itself the rightful owner of the entire eastern seaboard from Labrador to Florida. British and Dutch represenatives discussed the merits of their respective claims for years but nothing was accomplished to reach a definite agreement until one fine day in 1664 when a squadron of British ships appeared in the harbor and demanded the surrender of New Amsterdam. The Dutch forces, being unprepared to call a showdown, were obliged to turn the town over to the British. The community at that time had about 1500 inhabitants.

During the Dutch regime little was done to improve the harbor. All sailing ships in port anchored under the guns of the fort while small boats went ashore. The neighboring settlement on Long Island was not long established before transportation across the East River became in demand. Ferry service was established about 1640 thus developing one of the first waterfront facilities. While the first ferry boats were only canoes and rowboats, flat-bottomed scows to accommodate cattle and freight as well as passengers were introduced at a later date. About this time the first wharf for scows was built on the East River and in 1656 the forerunner of modern seawalls and bulkheads was built on the bank of the East River. It consisted of a row of planks intended to protect the shore from the washing of the tides. In addition to the foregoing there were, when the British took over, two small docks on the East River and ferry service to Pavonia (northern Jersey City).

* * *

Under British domination New Amsterdam soon became known as New York and during the following century prospered, expanding still more than before.

The evolution of the waterfront during this period has been pieced together from odd references. Mention is made of a stone dock having been built by the City in 1675 extending from Whitehall Street to Coenties Slip, and a contemporary sketch in 1679 showed a narrow pier and a portion of bulkhead constructed of unhewn logs laid horizontally to form a crib and filled in with earth. The latter type of construction persisted for many years and examples of this kind of bulkhead are still in use today.

In 1686 the Crown of England granted what has become known as the Dongan Charter (after the name of the governor at that time) to the then municipal corporation of New York. It was destined to have a great influence on the shape of things to come, so far as the waterfront was concerned, from that time on. It included many legislative, executive, and judicial powers and, among other things, it granted to the City of New York all land lying between the high and low water lines to use as was seen fit. The following year saw the first step in the series which eventually extended the waterfront of the city to its present limits. The City determined to build a new street along the East River on the line of Water Street between Whitehall Street and Old Slip. The water lots were to be sold by the City on the condition that the purchaser should make a street to the water and build a substantial wharf at the end of it. This scheme was not actually completed for many years. In 1721 it was decided to extend Water Street from Old Slip to Fulton Street under the same conditions. By 1707 ferry service to Long Island had been greatly improved. A brick inn for travelers and a landing place had been built while two scows and two small boats plied constantly between the shores.

The Cornbury Charter, in 1708, extended the jurisdiction of the City to include Brooklyn from Red Hook to Wallabout out to the low water line. In 1717 another Long Island ferry was established, landings being at Hanover Square and near Broad Street at the Great Dock, as the stone dock there had come to be known. The Broad Street sewer flowed through this dock emptying into the river, probably originating a practice which is still followed today whereby sewers are extended from the ends of streets to pierheads in order that sewage may be dropped within reach of the river currents.

By 1730, when the Montgomerie Charter was granted there were numerous small wharves, slips, and yards for shipbuilding and repairing along the East River and for the first time a few small docks were in use on the North River near Cedar Street. The Montgomerie Charter confirmed the two previous charters and, in addition, granted to the City a strip of land under water 400 feet wide measured out from low water line extending from King Street, North River to Corlears Hook, East River, except for that portion

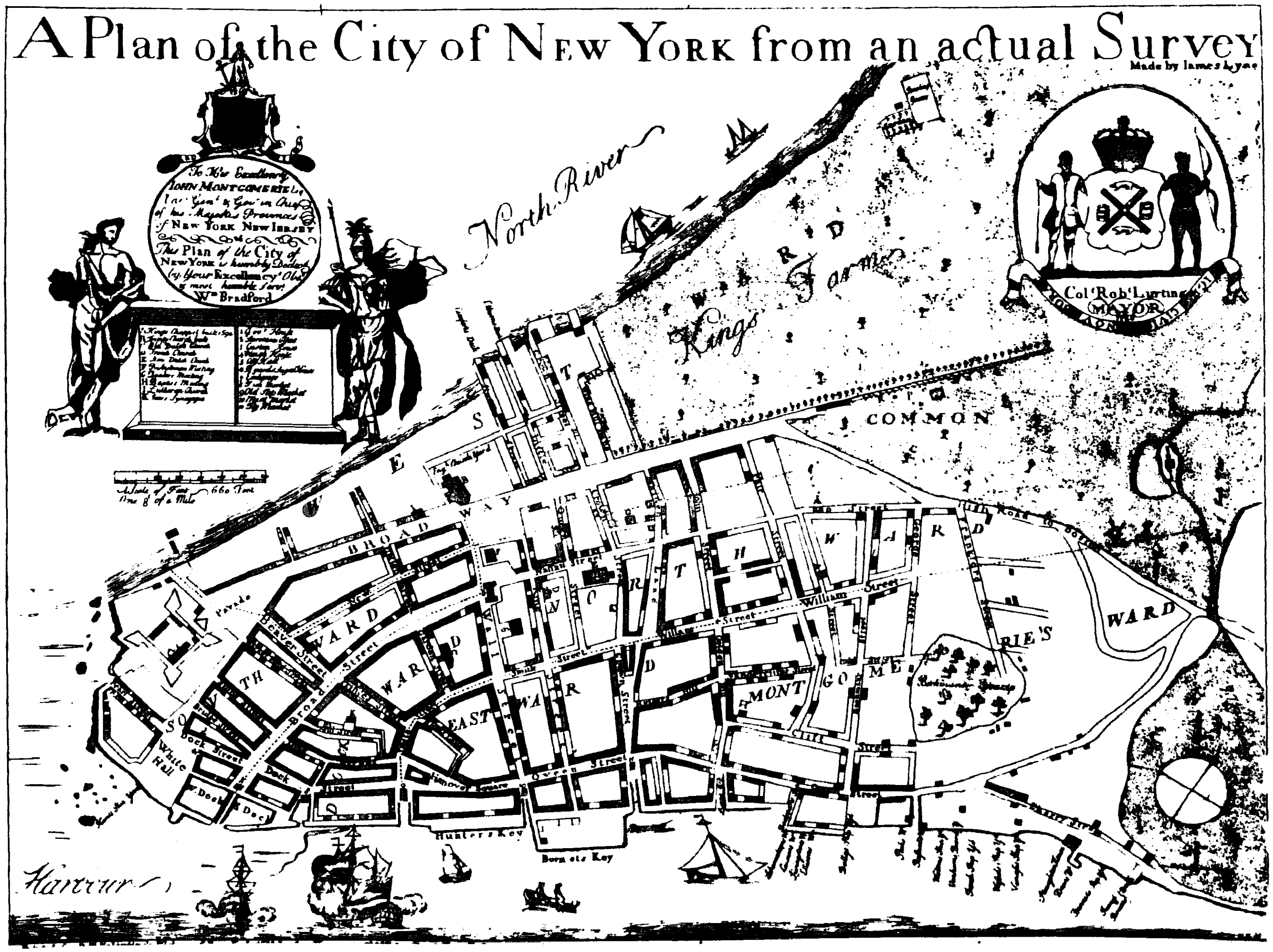


Fig. 8.- An early map of New York City, 1728.

in front of the Battery (Battery Place to Whitehall Street). On this 400 foot strip the City was privileged to act as it saw fit, which included reclaiming the land to the 400 foot mark and constructing wharves along that line. The only stipulations attached to this grant were that a 40 foot wide marginal way was to be maintained just inside the new bulkhead line for "convenience of trade and planting of batteries" and that consent to "wharf out" must be obtained from persons holding previous grants beyond the low water line. Although it was many years before the project then contemplated was carried to completion, the die was thus cast for the future aspect of New York Harbor.

In 1754 Staten Island was connected to the City by the establishment of ferry service, while in 1757 a lighthouse was placed on Sandy Hook and a ferry was established to Paulus Hook (Communipaw section of Jersey City). At this same time Staten Island and Bergen Point were linked by a ferry. Meanwhile packet-boats carrying mail and passengers were in operation between New York and Perth Amboy which, in those days, was the first lap in the journey to Philadelphia.

By 1770 the East River was built solid with docks to Corlears Hook and more facilities were de-

Fig. 9.- The Brooklyn ferry-house, 1746.

veloping on the North River. This growth of waterfront on the North River marked the beginning of a trend which eventually resulted in the major docks of the city being located there. This gradual shift was due originally to the greater depth of water and width of channel to be found in the North River, but later it was accelerated by the advent of railroad terminals on the Jersey side of the river.

* * *

During the American Revolution the population of New York dwindled from over 20,000 to less than 10,000 and the docks, from protracted disuse, fell into a bad state of disrepair. At the close of the war interest in the waterfront was renewed and the State of New York assumed control of and legislated all unceded crown lands under water in navigable streams. The City also became commerce conscious again and, in 1796, South Street and West Street were established. Under the terms of the charter the grants were measured out from the original shore line, so, to prevent the streets from following this irregular outline, it was decided to increase their width to 70 feet and lay them out in straight lines.

Two years later the State was petitioned to permit the construction of piers at right angles to the new marginal streets. Permission was granted and the City passed an act whereby piers would be sunk "with suitable bridges to accommodate ships and upon such construction as to permit the currents of the rivers to wash away the dirt". It was further enacted that no buildings whatsoever except the piers themselves were to be erected on the streets or wharves between them. This was the beginning of the existing pier and bulkhead system which is in existence to this day. The expression to "sink" a pier will be understood better after reading about types of construction in a later chapter. At that time timber piers were built up from the river bottom and were spanned by beams and decking in much the same manner as in bridge construction. The reason for building on piers in order that the current might flow freely underneath was to alleviate a disagreeable condition which had developed and which is described in a later paragraph. By the turn of the century there were about forty landing places on the East River and ten on the North River.

* * *

The Nineteenth Century witnessed tremendous changes in New York Harbor the causes for which were both manifold and to a certain extent interdependent. By virtue of the fact that, in 1807, the first successful steamboat was built and operated on the Hudson River, New York Harbor came to be known as the Cradle of Steam Navigation. By 1830 it was the world's leading shipbuilding port, contributing the Savannah which, built in a yard at Corlears Hook and launched in 1818, was the first steamer to cross the Atlantic. The process of replacing sails with steam-power required many years and was not yet completed at the end of the century. As a matter of fact an occasional sailing ship may still be seen today.

The size of new ships began to steadily increase and has continued to do so right up to the present time. As the ships grew in length, draft, and tonnage the terminal facilities for them naturally had to keep pace, necessitating longer piers, deeper and wider slips and channels, and larger storage spaces for cargo.

In 1825 a new method of transportation was introduced in the State of New York. The Erie Canal, which connected the Great Lakes with the Hudson

River, was completed and the resulting traffic between the interior of the country and the seacoast was transhipped in both directions in the Port of New York. To accommodate the large number of barges and ships occasioned by the canal more landing places had to be provided.

* * *

One of the first railroads to make its appearance in the United States was built in 1830 between Camden and South Amboy, New Jersey. Known as the Camden and Amboy Railroad, it replaced the stagecoach in the overland portion of the journey between New York and Philadelphia. The subsequent development and growth of American railroads was phenomenal and New York Harbor, due to its topography, was a naturally suitable location for the railroad tidewater terminals. When the railroads arrived at New York Harbor, as they did during the period between 1840 and 1890, the Port expanded with the construction of new freight piers, transfer bridges, and passenger ferries at a rate that far exceeded the expectations of those with even the greatest vision and foresight. So fast and so great was the growth that it was never feasible to completely modernize the terminal facilities. The original system, once established, grew to such magnitude in such a comparatively short period of years, that to change it, when the need was recognized, would have required such an expenditure of capital that the reorganization was economically precluded. Consequently there have been no radical changes in the freight terminals for eighty years, although improvements have been periodically made to the original system to meet immediate necessities.

Prior to 1840 coal mining in the United States was of inconsequential proportions, but, with the invention of the steam engine and its application in steamships, railroads, and in manufacturing, together with the use of steam for heating purposes, the demand for coal skyrocketed. By 1900 the United States was mining more coal than any other country in the world and a large volume of it was handled by the Port of New York both for export and local consumption.

Thus it is seen that the expansion of New York Harbor, which could be described graphically as a geometric progression, was coincidental to and parallel to the expansion of the entire nation, resulting not from any one activity but from a combination of many. To the factors already enumerated may be added the development of agriculture, manufacturing, steel mills, and immigration from Europe. All of these elements were more or less dependent upon one another, and each contributed in a measure, either directly or indirectly, to the growth of New York City and the need for additional waterfront facilities.

* * *

In order that the changes made along the waterfront may be followed in some degree of detail it is well to review the chain of events from the beginning of the Nineteenth Century.

By an act of the state legislature the 400 foot strips commenced by the Montgomerie Charter were extended, in 1807, to 75th Street on the North River, and to 40th Street on the East River.

During the time of our second war with England commerce stagnated and New York, along with our other seaports, suffered a decline. At the close of the war commerce quickly revived and repairs, improvements, and new enterprises were inaugurated along the waterfront.

In 1817 the first regular line of packet-ships to Liverpool, the Black Ball Line, was established. This line consisted of ships between 400 and 500 tons. Other lines soon followed and for the first time regularly scheduled transportation was available to Europe.

Prior to 1814 all of the ferry boats in service utilized oars or sails for motive power. The landing places of the principal lines had been considerably improved and included taverns and stables. The ferry slips consisted of several boom logs fastened together and anchored in such a manner as to guide the boats as they came in. Crude landing bridges were also in use. These were built so that they would float and thus conform with the stage of the tide. These early models of the ferry bridge had no gallows frame and had no overhead shelter whatsoever.

In 1814 horsepower was introduced to propel the ferries. The ferries were built with tandem hulls, the treadmill and paddlewheel between them. As many as eight horses were used on one boat. In the same year it was attempted to substitute steam-power for horse-power but for six years the horse-power proved cheaper and only one steamboat was in operation. In

1822 a new design brought the steamboats into prominence. They now had a single hull with side-wheels. At this same time floating landing bridges were provided with a gallows frame and counterweights, together with spring piles to guide the boats. These innovations were so successful that plans hitherto considered for spanning the Hudson with a stone arch bridge were discarded.

By this time a few docks had been built in Brooklyn and the piers on the North and East Rivers were numbered each way from the Battery.

Graphic descriptions of the appearance and condition of the docks in the neighborhood of 1824 are supplied by two contemporaries, the first a foreigner, the second an American.

"The slips run up a considerable way in the center of the buildings as though it were in the middle of the street. They are built or faced up with logs of trees cut to the requisite length, and allow the free ingress and egress of the water, and, being completely out of the current of the river or the tide, are little more than stagnant receptacles of the city filth, while the top of the wharves exhibits one continuous mass of clotted nuisance composed of dust, tea, oil, and molasses and where revel countless swarms of offensive flies."

"The time has not yet come for the formation of massive permanent quays in the Harbor of New York. Wood is still too cheap and labor too dear for so heavy an investment of capital. All the wharves of New York are of very simple construction: a framework of hewn logs is filled with loose stone and covered with trodden earth. The Americans are daily constructing great ranges of these wooden piers in order to meet the increasing demands of their trade. While the whole of the seven miles which fronts the City is lined with similar construction, if we except the public mall called the Battery which is protected from the waves of the Bay by a wall of stone. The wharves of New York form a succession of little basins which are sometimes large enough to admit 30 or 40 sail, though often much smaller. These irregular docks have obtained the name of slips."

While these slips were eventually filled in, many of the old names, such as Coenties Slip, Coffee House Slip, Fly Market Slip, Pike, James, Catherine, and so on are still retained.

In 1826 the 400 foot strips were again extended, this time to the Spuyten Duyvil on the North River and to the Harlem River on the East River, thus making the entire length of Manhattan Island available for use on both sides.

The federal government thus far had little or nothing to do with the waterfront or waterways, but in 1835 the first United States survey of the harbor was made. Prior to the survey, Gedney Channel was the only known passage through Lower New York Bay to the sea, but as a result of the survey, another natural channel, which was called the East Channel, was disclosed. This was improved many years later and renamed Ambrose Channel. The ships of the navy were, at that time, the largest afloat and had a maximum displacement of only 1,000 tons and a draft of 26 feet, so that improvements to the harbor approaches had not yet been found necessary.

The rapid growth of the Port caused many of the older piers in use at the time to be considered antiquated and obsolete, even at the still early date of 1836. A portion of a report of a committee on wharves in that year is quoted in part.

"Of the present piers or wharves the supports occupy in the whole extent, more than one half of the waterway. This occasions deposits against the solid blockwork parts. Mud accumulates and partly fills the spaces left between the blocks, thus checking the passage of the current caused by the tide. In the narrowest parts of the East River, the masses of stone thrown in to form the blocks have, in many cases, collapsed from the destruction of their wooden enclosures."

From this it can be seen that the piers founded on rock filled cribs were early recognized to be undesirable, but, because all dockbuilding was still done by hand without the aid of machinery, this type of construction persisted because it was the quickest and cheapest means of providing wharfage.

Beside the fact that many piers were in poor condition, it was deemed in 1840, that the docking facilities were not extensive enough to handle the volume of cargo which passed through the port. At this time, with 63 wharves on the East River and 53 on the North River, the waterfronts of Brooklyn and New Jersey began to develop appreciably. One of the major projects, located in Jersey City, was the construction in 1847 of the docks for Cunard Steamship Company.

By another act of the legislature the State ceded to the City title of lands under the 400 foot strips of water that have been previously mentioned. By so doing the State, while it still maintained jurisdiction over navigable waters, relinquished control of the land along the waterfront and the construction thereon. For a number of years various departments of the City administered the waterfront in their own way, until some changes were made in the system as is described later.

Navigation to New York City through Long Island Sound had always been hazardous even with a favorable tide. The passage through Hell Gate was narrow, tortuous, and studded with numerous rock obstructions. In 1853 the United States, for the first time, undertook to make improvements in New York Harbor. The work consisted of dredging and removing some of the rock obstructions at Hell Gate. Years later this project was expanded to include a large amount of dredging and the removal of Flood Rock, a description of which appears in a later chapter.

Further attention to the East River channel was attracted in 1855 when objections were raised to the manner in which piers were being erected, particularly in the vicinity of the Brooklyn Navy Yard. It was contended that the channel and harbor were being unduly encroached upon and the state legislature was petitioned to have certain offending piers removed and to lay out a pierhead line to prevent "injury to commerce". No definite lines were established at this time however.

As time went on the average dock and wharf underwent some changes. By the middle fifties the rock filled cribs, which served as supports for the wharves, were gradually being replaced by open piling which allowed the currents of the tide and river to move much more freely underneath. The use of steam-power to operate drop hammers undoubtedly strengthened the trend toward pile driving in preference to cribwork. The size, as well as design, of the wharves was also changing. By now the average length was about 250 feet, while some exceeded 300 feet.

An investigation relative to harbor obstructions in 1856 evinced an interesting bit of testimony concerning wharf construction at that time. It

Fig. 10.- New York Harbor with Governor's Island in foreground, 1855.

brought out that the pine planking used as decking had to be renewed in 4 to 5 years, that decks wore out more quickly using horse-power for the hoisting treadmills than when using the old man-power method, that the life of a pier was estimated to be 30 years, and that a new pier cost about $45,000 to build.

In 1860 the Great Eastern, then the newest and largest steamship, made its maiden trip to America. She drew 27 feet of water and there was considerable speculation as to whether or not she could enter New York Harbor. However, by waiting for high tide, the ship successfully passed over the bar through Gedney Channel and, after this severe test, the channel was considered adequate for the next 20 years.

About this time, to help one to appreciate how the aspect of Manhattan had changed, it was estimated that the average margin of land reclaimed from the rivers was well over 600 feet. There were 22 ferries connecting the island with its adjacent shores, while 7 railroads had already established their railheads on these shores. In addition there were 18 steamship lines operating in New York Harbor. The railroads, between their passenger service and freight service, were beginning to contribute a fair

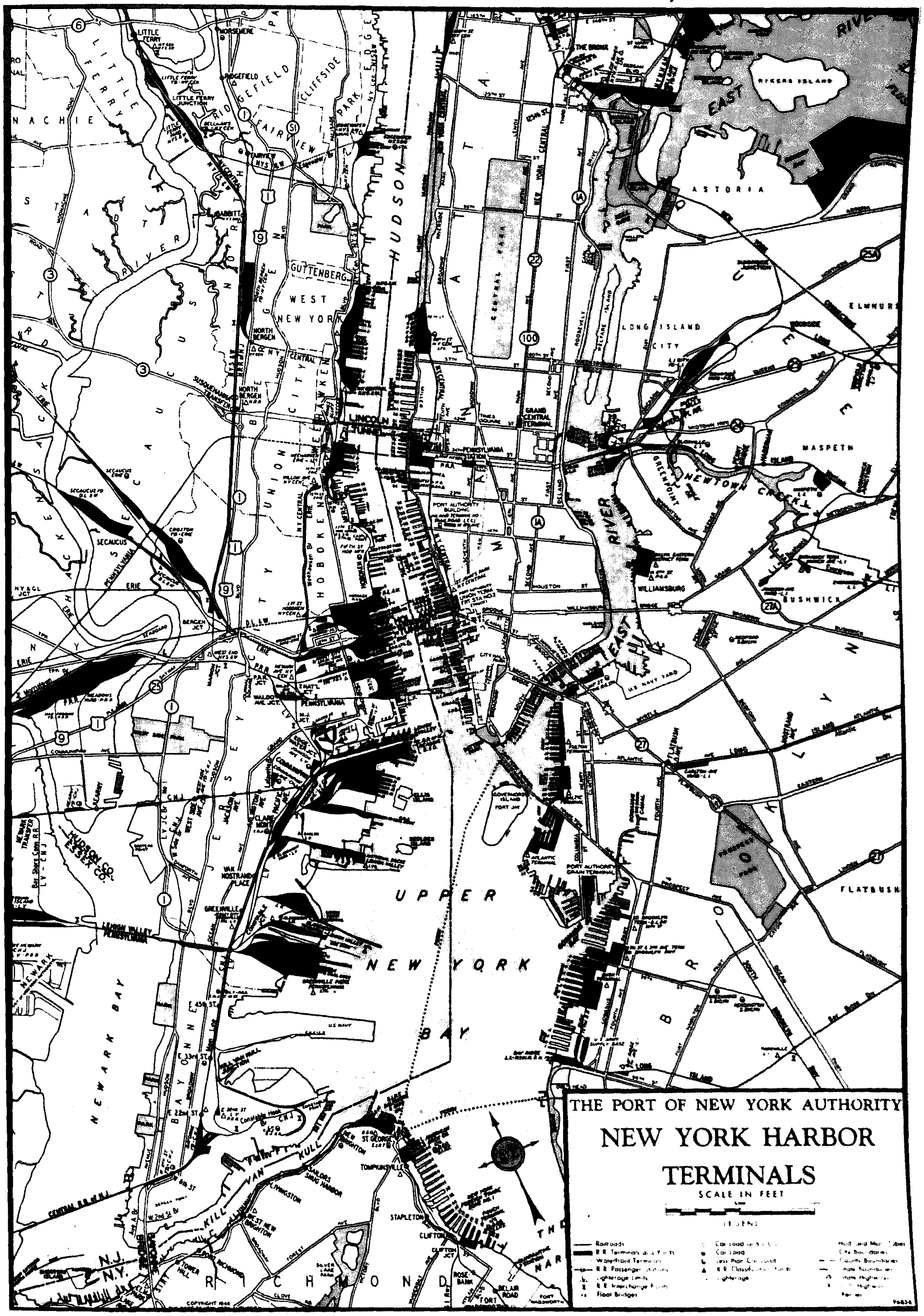


Fig. 11.- Harbor terminals, Port of New York.

share toward the total amount of waterfront construction and in 1866 the first railroad carfloats made their appearance.

* * *

At the close of the Civil War the demand for wharfage was again great, and again the subject of the condition of the docks was brought up. A committee was appointed by the City and another by the State Senate to investigate the situation. Their findings were in mutual agreement and, in 1866 their reports echoed what was well known and had been reported by an earlier committee 20 years before. They found that conditions were "deplorable", that all of the docks were wood and none except a very few were covered (which was in accordance with the law), that the structures were deteriorated, that the rock filled cribs supporting the short wharves which projected into the river obstructed the tides and caused the slips to fill up with sewage, that facilities were "not only inadequate and inconvenient but a danger and a disgrace", and that commerce was seeking better accommodations in other ports of entry on account of all the foregoing.

In all probability the reports were not exaggerated because, up to this time, the waterfront had been built almost entirely by private interests under no comprehensive plan. The City, as an expedient to get docks built in a hurry when the increase in commerce demanded it, had given the private interests an almost free hand to build on their water grants as they themselves saw fit. The types of facilities to be found between Pier 1 and 12th Street, North River, were most diverse but not all an asset to the waterfront. In this stretch was to be found, both fixed and floating, an assortment of lumberyards, brickyards, and boiler shops, also hay barges, and warehouses as well as dwelling houses.

In keeping with this hodgepodge was the City's system of administration of the waterfront at this time. Prior to 1870 the Commissioners of the New York City Sinking Fund issued the grants of land under water and leased wharf property. The Board of Aldermen could authorize the construction of new piers and bulkheads and the filling in of areas to be reclaimed. The function of the Superintendent of Docks was to see that proprietors kept their wharves properly maintained, while the Commissioner of Streets supervised dredging and filling in of waterfront property as well as the repairing of the water streets and the marginal way. The rents from city owned wharves were collected by the Comptroller, while the ships at the wharves were regulated by Harbor Masters.

As a result of the investigations it was decided that steps should be taken to bring all functions pertaining to the docks under one department and to commence a general rehabilitation of the waterfront. In 1870 the Department of Docks was created to accomplish this. The new department was given the exclusive power to control all waterfront property in New York City which included the wharves and bulkheads, the buildings on them, and the waters adjacent to them. New construction, repairing, altering, strengthening, leasing, and dredging were also placed under it, as were practically all other matters pertaining to the docks.

Plans were formed by the Dock Department whereby the old waterfront structures which were considered obsolete would be demolished, the slips filled, and new piers, both longer and wider, would be built in their place. It was also proposed to widen West Street to 250 feet, South Street to 200 feet, and to erect a granite bulkhead wall all along the bulkhead line. In collaboration with these plans the State of New York agreed to extend the 400 foot strips to 1,000 feet for construction of waterfront facilities. The Dock Department was authorized to acquire the necessary wharfage either by purchase or condemnation proceedings and, in 1871, work on the project was commenced between Canal Street and 11th Street on the west side. The granite walls were designed to be monumental in appearance and were built in a manner to insure their endurance. A description of this wall appears in Chapter IV.

* * *

While the City of New York was engaged in the improvement of its docks, influence was brought to bear upon the Federal Government to undertake the improvement of the waterways between the docks and the open sea.

Some of the earliest work was done under the River and Harbor Act of March 3rd 1875 and consisted of removing mud bars off Jersey City, New Jersey. At later dates the original project was enlarged and many others were begun as the interest of the Federal Government in navigable waters increased.

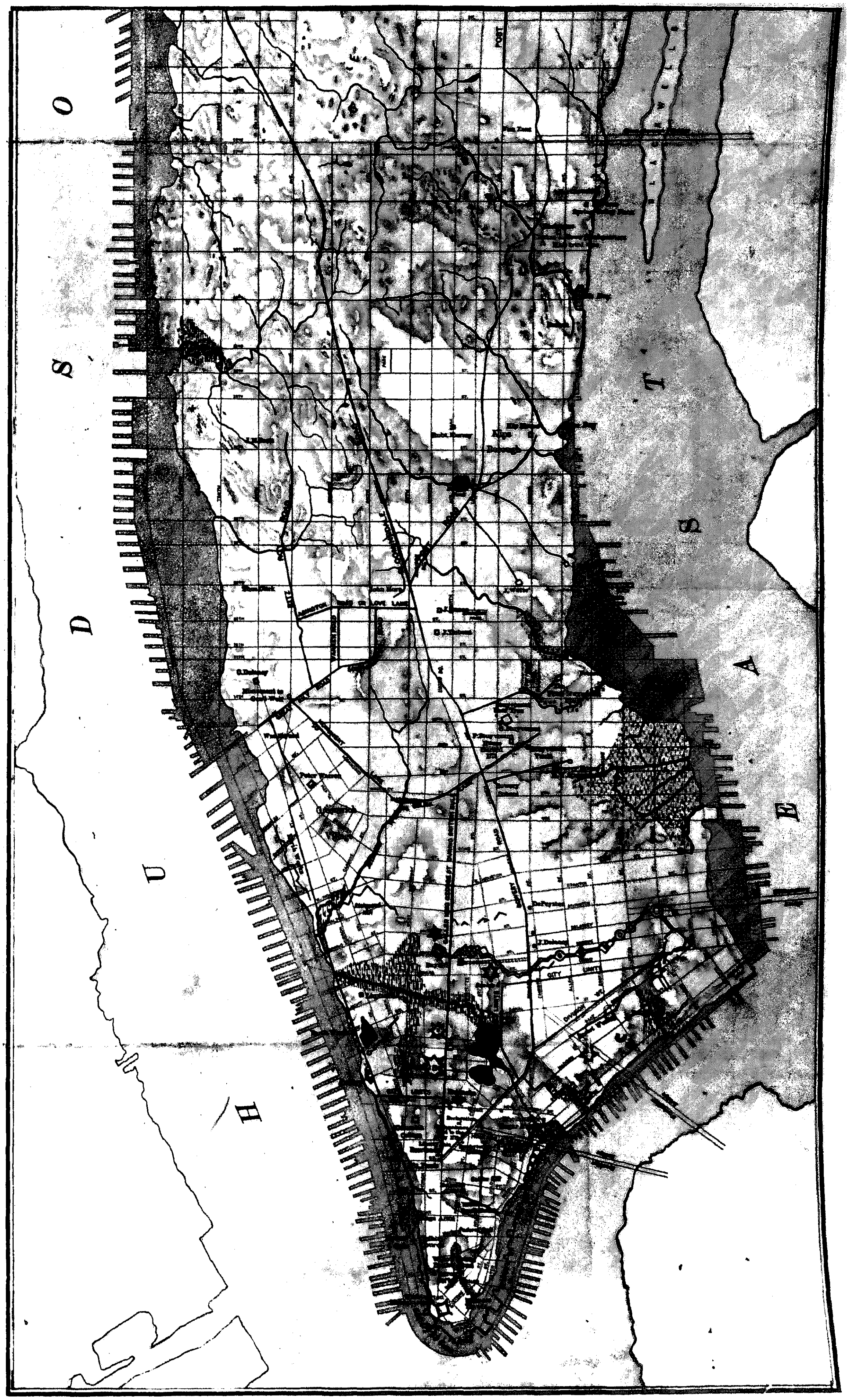

Fig. 12.- Lower Manhattan Island, as it was originally, in 17[illegible], and in [illegible].

By another River and Harbor Act in 1884, federal funds were appropriated to improve Gedney Channel through Sandy Hook Bar. This project was to provide a width of 200 feet and a depth of 28 feet below mean low water. At that time it was not universally believed that dredging alone would provide a permanent improvement and it was therefore proposed to strengthen the flow of tidal currents through the channel in an effort to make it maintain itself. To affect this the entrance of Lower New York Bay would have been contracted by a jetty from Coney Island, and the head of Sandy Hook would have been protected with riprap. This plan however had many opponents who held that the jetty would present a serious obstacle to navigation and that many small craft, not requiring a deep channel, would be forced miles off their course to enter the bay. Perhaps the high estimated cost of the project aided in the reaching of a decision to first experiment in dredging. The work was commenced in 1885 and, after several unsuccessful attempts which are described in Chapter VIII, a practical method of dredging ocean bars was developed.

At this time the use of steel had been introduced in shipbuilding and the former limits to the size of hulls were greatly exceeded. This was at least one of the reasons why, before the original project was completed, a still larger entrance to the harbor was deemed desirable. In any event the revised project provided a channel 1,000 feet wide and 30 feet deep at mean low water from the Narrows to the sea. This improvement, which included not only Gedney Channel but Main (Bayside) and Main Ship Channels as well, was completed in 1891.

By now the government was going in for harbor improvement in a big way. In 1896 dredging of the Bay Ridge, Gowanus Bay, Red Hook, and Buttermilk Channels to depth of 26 feet was authorized. In the meantime, so great had been the increase in draft of newly constructed ships that recommendations had been made to dredge a 40 foot channel. It was decided to improve East Channel, obtaining a depth of 40 feet and a width of 2,000 feet. The channel was renamed Ambrose Channel and the work, commenced in 1901, was finally completed in 1914.

Ambrose Channel had been completed for only three years before its extension through the Upper

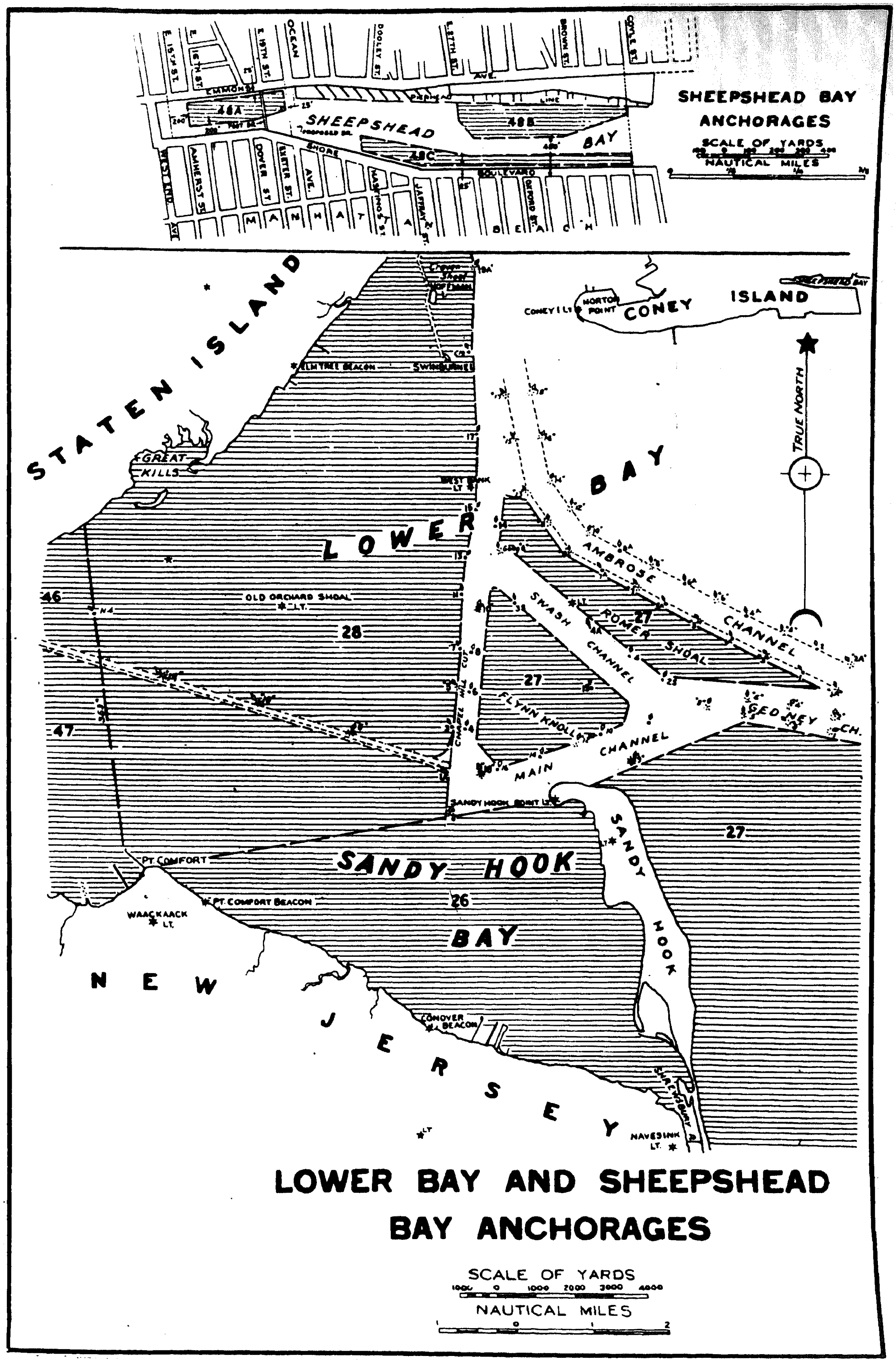


Fig. 13a.- Channels and anchorages in Lower Bay.

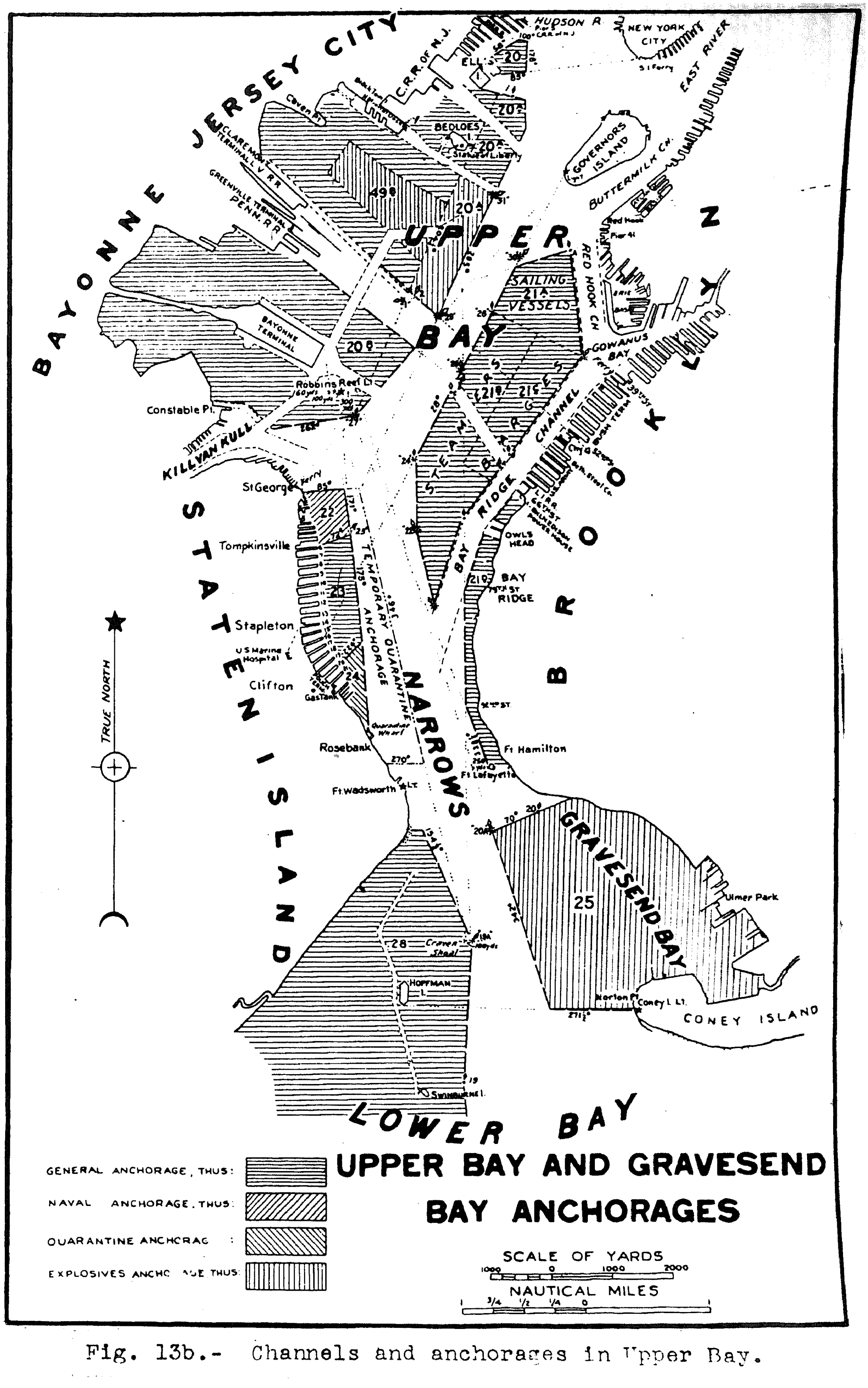


Fig. 13b.- Channels and anchorages in Upper Bay.

Bay was begun. This, the Anchorage Channel, was completed between 1917 and 1929.

In 1935 the North River Channel consisted of a 40 foot depth for its full width from deep water off Ellis Island to 59th Street, with an extension 750 feet wide and 30 feet deep along the Weehawken-Edgewater waterfront.

The most recent improvements in the North River were brought about by the advent of such ships as the Normandie and Queen Mary, both of which drew approximately 40 feet when loaded. In 1937 congress authorized improvement of the Ambrose, Anchorage, and North River Channels to provide a width of 2,000 feet from the sea to 59th Street. There was to be a depth of 45 feet to 40th Street and 48 feet deep between 40th and 49th Streets. The additional 3 feet was approved to provide sufficient water under the keel to facilitate the maneuvering of the large liners which berth there at the Trans-Atlantic Steamship Terminal.

Other important, though smaller, channels such as the East River, Harlem River, and the Kills have also been improved proportionately.

* * *

In 1888 two more changes were made pertaining to the use of land under water. The State granted to the City the strip along the Bronx waterfront from the present city line on the Hudson River to the Bronx River on the East River side. The other change was brought about by an act of congress, whereby the United States Government assumed control of navigable waters. The responsibility of fixing pierhead lines, bulkhead lines, channels, and anchorages, as well as maintaining depths of water adequate to meet the requirements of navigation, was turned over to the War Department. Thereafter there has been no local or state control beyond the pierhead and bulkhead lines. Since that time however, the New York City Dock Department has occasionally requested that the pierhead line be extended outward to permit the construction of longer piers to accommodate larger ships. The requests have usually met with favorable action, but the limit has been just about reached at the present time.

There are two important considerations which have to be made before permission can be given to further extend either the existing pierhead lines or bulkhead lines. The first has to do with the size of the ships which must be berthed nowadays. The largest Trans-Atlantic liners are over 1,000 feet in length and, when headed into their slips on the North River, they extend more than one third of the distance across the channel which is about 2,800 feet between pierheads. Ships in this position form a barrier across a large portion of the natural flow of the river and thus become both difficult to handle and an obstruction to other river traffic. To reduce the channel width any more would cause these conditions to become worse.

The second has to do with the volume of the tidal prism. Between the times of low tide and high tide a large volume of tidal water enters the harbor through the Narrows, the East River, and the Kills. Between high tide and low tide this same water plus the discharge of the Hudson, Passaic, and Hackensack Rivers, makes its exit through the same passages. The volume of water that thus enters and leaves the harbor between tides is equal to the tidal prism. The flow of these tidal currents has a scouring effect on the channels in the harbor with a tendency to help maintain them. There is a minimum volume below which the channels would no longer benefit from this scouring and would tend to silt up more rapidly. For this reason the Federal Government does not indiscriminately grant permission for the extension of pierhead and bulkhead lines when the result might be to unduly reduce this volume. Even where bulkhead lines have been established by the War Department it is necessary to obtain permission to fill in the area between the bulkhead line and the shore.

* * *

Since the beginning of the 20th Century the growth of the New York waterfront has continued as before. Occasionally new areas have been developed to fulfill the requirements of increased shipping volume and to accommodate the establishment of new industrial facilities. Likewise there have been times when the older and more obsolete piers were replaced with new construction as an improvement to the harbor.

In 1902 for instance, the City of New York commenced to build a series of piers on the North River in the vicinity of Fifteenth Street. They were designed to be both large in size and monumental in appearance with ornamental masonry work facing West Street. These piers, known as the Chelsea Docks, were for many years the pride of the City and the terminal for the larger ocean going steamships.

Several new industries have been developed largely during the past half century. The use of electricity both for lighting and for power, while originally introduced about 1890, spread tremendously in the last three decades. The noticeable effect of this on the waterfront has been the construction of numerous power plants, built at the waters edge to facilitate the delivery of coal which is used to furnish power for the steam turbines. Similarly, since the coal is towed to the plants in scows, facilities for transferring it from railroad cars to scows were required. Trestles were the early answer to this problem but today the greatest percentage of such coal is handled by car dumpers.

The invention and use of internal combustion engines which, during the last thirty years have led to the present great demand for petroleum products, was responsible for the development of another type of facility. Since most of the oil refined and distributed in the New York area is transported by means of tankers, a large number of oil docks have been constructed.

While not all commodities are in demand to the same great extent as coal and oil, there are others which, when handled in bulk, have warranted the construction of a special type of facility on the waterfront. Such facilities, as well as the two foregoing, are described in the next chapter.

* * *

When World War I ended, transportation interests in the Metropolitan area directed their efforts toward the improvement of port and terminal facilities in New York Harbor. To ascertain what might be accomplished, the New York and New Jersey Port and Harbor Developments Commission was appointed by the governors of both states. In the joint report made by the Commission in 1920 a plan was recommended whereby the waterfront would be eventually reorganized in the following manner:

1. Rebuilding the Manhattan piers and slips much wider.
2. Building piers with two stories for their full length and providing adequate driveways and ramps for both levels to speed the movement of freight on the pier.
3. Building multiple-story warehouses on

the marginal way for convenient storage of freight.

4. Constructing an elevated highway along the river to separate local and through traffic.
5. Gradually discontinuing ferry service and diverting traffic by means of tunnels. Using the space formerly occupied by ferry slips for new piers.
6. Eliminating the present rail terminals on the Jersey side by constructing a marginal belt railroad with a deep tunnel to Manhattan.
7. Dredging channels consistent with the traffic to all parts of the waterfront.
8. Removing and modifying bridge obstructions.
9. Building additional facilities for the New York Barge Canal traffic.
10. Forming a central authority with extensive powers, for the overall direction of a long range comprehensive plan for construction.

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10. Forming a central authority with extensive powers, for the overall direction of a long range comprehensive plan for construction.

Acting upon the recommendation of the Commission the States of New York and New Jersey, by adapting a compact which was effective April 30, 1921, established the Port of New York Authority. It was recognized that, due to the geography of the Port and to the fact that it would be difficult for two states to work together efficiently on the same project, such an organization would best serve the interests of the public. The Port Authority is a corporate municipal instrumentality which provides a medium through which the efforts of both states can be combined to promote and develop the commerce of the Port with emphasis on the improvement of transportation and terminal facilities. It is authorized by the states to exercise power within a radius of about 20 miles from the Statue of Liberty.

It may be seen that several of the recommendations made by the Port and Harbor Development Commission have since been carried out.

Perhaps results from the newly formed Port Authority were not coming fast enough to please all interests concerned, for about 1924 considerable criticism was voiced concerning the inefficiencies of the Port. It was claimed that European ports were far superior to those in America. More specifically it was claimed that such ports as London, Liverpool, Hamburg, and Rotterdam, each only one fifth the size of New York, could handle the same volume of traffic. Marseilles, it was claimed, averaged 1,500 tons per foot of quay as compared to New York's 150 tons. The reason for these comparisons, allowing that they may have been true, is easy to account for. New York Harbor had a wealth of space and had only to expand when the occasion demanded, whereas the foreign cities enjoyed no such natural harbors and their ports had to be carefully designed and built for the maximum of efficiency from what was available.

* * *

While New York has not produced the maximum possible efficiency from its natural assets, it may not be said that no effort has been made to provide modern,up-to-date cargo and passenger facilities. One of the more recent large scale waterfront improvements was completed on the North River in 1936. Representing the terminal facilities for the largest and most modern luxury liners, it consisted of the construction of Piers 88, 90, and 92, a project described in some detail in Chapter Eight.

Other plans to modernize the harbor were sidetracked when World War II broke out. While construction in the harbor continued at a high rate, the work done consisted primarily of building the Bayonne Navy Yard and such other facilities as were required by the Army and Navy.

At the end of the war in 1945, harbor improvement was again seriously contemplated. Thus far, at the end of each major conflict in which this country has participated, attention, after having been previously directed elsewhere for a long period, has reverted to the condition of the piers, thereby making a regular cycle. Again, as in years past, the poor condition of the older piers was publicized and plans were brought out for the rehabilitation of the waterfront.

One plan was proposed by the World Trade Corporation, an organization created by the New York State Legislature in 1946 to operate piers and warehouses, foreign trade zones, and so forth, for the improvement of commerce. Another proposal was advanced by the New York City Department of Docks. Its scope was not as broad as that of the World Trade Corporation, due largely to the fact that it would have to be financed by New York City which had other projects, such as housing, schools, and hospitals, which rate a higher priority.

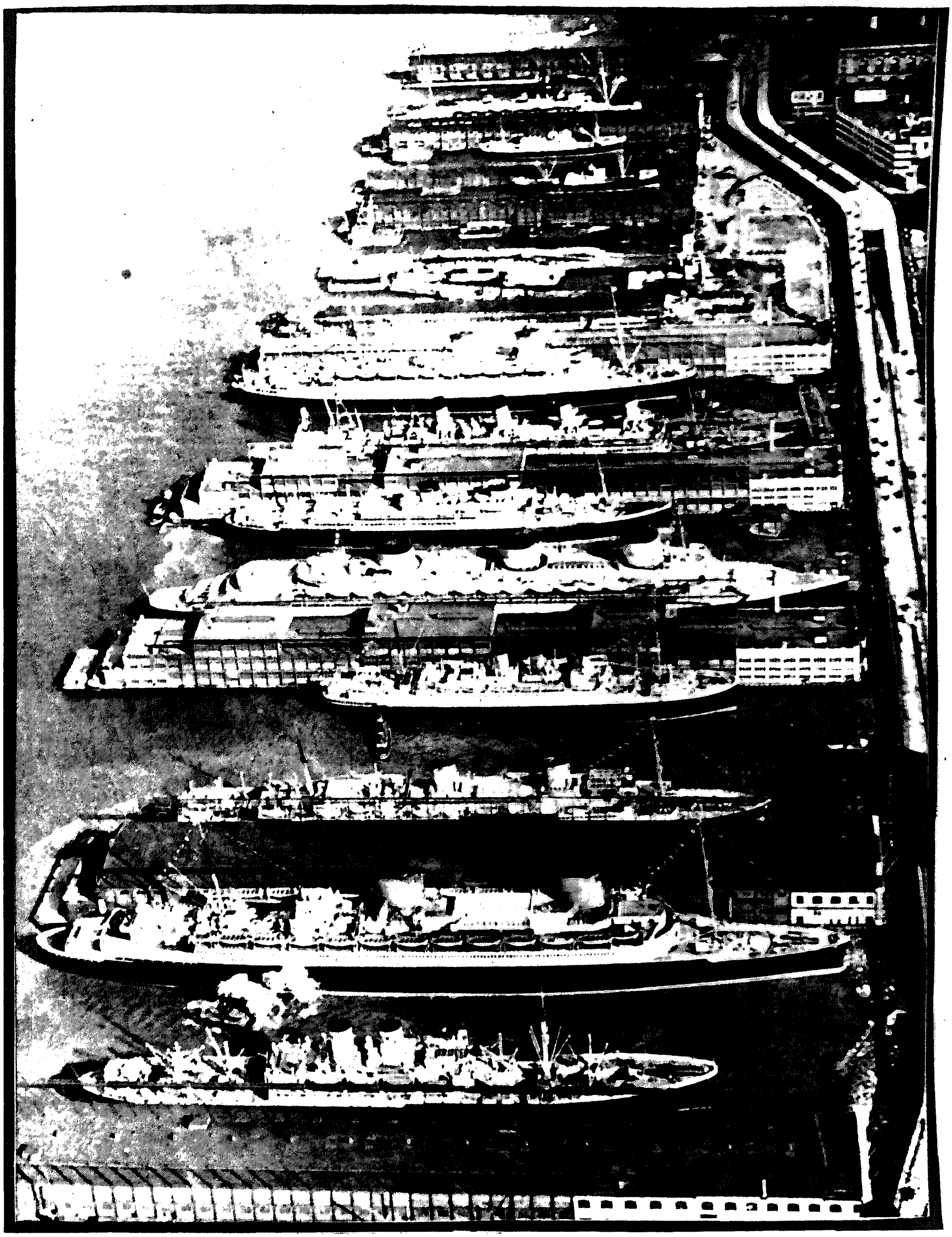


Fig. 14.- The Trans-Atlantic Steamship Terminal.

On the invitation of the Mayor of New York, the Port of New York Authority also submitted a proposal to rehabilitate and operate the New York waterfront. Its plan was by far the most comprehensive, outlining a plan whereby the docks could be modernized and made self-supporting over a 20 year period. This plan had much merit, but did not gain approval because revenue derived from the docks in New York might very possibly be diverted to enterprises in New Jersey where the Port Authority is equally interested.

Thus far, the City of New York has been unable to bring itself to allow such possible revenue to leave the City proper. Consequently the prospects of the Port Authority ever taking over the operation of the waterfront facilities of New York, as was contemplated when the compact establishing the Port Authority was made, are at present dim.

The World Trade Corporation appeared for a while to be in a favorable position for obtaining authorization to handle the operations. Had it taken over, the prospective revenue could not have been diverted out of the City, and the City could have recaptured the administration at any time it so desired by buying out the interests of the Corporation.

For reasons best known to New York's city fathers however, the plans of neither the Port Authority nor the World Trade Corporation were found acceptable. It was decided that jurisdiction over the docks should be retained by the City. The rehabilitation program therefore, in spite of the fact that sufficient funds to carry it out vigorously do not seem to be forthcoming in the near future, is to be commenced by the City's Department of Docks.

# CHAPTER THREE

## THE TYPES OF WATERFRONT FACILITIES

The New York waterfront at the present time is composed of a great variety of structures. Many are similar in appearance, a few are identical, all have one thing in common, a particular purpose to serve. The different types of facilities in use today are the result of a process of evolution which began in the early days of New York. It was found then that greater profits could be realized by investing in the construction of landing places which eliminated the expense of lightering cargo and passengers between ships and shore. Similarly it was found, as time went by and the volume of maritime traffic increased, that the development of larger ships necessitated longer docks and greater areas for the storage of cargo.

An observation of the waterfront will reveal that terminals for ocean traffic are not the only products of this evolutionary process. Interests other than those of overseas shippers were able to capitalize the harbor. The establishment of ferries and the advent of the railroads have already been described while the existence of shipyards has been alluded to. To best serve the interest of some industries specially designed structures have been erected, while others have been instituted for the benefit of commerce and transportation within the port itself. Following the dictates of greater economy and convenience, the designs of the various waterfront facilities have continually been changed until there is now a wide variety in existence.

In the Port of New York, as in any port, the principal operation performed is the movement of freight. This includes transferring it from railroad cars, trucks, and industrial plants to ships and vica versa. To accomplish this a system of piers and quays has grown up apace with the increase in volume of freight moved.

The great majority of steamship terminals are covered piers. Those intended for handling freight exclusively are usually one story structures while those utilized by lines in the passenger service are frequently two and sometimes, as in the case of the Trans-Atlantic Steamship Terminal at West 48th Street, three stories high. Most covered

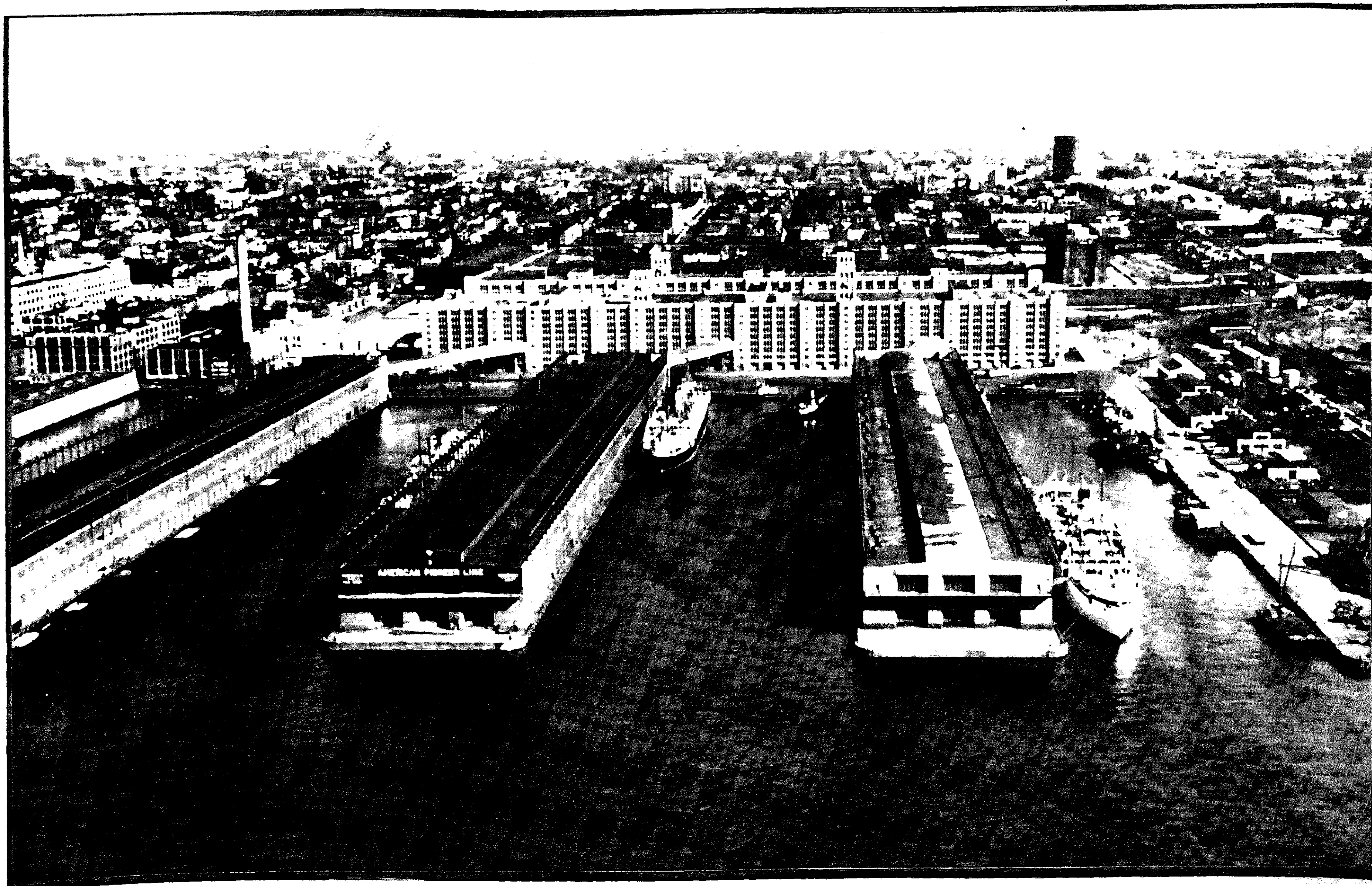



Fig. 15.- Covered steamship piers, U. S. Army Base, Brooklyn.

piers are provided with cargo doors on both sides along their entire length so that cargo can be moved directly between the pier and the holds of a ship no matter where the hatches happen to be. Tracks to provide access by railroad have been laid on many piers, located mostly in New Jersey, so that cars can be unloaded into the holds with one handling. Practically all have a driveway for trucks to permit the pickup and discharge of cargo at any point on the pier. Many of the older piers of this type, originally built during the era of horse-drawn vehicles, are so narrow that it is difficult for heavy truck traffic to move freely on them. The more modern piers have been built with much greater width to overcome this disadvantage.

At several locations in the harbor there are large warehouses built in conjunction with piers. They are situated at the bulkhead line and provide conveniently located storage space for freight. By utilizing this space both before the arrival and after the departure of ships, the heavy truck traffic usually coincident to ship movements has been considerably reduced. This type of pier-warehouse combination is illustrated by the Harborside Warehouse, Jersey City, Bush Terminal and the Army Supply Base, Brooklyn.

On Manhattan Island most of the covered piers have so-called bulkhead sheds built parallel to the marginal streets and closing the space along the bulkhead between adjoining piers. These sheds are provided with cargo doors and loading platforms facing the street to expedite the delivery of freight by trucks.

While the majority of the New York piers are for steamship traffic, such is not the case on the Jersey shore. In New Jersey, where most of the large railheads are located, a large percentage of the waterfront structures are railroad lighterage piers. These are both covered piers and open docks. The covered piers provide shelter for freight while it is being transferred from box cars to covered lighters which are in turn towed either to the freight piers of New York or direct to shipside for overseas shipment.

The open docks are used primarily for handling such heavy freight as is delivered on flat cars or in gondolas. Ordinarily these shipments are too large and heavy to be shipped in box cars. On the

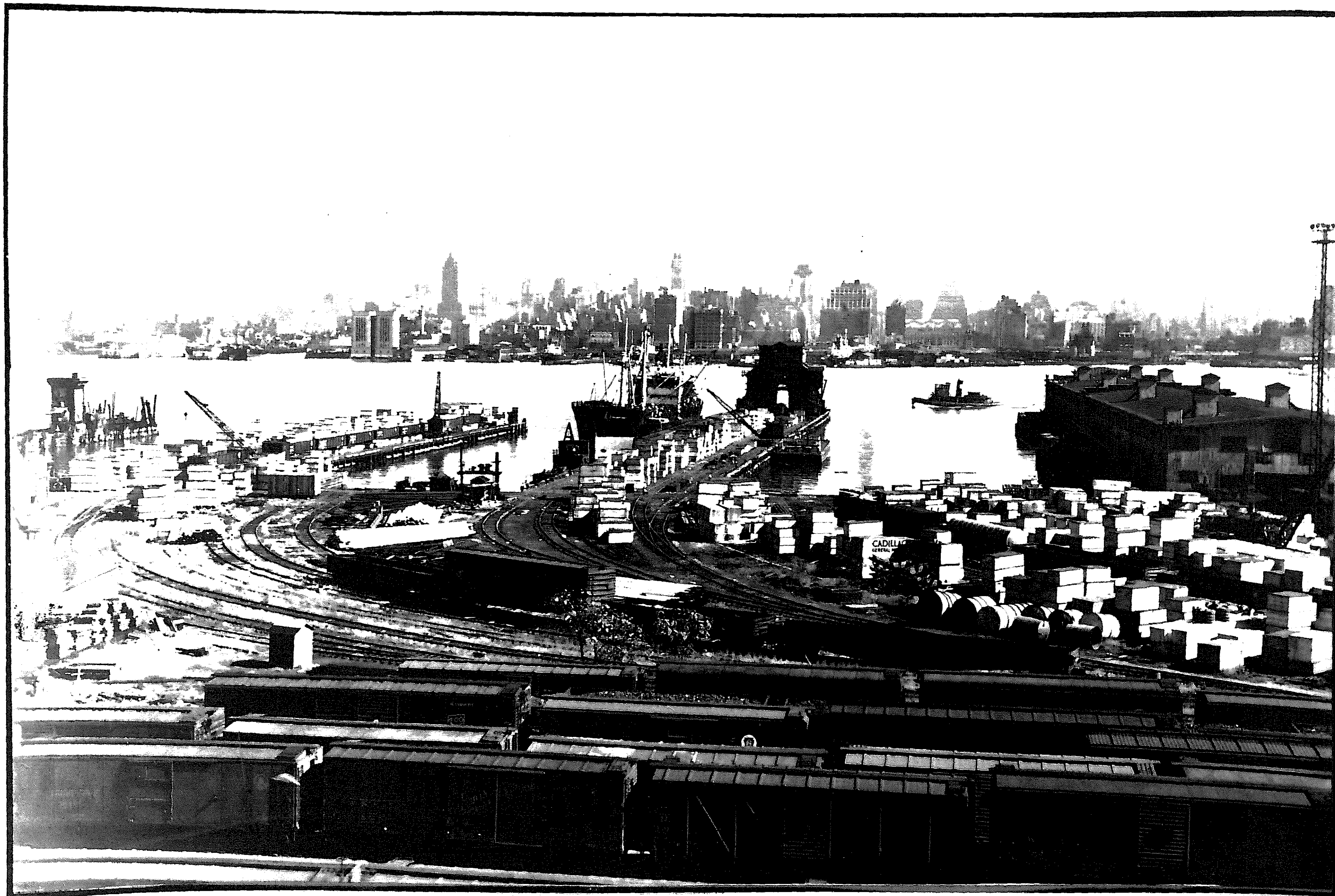


Fig.- 16.- Open freight piers, Erie Railroad, Weehawken.

open docks the unloading is usually done by gantry cranes that straddle the tracks and travel up and down the pier. From the piers the loads are transferred to deck scows which are then towed to their destination. Since not all open docks have gantries, steam lighters with hoisting gear are often used to unload the cars. When excessively heavy lifts must be made, large marine derricks are employed both to unload cars and to load the holds of ships. Sometimes steamships are berthed alongside open docks so that cars can be unloaded directly with the ship booms.

* * *

One of the earliest facilities to be developed on the waterfront was a landing place for ferry-boats. Today, while the total number of ferries in operation is on the decline due to the increased use of railroad and vehicular tunnels, they still form an important part of the port's system of transportation. All of the railroads terminating in New Jersey, except the Pennsylvania, depend entirely upon ferries to carry their passengers to New York. Between Manhattan and Staten Islands the only direct means of transportation is by ferry, while such islands as

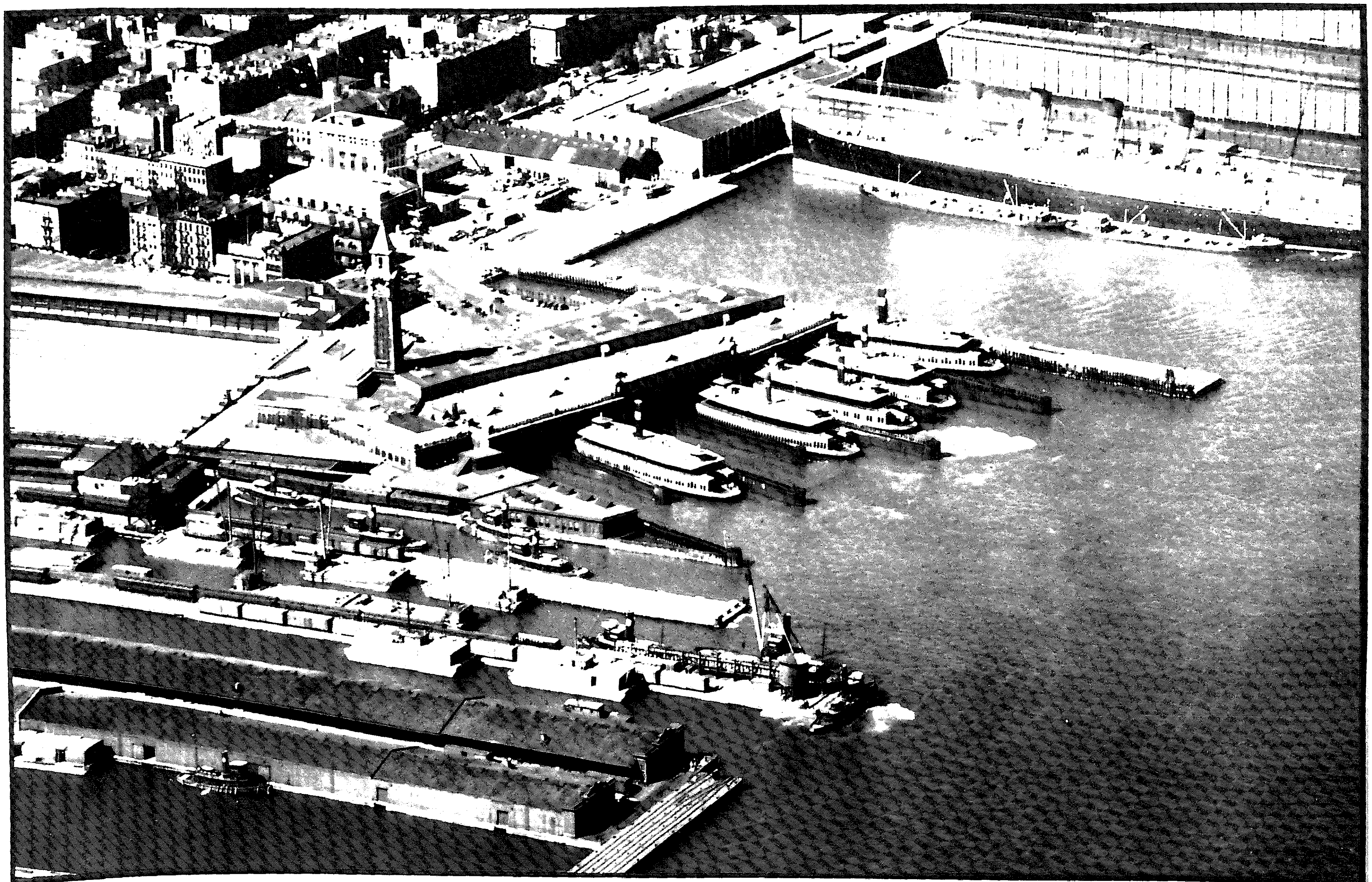


Fig. 17.- Ferry Terminal, Lackawanna Railroad, Hoboken.

Ellis, Governors and Rikers depend entirely upon ferries for connection with the adjacent shores.

Unlike those of early days, the modern ferry-houses are large, having slips to accommodate several boats at a time. Those serving the railroads contain waiting rooms, baggage rooms, and ticket offices, similar to a railroad station. They also have facilities for boarding the upper as well as the lower decks and the landing bridges, which are sheltered from the weather by overhanging sheds, are suspended from gallows frames and are adjustable to extremes of tide.

Another type of ferry widely used in the harbor today is the railroad carfloat. A carfloat is a large scow with tracks laid on the deck upon which railroad cars are transported between the New Jersey railheads and the railroad terminals and freight piers in New York.

In order to transfer cars to and from the floats, float bridges were developed. These are in effect, as the name implies, bridges which span the gap between the floats and the shore.

Were it not for tidal fluctuations, making this transfer would present no particular problem

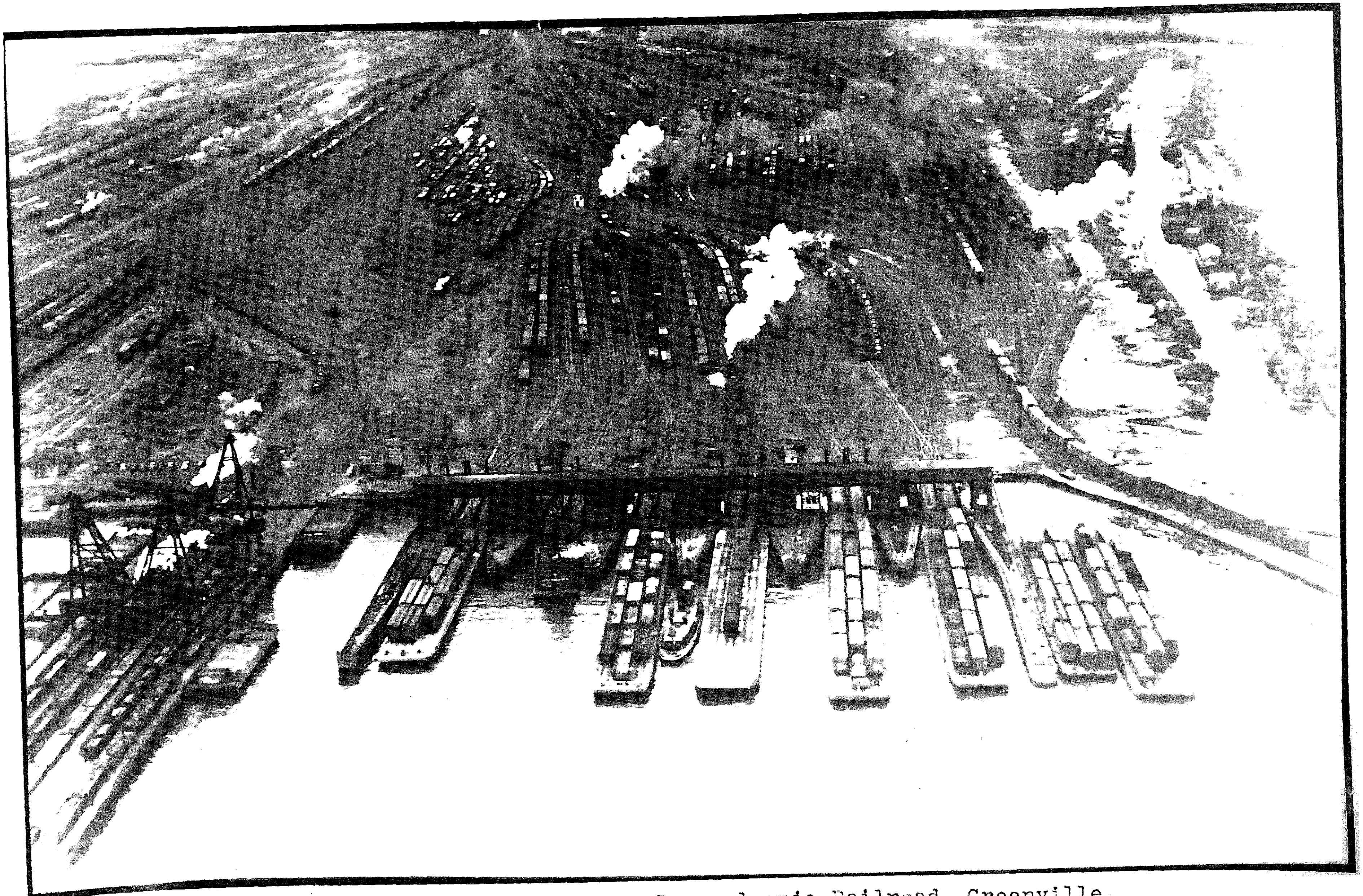


Fig. 18.- Float bridges, Pennsylvania Railroad, Greenville.

but, as it is, the outshore ends of the bridges must be brought to an elevation which conforms to the stage of the tide. In addition to this, compensation must be made for the rise and fall of the floats, as their displacement varies during the unloading and loading operations.

An older type, some of which are still in use, is the so-called pontoon float bridge. This consists of girders, the inshore ends of which rest on a rocking beam, while the outshore ends are supported by the buoyancy of a pontoon. This arrangement, since the end of the bridge is floating, has the advantage of being always at the proper elevation for all stages of the tide. Further, when a float sinks as cars are moved onto it, the pontoon end of the bridge to which the float is toggled sinks deeper also.

For cars not too heavily laden and small carfloats a pontoon float bridge works very well, but, as the railroad business increased, cars were built for heavier load limits and carfloats were built longer, wider, and with three tracks instead of only two. As a result it became no longer practical to design toggling devices capable of resisting the large stresses introduced by these increases.

The modern version of the float bridge consists of steel girders supported inshore on trunnions and outshore by a set of vertical screws suspended from a gallows frame. The bridge is raised and lowered by means of these vertical screws which are driven by electric motors while the bridge is counterweighted to lighten the load.

Many float bridges, both pontoon and screw operated, built before steel largely replaced timber in railroad construction, are still in operation. Instead of steel girders, these old models utilize trusses built up of timber struts and wrought iron counters.

A fairly recent development in the field of ferrying railroad cars is the so-called seatrain. A seatrain is a seagoing vessel built with four tracks on each of four decks and capable of carrying one hundred cars. They transport carload lots of goods between New York, the Gulf Coast, and Cuba without unloading the cars. A new terminal for loading these vessels was recently constructed At Edgewater, New Jersey where the cars are drilled onto a pier over which a large specially designed gantry

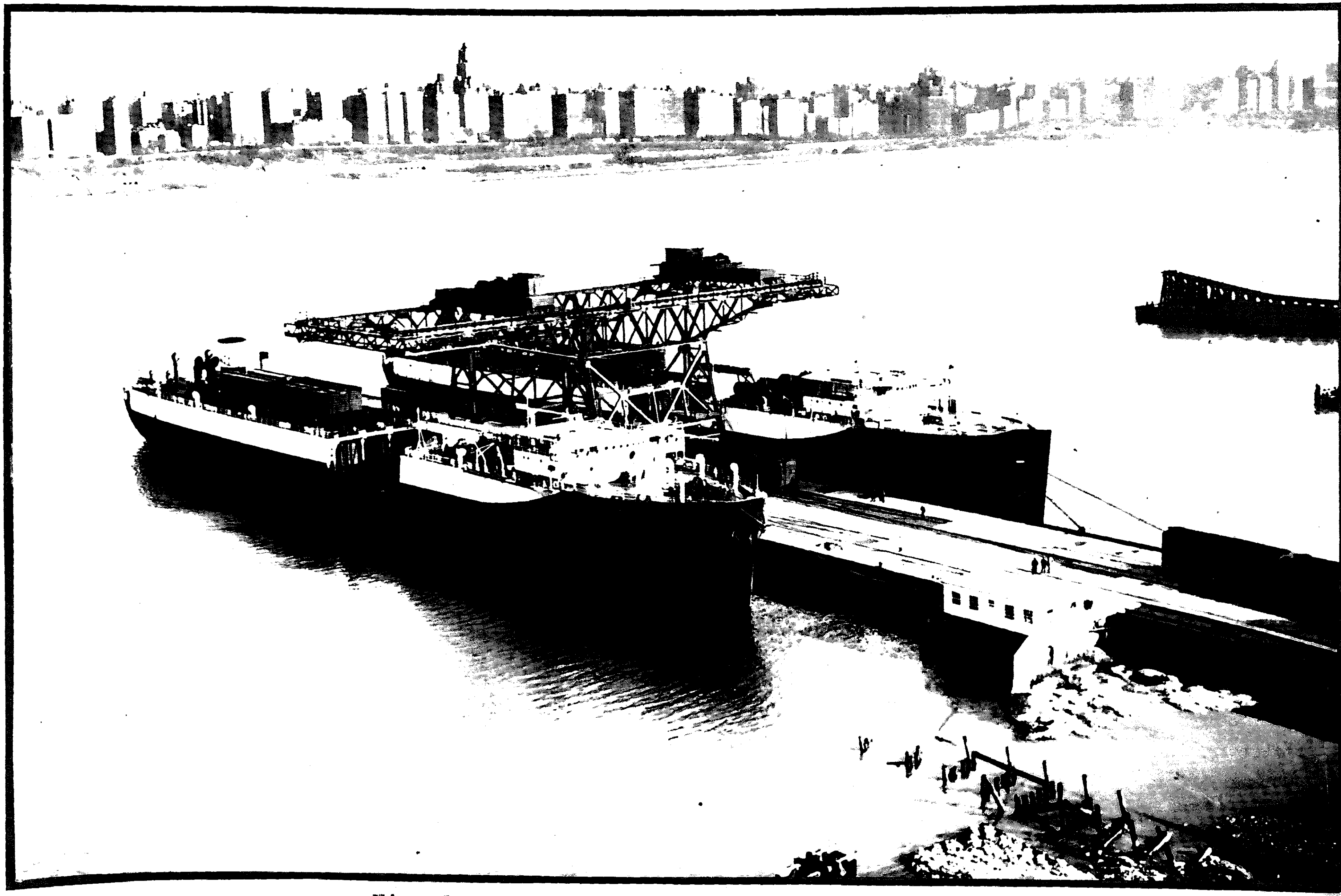


Fig. 19.- The seatrain terminal, Edgewater.

crane has been erected. The cars are hoisted one at a time and lowered to the tracks on board the ship. Details of the construction of this pier appear in Chapter Eight.

The latest innovation in ferrying was made in 1947. LSTs, obtained from the War Assets Administration, have been utilized as ferry-boats to transport truck trailers between New York and Albany. The dock for these vessels, located at West 23rd Street, is equipped with an adjustable ramp similar to the landing bridge used by conventional ferryboats.

* * *

In the unending quest for economy many schemes have been devised to reduce the amount of labor required to transfer cargoes to and from the holds of ships. There are some commodities which are shipped in bulk and sometimes it has been found practical to install mechanical equipment on the dock to handle it. There are several instances of such installations in New York Harbor.

More coal is carried to the seaboard by the railroads than any other commodity and most of it is unloaded at the waterfront. Each railroad has

(a) Baltimore and Ohio Railroad trestle, Staten Island.

(b) Berwind White Coal Company trestle, Jersey City.
(showing car vibrator)

Fig. 20.- Timber coal trestles.

one or more terminals where coal is transferred from the hopper cars to some means of water transportation.

To the problem of how to most cheaply unload the cars, the early answer was the coal trestle. Many are still in use throughout the country, but in New York Harbor there are only a few remaining. Built of timber, they extend out from the bulkhead like a pier. The tracks are high enough above the water to permit the coal to be emptied from the cars through their hoppers into bins or pockets and thence, by means of chutes, delivered to barges and so on, entirely by gravity. Recently vibrators have been installed on some trestles which engage the tops of the cars and agitate them so that the coal, even though frozen or otherwise stuck in the car, will flow rapidly through the hoppers.

Within the last fifty years coal dumpers were introduced obviating the necessity for most of the labor that is required on a trestle. With these machines the entire process of unloading coal is mechanical. Cars are pulled to an elevated platform called a tipple which is then raised, car and all, and inverted over a large pan or apron.

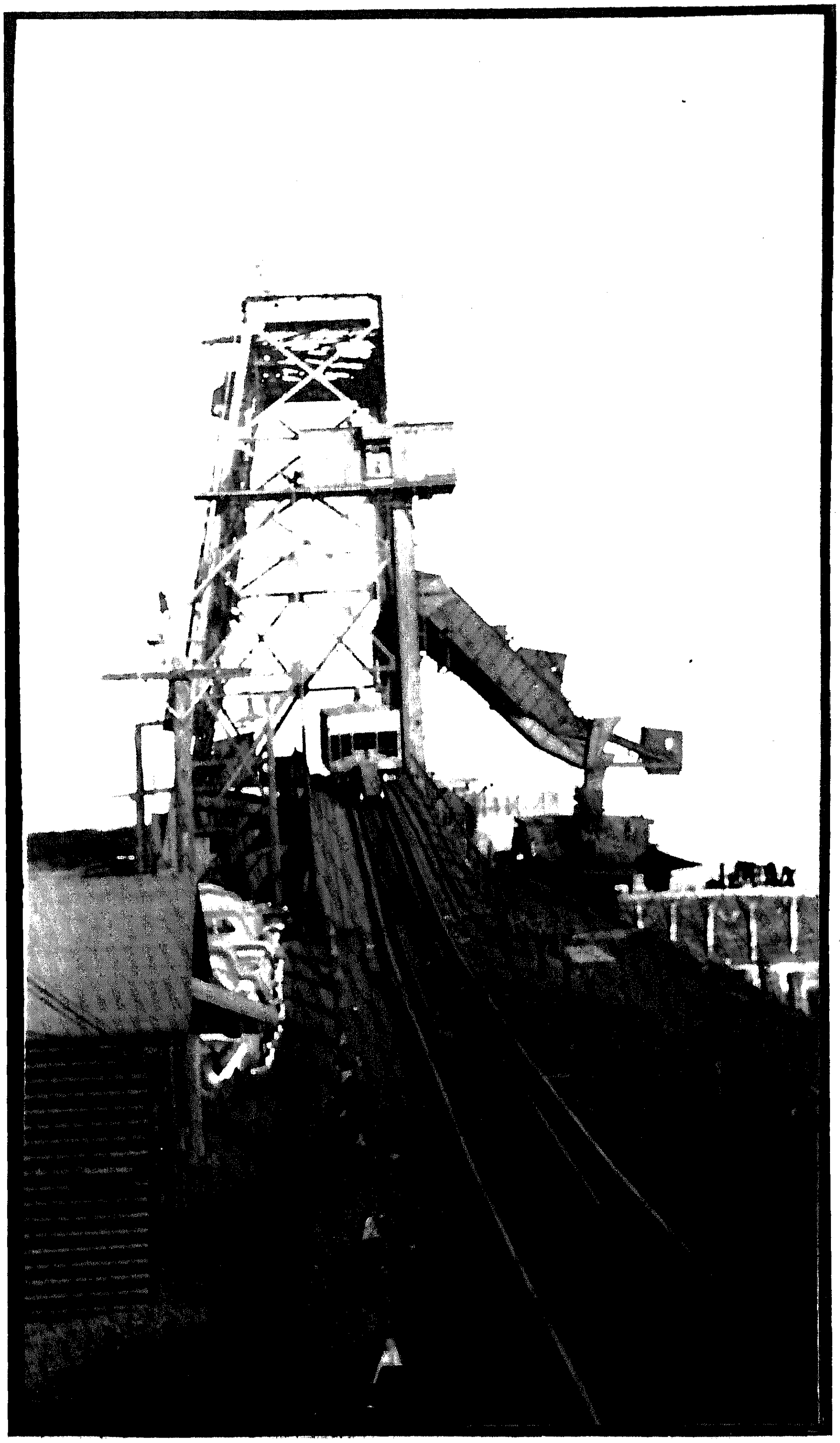


Fig. 21.- Car dumper, Seaboard Coal Dock, South Amboy.

By gravity the coal is then chuted through a telescoping downspout into the vessels below.

Before placing cars on the tipple it is often necessary, in the wintertime, to thaw the coal so that it will not stick in the cars or fall out in large lumps. To accomplish this a train of cars is run into a long, tightly closed shed where it is subjected to live steam for a period of time.

After a car is emptied into the pan it is rerighted, lowered, and pushed from the tipple by the next car, whence it runs by gravity to the empty car track.

A great amount of the coal delivered to New York in this way is consumed by electric power plants. Most of these plants are built at the edge of some navigable waterway so that the coal can be delivered conveniently and so that there is an ample supply of free cooling water for the condensers. While some of the coal is delivered by large colliers, the greatest portion arrives in the large coal barges which are loaded under the dumpers and trestles in other parts of the harbor. To unload these coal vessels most powerhouses have, over their wharves, extending booms with clamshell buckets

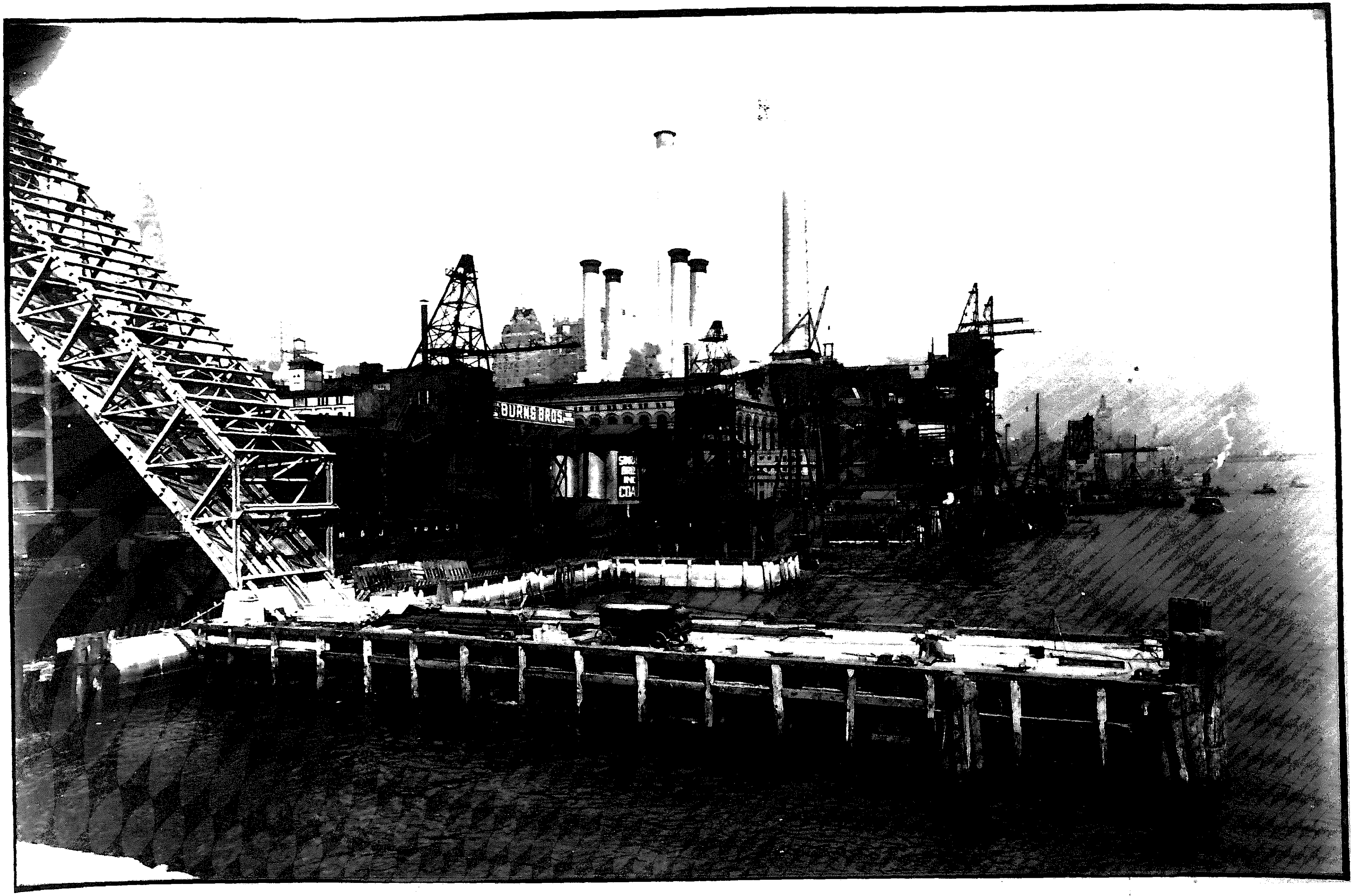



Fig. 22.- Powerhouse and coal yards, 14th Street, East River.

which hoist the coal high enough to dump it into bins or onto conveyors which carry it to outside storage piles.

Many wholesale and retail coal dealers have their yards and pockets located on the New York waterfront for the same reason of convenient water delivery. Like the power plants they unload the barges by means of clamshells.

Grain is another commodity great quantities of which are handled in bulk. Grain enters the port both by railroad and by barge but leaves principally via steamship. To economically transfer and store the large quantities which are shipped through New York, grain elevators were constructed. By means of the elevators the grain from cars and barges is unloaded and stored by both compressed air and conveyors. Discharging the stored grain into the holds of outbound ships is usually accomplished by gravity. Grain elevators, by virtue of their large outline and great height, frequently become landmarks on the margin of the harbor.

There are numerous large industrial plants located on the waterfront primarily because the raw material used in them can most cheaply be delivered

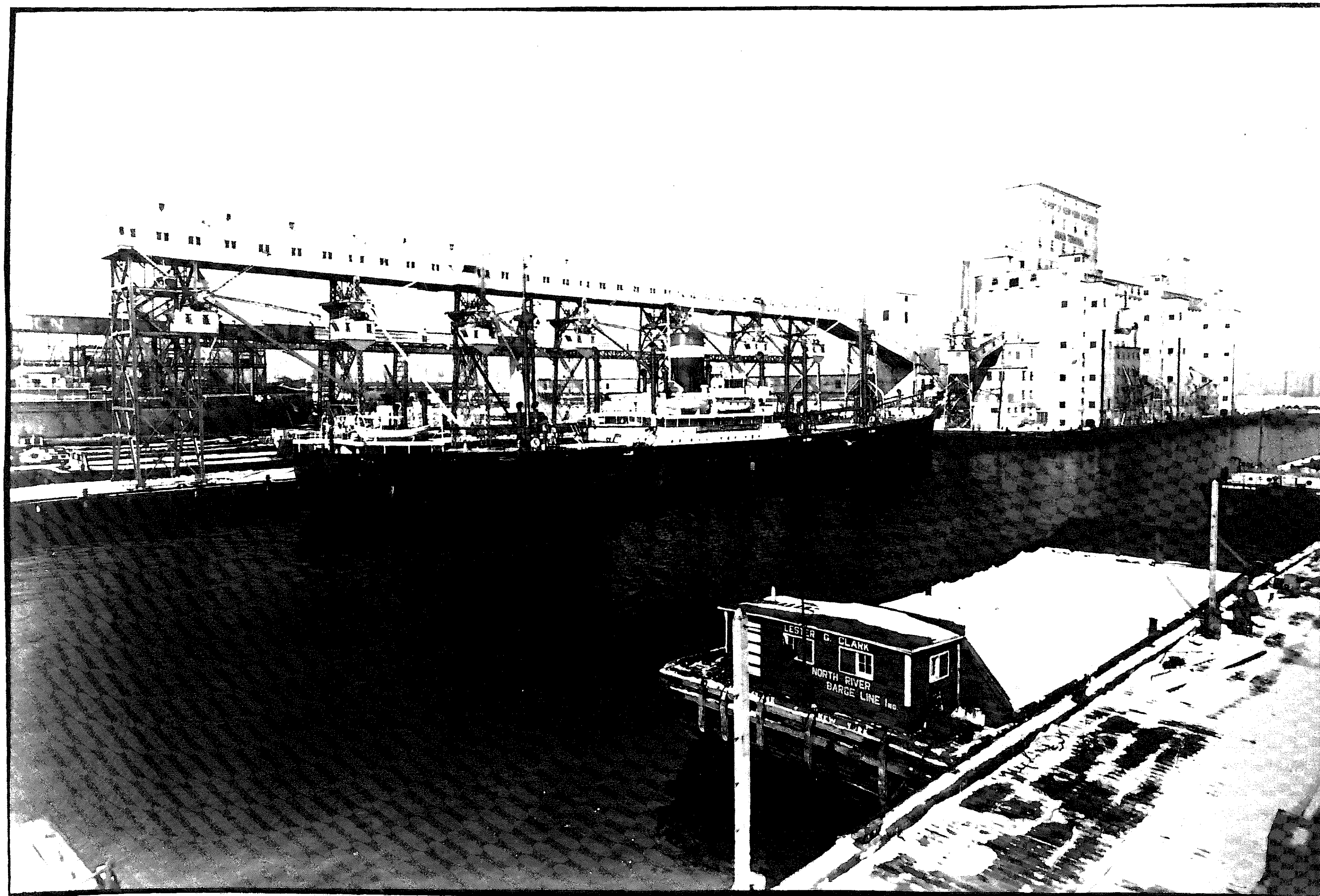



Fig. 23.- Port Authority grain elevator, Gowanus Bay, Brooklyn.

by ship. The raw material used in several of the plants is ore and delivered in bulk. Sulphur from the Gulf Coast and gypsum from Nova Scotia are two such examples. The ore is taken into the plants both by means similar to those used by the power plants and by systems of belt-conveyors and bucket-elevators.

Another commodity, shipments of which have greatly increased in volume during recent years, is petroleum products. A number of oil companies have established both tank farms and refineries at various locations on the perimeter of the harbor. The larger establishments are located on the Kills while smaller facilities for local distribution have been built at outlying points on the various navigable streams communicating with the harbor.

Tankers from the Gulf Coast and South America are berthed at the larger oil docks which are generally open, serving merely as tie-up racks while the cargo is being pumped ashore and as support for the pipe lines through which the oil is delivered to the tank farms. The docks at the outlying points are utilized in a similar manner but they are much smaller since only small craft are operated as tankers on

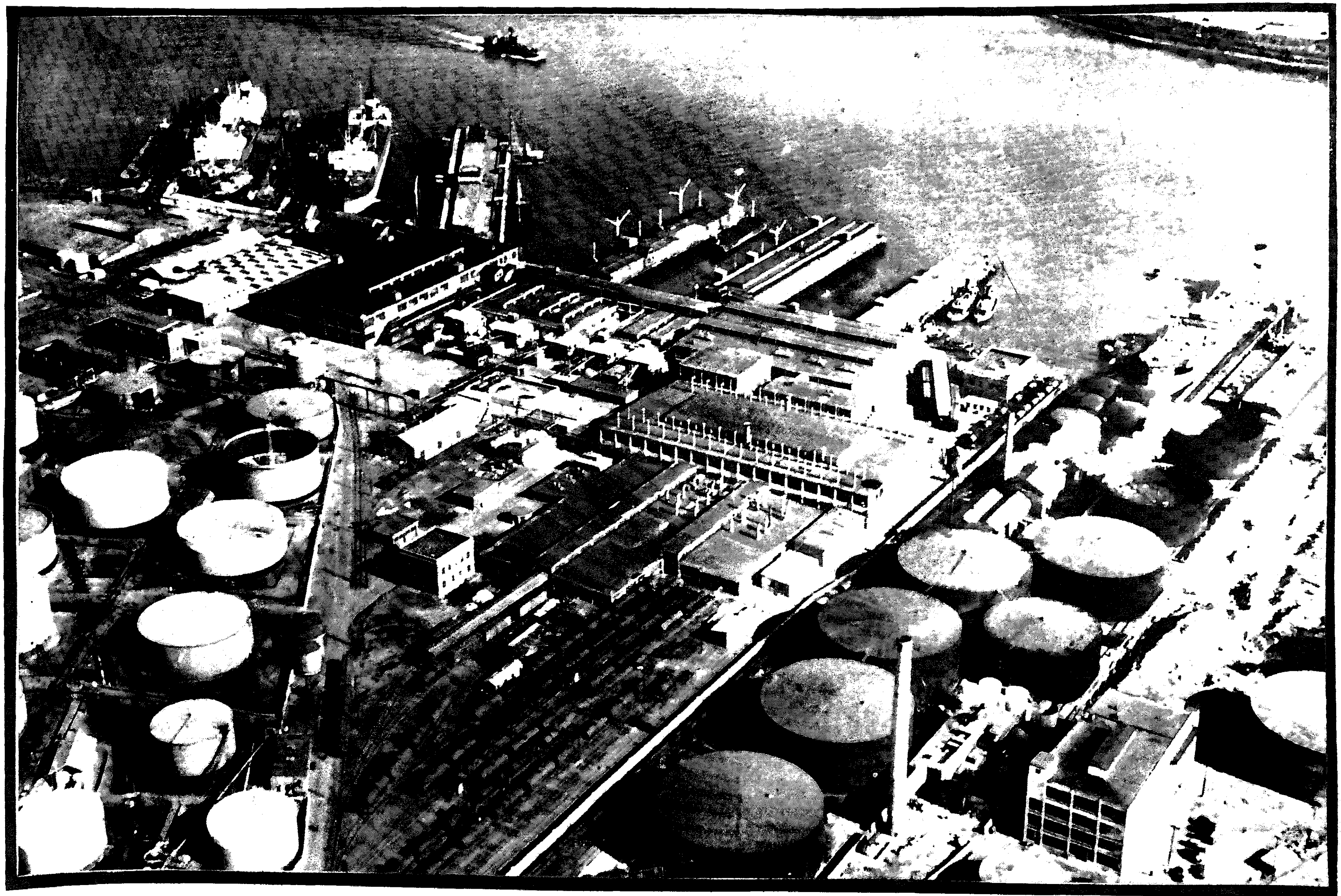


Fig. 24.- Refinery and docks, Standard Oil Company, Bayonne.

the inland waters.

* * *

Shipyards were in the early days and still are today of importance to the port. Both shipbuilding and ship repairing are carried on to a considerable extent.

The method most widely used to launch ships is that of constructing the hull on ways and, at any desirable time after it is capable of floating, causing it to slide into the water. The ways consist of large parallel timbers which serve both to support the hull on blocks during construction and to guide it when it is launched. The portion which is constructed on the shore is in effect an inclined timber trestle which slopes downward toward the water. From the shoreline out, the ways extend at a constant grade until water of sufficient depth to float the hull is reached.

Graving docks or drydocks are used both for ship repairing and shipbuilding. A drydock is a basin constructed of concrete and fitted with a floating gate or caisson. When the gate is in place the dock can be dewatered either to build or repair ships in the dry.

Drydocks are constructed with massive proportions to resist the lateral hydraulic pressure

(a) Inshore portion.

(b) Outshore portion.

Fig. 25.- Shipbuilding ways, Naval Shipyard, Port Newark.

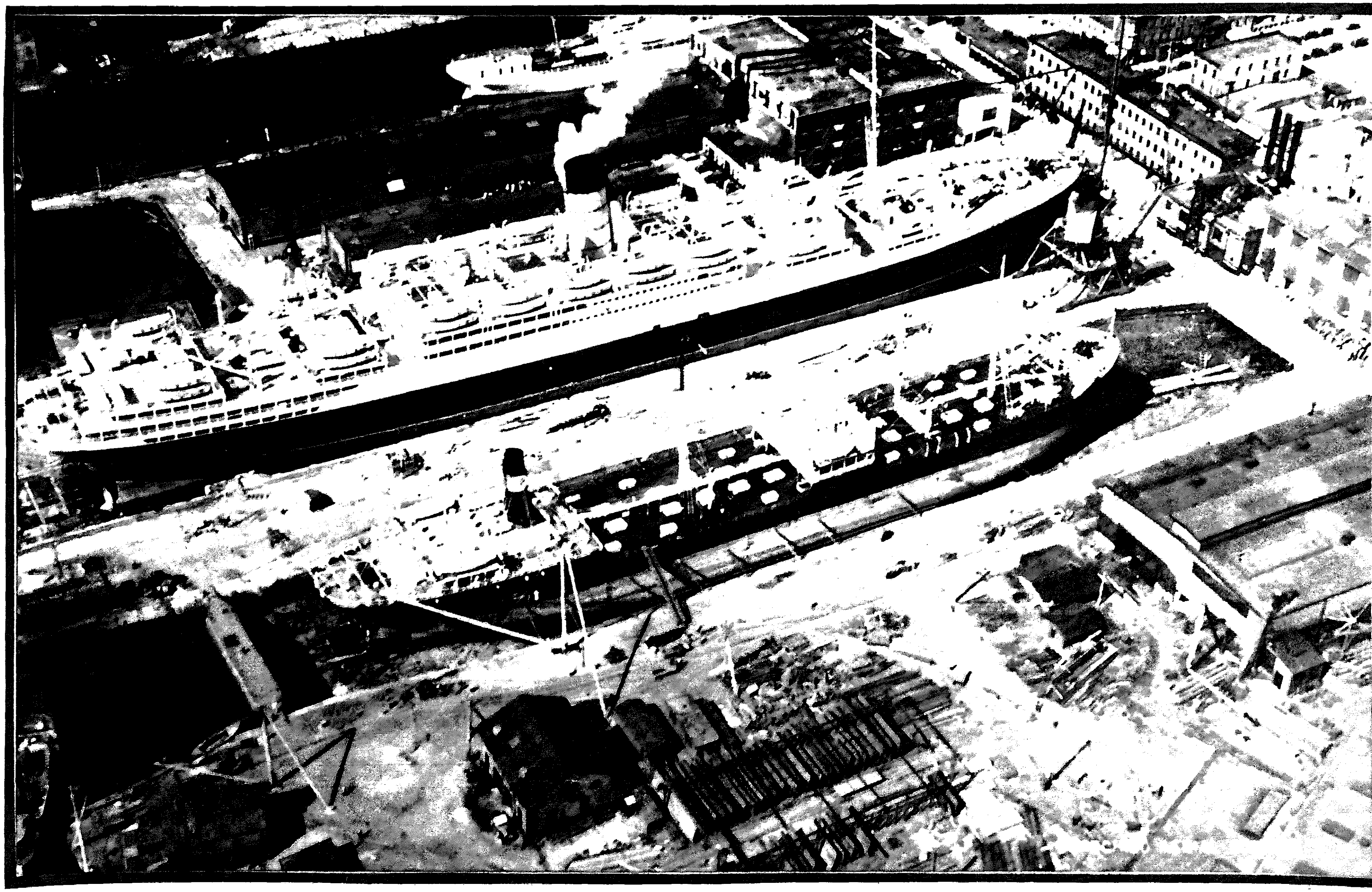


Fig. 26.- Graving docks, Erie Basin, Brooklyn.

against the walls and the uplift under the deck. Ships to be repaired are towed into the dock and centered over a set of previously arranged blocks upon which the keel and under plates will come to rest as the water level is lowered.

Floating drydocks, such as have been operated in New York Harbor, are ordinarily used to handle vessels smaller than seagoing ships. A large flat barge with high sides built up from the gunwales forms the general outline of a floating drydock. The hull and sidewalls contain ballast tanks which can be flooded to sink the dock and blown out to refloat it. While the tanks are flooded and the dock is down, a vessel to be drydocked is placed between the sidewalls. The tanks are then blown and the dock is raised, together with the vessel which rests on blocking arranged as in a graving dock.

Another method of taking craft out of the water is to haul it out on a marine railway. This facility approximates launching ways in appearance. It consists of a car or cradle mounted on wheels which travels on tracks inclined from the shore out into the water. The hull of the craft is secured to the cradle while it is submerged at the lower end of the

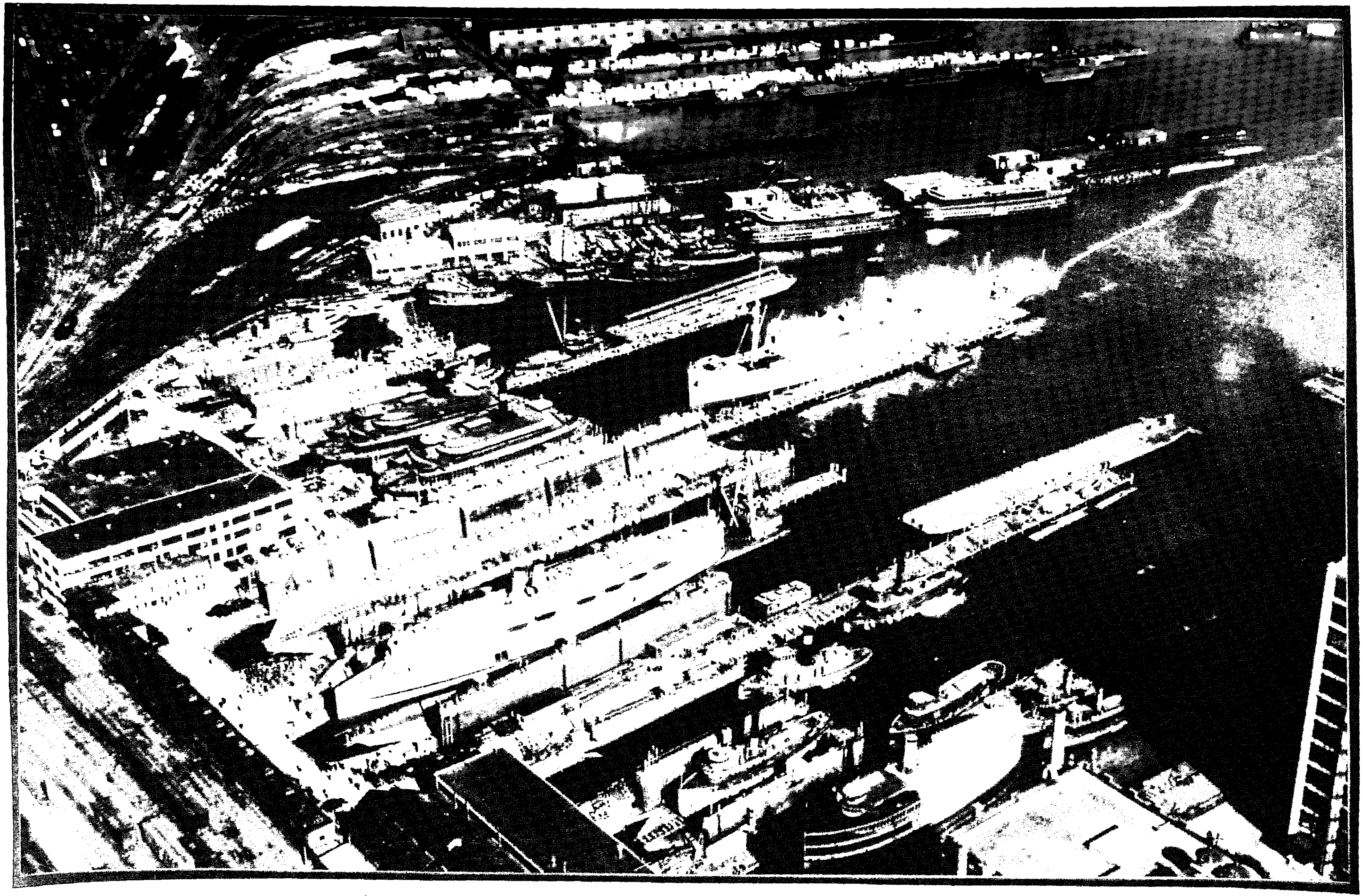


Fig. 27.- Floating drydocks, repair yard, Hoboken.

track and then hauled ashore by means of a winch. The outshore end of the track is supported on pile bents just as launching ways are, but the portion that is built on the shore may follow the contour of the ground rather than continue uphill at a constant grade.

The navy yards at Brooklyn and Bayonne have been built to service ships in a great number of ways. Both contain drydocking facilities for the largest ships of the fleet. In addition there are facilities for handling commissary stores, supplies, fuel, ordnance and so forth. The Brooklyn yard is equipped to perform all types of work pertaining to ships from making minor repairs to building ships from the keel up.

* * *

In connection with harbor development it sometimes becomes necessary to control hydraulic forces which may be manifested either by currents or waves. To accomplish this jetties and breakwaters are constructed. In locations exposed to the ocean where violent wave action may be encountered the structures are constructed of large rocks each of which may weigh fifty tons or more. At the other extreme,

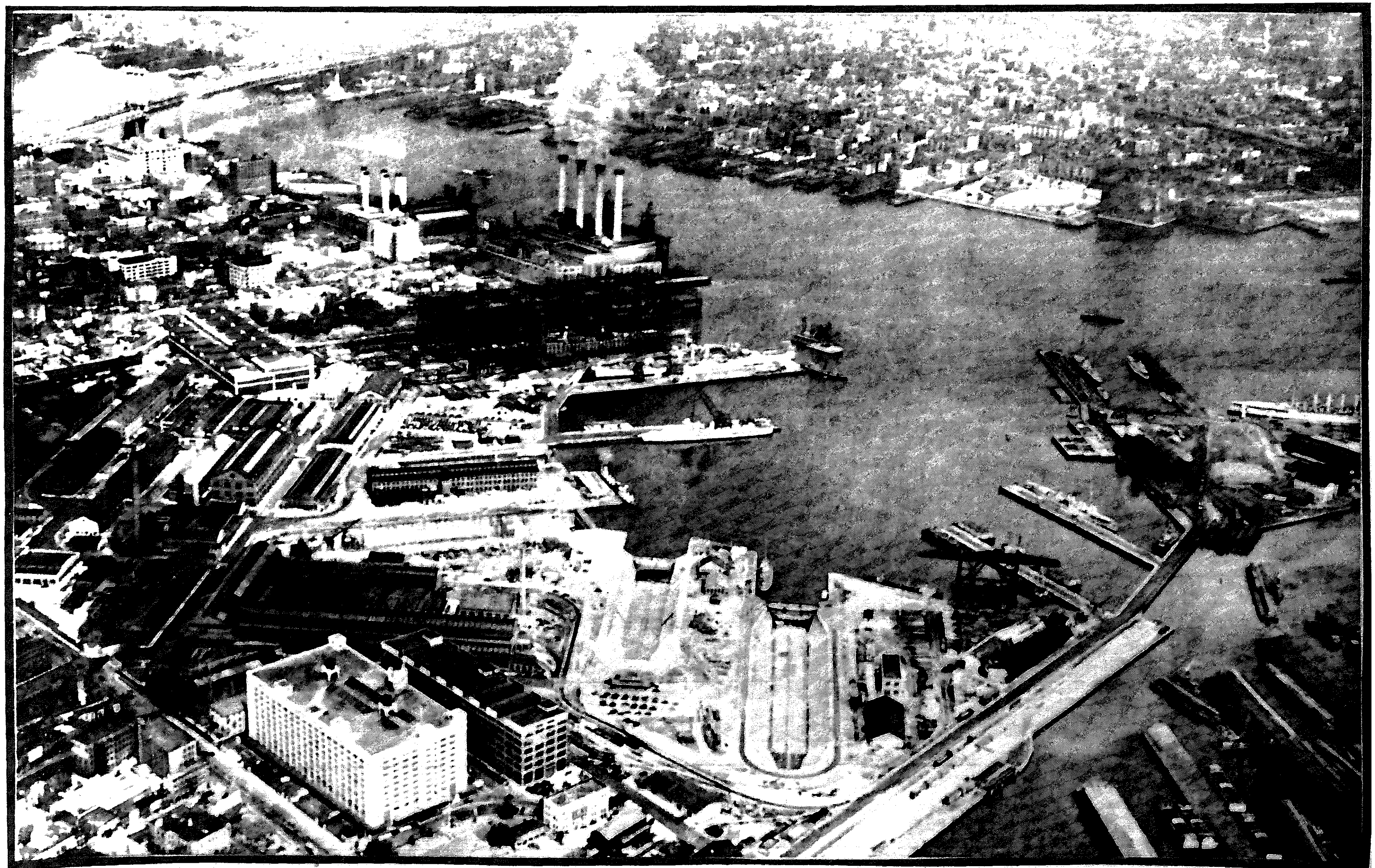


Fig. 28.- U. S. Navy yard, Brooklyn.

where the water is sheltered from the waves of the sea and where currents are not very strong, breakwaters have been built of timber piles and sheeting.

There is a differentiation between jetties and breakwaters. Jetties, strictly speaking, are structures designed to channelize or divert the flow of currents, whether they be river, tidal, or ocean currents. The purpose of a jetty may be, by channelizing a current, to maintain in it a velocity sufficient to prevent excessive deposition of silt and thus keep the waterway in navigable condition.

By constructing jetties designed to deflect currents, navigable waters can be protected from those which have a tendency to build up shoals and beach deposits.

Not many such structures have been constructed in New York Harbor, but at Rockaway Point and East Rockaway, Long Island there are large jetties to protect Jamaica Bay inlet and Long Beach Channel from shoaling. At the southern end of Newark Bay there is a jetty running east and west to divert the flow from the north and preserve the channel through the Kills.

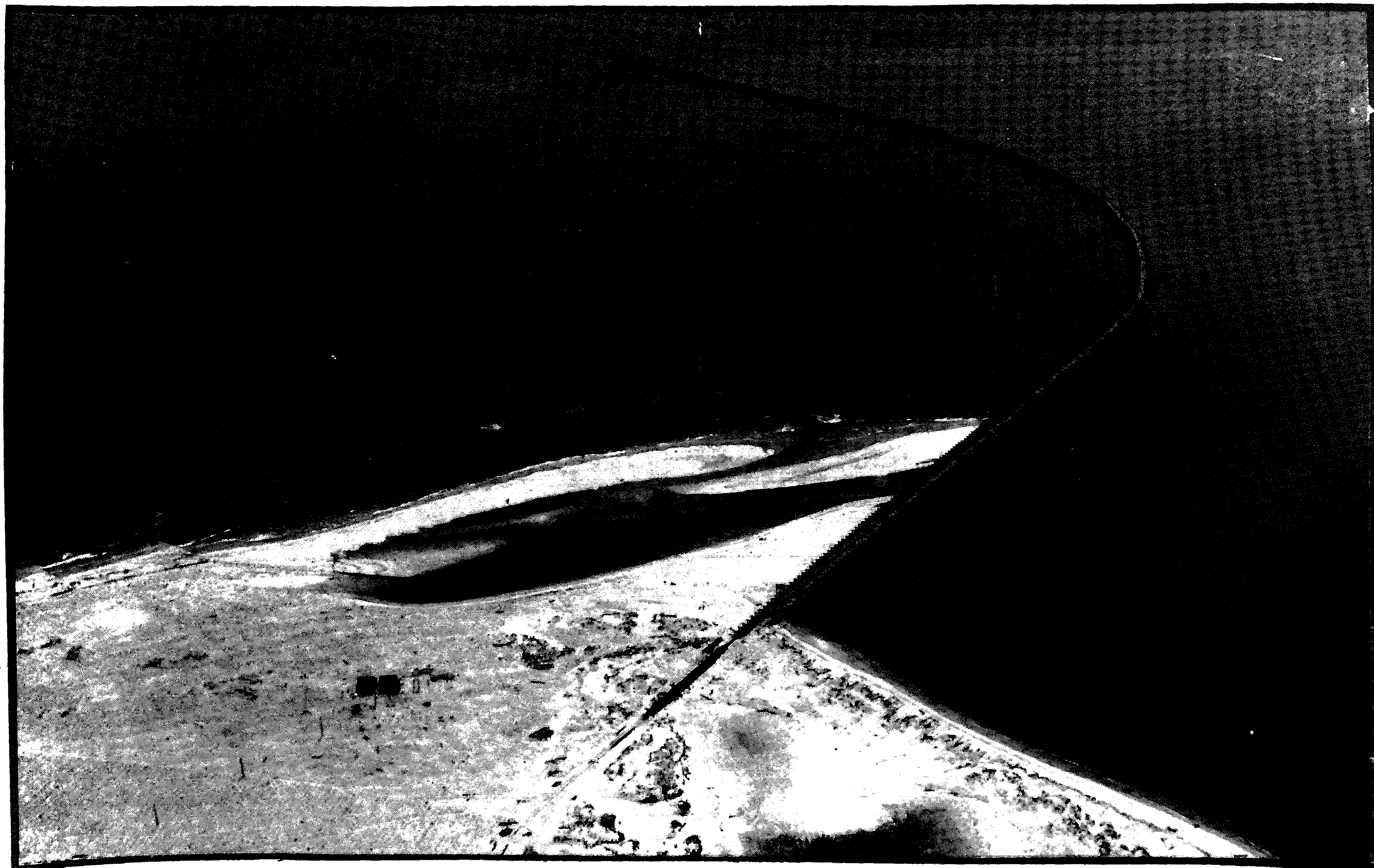


Fig. 29.- Jetty protecting Jamaica Bay channel, Rockaway Point.

Breakwaters, as the name implies, are structures designed to break the force of waves and provide a lee for ships or small craft. They may be identical in construction to jetties, differing only in their purpose.

Large breakwaters, or moles as they are sometimes called, are not required in New York Harbor because of the naturally existing sheltered conditions. The artificial arm of land which incloses Beard's Erie Basin, Brooklyn could be considered a breakwater since it does perform that function as well as that of being a wharf.

Icebreakers, while not in wide use, have proved beneficial in some locations within the harbor. The function of an icebreaker is to prevent ice from accumulating in large masses alongside piers or in front of float bridges where it can interfere with or hamper the movements of boats and barges.

To accomplish this purpose they have been constructed on the upstream side of the area to be protected so that the ice, moving toward the sea, as it sometimes does during the winter and after the spring breakup, will be deflected toward the center of the harbor. In this respect an icebreaker resembles a jetty but, unlike a jetty which is massive, an icebreaker may be of comparatively light construction that does not completely block the flow of the current. A common variety consists of timber sheeting secured to a narrow timber trestle, similar to a large picket fence.

There are places within the harbor where it is desired to protect land and property from the erosive action of waves and currents. This is done by erecting a seawall along the line to be maintained. A seawall is in effect a retaining wall with property on one side and the water on the other. Battery Park, Bedloes Island, Governors Island and Ellis Island are protected in this manner. Likewise the wall, which the City commenced to build years ago and proposed to extend around Manhattan Island along the bulkhead lines, may be considered a seawall. The various methods of construction employed in building this particular wall are described in Chapter Four.

* * *

Most of the navigable waters of the Port of New York are crossed by railroad and highway bridges. The more modern structures, as well as the older ones, have in most cases one or more of their piers founded either in or adjacent to the channels followed by maritime traffic.

Many of the bridges, particularly those over the Harlem River, are of the swinging draw type. Where this type of bridge has been erected the pivot pier is located on the centerline of the channel, permitting traffic to pass on either side. In the case of vertical lift, bascule, and high level bridges the piers, while they straddle the channel, are usually built as close to it as the government will permit.

The piers themselves vary considerably in construction. Some of the old piers were founded on timber cribs or open caissons, while more recent ones rest on pile-platforms. Foundations for the heavy piers of large modern bridges are built of concrete and set deeply on a firm stratum either within cofferdams or by means of pneumatic caissons. Concrete faced with granite is used almost exclusively for the upper portions of the piers which formerly were constructed of ashlar.

Another variety of bridge to be found in the New York area includes the railroad trestles and highway viaducts such as those which traverse the tidal flats and shallow waters of Jamaica Bay. They are low level structures and where they intersect navigation channels they are provided with draw spans. In general, the railroad structures are of timber on timber piles while the viaducts are of concrete and steel on precast concrete piles.

Boat basins, for the accommodation of small craft and pleasure boats have been constructed in various parts of the harbor. In them are provided landing places, mooring places and fueling facilities in a sheltered location. Frequently the shelter is obtained by such artificial means as a row of sheet piling.

In addition to all of the foregoing, there are still other facilities constructed in the harbor the existence of which is largely unknown. These are the subaqueous pipe lines which include water mains, gas mains, sewer outfalls, and tunnels for conduits together with submarine cables.

Water mains have been laid to the various islands in the harbor, those crossing the Narrows to Staten Island being the largest undertakings of this kind. Many gas mains have also been laid

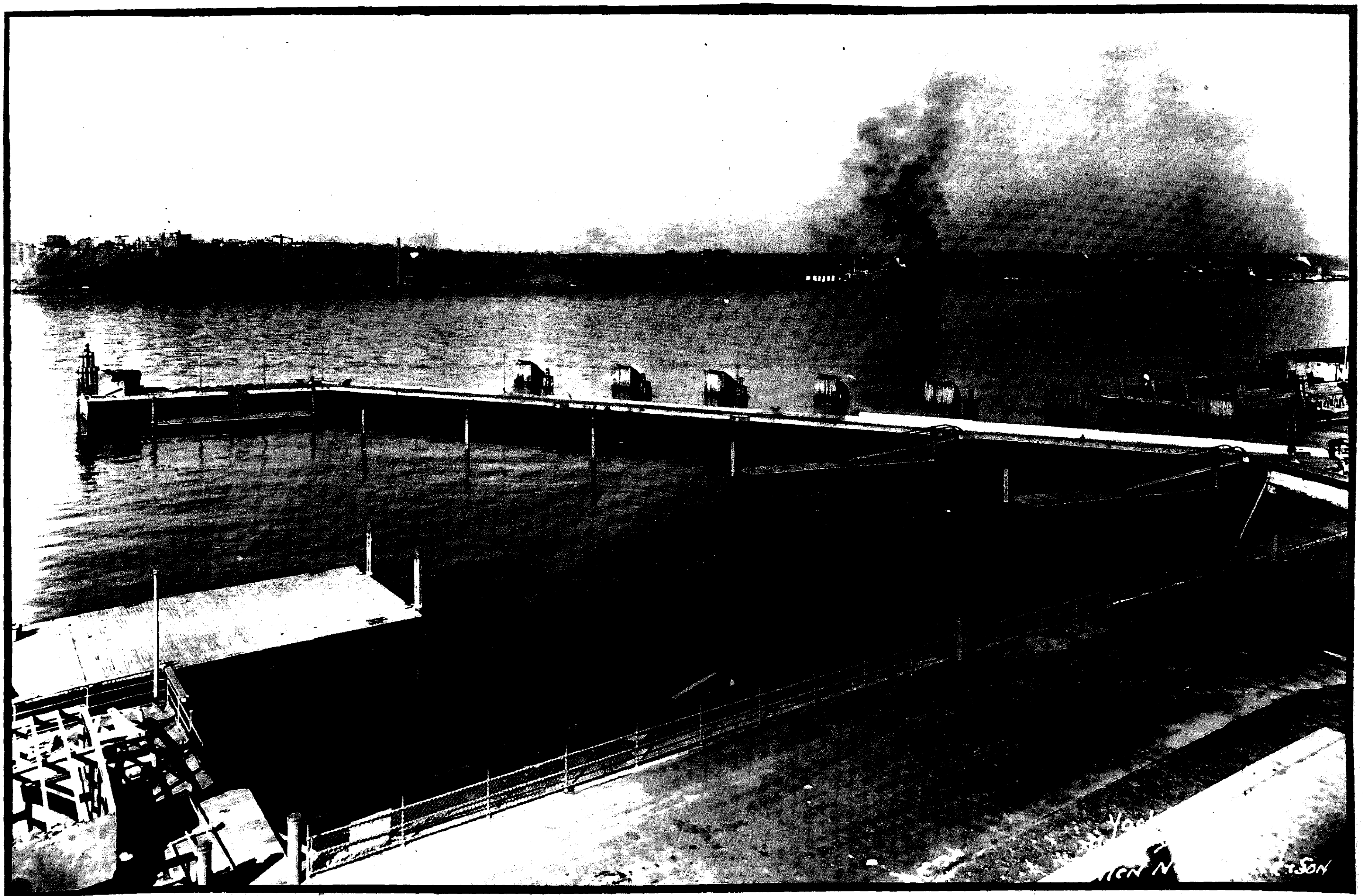


Fig. 30.- Boat basin, 79th Street, North River.

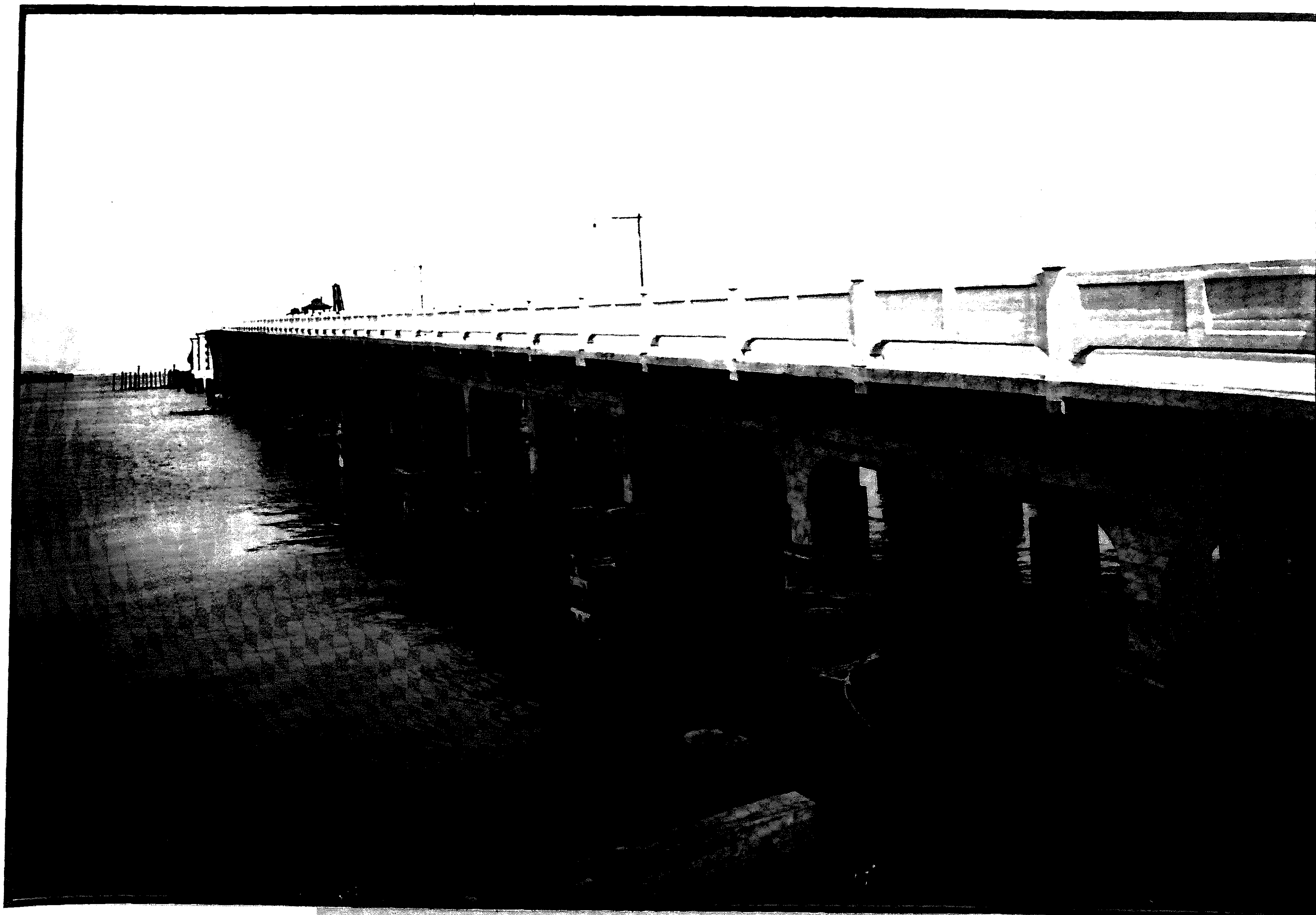


Fig. 31.- Cross-Bay Boulevard viaduct, Rockaway, L.I.

under water to serve those areas which are separated from the producing plants by waterways. Outfall sewers in the vicinity serve not only the communities bordering the harbor but distant areas as well. From Manhattan Island submarine cables radiate in all directions. Most of them are communication cables for telephone and telegraph, but power transmission lines are also to be found under the waters of the harbor.

## CHAPTER FOUR

## THE TYPES OF WATERFRONT CONSTRUCTION

Since the early days when the development of New York Harbor was begun, numerous structural schemes have been devised to enable vessels to effectively transfer their passengers and cargo to and from the shore. Not all of these schemes were able to pass the tests of practicability and economy and, as a result, many of them either were never actually adopted, or their application was confined to only a few projects.

To be practical, a waterfront structure must meet certain requirements. First, it must support the live loads imposed upon it and resist the forces of wind, waves, currents, ice and ships against its sides. It must be economical to build and repair and should be fairly resistant to rapid deterioration and fire. Neither the substructure nor the superstructure should be entirely rigid, but should have a degree of elasticity to prevent damage both to vessels and to itself. Lastly, it must have a depth of water beside it sufficient to accommodate vessels;

it must not obstruct the natural flow of currents in the waterway, and it must comply with local and federal regulations.

Originally, and for many years, timber was used almost exclusively as a building medium. This was due to the fact that timber was available in great quantity, nearby, and cheap. Several methods for utilizing timber to build docks were developed. Some of them, such as crib bulkheads and crib piers, were found quite satisfactory in their day and were used extensively until the advent of steam-power made pile driving a more economical proposition.

Plans calling for the use of materials other than timber, such as stone and iron, were in the early days and up to 1870, found to be prohibitively expensive and were given little serious consideration. During more recent years, with the production of large quantities of steel and cement, new designs have been found to be economically as well as physically practical. While these newer types of construction are finding favor more widely as time goes on, timber, due to its comparative cheapness is still predominantly used in the great majority of instances.

The various types of construction, some now obsolete, that have been employed to a considerable extent in New York Harbor are characterized in this chapter.

* * *

Sunken timber cribs were, for many years, the standard form of construction for providing both marginal docks and finger piers. Since timber was very cheap, the fact that large quantities were required for this type of work was not considered a disadvantage and, while few are built nowadays, many are still in service.

The first step in building a crib bulkhead was to ascertain by probings the contour of the underlying rock or hardpan and to plan the crib to conform to it in a "tailor-made" manner. The overburden was next dredged from the hardpan and then, starting over the area where the water was deepest, unhewn logs were laid parallel to the face of the dock. Next a course of transverse logs, or headers, were fastened across them. Another course of longitudinal logs followed and, as this process continued, a raft of logs crossed at right angles was built up. The raft was held in place over the spot where the

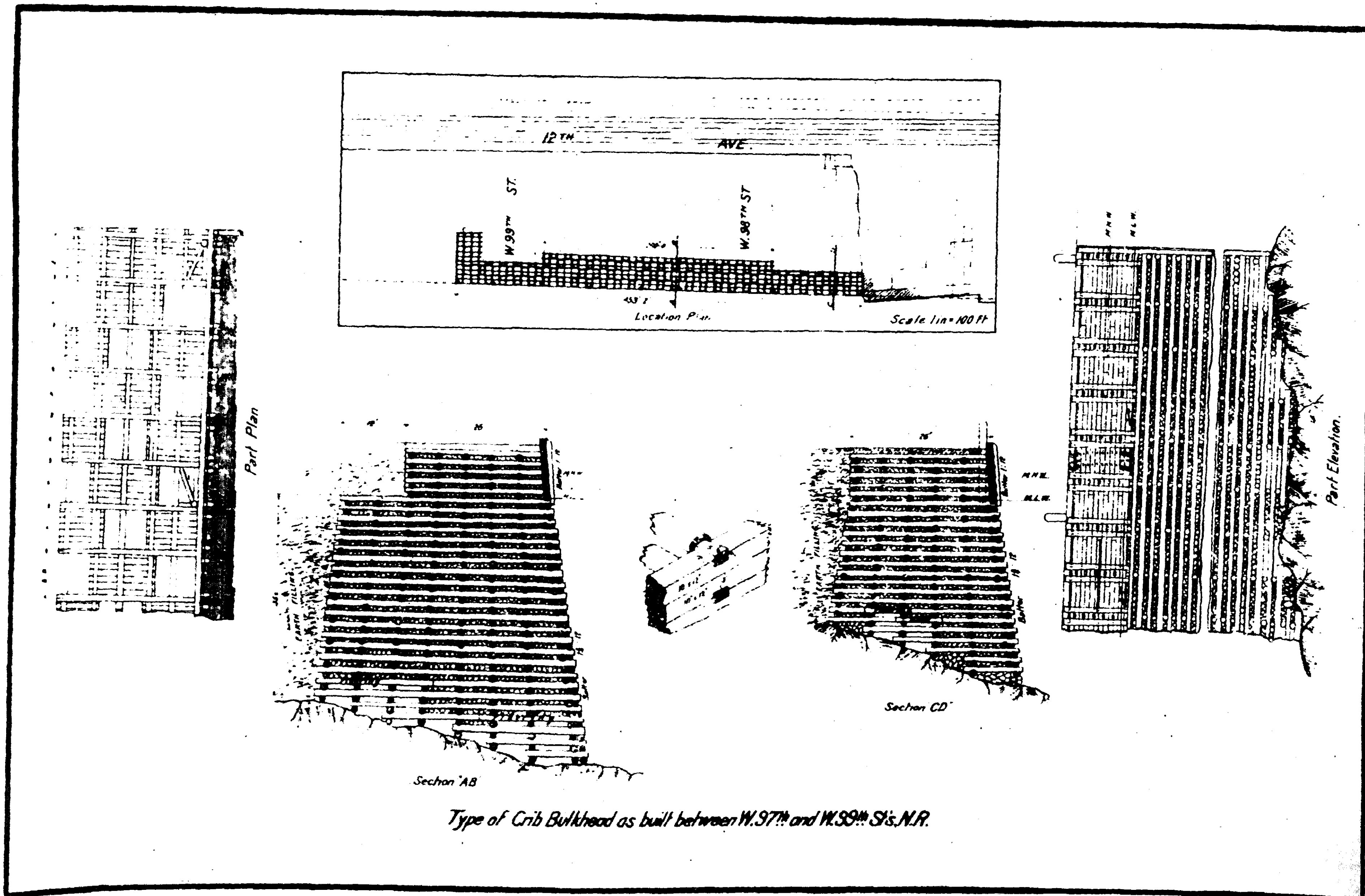



Fig. 32.- Typical sunken cribwork, North River.

finished crib was desired and weighted with rocks to make it sink. Alternate pockets formed by the crossed logs were floored, checkerboard fashion, and in these the rock was loaded until only the top logs remained above the water. This process was continued until the bottom logs came to rest on hard bottom. When the cribwork was completed, the box-like structure was filled in with refuse or excavated material and suitably graded.

In a similar manner rectangular cribs were sunk to provide foundations for piers built at right angles to the bulkheads. The only hewn timber required in this type of work was used to face the crib between the ground level and the low-water line.

* * *

Pile foundations have been developed to provide support for structures over material having low or no bearing capacity. In the case of most waterfront structures the loads are carried through water, soft mud, and/or semi-fluid saturated soil to strata capable of sustaining them. Loads may be transmitted from piles to the sustaining strata in either or both of two ways. In the first way the piles derive their bearing capacity from so-called skin friction only.

The piles in this case transfer their loads to the soil into which they are driven by the friction along their imbedded lengths. Piles of this type can be expected to develop some settlement in time.

The second and more reliable way is by end-bearing, wherein the piles act as columns between the applied loads and hardpan. Hardpan capable of supporting piles in end-bearing may be any of several materials, depending upon the locality. Sand or gravel and mixtures of sand, gravel and clay, as well as rock, cause piles to "fetch up" when encountered.

Foundation problems of different kinds have led to the use of piles in various ways. There are three general systems in which piles may be arranged to provide support. Most commonly used in waterfront construction are so-called pile bents. A pile bent consists of two or more piles driven in a row transverse to the length of the structure. The piles are capped or clamped together at the top and are usually cross-braced. A series of such bents constitutes the foundation for the great majority of docks and piers in New York Harbor.

Where concentrated heavy loads such as columns must be supported, pedestals are constructed upon groups of piles. These groups are symmetrical about their vertical axes and the number of piles per group depends upon the magnitude of the load imposed and the capacity of the individual piles.

In cases where heavy loadings are to be applied over a wide area, piles are driven at close intervals in both directions and suitably capped with a timber grillage or a concrete mat. Such a foundation as this might be used under a warehouse, power-house, or other large plant.

The piles themselves vary in kind, and the materials in common use for them are timber, concrete, and steel. Timber piles are obtained from trees having straight trunks and tops of five or more inches in diameter. At the present time most of the timber bearing piles driven in the harbor are yellow pine but, where lengths of 70 feet or more are required, Douglas fir is commonly used.

Timber piles are easy to handle and easily adapted to many varieties of structures. They are relatively strong for their weight and resist driving sufficiently well to develop the desired load capacity. In the case of friction piles, especially where lengths are 60 feet or more, in order to increase their re-

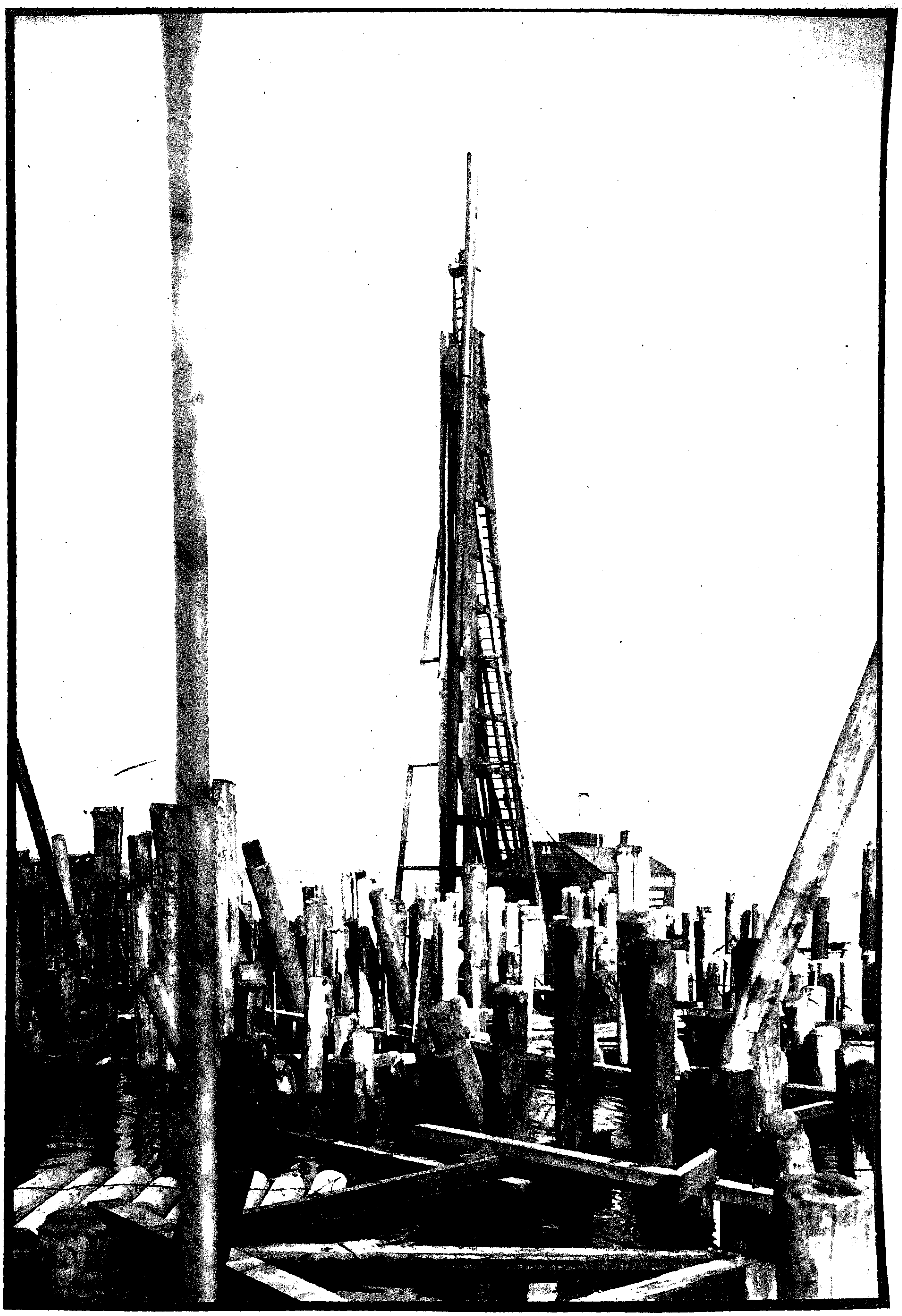


Fig. 33.- Timber piles, Ford plant, Edgewater.

sistance to driving and consequently their bearing capacity, it is common practice to use lagging. Piles may be either half lagged or fully lagged. The former is accomplished by bolting two pieces of timber, about 4 x 6 inches, to opposite sides of the pile (See Fig. 61). Fully lagged piles have four such pieces fastened to them. The length of the lagging corresponds to the length of that portion of the pile which is imbedded in the friction yielding stratum.

Where timber piles are driven to rock, or where they may encounter some hard driving before the desired grade is reached, it is customary to fit them with pointed steel pile shoes to preserve their tips and to facilitate driving. While their life may not be as long as that of concrete and steel piles, where they are accessible, it is comparatively easy and cheaper to repair deteriorated timber piles.

Concrete piles are of two general types, precast and cast-in-place. In dockbuilding, where the piles support structures over water, precast piles are used exclusively. They are generally cast with an octagonal cross-section or square with

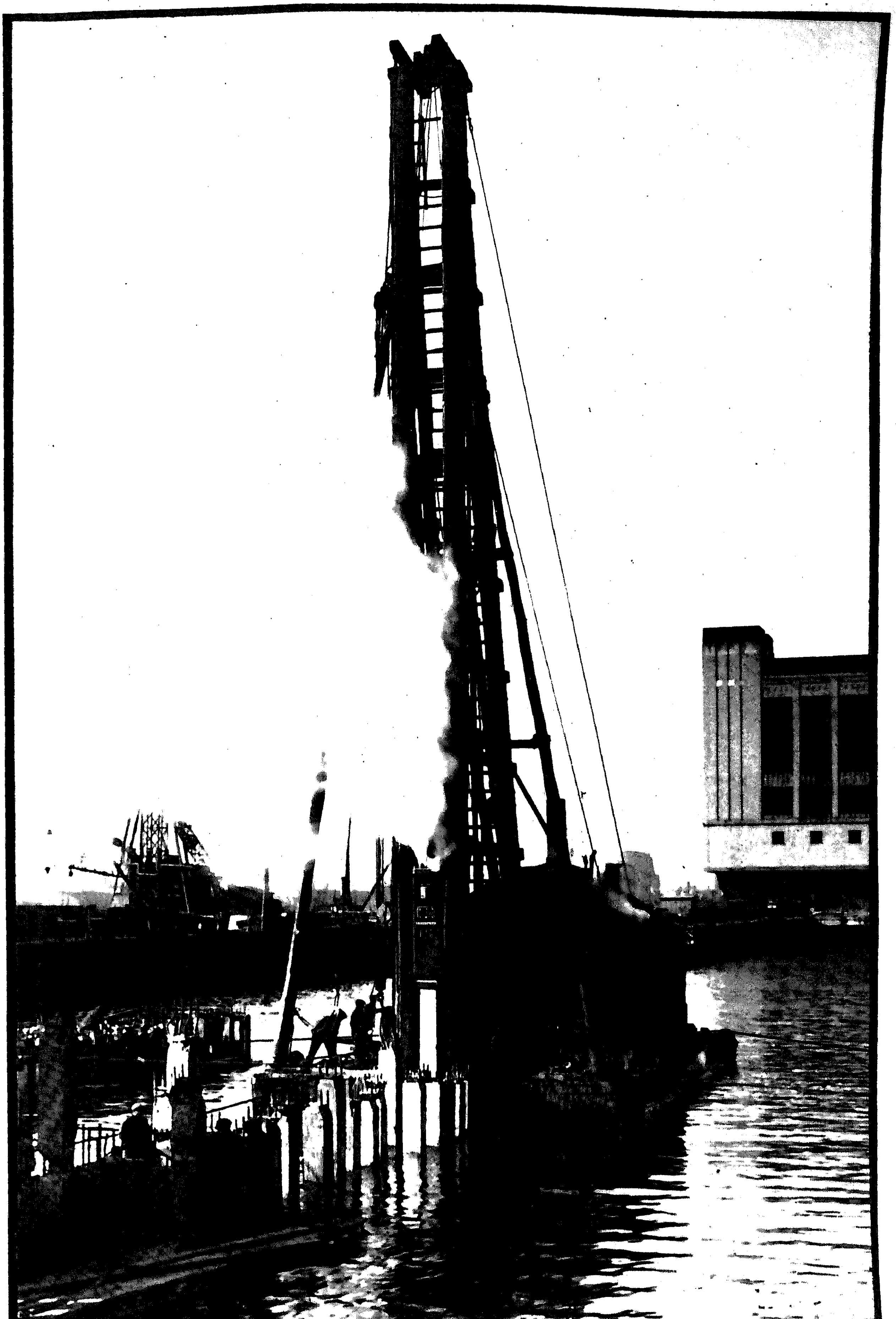


Fig. 34.- Concrete piles, Pier 34, North River.

chamfered corners. They are usually made with one end pointed for driving and most often they are not tapered. The concrete is reinforced both to provide the desired column strength and to resist bending and axial stresses caused by handling and driving. It is customary to cast concrete piles with steel loops projecting at about the third points to facilitate handling.

Concrete piles can, individually, support more than timber piles as columns, but they are not as good as timber piles in developing skin friction. Where hard driving is anticipated and where they are driven to rock, concrete piles also are provided with metal shoes.

Two varities of steel piles are in common use, H-beams and pipes. Steel H-piles have a number of points in their favor. They have high column strength and can stand up under hard driving. Their soil displacement is small, permitting close spacing where necessary, while their sharp points permit them to be driven through compacted sand, gravel, and hardpan that would ordinarily stop piles of timber or concrete. They are durable and will stand hard usage both in place and in handling. Except for long slender pieces they may be handled without much


Fig. 35.- Steel H-piles, Seatrain terminal, Edgewater.

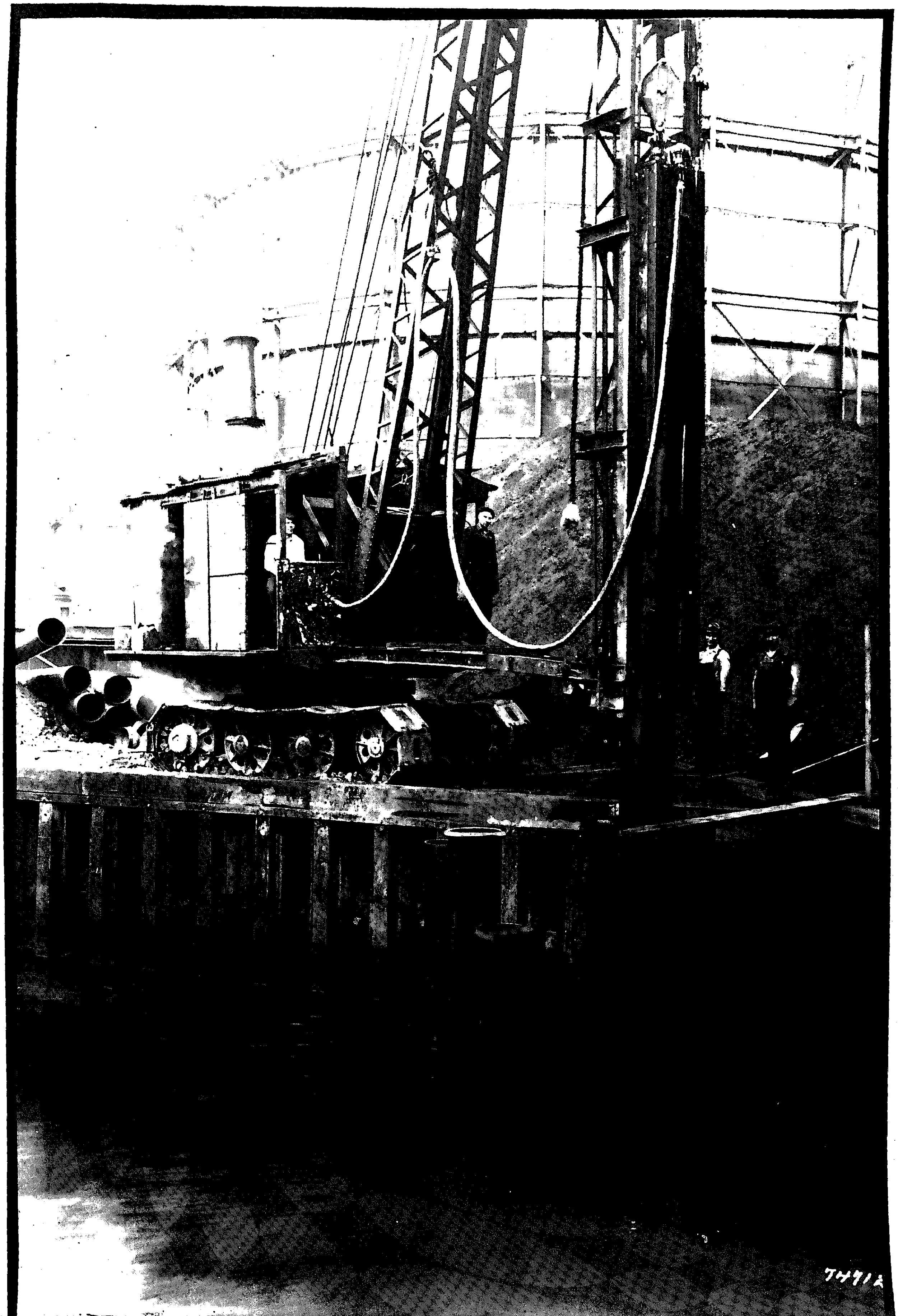



Fig. 36.- Steel pipe piles for coal conveyor, 14th St., East River.

risk of buckling.

Steel pipes or cylinders are also used as piles. When driven with the lower end open they are, after firm bearing is reached, generally cleaned out with a compressed air, steam, or water jet, and then filled with concrete. Others, having their lower ends closed with pointed shoes, are also filled with concrete after driving.

The upper portions of steel piles are frequently encased in concrete to protect them from the corrosive action of salt and brackish waters. While there are many other types and varities of bearing piles, many of which have been driven adjacent to the waterfront, they seldom come within the scope of the dockbuilding field and are not considered here.

* * *

Downward axial loads are not the only loads that piles may be required to carry. In some cases they may have to resist upward axial loads as well; a situation which arises in various ways. For example they might be required to support the weight of the concrete masonry of a large graving dock when the dock is full of water but, when it is dewatered, The same piles might have to resist the upward hydrostatic pressure tending toward flotation. Similarly, such facilities as revolving cranes tend to uplift their foundations on the side opposite the load. Where piles are expected to withstand such upward loads they are connected to the superstructure by some positive means usually designed specially for the particular situation.

Batter piles are driven in pile foundations to provide stability against lateral loads. In the case of docks and wharves, the lateral loads are caused mostly by the impact of ships against their sides.

In general, all piles that are driven through water act as columns throughout their unsupported lengths. Their bearing capacities are determined by means of various formulas which take into account the impact of the pile hammers and the resistance of the piles to driving.

In accordance with the New York Building Code, the allowable load for a pile, not driven to rock, may be determined as follows:

For a drop hammer: $$L = \frac{2WF}{d+1}$$

For a single-acting steam hammer: $L = \frac{2WF}{d+0.1}$

For a double-acting steam hammer: $L = \frac{2(R+Ap)S}{d+0.1}$

Where L = The allowable load on pile in pounds,

W = The weight of the hammer in pounds,

R = The weight of the driving ram in pounds,

F = The fall of the hammer in feet,

S = The stroke of the piston in feet,

A = The area of the piston in square inches,

p = The mean effective pressure of the steam or air in pounds per square inch, and

d = The average penetration of the pile under the last five blows, after a point has been reached where successive blows produce equal penetration, in inches.

Several stipulations are made concerning the use of the foregoing. With reference to the double-acting hammer formula, the term (R+Ap) may not exceed the weight of the entire hammer. Where piles are driven in water they should be considered as columns throughout their unsupported lengths, allowable loads to be governed accordingly. On timber piles having 8 inch tips the maximum allowable load is 20 tons, while those having 6 inch tips may carry only 15 tons.

* * *

Following the introduction of the pile driving technique, a type of structure was developed which, combining the features of a pile foundation and cribwork, came to be known as a pile and crib gridiron. It is adaptable both to the construction of bulkheads and, with a suitable timber grillage, to the support of heavy loads.

Piles, spaced evenly in both directions, are driven to hardpan, cut off at low-water level and capped with squared timbers. From low water up, the construction is similar to that of the old-fashioned crib, except that the crib timbers, instead of being sunk into place, are built up from the caps. Upon completion of the timber work, the crib may be either filled in and graded or provided with suitable decking.

* * *

The great majority of the waterfront structures in New York Harbor are piers. Piers, which are wharves built projecting outward from the shore, are constructed in a number of ways.

Among the earliest forms of pier were those sections of filled-in land behind the perimeter bulkheads of the old slips. Similarly, by completely filling-in cribwork, were constructed the original wharves that were built out from the shore as piers. This was the type of construction that caused the water within the slips to become virtual cesspools because cleansing currents were blocked. Filled-in piers have not been built on the Manhattan waterfront for many years, but in other parts of the harbor there are some still in service. They are isolated cases and, in general, are located where they will not block the current and will cause no offensive conditions to arise. In the more modern piers of this type, instead of utilizing cribwork, the fill is usually retained by some kind of a sheet-piling wall or a platform wall.

The block and bridge type of pier was developed as an improvement over the solid fill type and was used extensively before the practice of driving piles became popular. When it became generally recognized that filled-in piers were objectionable around Manhattan Island, the same old type of cribwork was adapted to a different scheme. Blocks of cribwork were sunk at intervals from the shore, between which the current could flow. These blocks were connected with heavy bridging timbers and then decked to serve as piers.

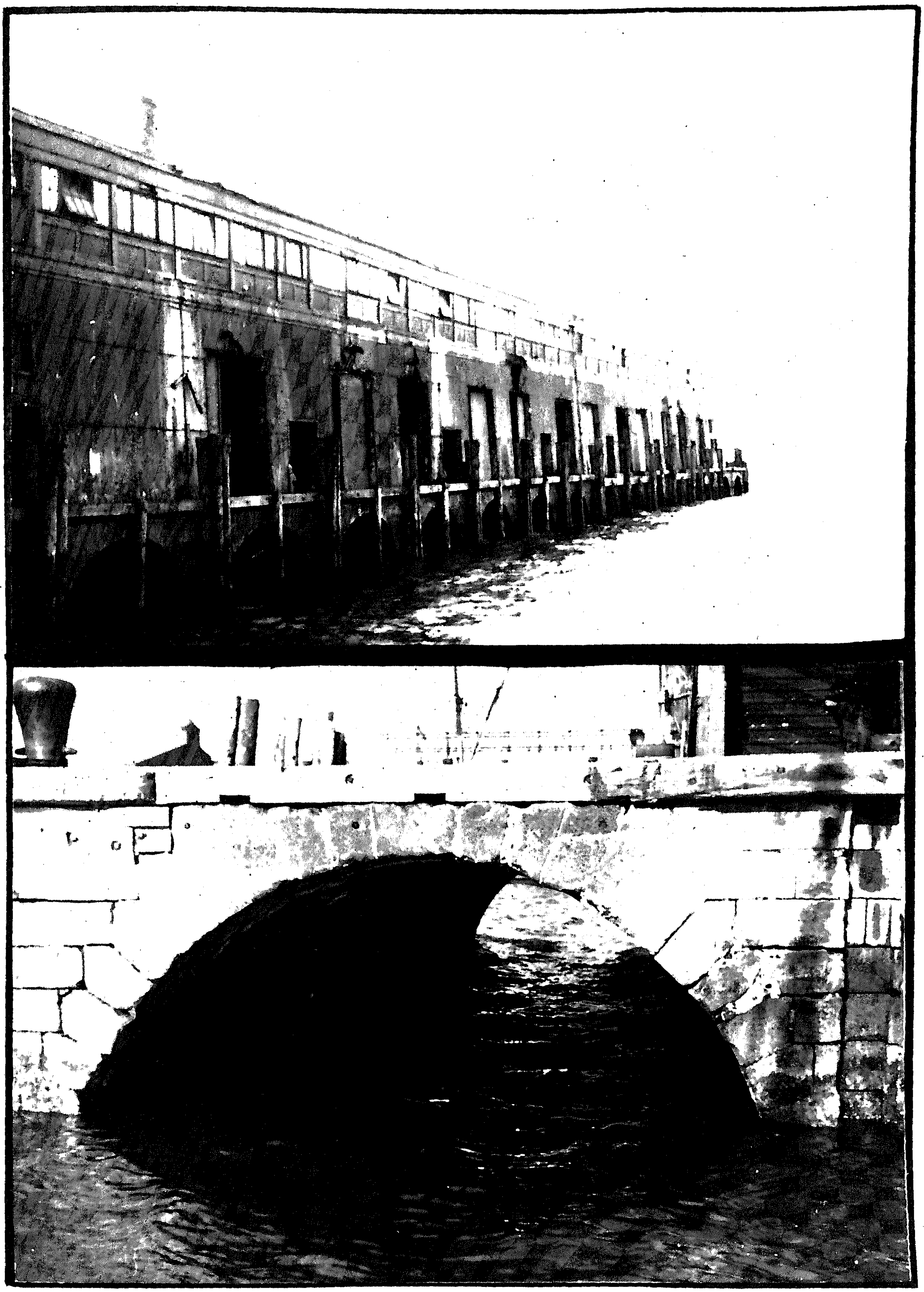


Fig. 37.- Block and bridge type pier, Pier 1, North River.

In 1871 construction was begun on a block and bridge pier founded upon masonry blocks resting on solid rock. This was Pier 1, North River, and it is still standing today. It is about 450 feet long and 80 feet wide and consists of 18 semi-circular concrete arches. The sides of the arches are faced with granite both to protect the concrete against ice and from spalling, and to give it a pleasing appearance, since it is the first pier visible to inbound ships. The blocks or, in this case, the cross-walls of the arches, are 5 feet 6 inches thick and made of precast concrete blocks set in place by derricks together with divers. The bottom blocks rest upon concrete mats which were poured, after dredging the muck, by bottom-dump buckets into weighted forms directly upon the rock bottom.

Pier A, at the Battery next to Pier 1, was similarly built upon masonry blocks in 1875. Instead of transverse arches spanning the spaces between the blocks there are wrought iron girders. The girders are at the spring line of small longitudinal arches which support the deck. These piers represent the only two of their kind ever to be built in New York. The chief reasons that this type of pier never became popular were the slowness of their construction and the fact that vessels were damaged upon coming in contact with the rigid masonry.

* * *

Pile-platform piers rapidly replaced the block and bridge type as soon as steam-power was successfully applied to pile driving. Many variations of this type of construction are now possible by the combination of timber, concrete, and steel materials in different ways. The pier designs prevalently used at the present time provide that the piling, regardless of its kind, extend up to the level of the deck.

Some piers of this variety are still constructed entirely of timber because timber construction has remained popular for several reasons. In New York Harbor timber piles have not been seriously damaged by marine borers; timber is still a comparatively cheap building material both to buy and to handle, and timber piers have the greatly desired quality of resilience. This last feature may well be the most important because piers which have a degree of give to them do not damage the sides of ships as do rigid structures. Furthermore, where piers are supported on piles driven in deep mud without reaching firm footing, so that some settlement is anticipated, timber construction is preferable because it can withstand considerable uneven settlement without suffering damage sufficient to necessitate repairs.

Where timber is used throughout, a typical pier would be constructed as follows. The piles are driven in bents and either capped with 12 x 12 inch cross caps or clamped together with a pair of 6 x 12 inch timbers. The outside row of bearing piles, called line piles, are capped with a longitudinal 12 x 12 inch side cap which supports the outer ends of the cross caps. The individual bents are braced with 5 x 10 inch timbers both diagonally and horizontally at low water. Additional lateral stability is provided by driving batter piles on each side of the pier at alternate bents. Generally the bents are driven on 10 foot centers and the individual piles are spaced 5 feet apart in the bents.

At the outboard end the bent spacing is increased to 20 feet for several bays to provide better passage for driftwood and ice that the current might carry. The outer bents contain nearly four times as many piles, being in double rows and spaced only

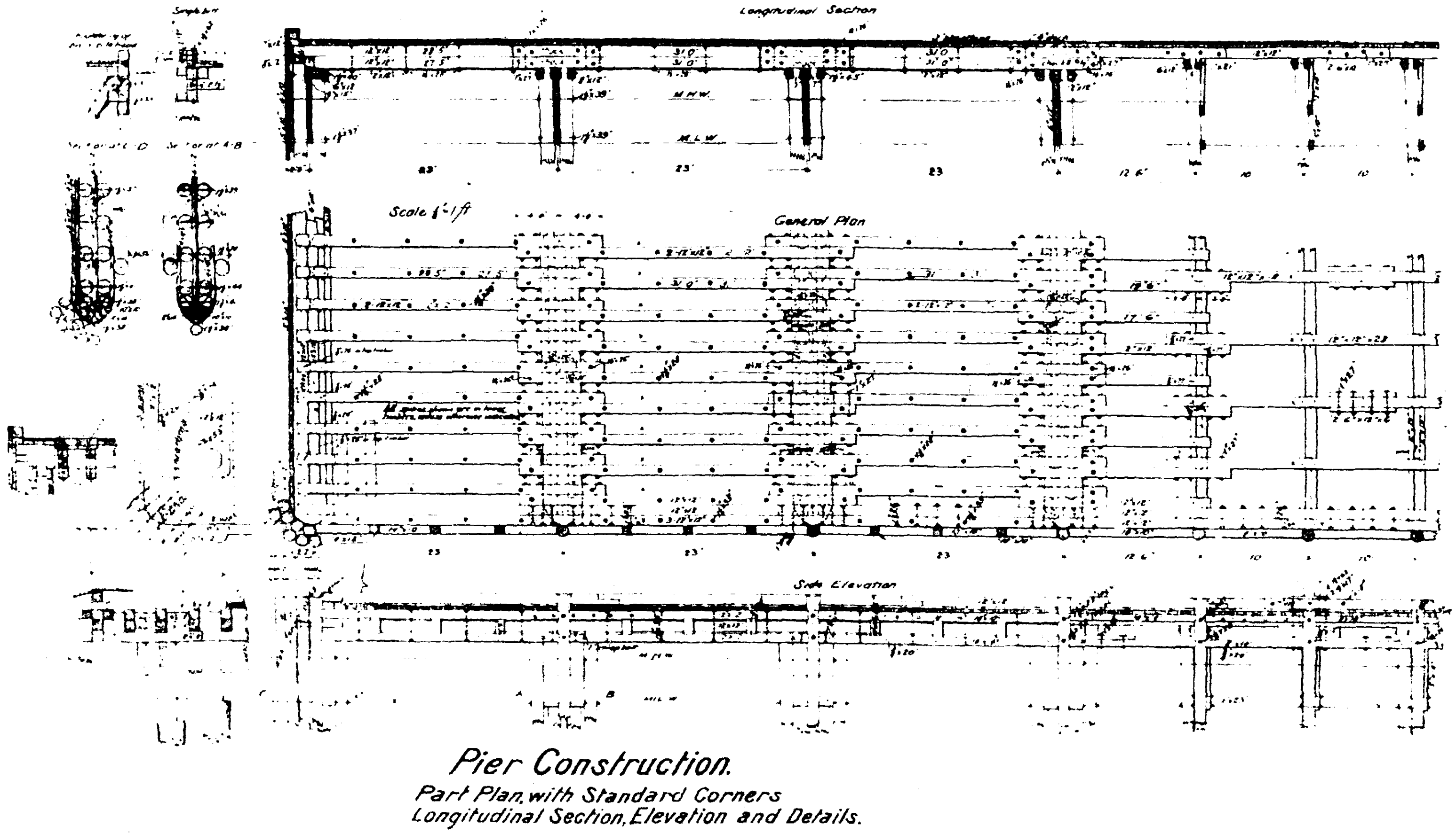
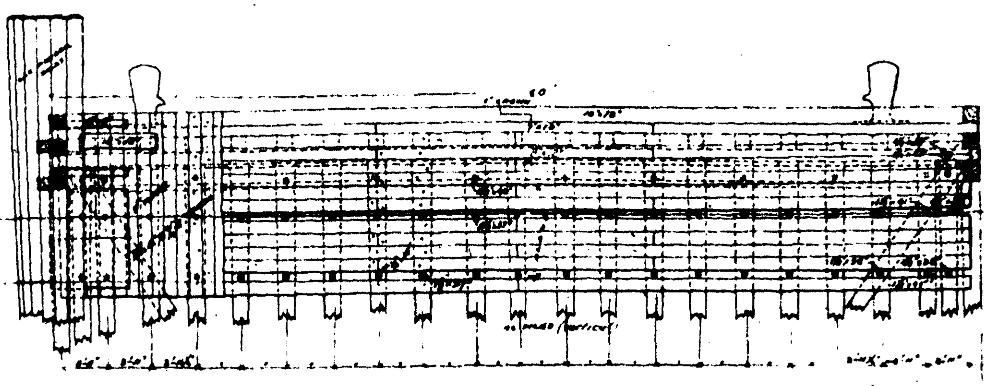
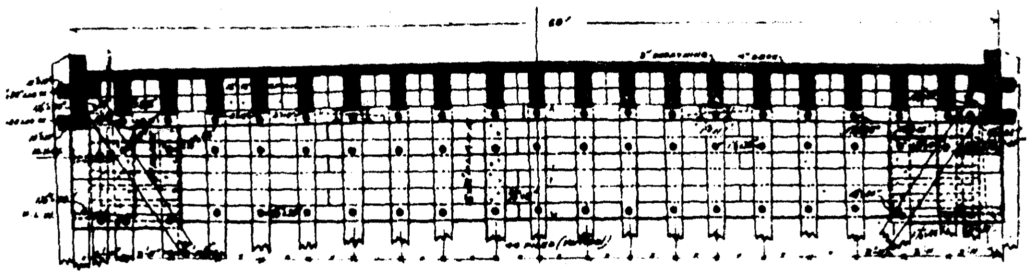


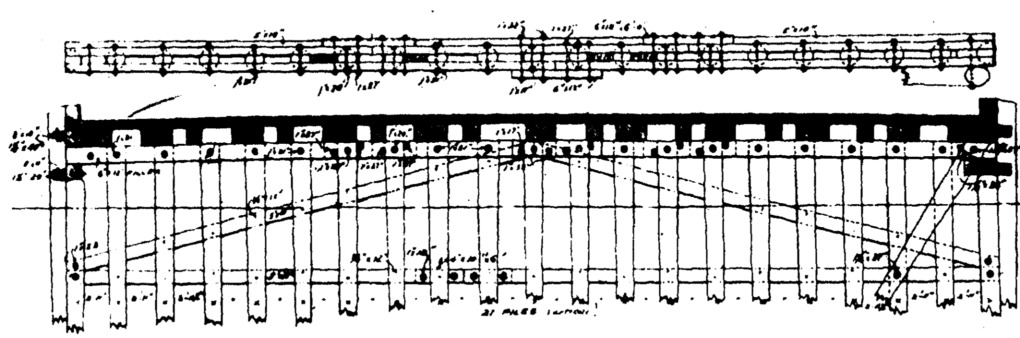

Fig. [illegible].- Timber pier construction (plan and elevation).



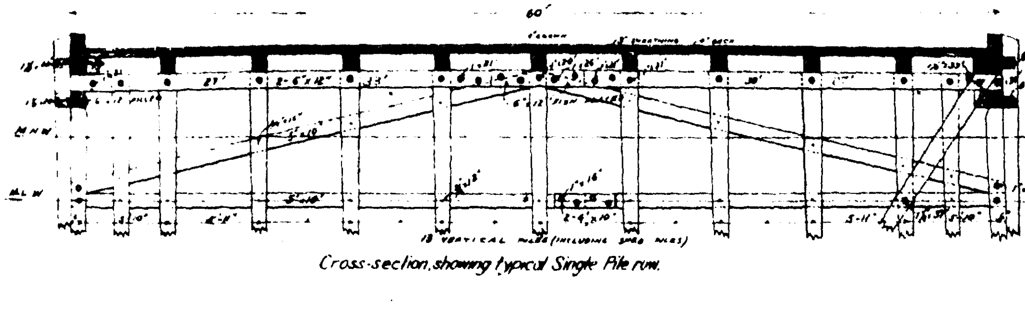
*Elevation, outer end of Pier*



*Cross-section, showing typical Double pile row.*



*Cross-section, showing doubled-up single pile row.*



*Cross-section, showing typical Single Pile row.*

Fig. [illegible]. - Timber pier construction ([illegible]).

3 feet apart. This provides both the necessary bearing capacity for the increased span and greater strength and stability at the outer end where the greatest forces are exerted against the pier by ships being warped into the slips.

Spanning the bays between pile bents are 12 x 12 inch rangers. These are spaced at intervals similar to those of the piles in the bents and are, as nearly as possible, placed directly over these piles. At the outer end where the spans are long, the rangers are doubled up, placing two timbers one over the other and decreasing the spacing to 3 feet.

The deck consists of two layers of 4 inch timber. The lower, the subdeck, is laid transversely and the upper, the wearing course, is laid either longitudinally or diagonally. Many piers having a timber substructure have been provided with a reinforced concrete deck. The concrete is usually about 10 inches thick and protected with an asphalt wearing surface. Frequently the concrete rests directly upon the timber cross caps, but sometimes the pile heads are imbedded in what approximates concrete cross caps.

Not many, but some piers, or at least portions of piers, in New York Harbor are built of reinforced concrete. The piles are precast reinforced concrete the heads of which are imbedded in reinforced concrete girders. Pier 34, North River, is such a pier, combining both concrete, steel, and timber in its substructure to support a reinforced concrete deck. This pier is unusual in design and its construction is described in Chapter Eight.

Steel, too, has been used to build piers. Either H-piles, heavy pipes, or cylinders serve as the piling, while rolled structural shapes are substituted for the various corresponding timber elements of the pier substructure and the deck is usually of reinforced concrete. Steelwork of this kind is comparatively a newcomer in the dockbuilding field and popular practice is at present to electrically arc-weld the connections.

In contrast with reinforced concrete and steel construction which, to date, has not found wide use in pier substructures around New York is another variety of the pile-platform pier that has been utilized to a considerable extent. It is the so-called low-water platform. Piers of this type are built on timber pile bents which are cut off at or near the low-water level, capped, and decked with a 6 inch course of timber. Along the edges of the platform several heavier timbers are placed as rangers to carry the weight of a concrete retaining wall. The area inside the wall is then filled to the desired grade and either paved or used to carry railroad tracks. This type of pier has the advantage of being less susceptible to decay since the timber portion remains wet practically all the time. However, when timber in this type of pier does deteriorate it is practically impossible to renew it.

All piers, regardless of what kind of material is used in their construction, are furnished with a fender system of some kind. The various different systems of fendering are described in later paragraphs.

* * *

Bulkhead walls or retaining walls are required for the construction of marginal wharves, solid-filled piers, and for seawalls. Such walls must be able to withstand the action of waves and ice, prevent erosion of the shore, and resist the forces tending to overturn them or to make them slide exerted by the fill material and its surcharge. Those walls which are intended to afford wharfage space must in addition

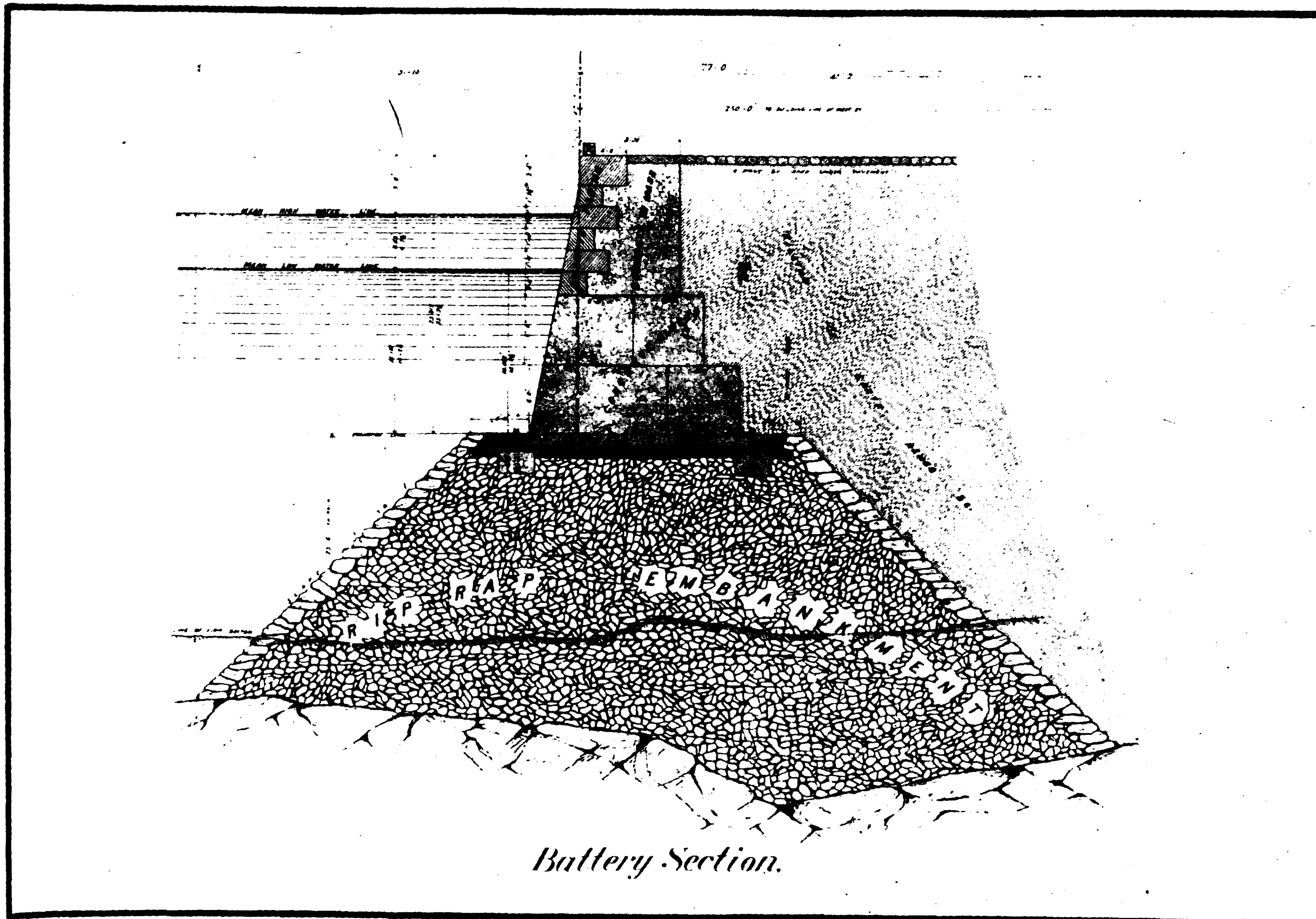



Fig. 40.- Concrete block wall on riprap, as built at the Battery.

provide a nearly vertical face next to water deep enough to permit the docking of vessels close alongside.

A simple but effective form of retaining wall is obtained by placing a bank of riprap. Such a wall cannot be overturned and is not very apt to slide. Compared to other types of wall, such as concrete and stone masonry, riprap is very cheap but, due to its sloping sides, it is not usable as a wharf without combining other elements of construction with it to provide a vertical face.

Figure 40 shows how a bank of riprap was used to take the greater part of the earth fill thrust while a wall of precast concrete blocks was built to take the rest and at the same time provide the required wharfage. The concrete mat which provides an even bearing for the blocks was placed with dump buckets and leveled off in forms anchored in place. The underwater work and the placing of the blocks was accomplished by divers. The upper portion was constructed in the conventional manner.

In some instances, where the water is not too deep, it is desirable to carry a concrete gravity wall down to rock. Figure 41 shows the type of wall that

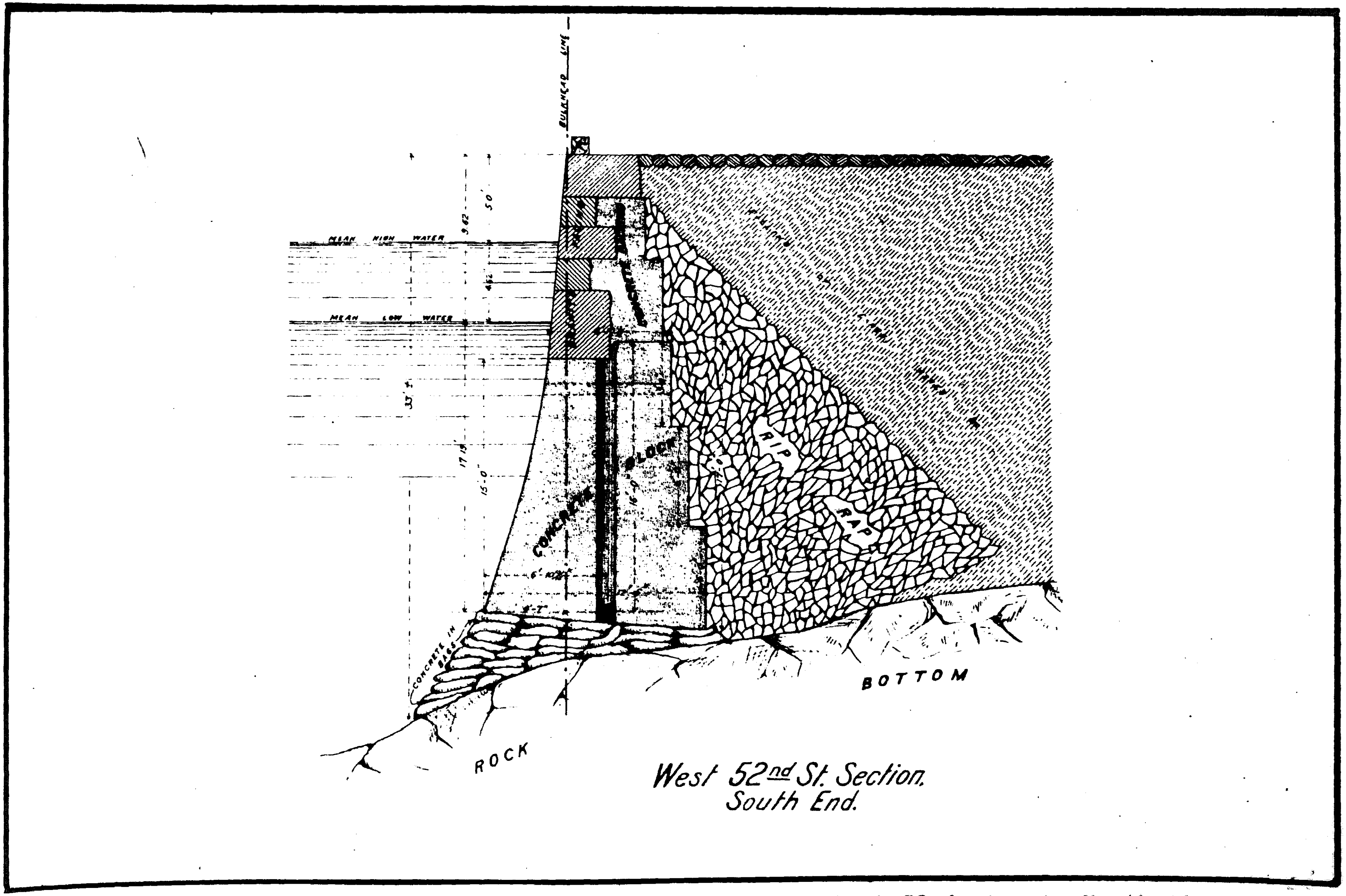


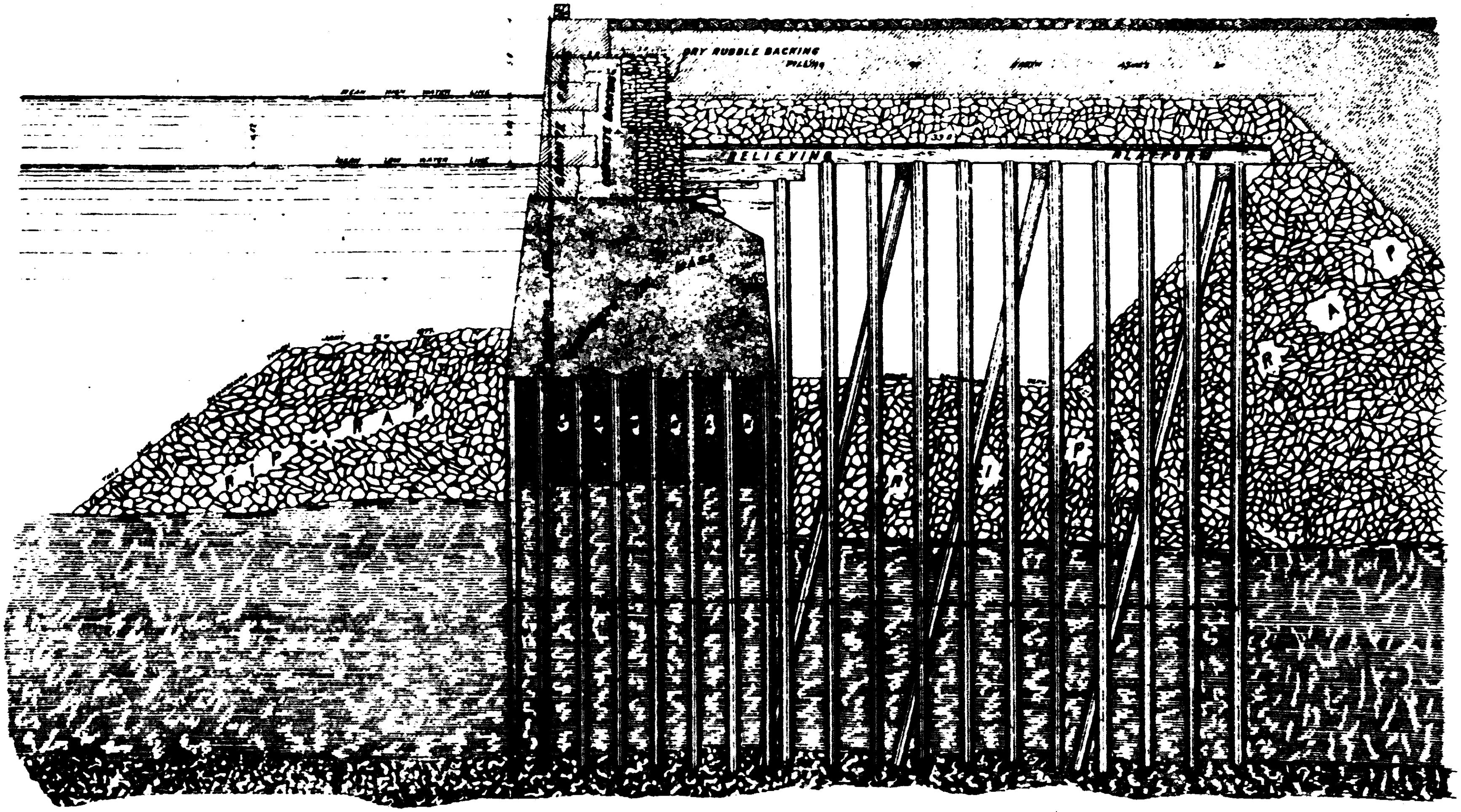

Fig. 41.- Concrete block wall on solid rock, as built at 52nd Street, North River.

was constructed in the vicinity of the Trans-Atlantic Steamship Terminal. There, the large precast blocks that were used weighed 70 tons each. The irregularities in the surface of the rock were first graded by placing bagged concrete. Before the blocks were lowered a layer of concrete was placed over the bags and leveled off with a heavy straight-edge. The placing of the bags and the straight-edge work was done by divers.

In order to reduce the pressure against the blocks, a bank of riprap was placed behind the wall and, to minimize lateral disalignment, the large blocks were keyed.

The fact that this type of wall was well designed and durably built was well demonstrated while the Trans-Atlantic Steamship Terminal was under construction. Portions of this wall were exposed in the dry inside the cofferdam and it was found that the bagged concrete was still in its proper place, in good condition, and that the large blocks had not moved.

Concrete blocks used in the manner illustrated by Figures 40 and 41 were poured in the dry in a yard and brought to the job site on barges where they were



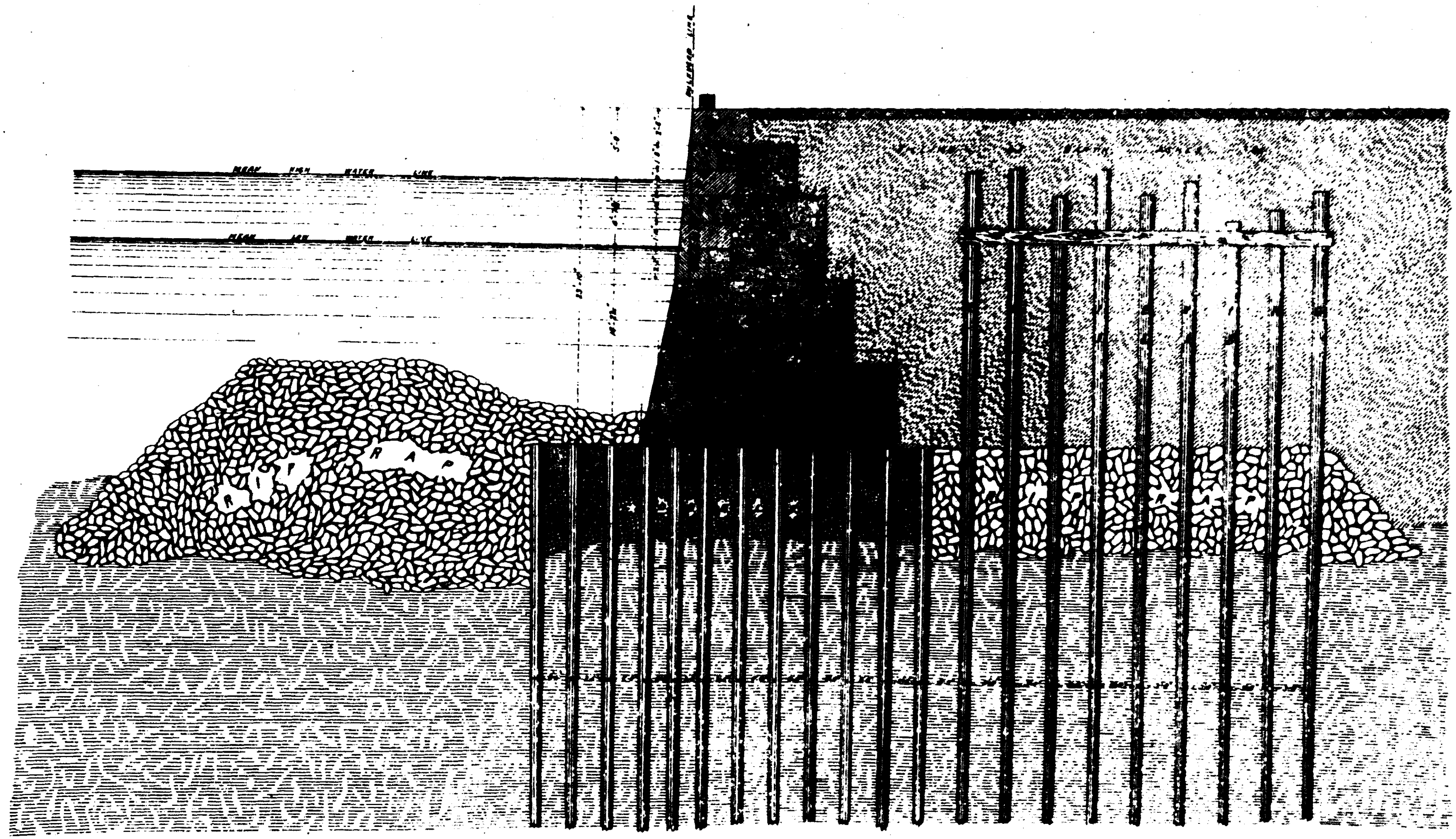

*Canal St. Section,*

Fig. 42.- Mass concrete and relieving platform, as built on North River.

placed by means of the old-fashioned derrick depicted in Figure 66. At that time, about 75 years ago, this precast concrete was known as "beton blocks".

Beton blocks were not used exclusively for constructing concrete gravity walls. Some were poured inside cofferdams and founded directly upon the rock surface. Others were poured in open forms or caissons that were weighted and sunk into place. An example of this latter type of construction, which was known as "beton en masse", is illustrated by Figure 42.

Nor are all gravity walls founded on rock. Figure 43 shows a wall of beton blocks resting upon piles where rock bottom was excessively deep. The piles were driven to rock through soft material and cut off at about 15 feet below mean low water. The space between the pile heads was filled with cobblestones up to about 2 feet below the cut-off. Mass concrete was placed on top of the cobblestones to fill the space up to the pile heads. To relieve some of the earth pressure, rows of piles were driven behind the wall and stiffened by a layer of riprap deposited on the mud around them. The heap of riprap in front of the wall was placed to help counteract the weight of the fill and thus tend to prevent any



*Christopher St. Section.*

Fig. 43.- Concrete block wall and relieving piles, as built on North River.

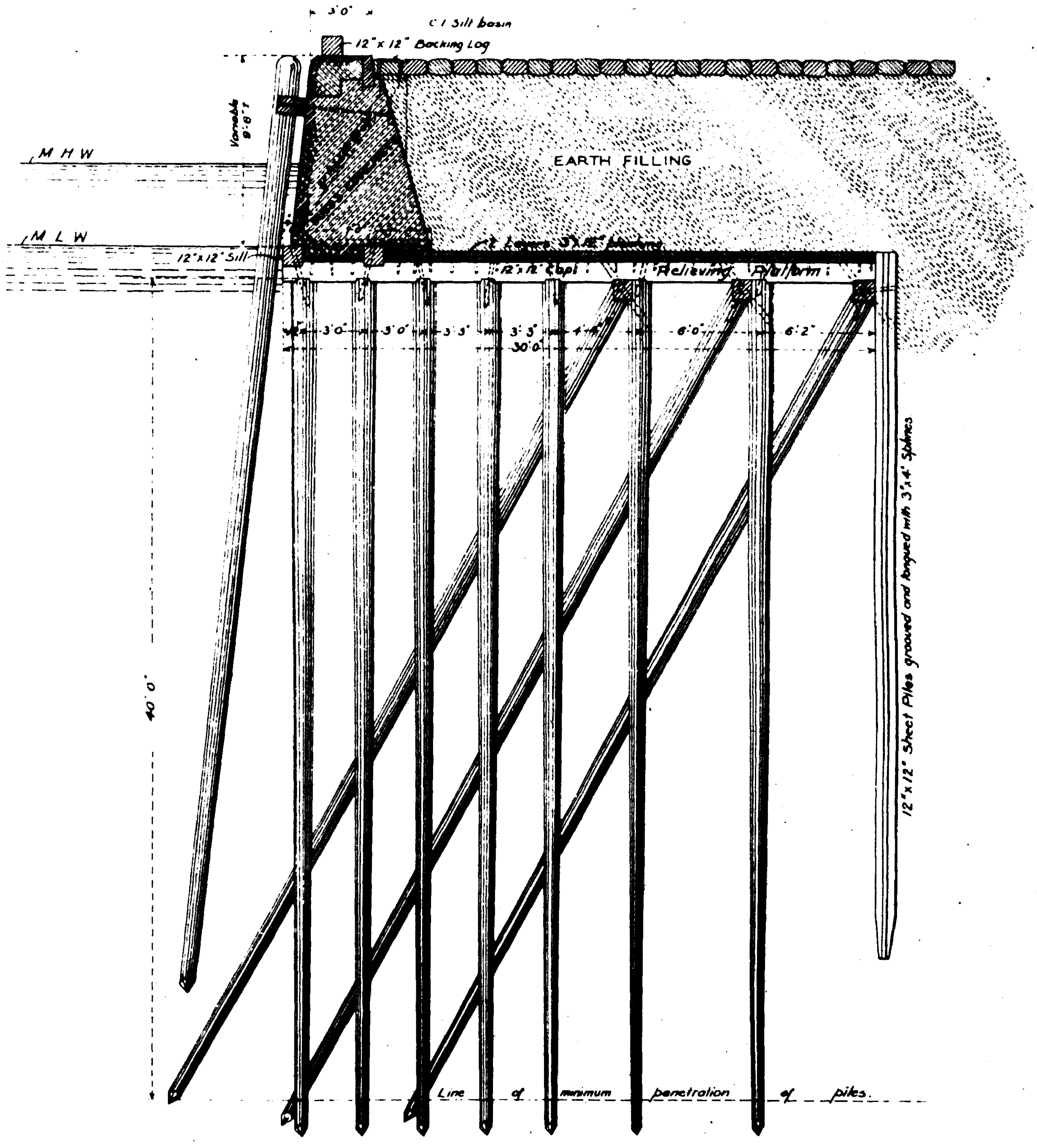
movement under the wall that might be set up by the formation of a mud wave.

* * *

A relieving platform wall is a retaining wall built upon the edge of a pile-platform. Some platforms are built over the natural slope of a bank, extending outboard far enough to obtain the desired depth of water. The slope may be artificially steepened to reduce the width of the platform so long as a safe angle of repose is maintained. Where an excessively wide platform would be required because soft material would prevent a slope from standing, a bank of riprap is sometimes used in conjunction with the platform wall.

Figure 42 illustrates a variety of relieving platform wall, and shows how a pile of riprap is used to prevent the fill from flowing under a relieving platform where it could exert pressure against the wall. The wall in this case is a "beton en masse" gravity wall, poured by buckets into forms that were sunk in place around the cut off piles.

A relieving platform wall built at Wallabout Basin, Brooklyn is illustrated by Figure 44. This wall was constructed at some distance in from the




*Bulkhead Wall as built at Wallabout Basin, Brooklyn,*

Fig. 44.- Relieving platform wall, as built at Wallabout, Brooklyn.

existing shoreline, and the waterway outside was dredged up to it after its completion. There, instead of riprap to prevent the fill from escaping underneath, heavy sheet-piling of 12 x 12 inch timbers, grooved for 3 x 4 inch splines were driven at the rear of the platform. No tie-rods or anchors were used but the sheeting was supported laterally at the top by the thrust of three rows of batter piles.

Of all the platform walls to be constructed, perhaps the most remarkable is the one designed in 1876 for the New York Department of Docks and illustrated by Figure 45. It incorporated the use of 70 ton "beton blocks" and was built where the mud, in some places, was 170 feet deep. To prepare for its construction, a trench was dredged in the mud about 30 feet deep by 85 feet wide. On the slopes a light layer of cobblestones or gravel was deposited to retard the flow of the mud and enable the trench to retain its cross-section. Then the piles were driven, straightened up with the aid of guide-logs sunk for this purpose between the longitudinal rows, and stay-lathed. Next cobblestones and riprap were deposited up to elevation minus 18.00. The cobblestones, being more compact, were used between the piles.

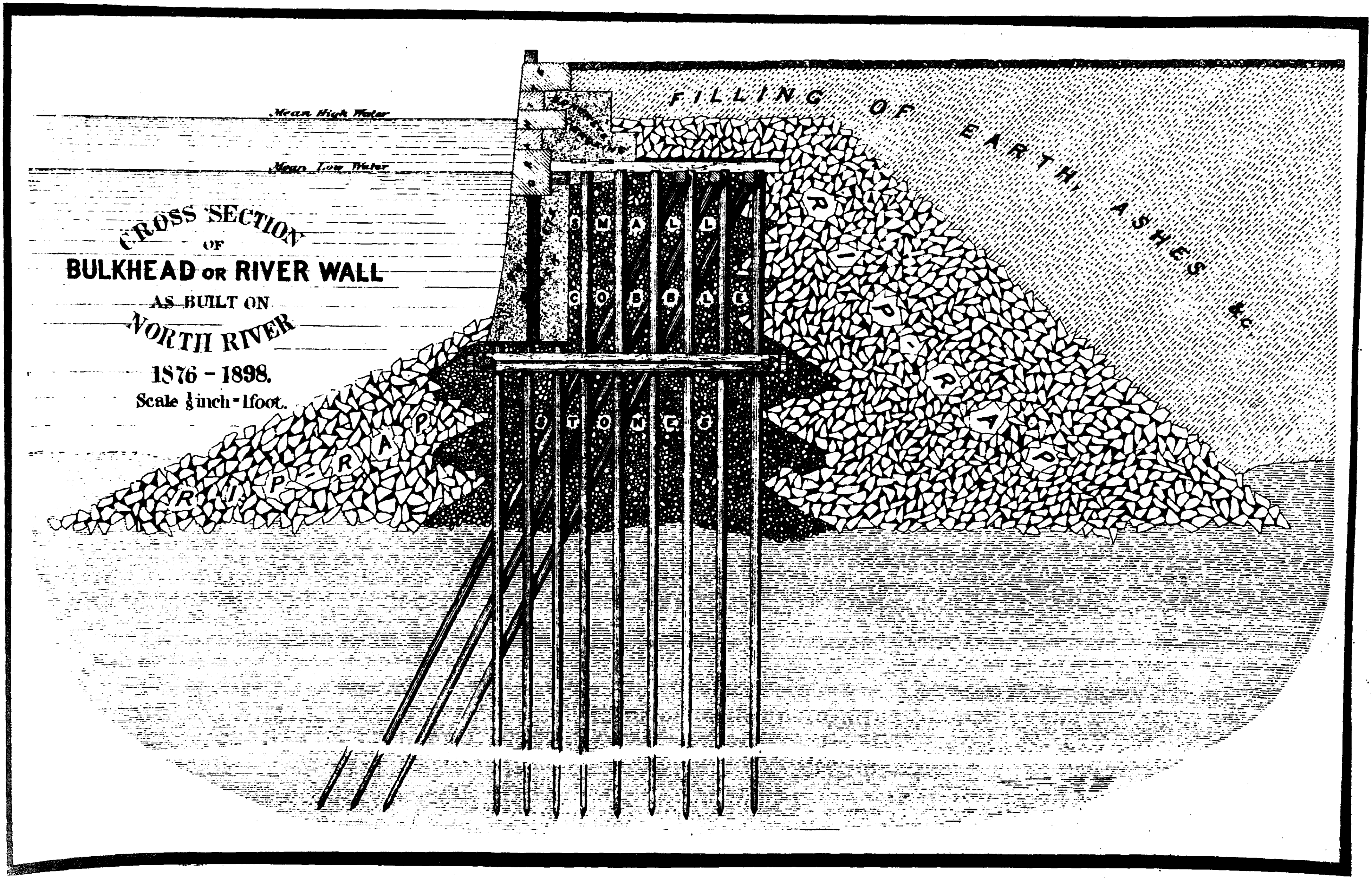



Fig. 45.- Relieving platform wall, as built on the North River (1876-98).

Binding frames, in 24 foot sections, were then slipped over the transverse rows of piles and weighted in place on top of the cobblestones. This was done to hold the pile group together and prevent any possible pushing out of the front three rows from under the blocks.

Since piles cannot be accurately spaced under water, and since it was desired to ascertain that all of the piles supporting the blocks were performing their full duty, it was considered necessary to locate the cut off pile heads. To accomplish this a screen, having about a one inch mesh, on a heavy frame was lowered by a derrick to the pile heads. Then a diver marked the location of each pile by snapping a hook on the screen. Thus any piles outside the limits of the base of the concrete, or too irregularly spaced, were spotted and extra piles were driven where necessary.

At that depth pile cut-offs cannot be made exactly at the same elevation, so measures were taken to insure uniform bearing under the blocks. A net-work of rope was stretched on a frame somewhat larger than the base of the blocks and, when a block was ready for setting, two sheets of burlap, filled like a mattress with freshly mixed concrete mortar, were placed on the frame and lowered to the tops of the piles. A diver then cut the rope netting and the frame was removed, immediately after which the block was set. The pile heads, by pushing into the soft mortar to varying degrees until the block came to rest, enabled each pile to carry an equal load.

Behind the masonry portion of the wall and between the piles the space was filled with cobblestones. Then the granite facing was laid, the platform built, the riprap embankment deposited, and the fill placed as shown. The underwater pile cut-offs both for this wall and for those in Figures 42 and 43 were made by a circular saw mounted on a vertical shaft and lowered from the scow of a piledriver.

It is of interest that, in the low-water platforms built at that time, no metal fastenings were used. The timbers and piles were connected by means of wooden dowels or, as they were called, treenails which may be noted in Figure 44. It is also of interest that these old wooden pin connectors, some of them as large as 3 x 48 inches, have been found to be in first class condition when exposed during the recent demolition of some old structures.

* * *

A sheet-piling wall is a type of retaining wall constructed by driving a row of close sheet-piling. The sheet-piling is supported at the bottom by the lateral resistance of the material into which it is driven, while the top is supported by means of tie-rods and anchors.

The dependability of this type of wall is governed to a very great extent by the amount of lateral top support afforded. Numerous methods to assure adequate support have been designed utilizing tie-rods, anchor piles, and concrete anchor walls. Any method that does the job may be considered satisfactory, but one that omits the use of anchor piles is looked upon with skepticism because of the uncertainty of the safe angle of repose and the horizontal compressibility of material placed as fill behind a wall. Such walls are constructed with comparative ease and, since the development of steel sheet-piling, have gained wide popularity and use.

Timber has been used in this type of construction and is comparatively cheap in first cost, but the timber above the water line rapidly decays in a few years necessitating extensive repairs. A typical timber sheet-pile bulkhead wall is constructed in the following manner. Timber piles are driven plumb, about 4 feet apart, on the line of the desired face of wall. The depth to which the piles must be embedded will depend upon the depth of the water and the physical characteristics of the soil into which they are driven. The piles are cut off at the grade of the fill, or higher if it is so desired.

A timber wale, perhaps 8 x 10 inches, is then fastened to the backs of the piles a few feet below grade while another is similarly placed near the low-water line. The sheeting, which may be either square-edged or tongue and groove, is driven close behind the wales until it has sufficient penetration to hold the tips.

Heavy tie-rods are placed at alternate piles. Passing through the pile, they extend back for a distance considered to be beyond the top of the natural slope of the fill material. The tie-rods, as stated before, are most reliably anchored by piles, but other methods are sometimes used depending upon local conditions.

This type of wall was constructed along the shores of Newark Bay to retain filled-in areas but not to provide wharfage. In this particular case the wall was additionally supported by batter piles, at 8 foot centers, driven outside the wall.

Reinforced concrete sheet-piles are used in much the same way as timber. They also are used to advantage in the construction of filled-in piers and at the rear of relieving platforms. The tops of such sheeting are often cut near high water and capped with concrete. The concrete caps have been so designed that they hold the tops of the sheeting in line, provide a girder through which to run tie-rods, and form the upper portion of the wall between cut-off elevation and grade of the fill. The sheet-piles themselves, in order to secure tight joints, may be cast with tongue and groove edges or with steel interlocking flanges.

The use of steel sheet-piles in waterfront construction has spread widely during recent years. One of its popular applications is its use as a bulkhead wall. In this type of wall, as in those of timber or concrete, the most important considerations are those of adequate footing and anchorage for the sheeting.

The sheeting is held in line at the top by means of wales, usually a pair of channels back to

Fig. 46.- Reinforced concrete sheet-piling with steel interlocks.

back, located at or near the water level. The wales, in turn, are tied back to the anchor piles by means of large rods and heavy plate washers. The wales and rods are located, so far as is practical, at an elevation which will reduce to a minimum the spans of the beams formed by the sheet-piles and loaded by the earth pressures behind them.

To finish the bulkhead wall, a cap of timber, concrete, or a rolled steel shape is placed over the ends of the sheeting. Timber fendering is added to the face for the protection of vessels.

When interlocking steel sheeting was first introduced it was all of the flat or straight web variety. This was used for all types of work to which sheet-piling was adaptable until, experience having proved its value, other shapes were developed. At the present time it is rolled in three general shapes which vary in thickness and weight to meet specific requirements.

An early improvement over the straight web for bulkhead construction is the arch type sheeting which provides a greater section modulus to resist bending. More recently introduced are Z-piles which are superior to the arch type inasmuch as they develop

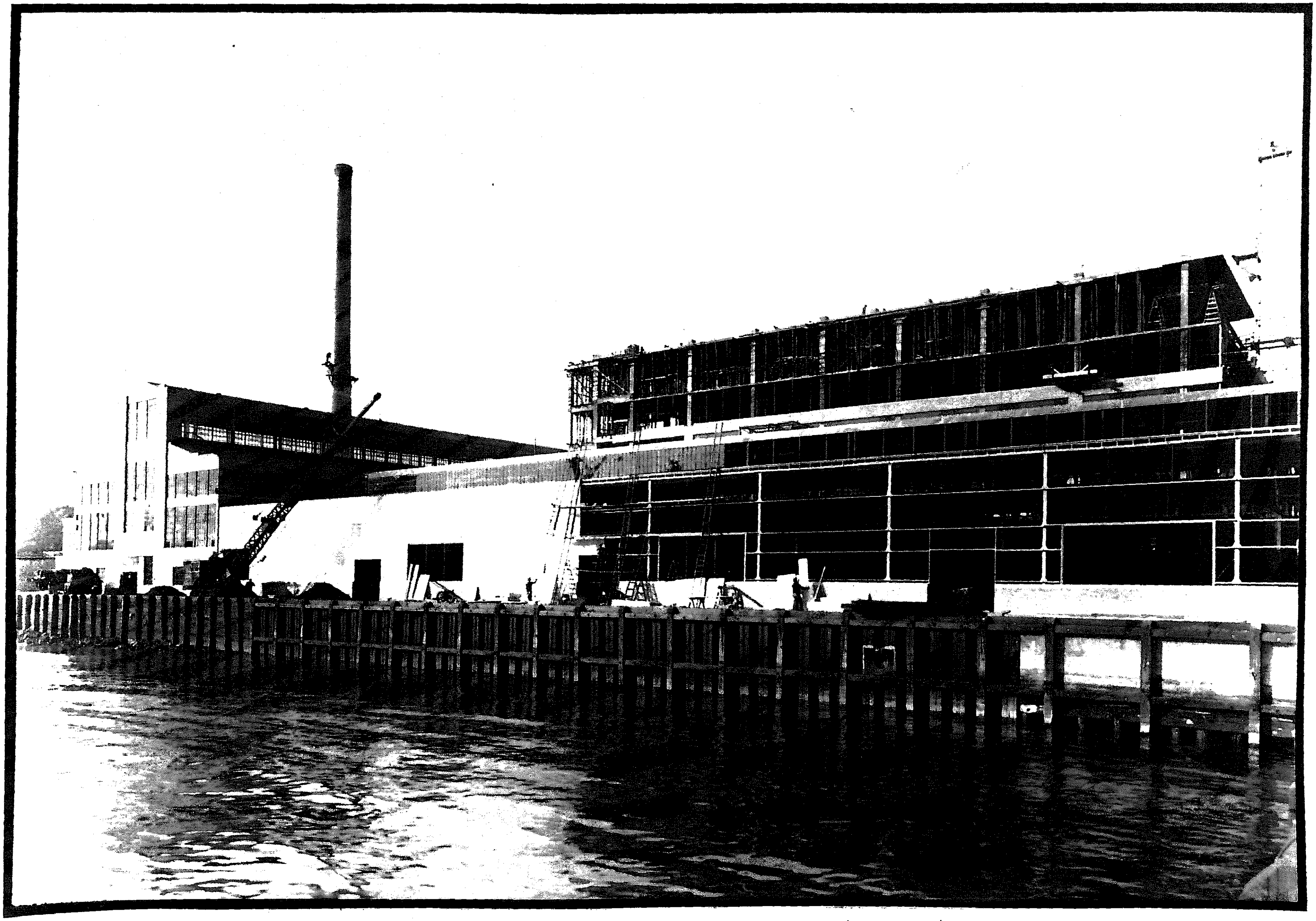


Fig. 47.- Steel sheet-piling bulkhead (Z-type).

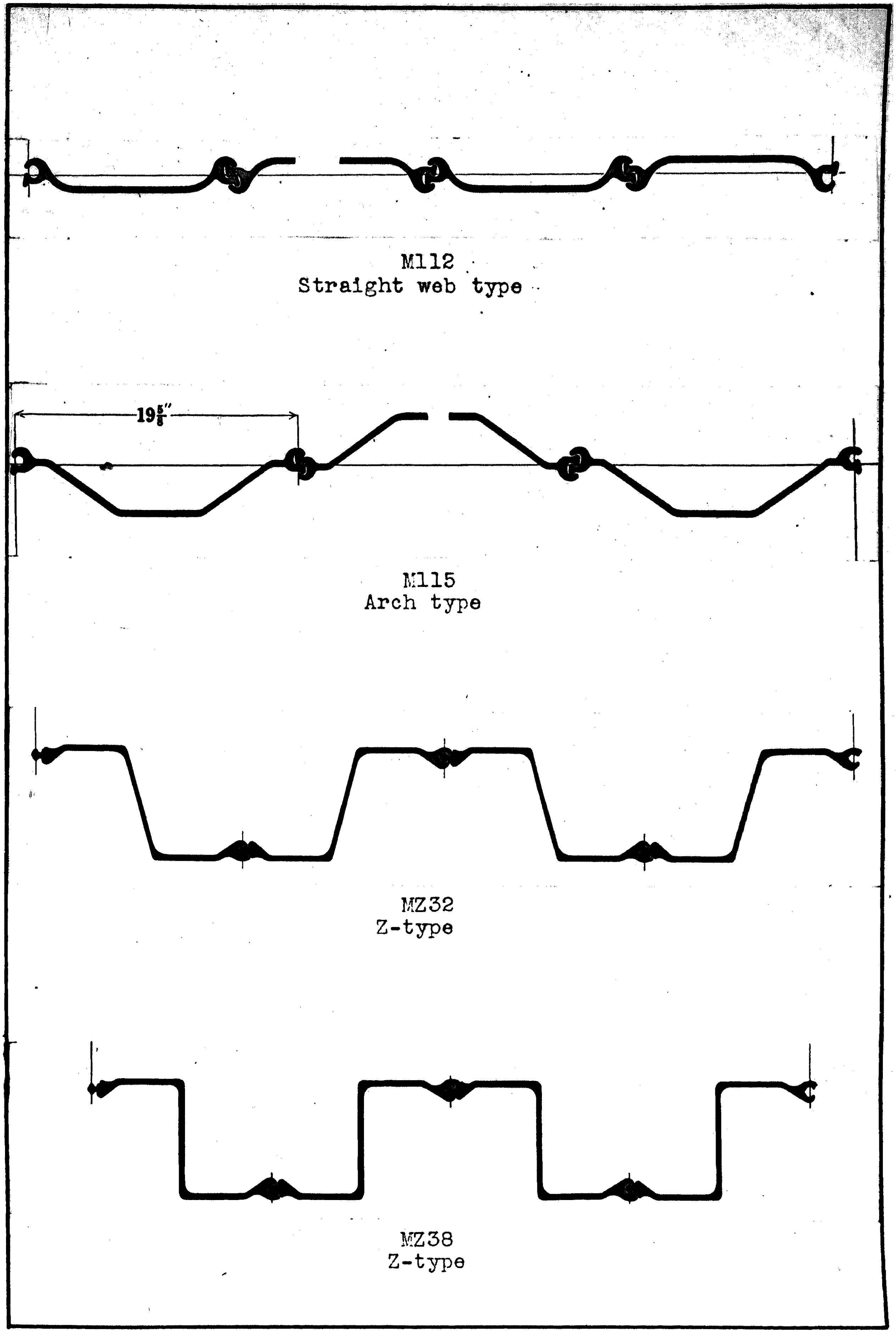



Fig. 48.- Types of interlocking steel sheet-piling.

a still higher section modulus for a given weight of steel. In addition, they have the same resistance to bending whether taken singly or interlocked with other piles, and the interlocks are located where the shear developed by bending stresses equals zero, so that slippage on that account is eliminated.

Other advantages of steel sheeting are its ability to withstand hard driving through material and obstacles that would be disastrous to timber or concrete, its great strength in bending which necessitates only one wale even where water may be 40 feet deep, and its near water-tightness due to the close fitting of its interlocks. In spite of the toughness of steel, where the driving is exceptionally hard, as through riprap or gravel with boulders, the ends of the piles may be crumpled and the interlocks torn.

In addition to bulkhead walls for docks and wharves, steel sheet-piling has been adapted to other types of construction. Jetties and breakwaters have incorporated its use as have seawalls and groins. Cut-off walls behind low-water platforms also can be driven advantageously with steel sheeting. Underwater concrete foundations, such as bridge piers, are often formed with steel sheeting which can be withdrawn after the concrete sets, or left in place as part of the structure, as may be desired.

The extent to which cofferdams can be used has been widened greatly by the development of interlocking steel sheeting. The comparative ease with which it can be driven, the certainty and water-tightness of the interlocks, and the ability to pull it and reuse it elsewhere are all contributing factors.

To meet the requirements of the various uses to which it may be put, two principal types of steel sheet-piling are made. Where high beam action is required arches and Z-piles are used. For hard driving, temporary work involving pulling and redriving a number of times, and for cofferdams of the cellular type where high interlock strength is required, the sheet-piling of the straight web variety is rolled with extra large and strong interlocks.

* * *

The successful completion of bulkhead or retaining walls of any type very often depends upon knowledge and appreciation of mud wave action. Muck and some soils, when saturated as in subaqueous locations, have the physical characteristics of a viscous fluid and sluggishly conform to hydrostatic principles. As a result, the stability of such material is low and its equilibrium can easily be destroyed. When for any reason its equilibrium is disturbed the resulting motion, which possesses great destructive potentialities, is termed a mud wave.

There are numerous instances in the past where structures have been damaged or destroyed by the action of mud waves in the material in which they were founded. The forces exerted may become tremendous, capable of overturning or laterally displacing heavy masonry or sheet-piling walls, laterally moving entire pile foundations, or shearing off piles the points of which are imbedded in sand or clay firmly enough to resist the lateral forces.

Mud waves are commonly caused in several ways. Perhaps the most common is the placing of a heavy surcharge, such as a stock pile of coal, upon filled-in material under which lies a stratum of semi-fluid soil. In this case the surcharge sinks into the soft substratum and displaces it laterally. Occasionally the soft material may be heaved upward, causing a raise in grade of the surrounding area. The pent up lateral pressure may reach sufficient magnitude to cause a bulkhead wall to "go out".

Another way similar to the first, by which a mud wave may be set up, is by improperly placing fill. In the construction of a bulkhead or retaining wall, the placing of the fill is generally not commenced until after the wall is completed. Then, if the substratum is soft, the fill should be placed commencing immediately behind the wall and progressively inward. Thus any mud wave action is directed away from the wall, to dissipate itself against the shore. Usually it is much more expedient to dump fill inshore first, bulldozing it outward, and the temptation to do so is great. Failure to reckon with the possibility of a mud wave however, usually proves to be detrimental to the wall.

Mud waves can also be caused on a smaller scale by the driving of piles. Where piles are driven through muck, the volume of each pile must be displaced and forced aside. Some of this displaced material moves vertically to cause "bulking", which is a raise in elevation of the river bed. The remainder moves under pressure laterally. Such a wave sometimes manifests itself by pushing previously driven pile bents out of line or by causing movement in a closely adjoining structure. While driving the numerous large concrete piles for Pier 34, North River, a mud wave was set up sufficient to cause a movement, perceptible with a transit, in the alignment of the Holland Tunnel tubes.

While not a frequent occurrence, it has happened that a mud wave caused movement and damage in a structure so remote from the center of activity that the operation responsible was not suspected. The operation in question was an extensive dredging job involving the removal of a large quantity of semi-fluid material. The result was a lateral flow of similar material from the surrounding areas. A pile supported structure located a quarter of a mile or so away was within range of the wave and was subjected to an "inexplicable" foundation movement.

* * *

Fender systems are constructed around the perimeter of waterfront structures both to prevent injury to the substructure by abrasion and collision and to absorb part of the impact of vessels against their sides. The kind of fendering depends upon local conditions which are caused by waves, swells, or currents and upon the type of vessels which are to be berthed alongside.

Where substructures are built of wood, protection against abrasion is all that is required, since the elasticity of this type of construction is sufficient to absorb impact. Rigid structures, such as those built on concrete and steel piles and with the rest of their substructures of similar material, need compressible fenders to protect both the pier and the vessels using it.

In New York Harbor no particular problem is introduced by waves and swells because of the sheltered location of most of the docks. Only a few docks of concrete construction are so rigid as to require compressible or spring fenders. Where such fenders are needed they are constructed in two principal ways.

The first consists of a row of fender piles driven parallel to and at a distance of several feet from the face of the dock. These piles are fastened to horizontal wales and protected with chocks bolted to the wales between the piles. The momentum of vessels coming in contact with such a fender rack is greatly reduced before the tops of the piles are pressed far enough to contact the dock proper. A variation of this system utilizes heavy coil springs between the rack and the dock.

The other way, used where the water is so deep that springing fender piles would likely be broken, consists of vertical fender blocks. The blocks, heavy pieces of timber long enough to cover the area against which vessels might make contact, are fastened to the dock combining the use of heavy springs to act as shock absorbers.

The great majority of the New York docks are provided with fixed fenders. Of this type there are many variations, a few of which are used extensively. Nearly all fender systems are constructed of oak timber because of its hardness and resistance to abrasion and because it will not damage the sides of steel hulls.

Wharves that are used by large vessels usually have a fender system consisting of fender piles and horizontal fender timbers called caps and chocks. The fender piles are driven close outside of each line pile of the dock and bolted to the side cap. The fender cap is mortised to fit snugly over the head of each pile and bolted to the backing log. The fender chocks, usually a single row bolted to the side cap, are also framed to fit tightly against the fender piles with bevelled ends which tend to hold the piles against the

Fig. 49.- Fender piles, cap, and chocks.

Fig. 50.- Close fender piling.

dock and prevent them from rolling. In some cases a double row of chocks is used but this is uncommon. Fender systems are secured to concrete dock walls by means of anchor bolts.

For docks at which the water traffic is mostly tugboats, barges, and carfloats, rows of fender piles driven closely together (Fig. 50) or horizontal sheathing is also used for fendering. Both the close piling and the sheathing is intended to prevent the corners of carfloats, low barges and so forth from getting under the pier between bents and causing damage to the substructure. Damage is often incurred by docks with open fendering when the corner of a barge gets caught under its side on a rising tide.

Horizontal sheathing, which usually varies in size from 5 x 10 inch to 6 x 12 inch, is spiked to a row of piles driven just outside of the line piles and side cap of the dock. The piles in this row are spaced about 2 or 3 feet apart both to provide sufficient means of fastening and to brace the sheathing against excessive bending and breaking. Railroad sheathing is the term applied to horizontal sheathing arranged as shown in Figure 51. Solid sheathing (Fig. 52) serves the same purpose but presents less

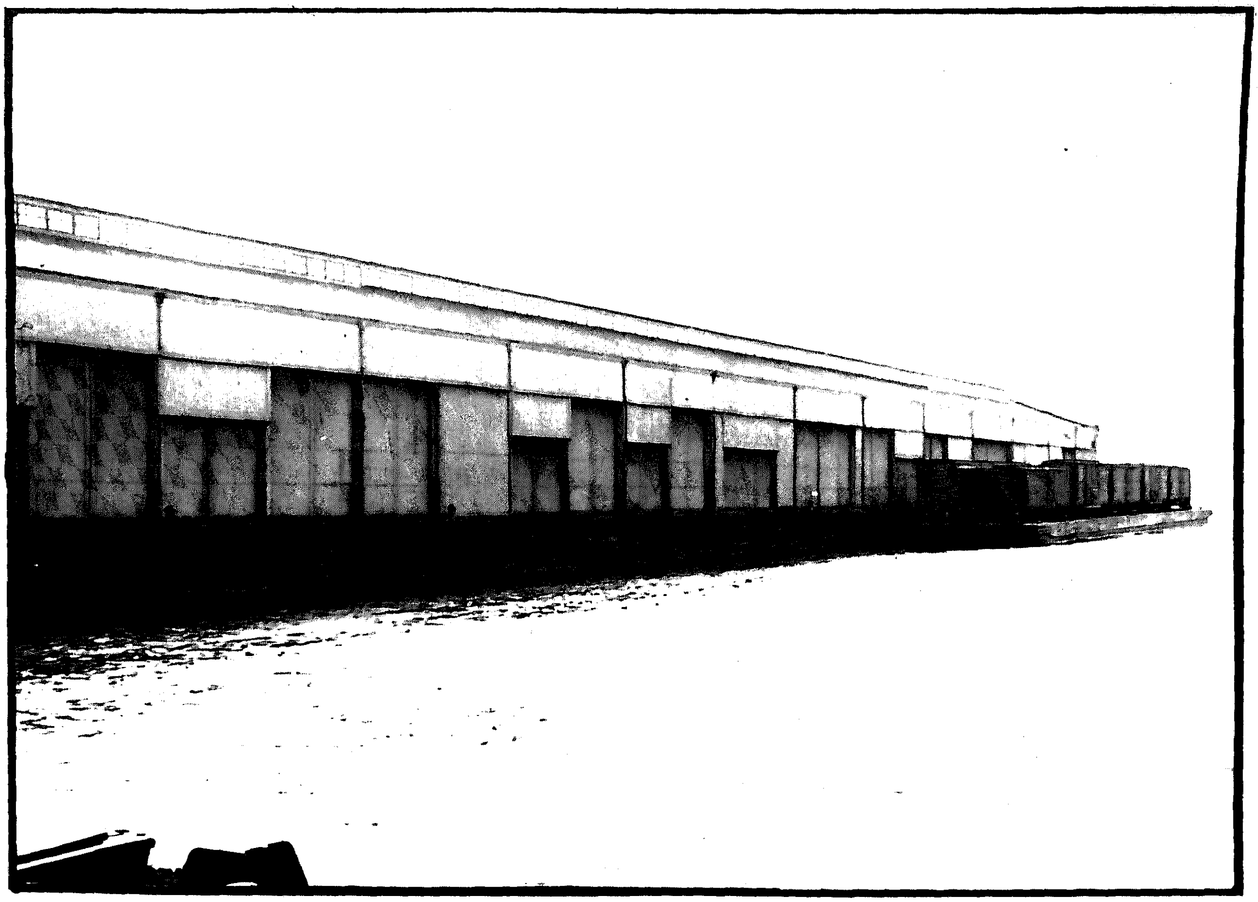


Fig. 51.- Railroad sheathing.

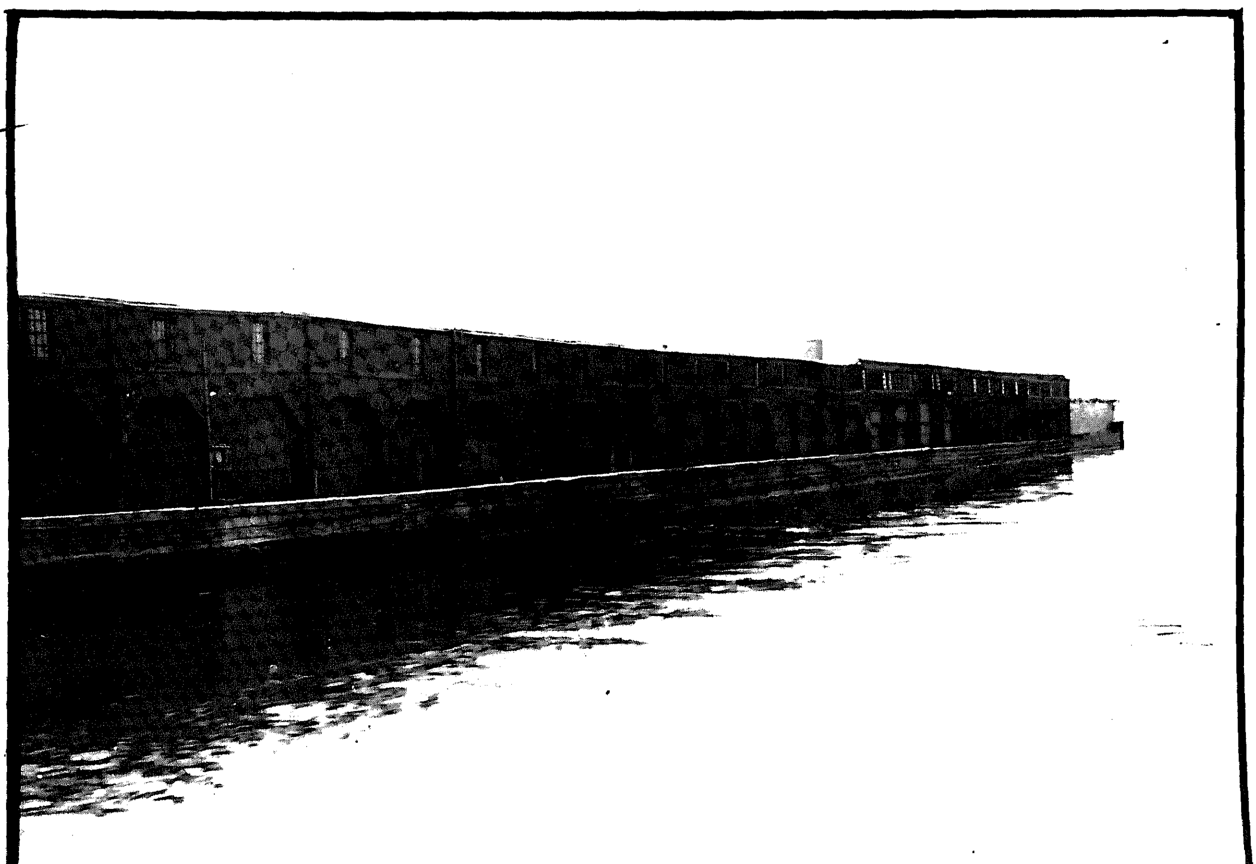


Fig. 52.- Solid horizontal sheathing.

chance for some projecting part to snag the timbers and loosen them.

The outboard ends and round corners of piers are usually protected with vertical sheathing or a row of fender pile driven close together (Fig. 53). Either provides a medium that can easily be made to conform to the shape of the pier. The outboard corners of most piers built now have square corners that are protected with a cluster of extra large high piles (Fig. 54). These serve a dual purpose by also providing additional lateral stability at the ends where maximum thrusts are exerted by ships as they are warped into and out of the slips.

Floating fenders are sometimes used, either alone or in conjunction with fixed fender systems. This variety sometimes consists of several large logs, often old piles, masts, or booms; hence the name boom-log by which they are commonly known. In other instances float stages, or camels (Fig. 49), constructed of sawn timbers are used.

In either case, the logs or stages are moored so that they are able to rise and fall with the tides and breast the sides of vessels alongside the dock. Floating fenders work best against concrete piles

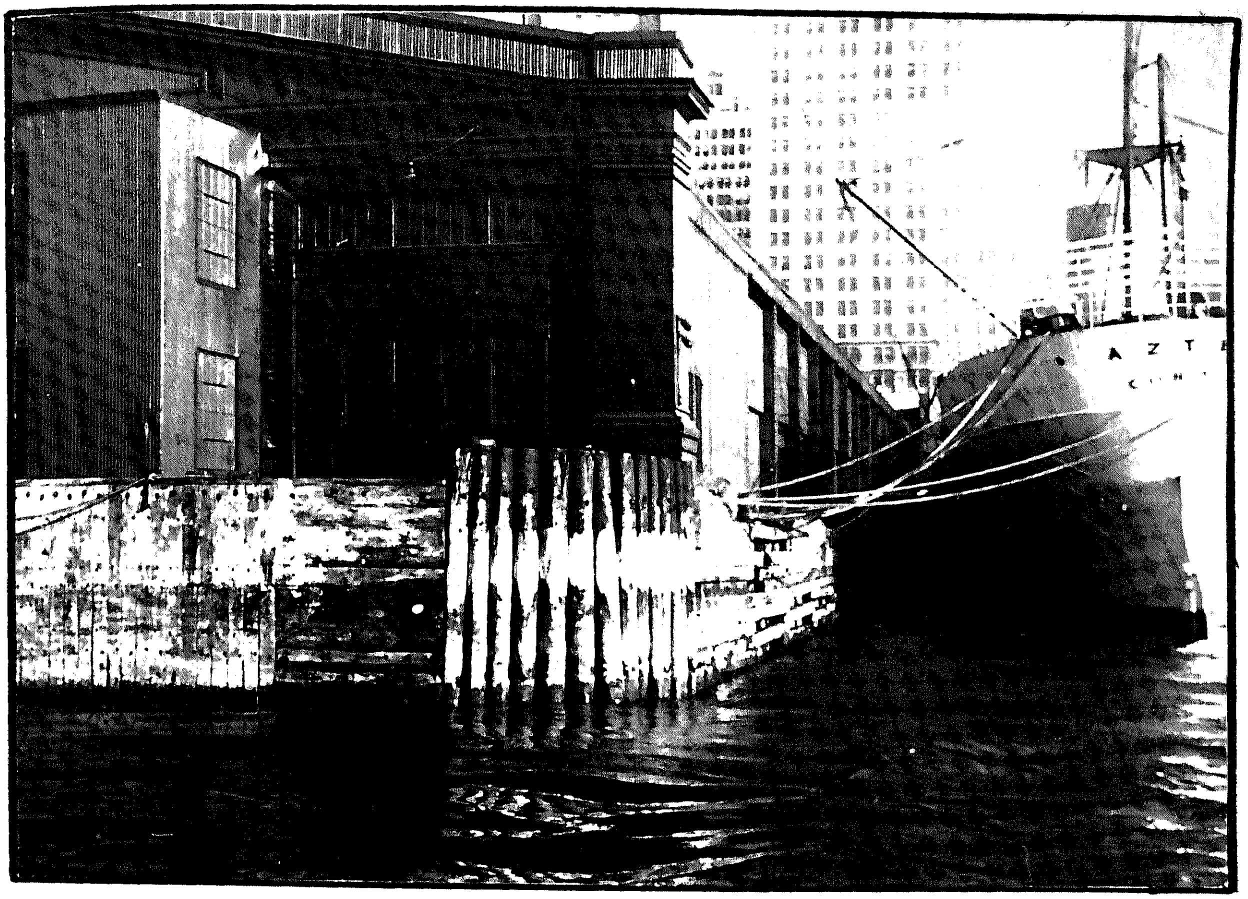


FIG. 53.- Vertical sheathing and close fender piling.

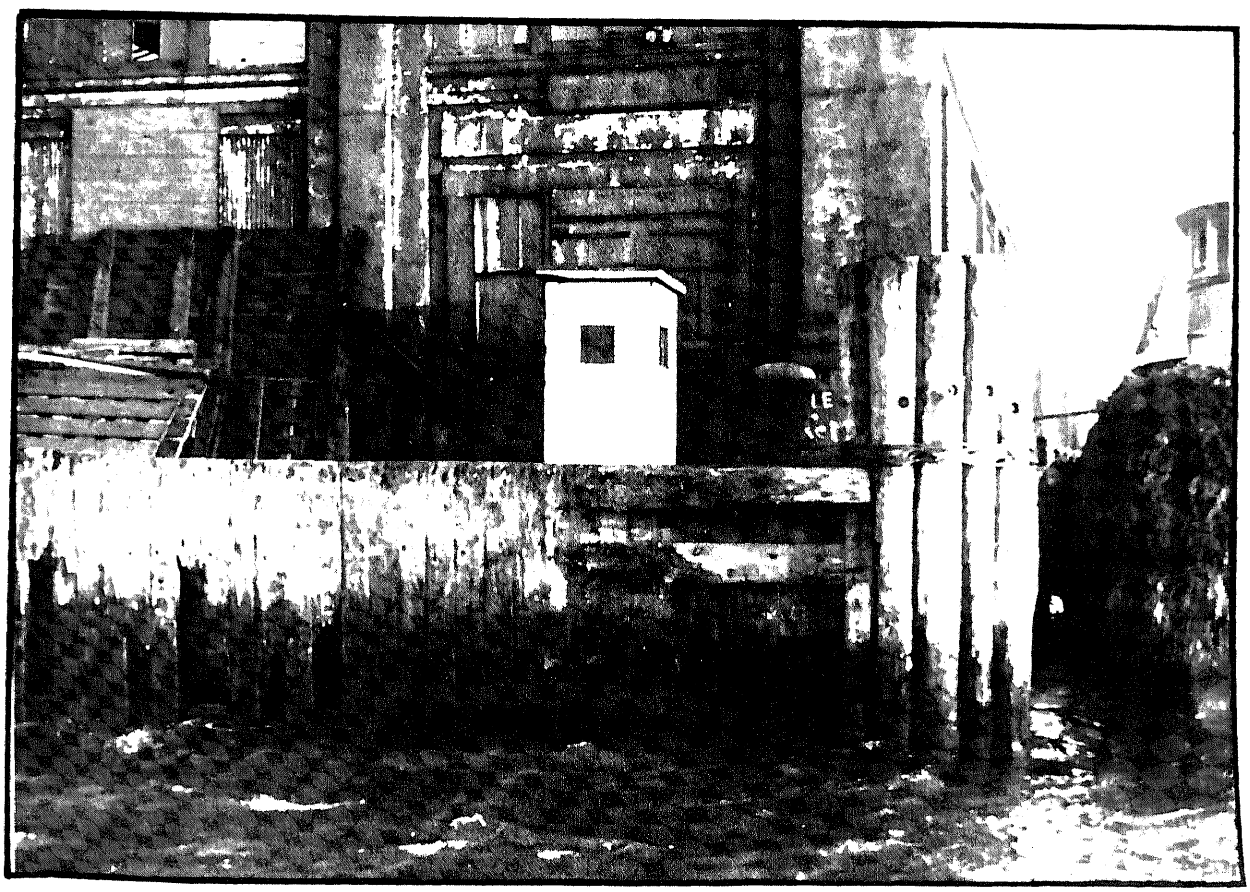


Fig. 54.- Corner cluster fender piles.

which are better able to withstand the wear and concentrated bending loads imposed by the pressure of the floats. Float stages are, however, used satisfactorily at some of New York's largest piers which are built on timber piles.

Another type of fendering has no connection whatsoever with wharves. This group includes those which are constructed around bridge piers. These are of two principal kinds, each of which serves two purposes: to protect the bridge structure and to prevent damage to vessels. In all locations where swinging draws are in service, the pivot piers, as previously stated, are situated in the center of the channel. The fenders for these pivot piers, sometimes called flat-irons, are so constructed that they extend beyond the draw span in its open position. In the past they were constructed of cribwork, but now piling and timber framework are used to support a sheathing of timber. The framework is stoutly braced and the sheathing is protected at the corners with heavy armature plates.

The approach piers of the swinging drawbridges, and the piers of other draw and high-level bridges which straddle the channels are provided with fenders

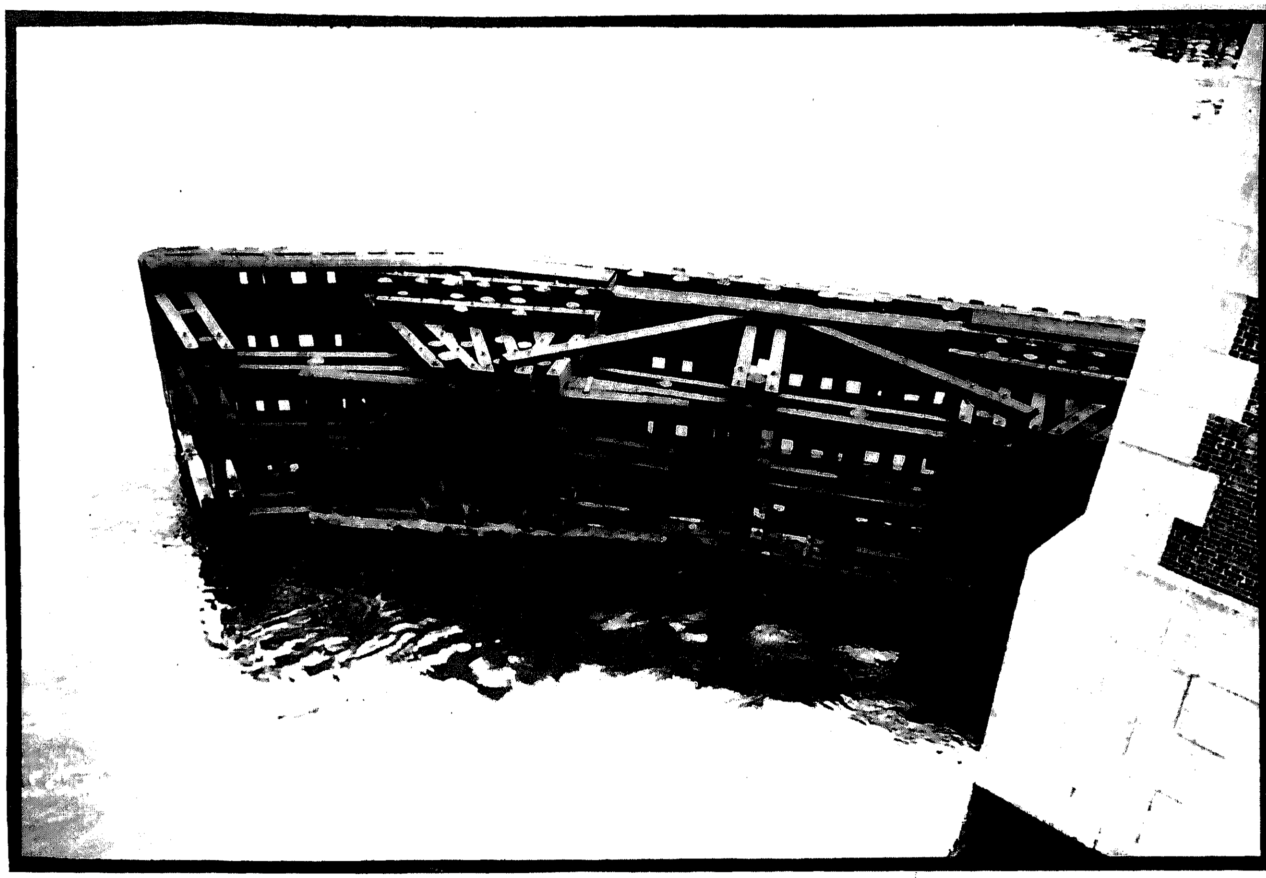


Fig. 55.- Bridge pier fender.

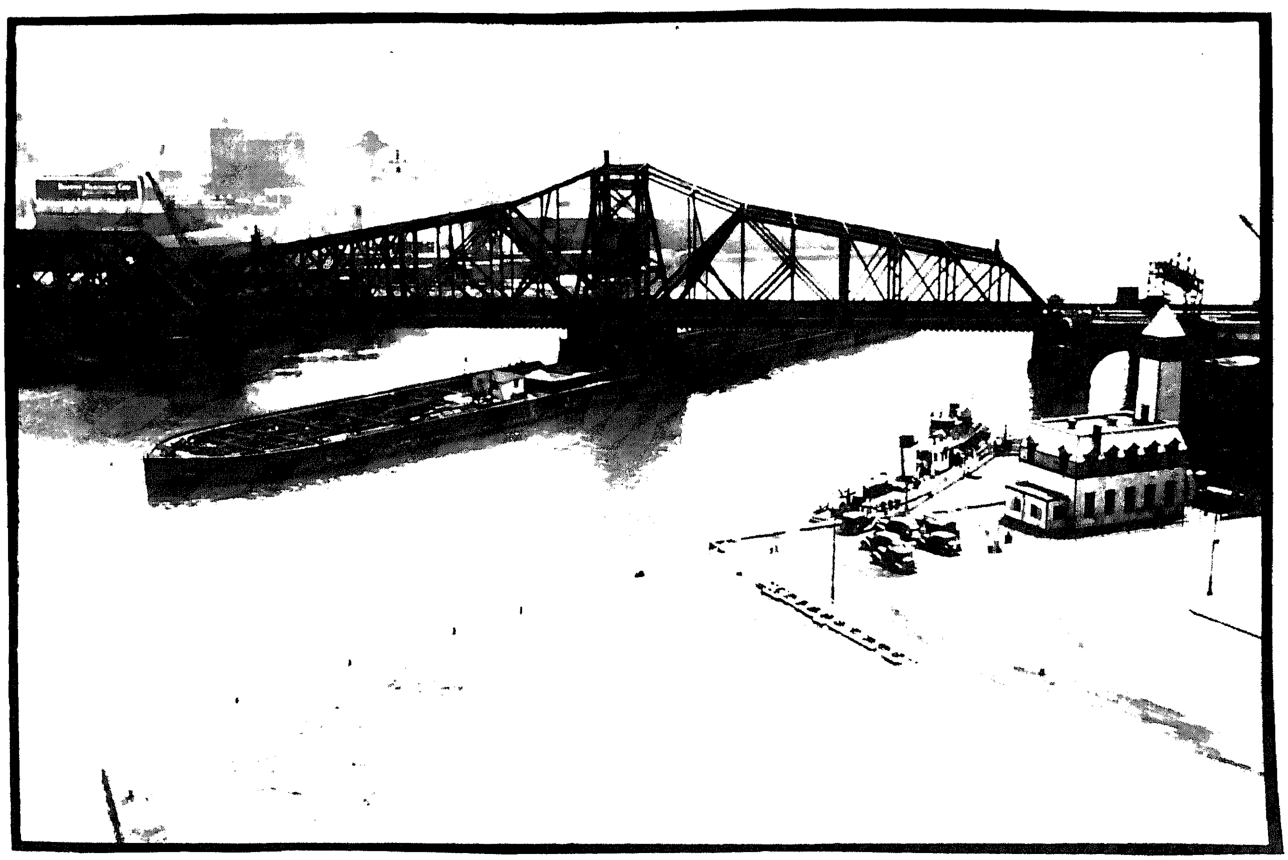


Fig. 56.- Swinging drawbridge fender.

wherever shipping can come in contact with them. In general, these are placed only on the side facing the channel and frequently consist of vertical sheathing fastened to wales which are either supported by piles or bolted to the masonry of the pier.

* * *

Mooring devices are usually built or installed as appurtenances to some waterfront facility. There are certain other types however that are provided specifically for the temporary mooring of vessels which are not transferring cargo.

One type of such devices are those which are located in the areas of the harbor designated as anchorages. They consist of large buoys to which heavy concrete or iron anchors are attached by heavy anchor chains. The buoys are fitted with large rings to which vessels can be made fast. These anchors are spotted in positions calculated to afford a maximum number of berths and at the same time permit vessels to swing about on their chains without colliding with adjacent vessels.

Another type consists of tie-up racks. These, intended generally for barges or other small vessels, are usually constructed as a light trestle with no more than a fender, a foot-walk, and some means for securing lines. Racks of this type are used mostly by barges standing by, waiting to be loaded or unloaded, or as a "parking place" when not in transit.

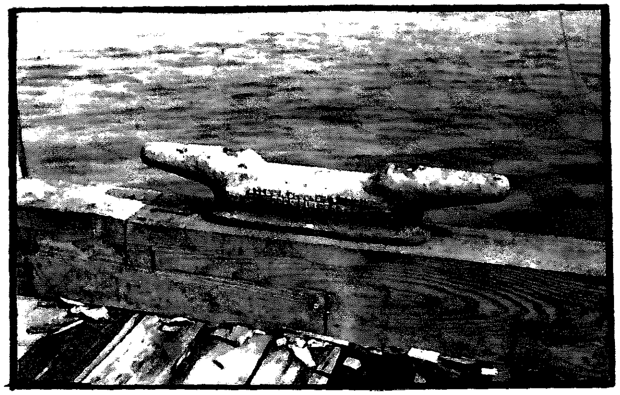
Important parts of ferry terminals and float bridges are the racks which may be seen in Figures 17 and 18. They are constructed to help steer the boats and floats to their moorings and to hold them in position against the wind and tide while transfers are being made to and from shore. They serve the added purpose of protecting from damage by collision vessels which might be in an adjoining slip.

These racks consist of rows of piles fastened together with horizontal wales and faced with vertical sheathing. At their inboard ends they conform in outline to the shape of the boats using the slip, while the outboard ends, terminating in clusters of large fender piles, flare out to facilitate entry. The entire structure is intended to be non-rigid and sways under the impact of incoming vessels, thus lessening the shock while guiding them in.

In conjunction with the various types of construction already described in this chapter it is necessary to provide some means of securing the mooring lines of vessels. Some wharves have, in addition to the more common devices described later, mooring piles and dolphins. Mooring piles are extra large piles driven back from the face of the dock and left extending about 4 feet above the deck. They are braced against the substructure of the dock to augment their own cantilever action.

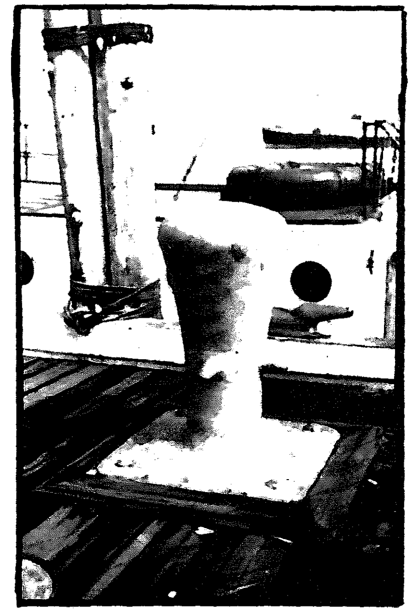
Where a vessel extends much beyond the end of a wharf some means of securing lines, other than those located on the wharf itself, must be provided. In such a case one or more dolphins are usually employed. A common design for a dolphin utilizes 13 piles. The center, or king pile, is driven first and is the longest pile of the group. Then 6 piles are driven with a slight batter around the king pile and securely fastened to it with cable. The last 6 piles driven, being longer than the first 6, are fastened to the king pile above them.

Along the margins of docks and wharves themselves are located devices of cast iron or cast steel designed to afford means of securing the mooring lines of the vessels berthed there. They are so shaped that they do not unduly chafe the lines or cause sharp bends in them. Most of them have protruding knobs or "horns" to prevent lines from slipping over their tops.

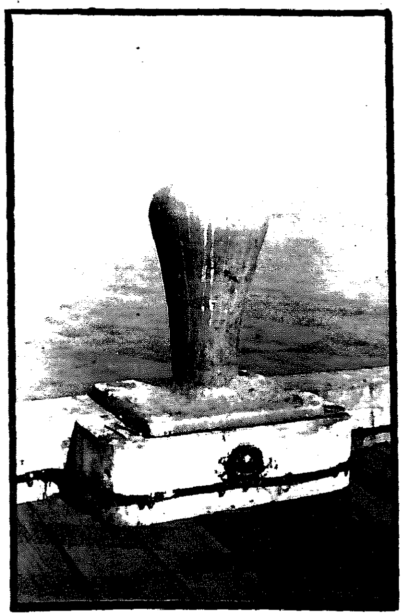


(a) Dock Department cleat.

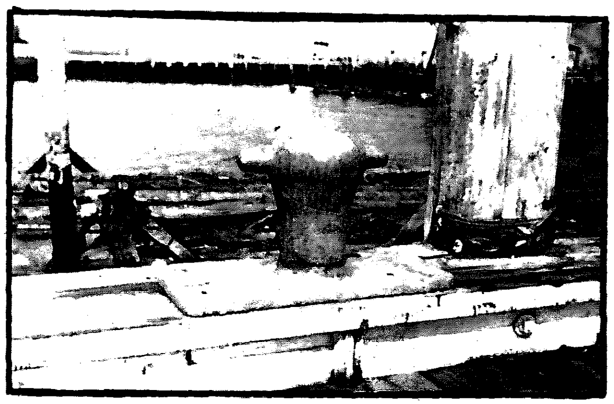
(b) Cast iron double bitt.



(c) Corner mooring post.



(d) Bollard.



(e) Cast iron single bitt.

(f) Cast steel single bitt.

Fig. 57.- Types of mooring devices.

The largest of these are known as mooring posts and, when located at the ends of wharves with horns as shown in Figure 57, they are called corner mooring posts. They stand four and a half feet high and weigh 2200 pounds. Corner mooring posts are made extra large and strong and are securely bolted to the substructure timbers to withstand the great tension often developed in hawsers while warping ships around the corner of a pier.

Bollards, in appearance, resemble small mooring posts. They are generally located about 60 feet apart and are bolted down through the side rangers and side caps which have solid blocking between them. They vary in size, ranging from 20 inches high and weighing 600 pounds to 42 inches high weighing 2000 pounds. Bollards are commonly utilized on the piers at which the larger ships are berthed.

Single bitts are spaced and secured in a manner similar to that employed for bollards. They are very commonly used on steamship piers and like bollards, single bitts are used to secure the lines of large vessels. Although intended for steamers of the smaller variety, they are frequently used to moor the largest ships which enter the harbor. They stand 26 inches high and weigh 900 pounds.

Double bitts and cleats are used on docks where tugboats, lighters, barges, and carfloats tie up. They are sometimes spaced more closely together than bollards and single bitts because more small vessels may use the side of a dock at one time. They are designed for securing smaller lines, to permit turns to be taken about them for snubbing, and at the same time to permit deck hands to heave looped lines over them with ease.

Double bitts, which vary in shape, are not in common use. The one depicted in Figure 57 is 26 inches high and weighs about 900 pounds. Cleats, on the other hand, are the most widely used of mooring devices. They are made with many minor variations but the standard size and shape for New York City, as shown in Figure 57, is 43 inches long and weighs 175 pounds. Both double bitts and cleats are generally bolted down through the backing log or side ranger, passing through intermediate blocks to the underside of the side cap.

Occasionally, but not often, iron rings are fastened to the sides of docks for securing lines. Equally seldom are used sections of vertical pipe, filled with concrete, mounted on the dock. In the past, stone and concrete mooring devices have been tried, but they have proved unsatisfactory. Concrete is too rough and chafes lines, while stone does not suitably resist tension and nowadays is too expensive to cut.

* * *

Jetties and breakwaters, while they serve somewhat different purposes, may be constructed in the same or a similar manner. They usually incorporate in their construction large pieces of quarried rock or a combination of such rock and steel sheet-piling.

One type of construction consists of a single row of steel sheet-piling driven longitudinally on the centerline, with an embankment of rock built up on each side. Another, known as the cellular type, consists of a series of U-shaped pockets formed and joined to one another by interlocking steel sheet-piling. The pockets are filled with rock and capped with large derrick stones. A third, the type built at Rockaway, is constructed of rock only. The core is composed of pieces ranging in size from chips to 6 tons, while the slope stones and cap stones range from 6 to 65 tons.

The large derrick stones required for structures of this kind are towed from the vicinity of the quarry to the site of the job on barges and placed by marine derricks. At the same time, work is usually carried on from the shore as well. To facilitate the shore work, timber trestles are built to support either a railroad track or a truck ramp over which the smaller rocks can be hauled. The side-dump cars and dump trucks which are used in this connection deposit their loads around the piling of the trestle which is left in place. A travelling crane, which is advanced as the work progresses, is usually used to construct the trestle, drive the steel sheet-piles and to help handle the rock.

Other methods of breakwater construction, such as placing precast concrete blocks and sinking concrete caissons in place, are practiced in other regions, but in the vicinity of New York these types are absent.

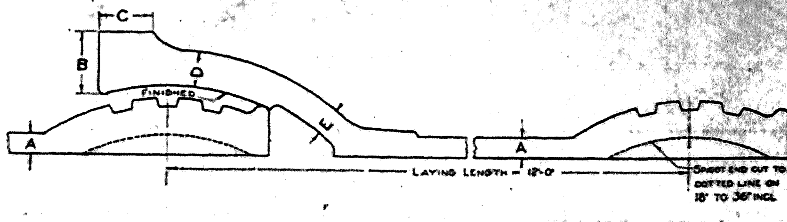
* * *

The utility lines constructed under the waters of the harbor, as outlined in the foregoing chapter, are in two principal categories, pipelines and cables. Both, while their physical characteristics and method of laying may widely differ, must fulfill similar requirements if they are to be considered successful installations.

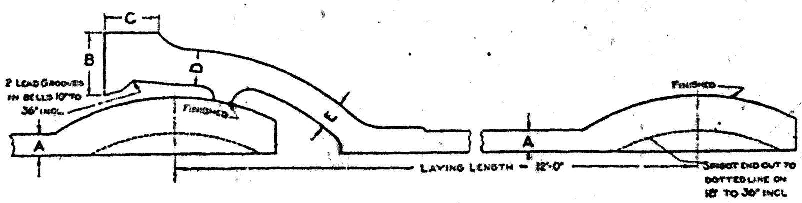
In traversing the distance between points on shore it must be assured that they will be safe from fouling and damage by anchors and dredge spuds and from damage by the possible sinking of a vessel over them. Finally, possible future improvement of the waterway must be considered, so they are located below the depth of probable dredging.

Obviously, in order to meet these requirements, the first step in laying the line in to excavate a trench to the proper depth. After the line is laid, by various means depending upon its kind, the trench is backfilled. In the case of pipelines, protection is often provided by a blanket of riprap or, in the case of cables, by partially backfilling the trench with concrete placed by bottom-dump buckets or the tremie method. In this way the lines are also protected against possible exposure by the scouring action of the harbor currents.

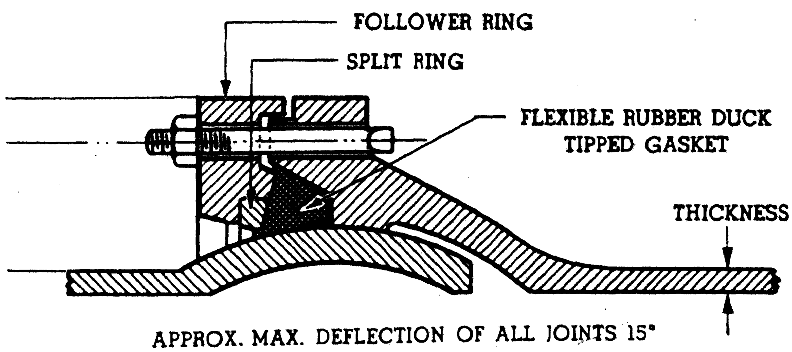
A number of subaqueous pipelines have been laid to supply water to the various islands in the New York area. To facilitate construction and to secure tight joints a number of special flexible joints for cast iron pipe have been developed,



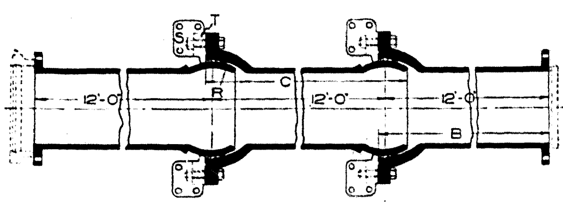

(a) Ward Type



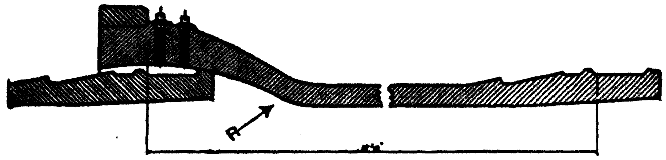

(b) Metropolitan Type




(c) Usiflex Type




(d) Flanged collar type




(e) Narrows Siphon Type

Fig. 58.- Types of subaqueous pipe.

several of which are shown in Figure 58. Type (b), known as the "Metropolitan" joint differs from type (a) in that when the joint is deflected the lead calking remains in the bell instead of the grooves, thus preventing it from being scraped or shaved.

Where an appreciable current is encountered types (c) and (d) are more satisfactory because, with their flanged collars and bolted connections, they cannot readily be pulled apart. The bolts and nuts, to resist corrosion, are made of bronze or gun metal. For deep water work type (e), which was designed originally for the first Narrows siphon, provides a combination of tightness and ease of laying superior to the others. It was found to be so satisfactory in the first Narrows siphon, a 36 inch line, that it was used again later in the second, a parallel 42 inch line. In type (e) joints, the entire bell instead of only the surface is calked with lead. This is done by forcing more lead into the joint through the holes in the bell by means of gib screws.

Pipe of this kind is usually laid by means of a cradle (See Fig. 93) similar to the one employed for the construction of the Narrows siphons which is described in Chapter Eight.

Other large pipelines, for water and gas mains, sewers, and tunnels have been laid in straight sections, fitted and calked by divers. For example, there are 72 inch cast iron gas mains; the Coney Island sewer outfall is a 72 inch reinforced concrete pressure conduit, and the New York Telephone Company's cast iron tunnel for conduits under the Harlem River is 108 inches in diameter.

Practically all this pipe laying is done with floating derricks and, to minimize the number of underwater joints to be made up, several sections are usually put together on deck and lowered with a strongback. Collapsible pilot points are fastened at the end of each assembled group to help the diver to insert the spigot into the bell of the adjoining section. On some projects the sections of pipe have been floated by pontoons which were gradually flooded, thus lowering them to the bottom.

Many of the larger pipelines do not rest directly on the bottom of their excavated trenches. Instead they are laid on a series of pile bents, both to prevent settlement which would tend to open the joints and, to a lesser degree, facilitate attaining the proper grades. In addition, particularly in the case of gas mains and tunnels, the pipes are frequently protected against any tendency to float by metal bands which securely anchor them to the bents. The bents themselves are either driven with a steam hammer rigged for submarine driving and cut off under water by a diver, or driven with a regular hammer and a follower. Often where a follower is used, it is attempted to drive the piles just a little below grade so that the difference can easily be made up with shims.

Submarine cables, whether for power or communications, are laid in pre-excavated trenches from the deck of a boat or derrick. The cables are unwound from reels which are mounted on deck and, to prevent damage to their sheathing, are allowed to run over the side on rollers. Ranges set up on the shore serve as guides for the proper alignment during the laying process. Frequently several cables are laid at one time in the same trench. It is customary to have cables inspected by a diver after the laying is finished to ascertain whether they lie within the trench as intended. When they are found to lie satisfactorily the trench is backfilled.

Where cables enter and leave the water, the trenches are sometimes shored by means of two rows of

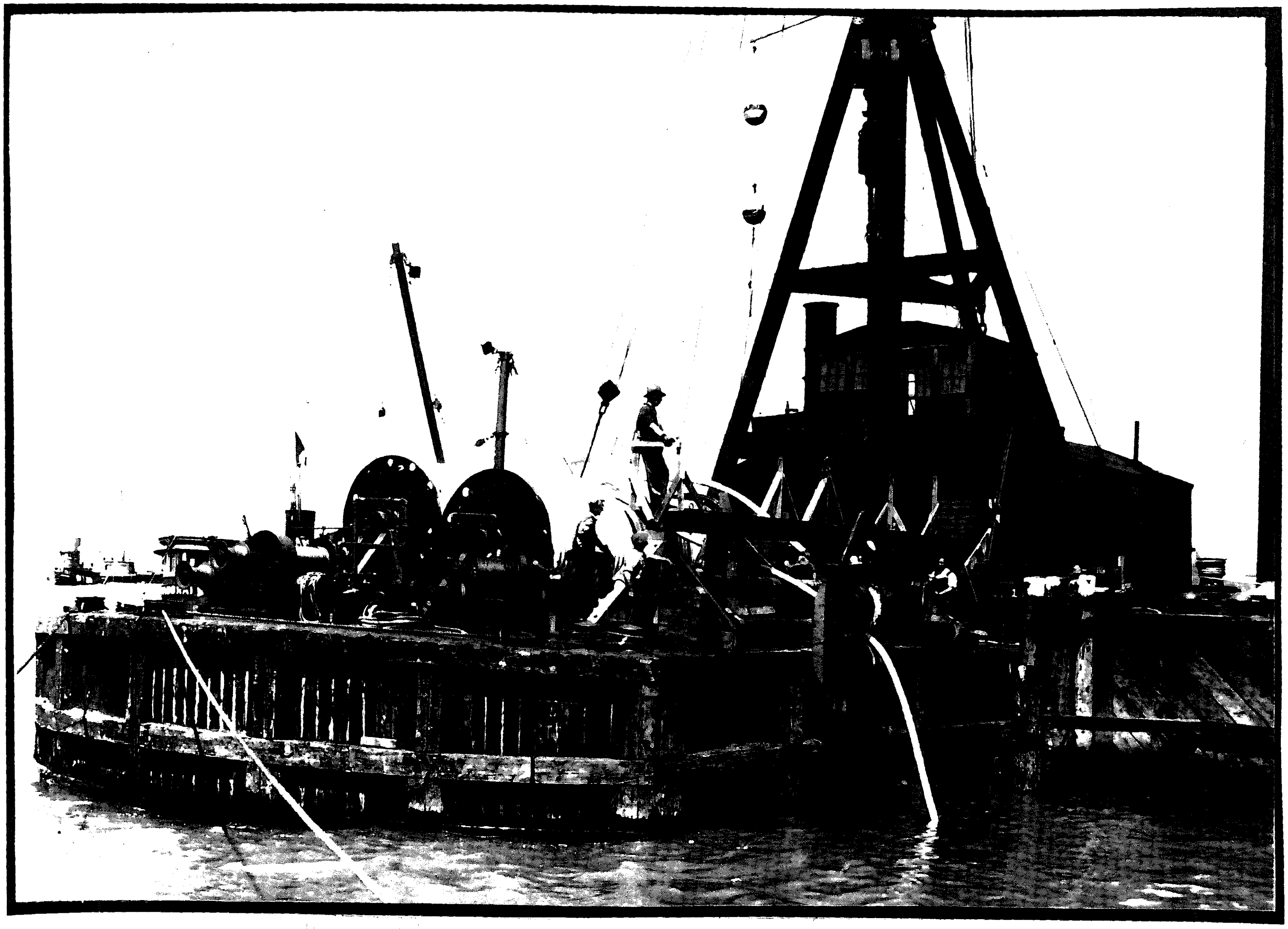


Fig. 59.- Subaqueous cable laying, East River.

steel sheet-piling. These may be used afterwards as forms for placing protective concrete and may be left in place as part of the installation.

* * *

Dredging is the term applied to the operation of excavating subaqueous material. There are five principal purposes for which dredging operations are carried on. Two of these do not exist within New York Harbor. They are the construction of dikes and levees, and the procurement of material, such as sand and gravel, for commercial use. The remaining three constitute important phases of construction. They include the establishment and maintenance of channels in navigable waters, together with slips alongside wharves; land reclamation, or the making of artificial land areas, by filling in tidal flats, and work in conjunction with the construction of foundations.

The larger and better known dredging projects, which have been carried out under the auspices of the federal government, have already been outlined in a previous chapter. In connection with this type of work there are a number of factors to be considered. To attain the desired depth of water, the slope of repose of the bottom material frequently must be taken into account and side slopes must be cut back sufficiently to assure some degree of permanence. Another problem arises in attempting to provide sufficient depths for the passage of very large ships. It would at first seem necessary to dredge to a depth of only a foot or so below the draft of the largest anticipated vessel at low tide to have a satisfactory channel. Such is not the case however, and ships may be grounded as a result of a phenomenon called "squatting". Large ships under way have been observed to squat four feet below their nominal draft. This phenomenon occurs to the greatest degree in shoal water; it mostly effects the stern of the ship and it varies in degree as a function of the speed of the ship.

Where dredging is required in slips or in front of marginal wharves care must be exercised to avoid overdredging. It has frequently happened, where greater depths of water have for some reason been desired, that dredging was perfunctorily commenced with the result that adjacent structures have been either damaged or destroyed. A cribwork bulkhead is particularly vulnerable to damage should the bottom near it be dredged below its lowest timbers. Pile foundations and sheet-piling bulkheads may likewise be induced to "go out"

Fig. 60.- Hydraulic fill for the U. S. Navy yard, Bayonne.

when the stability of the soil in which they are driven is disturbed. In such cases as the foregoing, the net effect of overdredging is to cause an underwater landslide.

The task of maintaining the water in slips and channels at the desired depth is an unending one. Both the currents of the several rivers and the tidal currents conspire to make work within the harbor for the dredgers. During the course of a year slips are likely to silt up from 2 to 4 feet, depending upon their location. In addition to the silt, refuse from both ships and shore adds to the work.

At the present time areas transversed by vessels in New York Harbor are well dredged and to a great extent free from hazardous obstacles, but to attain this condition required a great deal of work over a long period of years. To illustrate how difficult it was to clear so large an area, there was discovered, some years ago, a pinnacle rock located not far off the battery that eluded dredgers for about 200 years before its existence was evinced by a ship striking it.

Land reclamation has been carried on to a great extent along the perimeter of the harbor. Perhaps the greatest amount of filling in was accomplished by dumping refuse and excavated material from the land side, but in many places the fill was placed by dredges. Hydraulic dredging is probably the most economical method of placing fill because in one operation the material is both excavated and delivered to the point where it is desired.

A fairly recent example of a large scale operation of this type is the formation of the land for the U. S. Navy yard at Bayonne. On this job a steel sheet-piling bulkhead was constructed around the perimeter of the area and the fill was pumped in. By means of flexible pipelines the dredges were free to move about the surrounding area making the desired depth outside and placing the fill at the same time.

Many areas which are now dry land were formed in a similar manner, while some others were formed by the disposal of material dug by dredges of other types. Years ago there was an area in the vicinity of Caven Point, Jersey City which was owned by a dredging company and utilized as a disposal point. This saved the expense of towing and dumping scows at sea and avoided considerable losses of time on account of fog and stormy weather. While sufficient depth of water remained, bottom-dump scows were emptied directly over the area, but later it was filled in above the high-water line by transferring the material to dump cars which travelled on temporary trestles and deposited the fill wherever it was desired.

As mentioned with reference to bulkhead construction, proper care must be exercised to prevent damage by the formation of mud waves. Wherever dredging is done in semi-fluid material or when the dredged material is used for fill over a semi-fluid soil, the potentiality for destructive forces is ever present.

Dredging in conjunction with foundation construction has already been referred to earlier in this chapter with regard to cribs, block and bridge type piers, and bulkhead walls. Dredging frequently is resorted to also in connection with cofferdam and caisson work where it is necessary to remove such obstructions as boulders and sunken timbers or hulks.

Sometimes it is desired to dredge an area to a specified depth before piles are driven in it. Where the bottom material is saturated soil or muck it is to be remembered that while the pile driving is in progress the depth will be reduced as a result of bulking, hence overdredging may be required accordingly.

In general, there are a few things that apply to all types of dredging. It is important that care be taken to avoid damage to submarine utilities by both the actual digging itself and by the spuds of the dredges. While dredging, the operator must know the stage of the tide at all times in order that he can dig to the proper depth. For this reason it is customary to put up a tide gage. For the convenience of the operator, the gage is often set so that the zero would be the elevation to which he must dredge. Thus, no matter what the stage of the tide, the gage will read the depth of water required.

An important operation closely allied to dredging is the taking of soundings. Soundings are generally taken before and after dredging operations and the results frequently effect the amount of payment received by the dredger. It is customary to pay for dredging by the cubic yard removed and the yardage is commonly determined by scow measurement. Scow measurement is usually specified because it has been found that, in dredging mud, the yardage computed from soundings increases about 15 percent due to swelling as the material is removed. Each company owning bottom-dump scows has a certified measurement of volume, made flush with the combings, for each scow. When a scow is filled to the satisfaction of interested parties, the nominal yardage is taken. Since it is not practical to dredge uniformly enough to obtain a plane surface, a dredger is permitted to overdredge one or two feet of material for which he can receive payment. Upon completion of the project, should soundings indicate that the allowable limit was exceeded, the computed excess yardage is deducted from the scow measurements.

The materials to be dredged in New York Harbor vary all the way from soft muck to ledge rock and the various types of plant utilized to cope with the different conditions are described in Chapter Six.

* * *

As inferred in foregoing paragraphs by references to deterioration, damage, and so forth, work on a waterfront facility does not terminate indefinitely upon the completion of the structure. Fender systems must constantly be maintained lest subsequent collisions and abrasion cause damages to progress into the substructures and sheds which are much more expensive to repair.

The serviceable life of a fender system is unpredictable, since, barring accidental damages and with light usage it may last for 10 years. As is more often the case however, partial repairs are required before the first year has passed.

The following table, prepared from a study of pier maintenance in New York Harbor by C. W. Staniford and E. G. Walker, was published in the Transactions of the American Society of Civil Engineers, Volume LXXVII, 1914. The data in it represents the life expectancy of the various parts of a timber pier, as of 40 years ago.

Maintenance of Timber Piers

| Item | Percentage of total original cost | Renewal required | Percentage of average annual cost of renewal |
|---|---|---|---|
| Bearing piles | 34.7 | 1/3 every 20 yrs. above M.H.W. | 0.58 |
| Caps and rangers | 24.4 | 1/2 in 20 yrs. | 0.61 |
| Bracing | 7.1 | 1/2 in 20 yrs. | 0.18 |
| Sub-deck | 11.3 | Every 15 yrs. | 0.75 |
| Deck sheathing | 12.0 | Every 6 yrs. | 2.00 |
| Fender piles | 4.7 | Every 12 yrs. | 0.40 |
| Fender chocks and vertical sheathing | 4.0 | Every 10 yrs. | 0.40 |
| Backing log | 1.8 | Every 8 yrs. | 0.23 |

During recent years a trend has developed wherein the serviceable life of dock timbers has shown a decrease.

This is probably due to a combination of several factors. In the first place, most of the tugboats, scows, and so forth, which came in contact with the docks years ago, were constructed largely of wood. Today many of them are constructed of steel or, if of wood, they have iron wearing strips along their sides. In either case the timber against which they rub suffers considerably more than before.

In addition, the timber used in construction today does not appear to have the same quality as that which was used years ago. The bearing piles used in the past were frequently over 20 inches in diameter; today a diameter of 14 inches measured at 2 feet from the butt fulfills most specification requirements and, due to the higher cost for larger diameters, few are driven over size.

Furthermore the timber itself, particularly southern yellow pine, does not always have the durability that it used to have. This is due largely to the fact that the trees from which the timber is cut have been tapped for turpentine, thus reducing the amount of preservative sap present.

Repairs to fender systems and renewal of timbers around the edges of a pier are made with comparative ease, but interior timbers and piling require much more work. Interior bearing piles, which generally rot above the low-water line, are plumb posted or bench capped since it is not practical to redrive new piles. Where marine borers are absent, as in the greatest portion of New York Harbor, the lower portions of the piles are usually good any way, and to pull them would be a waste of material.

Plumb posting is done where a lone pile in a bent requires repairs. This is accomplished by cutting the pile off below its deteriorated portion, usually near low water, and framing a 12 x 12 inch timber to fill the gap between the cut-off and the cross cap. The timber is spliced to the pile and cross cap with two heavily bolted 4 x 12 inch fish plates.

Where two or more adjacent piles in the same bent require repairs, they are all cut off at the same elevation and a 12 x 12 inch bench cap is spiked across all of the stumps. The space between the bench cap and regular cross cap is then filled with 12 x 12 inch posts over each pile which are spliced in a manner similar to that used in plumb posting.

Structures built of stone, concrete, and steel develop the need for repairs as well as those of timber.

Stonework, one of the older types of construction, where the binding mortar has been washed out of the joints and crevices (See Fig. 37), must periodically be pointed up to keep the pieces tightly in place.

Concrete spalls and occasionally crumbles, eventually reaching a point where repairs must be made. Repairs are sometimes made by cleaning the surface of the old concrete and placing new in the cavities. In mass concrete, anchor bolts are often set to secure bond between the original and the patches. Where reinforcing steel has been exposed and rusted, the steel may be strengthened by welding additional rods to the existing ones, while wire mesh may be tied to the steel to give added bond to the new concrete. The development of a method using cement mortar "guns", known as guniting, has greatly facilitated concrete repair work. Gunite is usually applied over a mat of wire mesh secured to the existing concrete.

Structural steel, when corroded to the extent that cross-sectional areas are considerably reduced, is often strengthened by welding. Additional plates may be added to webs and flanges and corroded rivet heads may be built up by welding.

The maintenance of waterfront facilities occasionally involves minor alterations and additions as well as the actual repair work necessitated by deterioration and damage. As an interesting example of this phase of the work is the case of a marginal dock formed by an old typical sunken crib bulkhead wall. The crib rested on a sand bottom at an elevation of minus 25 feet, mean low water. Proposed improvement of the channel in front of the dock called for an increase of 4 feet below the existing depth which also was 25 feet.

It was feared that the sand under the crib would, as the dredging progressed, move laterally seeking its natural slope of repose and, if nothing were done to prevent it, would cause the failure of the bulkhead wall. A novel scheme was successfully worked out whereby the safety of the crib was assured. Straight web steel sheet-piling in 15 foot lengths was driven vertically at the toe of the crib. It extended from 5 feet above the existing bottom to about 5 feet below the proposed bottom. The sheet-piling was driven with a steam hammer together with a follower which was disconnected by a diver after each section was driven.

Then timber fender piles were driven immediately in front of the steel sheet-piling with about the same or somewhat greater penetration. These piles were then bent back and firmly secured at the top of the dock so that they pressed and acted as long levers against the tops of the sheet-piles. The sand under the crib was permanently confined and subsequent dredging had no deleterious effect upon the bulkhead.

Work such as the foregoing, together with the periodic alterations necessitated by changing dock operations, by the use of new equipment, or by the berthing of ships of a different type, is classified as maintenance in differentiation from new construction.

* * *

Some structures are for various reasons founded upon solid masonry and, for those that extend below the water level, some means must be provided for constructing subaqueous foundations. Most common in this respect are the piers for bridges and the shafts for tunnels.

A cofferdam is a water-tight structure built around the site of a foundation which is to be constructed below the elevation of normal water level. The enclosure formed by the dam is pumped out or, in construction phraseology, dewatered to permit excavation and construction to be carried out in the dry. In general, cofferdams are divided into two main classes, those built inland and those built in water. A land cofferdam is an excavation below the ground water level. The surrounding sides may be banks of earth with stable slopes or of earth retained by some form of sheeting and bracing. A water cofferdam may be one of several varieties which are constructed in open water.

Of the latter class the simplest form consists of an earth dike or embankment. With a low head of water outside, a dike of ordinary fill may suffice but, where the pressure is great enough to cause the permeation of water through the fill, a core wall may be incorporated. The core wall may consist of puddled clay or a row of sheeting.

Another variety of cofferdam suitable where pressure heads are low is constructed by driving parallel rows of piles to support wales and sheeting facing the inside. Between the rows of sheeting a mixture of clay, gravel, and so forth is tightly rammed to block the flow of water.

In greater depths of water sheet-piling provides the most satisfactory form of cofferdam. In the early days and up to the time when interlocking steel sheet-piling was introduced timber sheet-piling was used. Due to its relative cheapness, timber was delivered to a cofferdam job site by the carload and the construction was left up to the carpenter boss. Both the bracing and the sheet-piling itself were formed by the lavish use of 12 x 12 inch timbers.

Heavy sheet-piling has been formed by bolting three 12 x 12 inch timbers together with a 3 x 4 inch piece for a tongue on one edge and two 3 x 4s for a groove on the other. The resulting sheet-pile is 12 x 36 inches and usually about 40 feet long. The original Wakefield sheeting, which has been used extensively in the past, is made by bolting three planks together so that the center one forms a tongue while the outside two form the corresponding groove.

The development of steel sheet-piling greatly facilitated the construction of cofferdams and made it possible to reach depths hitherto unattainable by the use of timber alone. The great strength of steel, the strength and water-tightness of the steel interlocks, and the long lengths to which steel sheet-piling can be rolled are the factors which make it much more advantageous.

Various methods, depending upon the hydrostatic heads encountered, have been adapted to utilize steel sheet-piling. For low heads a single row of straight web piling braced with timber may be used. For higher heads, where the required amount of timber framing for bracing would be excessive, steel bracing is used. For very deep cofferdams double rows of sheet-piling are sometimes driven with transverse lines which divide the intervening space into rectangular compartments (See Fig. 96).

Where the area to be enclosed is so great as to preclude the use of interior bracing, self-sustaining cofferdams are constructed. A type developed to be self-sustaining is the so-called cellular cofferdam wherein the steel sheet-piling is driven to form a series of compartments the ends of which are straight lines and the sides of which are curved, convex outward (See Figs. 61 and 95). The cells are filled with excavated material to give the structure the properties of a gravity dam and, when deemed necessary, sloping banks are built up against the outside to provide additional stability.

When subaqueous excavation within a cofferdam reaches sand, it is very apt to be quicksand or, as called on Manhattan Island, bull's-liver. Steel sheet-piling does not preclude quickness within the dam and boils may occur by water entering under the toes of the sheet-piles. Such a condition may be relieved by sinking well points and pumping, while the driving of piles

Fig. 61.- Cellular steel sheet-pile cofferdam, 48th St., North River.

sometimes helps to consolidate the quicksand. Where boulders exist serious difficulties are to be encountered in driving sheet-piling and it is usually more practical to utilize a caisson.

* * *

A caisson, in engineering terminology, is a water-tight chamber of timber or iron used in the construction of subaqueous masonry foundations. Originally the term was applied to a large floating timber box which was gradually sunk in place by filling it with masonry. Such caissons were brought to rest upon a level bed of hardpan prepared by dredging or upon a group of piles driven and cut off at the same elevation.

Open or wet caisson are the terms applied to a framework having timber walls but no bottom which is floated to the desired location, sunk, and held down by weighting. It thus forms an enclosure inside of which mass concrete can be poured and allowed to set without being disturbed by the washing action of tides and currents. Both of the foregoing types of caisson are left in place as a part of the foundation.

The modern version of a caisson is an adaptation of the diving bell principle. This principle is simply illustrated by pressing an inverted drinking glass to the bottom of a pan of water. The water is largely excluded by the presence of the slightly compressed air within it. To lower the water level to the rim of the glass it is necessary to increase the air pressure within it until it equals that of the hydrostatic pressure at the rim.

By constructing a suitable water-tight chamber, open at the bottom and sealed at the top, it is possible, by utilizing this principle, to excavate for and construct foundations under water. Such a chamber, together with the appurtenances necessary for furnishing compressed air and access and egress for both men, excavated material, and concrete, is known as a pneumatic caisson. Formerly caissons of this type were constructed of timber but in recent years the use of concrete and steel has almost universally been adapted.

The common form of pneumatic caisson in use today for bridge pier and tunnel shaft construction consists of a large box made of adequately braced steel plate. The sides are vertical and the interior is divided into two compartments. The lower one, the working chamber, has a low overhead under which the necessary compressed air is maintained. In the upper compartment, which has a substantially constructed deck, the necessary con-

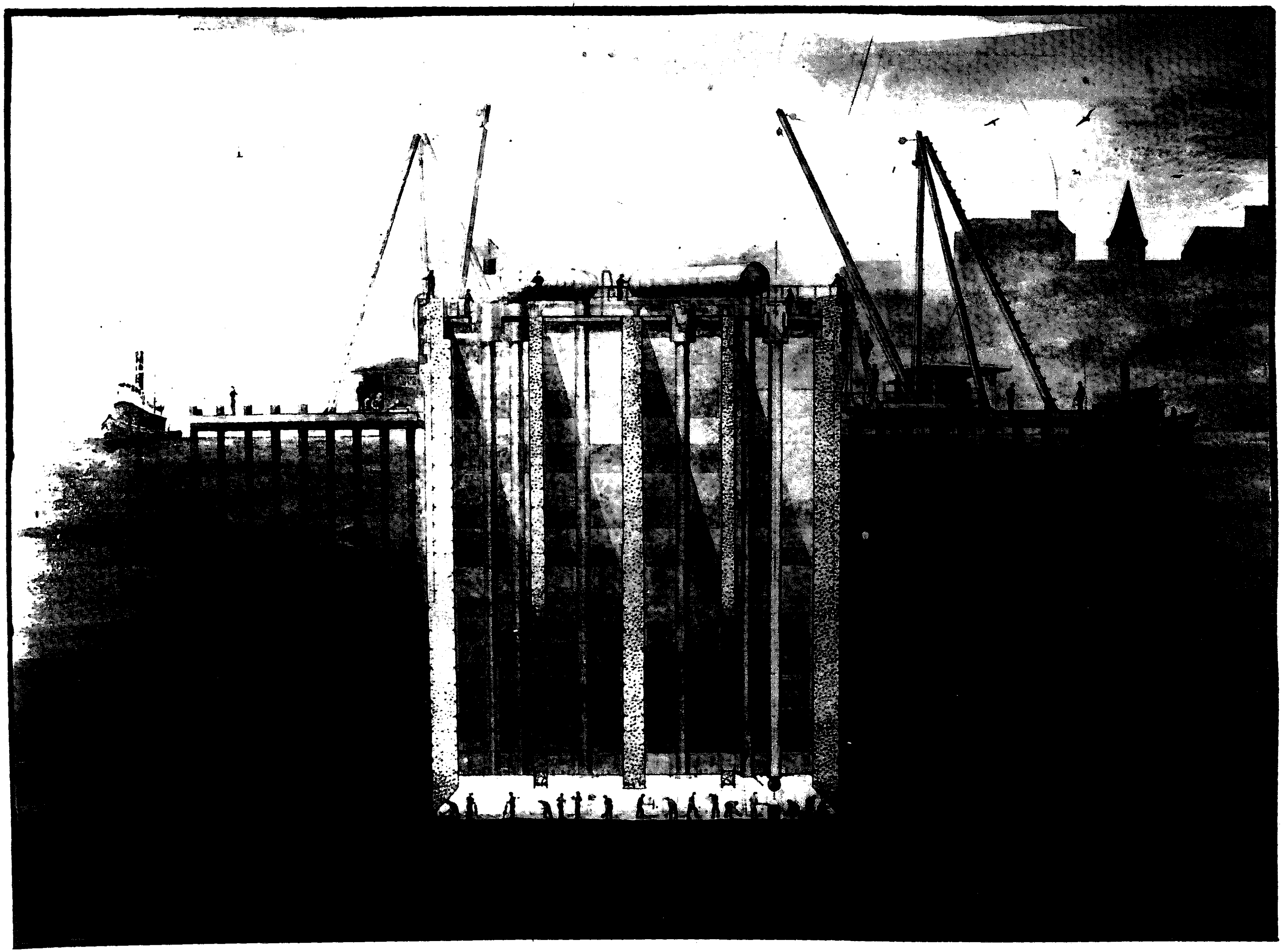


Fig. 62.- Pneumatic caisson for ventilation shaft, Holland Tunnel.

crete is poured in free air to weight the caisson sufficiently to make it sink. From the upper deck to the working chamber there are one or more passageways. Usually there are several, one used only for the workmen and the others for removing excavated material and placing concrete. All must be provided with a chamber called an air lock through which passage must be made to prevent the loss of pressure within the working chamber. The man lock, as the one used by workmen is called, is provided with valves with which the air pressure can be gradually increased from atmospheric to the working pressure as men are entering and vica versa upon leaving.

To facilitate sinking, the lower rim of a caisson is generally provided with a cutting edge and, where sinking meets with stiff resistance, it sometimes becomes necessary to overcome the friction between the shell and the soil by loading pig iron upon the upper deck. To hold the caisson in the proper location and to maintain it in a plumb position during the sinking process, a row of piles connected together with wales, is usually driven around its perimeter. In many instances the caisson is constructed over the site upon which it is to be sunk. When this is done, assembly is started with the lower portion and the upper parts are added progressively, while the caisson is permitted to sink gradually in much the same manner as an old-fashioned timber crib.

After a caisson has been sunk to the level at which it will permanently rest, the working chamber must be filled with concrete. When concrete has been poured to a depth at which its weight equals the hydrostatic pressure outside, the caisson is said to be sealed, the air pressure can be let off, and the concreting can be finished in free air.

About 100 feet, at which the necessary air pressure is 43 pounds per square inch, is the maximum depth to which pneumatic caissons may be sunk. Theoretically they could, of course, go much lower but the workmen are the governing factor in this case, and greater working pressures would be both injurious to the men and in violation of government regulations.

* * *

When a pile supported structure is to be built in a location where the elevation of hardpan or firm footing is not known, it is customary to ascertain the pile lengths required by driving test piles. Similarly, where it is known that the piles will depend for support upon skin friction rather than end-bearing, it is necessary to ascertain what size of pile and depth of penetration are required to develop the desired load bearing capacity. In such instances the results obtained will be worthless should the area be dredged in the interim between test pile driving and the driving of permanent piles. This is obviously due to the fact that the pile penetration has been reduced.

Where hard bottom underlies the soft stratum, it suffices to drive test piles only to the point at which they fetch up. Continued hammering serves only to break or broom the tips of timber piles and may batter and bend the tips of steel piles. It is customary to simultaneously determine the average penetration per blow of the hammer while test piles are being driven. This serves both to ascertain, by the proper application of an appropriate pile driving formula, what allowable bearing capacity can be developed and to indicate the ease or difficulty of driving to be anticipated.

In order that the results of driving test piles, particularly timber test piles, may be considered reliable the piles should be pulled and their tips examined. Overdriving is made evident by brooming, and erroneous assumptions of pile lengths can be corrected if the ends of the piles are broken off. In general, the same size and type of pile as will be driven permanently should be used for the test piles. In fact, where a large number of test piles are to be driven, they are sometimes located so that many of them can be left in place as part of the job.

Occasionally, before a type of foundation to be adopted is decided upon, or in making preliminary investigations for tunnels, caissons or cofferdams, information regarding sub-soil conditions is desired in detail. In order to provide such information test borings are made. Wash borings and core borings represent the two principle types employed in sub-soil exploration. The data for the cross-sections shown in Figure 6 were obtained from a combination of both.

A wash boring is made by sinking a casing of heavy pipe about 3 inches in diameter into the ground. Within the casing a drill bit with a hollow shank is worked up and down to chop and loosen the material encountered. Water, under pressure, is forced down through the hollow shank and bit so that it washes the loose particles up through the annular opening between the casing and the drill shank. At intervals the bit is withdrawn and a sampler is inserted. The sampler, a a section of pipe or an inverted cup-like device, is driven into the soil below the casing and withdrawn containing a sample of material encountered at that particular elevation. By noting the resistance of the sampler to driving the hardness or compactness of the stratum may be estimated. Samples that are obtained in the foregoing manner are called dry samples.

In comparison to a dry sample is a so-called wash sample. Wash sampling consists merely of catching the wash water from various depths in a bucket. The sediment is collected, placed in a jar, and called a sample. Such a sample, of course, is not representative of the natural soil conditions and at best can indicate only the elevation at which some change in the nature of the soil occurs. Wash samples are of little value and it would be difficult to justify their use when dry samples can be obtained at only a slightly higher cost.

Very frequently the term wash boring is loosely used. Strictly speaking the washing process is only a method used to sink a test-hole. However, unless dry sampling is distinctly specified, wash boring may be construed to mean wash sampling.

Core borings are usually larger in diameter than wash borings and are, in soft material, obtained by driving a casing inside of which a brass pipe is pressed and withdrawn at regular intervals. After each withdrawal the sample is removed. In hard clay or rock a saw-tooth, chilled steel, or diamond bit is lowered through the casing and sunk by means of rapid rotation. At intervals the bit is raised and the core removed. By this method a complete series of core samples is obtained from the top to the bottom of the test-hole.

* * *

Sometimes, during the course of a construction project, demolition is included in the program. Demolition is actually the process of construction in reverse but it may represent not only a large portion of a job but, in some instances its entirety.

The most common occurrence which necessitates demolition work is the making way for new structures where old ones are already located. The condition of the structures to be demolished may range from that of dilapidation due to a period of disuse and non-maintenance or destruction by fire to that of good maintenance and serviceability. In any case it is generally required that not only the superstructure be removed but also all of the pile stumps and cribwork that may lie within the job limits.

The removal and disposal of the wreckage can frequently be carried on both from the land and from the water simultaneously. Cranes and trucks provide the usual means of removal on land and if railroad tracks are conveniently located adjacent to the site, junk or salvaged iron and steel is most economically loaded directly into cars.

From the water floating derricks are used to perform the wrecking. Iron and steel framework is usually loaded on deck scows and towed to a dock for either salvage or junk. Broken masonry and small sinkable debris is often permitted to fall into the water and is removed later during dredging operations. Old timber and piling pulled from the substructure are loaded on catamarans and, if not fit for reuse, towed to a wood yard for disposal.

# CHAPTER FIVE

## CONSTRUCTION MATERIALS

The selection of materials for use in the construction of waterfront facilities is influenced by a combination of several factors. Strength, weight, durability, resistance to fire, and availability are important considerations, but in the final analysis the governing factor is very apt to be the cost. The cost in this case shall be construed to include not only the initial expenditure for the original construction, but also the subsequent periodic expenditures for the maintenance of the completed structure. Economical selections are made by comparing the length of service and maintenance requirements anticipated for the various prospective materials. At the same time, however, selections are not made without due regard to existing building codes and to the requirements of the Fire Underwriters.

Timber, no doubt, is not only the first, but also the most extensively used material in building construction. Timber produced for building construction in North America falls into two main categories.

The first group, the product of coniferous trees, is sometimes known as softwoods. The other, cut from deciduous trees, is frequently termed hardwoods. Actually these common terms are loosely used and not strictly accurate, for many of the coniferous woods are quite hard while some of the so-called hardwoods are comparatively soft.

A cross-section of an American timber tree displays on the outside the bark, and in the interior a series of concentric rings which are known as the annual rings. The rings next to the bark are usually lighter in color than those on the interior. This outer portion is the living part of the tree and is known as the sapwood. The interior portion, which has ceased to live and is only of structural importance to the tree, is known as the heartwood. The strength of heartwood and sapwood, all other physical conditions being the same, is equal. Sapwood however is more vulnerable to decay and insect attack. For this reason a large percentage of heartwood is usually required in timber specifications.

Seasoning is the term applied to the drying out of green timber. The general effect of this process is an increase in the strength of the timber. The most satisfactory method of seasoning is air-seasoning which consists of exposing the green timber to natural air currents while it is shielded from the weather. To be seasoned properly timber should be piled level, well off the ground, and supported at frequent intervals in its length. Each layer should be separated, thereby permitting the air to circulate freely around each piece. A timber of the softwood group can be expected to shrink from 3 to 4 percent in width during seasoning, while hardwoods will shrink from 5 to (in the case of some oaks) 10 percent.

Since it requires many months to thoroughly air-season timber, kiln-drying has been introduced to speed up production. Timber tends to become brittle when exposed to excessive heat, therefore the kiln temperature must be carefully regulated. The tendency toward brittleness can be reduced by means of steam baths before drying.

Of the various timber species suitable for building material, those which have been extensively used in New York Harbor for dock work are described in the following paragraphs. The majority of such timber is obtained from coniferous trees.

Southern Pine is the name applied to a number of species of pine which grow in the South from coast to coast. After barking and trimming, or sawing there is no practical way to distinguish one from another, so that Long Leaf, Short Leaf, Loblolly, and others are collectively grouped under that name. The strength of timber produced by the different species is about the same, provided that other factors such as density, knot structure, slope of grain, and straightness are the same.

Southern Pine is a heavy and strong timber and, with a good pitch content very durable. While it will decay in damp places, in locations where it is kept dry, completely buried or submerged, it will last indefinitely. Its heartwood is not readily penetrated by preservatives but the sapwood can be satisfactorily treated. Southern Pine is considered one of the best structural timbers although the quality of that which is currently produced is not up to old standards. This is due to a great degree to the tapping of the trees for turpentine before they are cut.

Douglas Fir, sometimes known as Oregon Pine, is a western product but, due to the growing scarcity of good structural pine, it has been used in New York in increasing quantities. It is the only good structural timber which produces first-class piling in long lengths. The trees grow straight to lengths well over 100 feet. It has only a thin layer of sapwood and does not absorb preservatives as well as some other species, but the heartwood resists decay fairly well. In strength, Douglas Fir is equal to southern pine.

White Pine makes excellent timber and its sapwood takes preservatives well. It was formerly used in heavy construction but now, no longer plentiful, it is too expensive for dockbuilding.

Spruce is a timber of structural value but it is produced in small quantities. There are several species in the East all of which are quite similar in appearance, comparatively light, and having tough fibers. It has proved to be good for submerged timber work such as cribs, cofferdams, and piling because it preserves well under water, resisting against barnacles, and so forth longer than other species. It does not however take treatment readily and, without it, decay sets in above the waterline rather rapidly.

Most of the building timber obtained from deciduous trees is oak of which there are about a dozen species used commercially. All oaks are heavy, hard, and strong, but for commercial purposes they are divided into two groups, the White Oaks and the Red Oaks.

The White Oak group includes White Oak, Chestnut Oak, Live Oak, Rock Oak, and other species less well known. These are less porous and more resistant to decay. White Oaks cannot be properly treated when green and even after air-seasoning only the sapwood will absorb creosote.

The Red Oak group includes Red Oak, Scarlet Oak, Pin Oak, Black Oak, and so forth. This group will absorb creosote fairly well, but if treated green, the quality of the timber is impaired.

Mixed oak, a common phrase, includes all species of oak and sometimes hickory and is usually called for in specifications where untreated timber is to be used. All oaks should be air-seasoned before creosoting and the Red Oaks are preferable for this purpose.

Locust is a wood of great durability. It has wide annual rings and its hardness, equal to that of White Oak, increases with age. It has no superior in damp places or underwater and was formerly used to make the treenails with which many of the old docks were fastened years ago.

Greenheart is a tropical timber grown in the Guianas, South America. It is much harder and stronger than American timbers and, once in place, it stands up very well. There are however, disadvantages to it. It has a great tendency to check and warp as it dries, frequently splitting before it is used. The ends of Greenheart timbers are often bound with metal straps for this reason and pile heads are fitted with heavy iron bands before driving.

In addition to being so hard that it is difficult to work and dulls tools rapidly, it is so heavy that it will not float. This necessitates greater than usual care in handling both in transportation and on the job. Many are the pieces of Greenheart timber and piling which never became part of the structure for which they were intended, being lost because of their inability to float. Being imported, it is considerably more expensive than local timber in first cost, but its installation is frequently justified by reduced maintenance charges.

The Southern Pine and oak produced in the eastern states is shipped to the New York area mostly by rail. That which is destined for dock work is unloaded at an open dock where timbers are usually placed on deck scows, while piling is usually placed on catamarans, for transportation to the job. Sometimes, when the job lies within free lighterage limits, it is cheaper to have them delivered directly to the job on railroad lighters.

Douglas Fir, which constitutes the bulk of western timber, arrives mostly by ship. For use in the harbor it is put over the side into the water and made up into rafts which are towed to the job.

For small jobs, which do not utilize shipload or carload lots, timbers are usually delivered from lumber yards to the site on trailer trucks, but piling is practically always brought in on catamarans or lighters.

Deterioration of timber in waterfront structures is caused in a considerable number of ways. Decay, insects, marine borers, abrasion by ice, and the wearing out of decks and fenders due to normal use represent the commonest causes. Fire and collisions by vessels, while by no means uncommon, accomplish destruction in such a short time that they can hardly be classed as deterioration.

Decay of timber is due to the action of that low form of plant life known as fungus. Fungus requires for food certain substances which are found in wood and, as these substances are consumed, the wood becomes rotten. In addition to a food supply, fungus requires a certain amount of air, moisture, and heat in order to thrive. An excess of air or moisture is not conducive to its growth, and timber that is subjected to the free circulation of air at all times, or timber that is permanently immersed in water, or buried to the exclusion of air will not rot. However, timber that is alternately wet and dry will be found subject to rapid decay and those portions of timber wharves that are alternately covered and exposed by the tides are the most susceptible to decay. Piling usually deteriorates most rapidly just below the high-water mark where the timber has a chance to dry out before the rise of the following tide. The easiest and most certain way to prevent decay is to poison the food supply of the fungus. This can be accomplished by treating the timber with a suitable preservative.

Two types of insects cause damage to timber structures in amounts sufficient to attract attention. In North America termites, of which there are two varieties, rank second to decay in the destruction of timber. The dry wood termite flies, needing no contact with the ground, but is not often found on the East Coast much further north than Norfolk, Virginia. The subterranean termite must always have moist surroundings with access to the ground and is found in nearly all parts of the country. No variety of timber is known to be immune to termite attacks but Redwood, heart Cypress, and Yellow Pine with a large pitch content have been found to be less susceptible.

Wharf borers are the larvae of a winged beetle. This insect lays its eggs in holes or crevices in timber. The damage is done when the eggs hatch and the larvae commence to eat into the wood. They do not work below the waterline but seem to be most active just above high-water mark and in timber that is wet by salt spray. Immunity from attack by all insects can be obtained by proper treatment with a preservative. Docks and wharves in New York Harbor have not suffered to any appreciable extent from damage caused by any insect action.

Marine borers constitute a group of animals that are highly destructive to waterfront structures. No species of wood is entirely immune from attack and a few forms of borers are capable of drilling into even shale, limestone, and concrete. Fortunately none of this latter type are native to New York Harbor. The marine borers are divided into two main groups, the Molluscans which are related to clams and oysters, and the Crustaceans which are related to prawns and lobsters.

Among the Molluscans there are the Teredos or ship worms and the Pholads or boring clams. The adult Teredo looks like a worm with teeth,- having at its head two calcareous shells provided with teeth for cutting into timber. In the center of the photograph (Fig. 63) is shown, on the right, the two shells detached from the body. On the left are two pallets, detached from the tail, which are used when necessary to close the entrance to its burrow. In the larval stage this animal has two small hinged shells and is able to travel about similar to other bivalves. At the end of its traveling stage it comes to rest on whatever object it happens to contact. If contact is made with timber, the borer, by opening and closing its shells, cuts into the wood and creates a burrow which it lines with a smooth surface similar to the inside of an oyster shell. After becoming established within the timber the larva changes to the adult

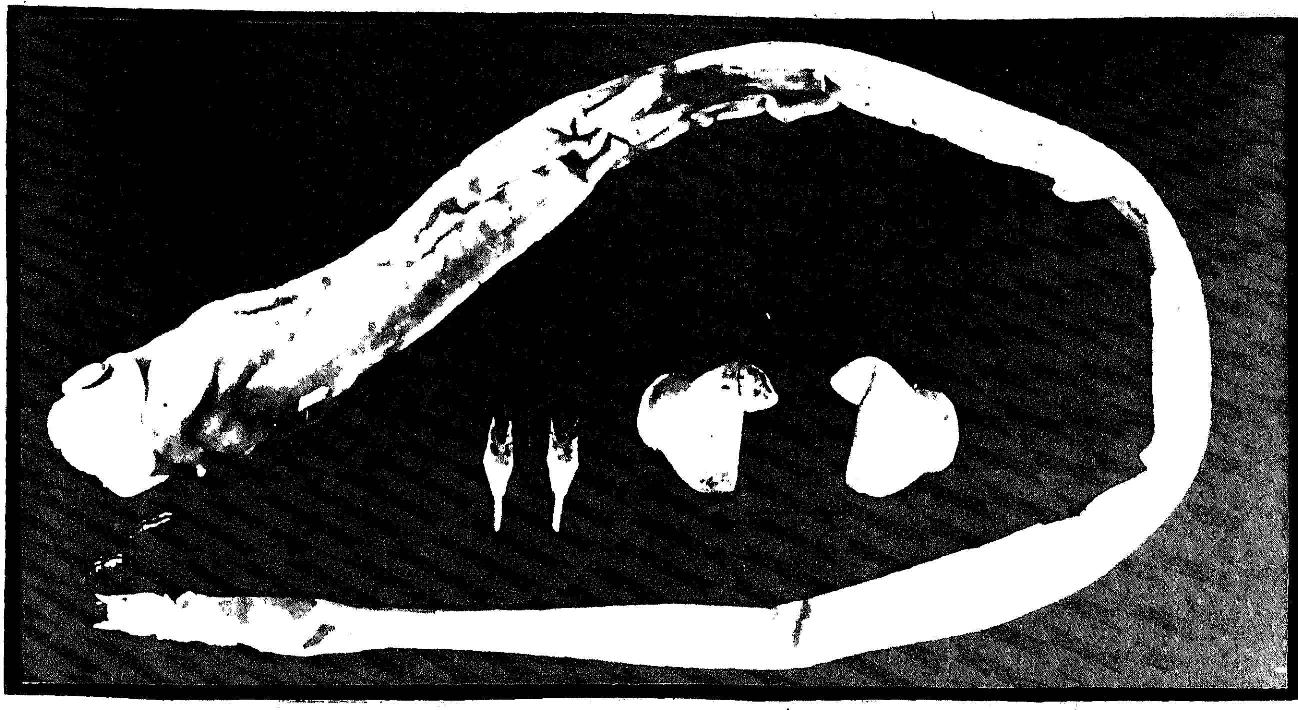


Fig. 63.- Marine borer (Teredo Navalis).

Fig. 64.- Marine borers (Limnoria Lignorum).

stage which commonly ranges in size from 3/8 inch in diameter and 5 or 6 inches in length to 1 inch in diameter and 4 or 5 feet long depending on the species. One species, which to date has been found only in some of the islands of the Pacific, attains a diameter of 3 inches and a length of 3 feet. An unprotected pile subjected to a heavy Teredo attack may be completely destroyed by perforation in as short a time as 6 months.

The members of the Pholad group, while they also use their shells for boring, do not deposit a lining in the burrow. It is a certain species of this group that can bore into rock and concrete as well as wood. They may attain a length of 2 inches and a diameter of 3/4 inch and, under a heavy attack by Pholads, a pile may be reduced in diameter as much as 4 inches in one year.

Among the Crustaceans are found Limnoria and Chelura. Limnoria is the most common species of this group. It resembles a wood louse (Fig. 64) and is only 1/4 inch in length. Its size however is no indication of its destructive power, for by chewing with its strong mandibles it makes shallow burrows about 3/4 of an inch long. Destruction of timber is a progressive process since each layer destroyed exposes a new surface to attack. The large numbers in which Limnoria sometimes occur make them something to be reckoned with. Under heavy attack a pile may lose 2 inches of diameter in a year.

Chelura resembles a miniature shrimp and is related to the common sand flea. It is only slightly larger than Limnoria and is usually found in the same locality. In destructive ability Chelura may sometimes exceed Limnoria.

Up to the present time marine borer action in New York Harbor has been confined to that of Teredo and Limnoria. Teredo activity in both the inner and outer harbor reached a peak in 1941 after which it dropped and practically disappeared for several years. In the last two years light attacks were again noted but tests have shown no serious action within the inner harbor. Limnoria action similarly reached a peak in 1941 and a low point in 1942 at which it has subsequently remained.

While evidence of Pholads and Chelura has not yet been discovered in New York Harbor, there is a possibility that it will eventually appear. In 1935 Chelura appeared for the first time in Boston and in other New England harbors in great numbers where it proved to be more destructive than Limnoria.

Fig. 65.- Work of marine borers on timber piling.

Contrary to what was formerly thought, marine borers do not extract food from the wood in which they burrow. They use the burrows to avoid their natural enemies and they feed upon micro organisms in the water in the same manner as the more conventional shrimp and oyster. It is believed that the erratic nature of the attacks which have been made thus far is due to the fluctuations in the supply of food available in the water. The possibility exists that, as pollution by sewage in New York Harbor is reduced, there will follow an increase in marine life, including borers. With this prospect in view test boards, in which borer action is studied, have been planted in various parts of the harbor. It is anticipated that any adverse trend indicated on the test boards will serve as a warning to be on guard and take whatever corrective measures may seem prudent.

Numerous schemes have been devised to protect timber piles from marine borers. Wrappings, painted coatings, casings, and sheet metal sheathings have been tried. Generally speaking either the high first cost or the difficulty in handling during installation have caused these schemes to be impracticable. The only good protection so far developed and obtainable at a reasonable cost is impregnation with a preservative. The most reliable and widely used preservative is coal tar creosote. This protection does not last indefinitely because over a period of years the creosote leaches out of the wood until in time the residual is no longer offensive to the borers.

* * *

Concrete ranks second to timber in importance as a dockbuilding material. It is stone, artificially formed by mixing rock fragments, sand, cement, and water in such proportions as experience has taught will give the best results for the purpose intended. The two most common uses of concrete in waterfront construction are the formation of retaining walls on pile platforms and of decks for piers and quays.

The advantages of concrete are that it does not decay, does not burn, and marine borers in the vicinity of New York cannot penetrate it. When it is well made, concrete does not readily disintegrate. To be well made however, it must, in addition to being mixed with the proper proportions of aggregates and cement, be protected from the washing action of tides or currents before it has hardened.

It is undesirable to pour concrete into a form which contains water because so doing may result in a portion of the cement being washed from its proper place in the mixture. Concrete carelessly poured in wet forms may be expected to crumble after it has been exposed to the elements. Concrete, being porous, is susceptible to damage by frost action. During the periods of high tide the pores become filled with moisture which, in the winter time, may freeze when the tide falls. Due to expansion of the moisture in this process, small pieces are spalled off.

The porosity of concrete likewise enables moisture to reach reinforcing steel and cause it to rust. Where it is close enough to the surface, the rust, which requires a greater volume that the original steel, spalls off pieces of concrete by pressure from within. There are products on the market today which, when added as it is mixed, make concrete completely impervious to moisture. They have been used successfully to provide waterproof walls below water level and can be used to minimize, if not entirely prevent, damage caused by moisture entering concrete as just described. Floating ice, carried by the currents within the harbor, also causes deterioration by abrasion to concrete as well as to timber.

Precast concrete has a good performance record, an example of which is the beton block bulkhead walls built some fifty years ago. Many of these blocks are still in good condition, but it is to be remembered that, for the most part, they were set below the tidal range.

Precast piles are subject to the same variety of deterioration as concrete poured in forms but they should be of a better grade of concrete because they are poured in the dry and thoroughly cured before they are driven. They are therefore better able to withstand the action of the elements. However, when concrete piling does deteriorate, it creates more of an immediate problem. Only a small amount of spalling materially reduces the cross-sectional area of piling and may expose the reinforcing to corrosion, thereby reducing their bearing capacity.

One of the principal sources of the aggregates used for making concrete in New York Harbor is the north shore of Long Island, where sand and gravel is dredged from the beaches. The other source is up the Hudson River, where crushed rock is obtained from quarries. From both of these locations the aggregates are shipped by means of large barges to the numerous waterfront yards of building material dealers. Where large quantities of concrete are mixed on the job rather than purchased ready-mixed, the aggregates are delivered directly to the work site on the barges.

Cement used in this locality is manufactured principally in eastern Pennsylvania. It is shipped by rail, either in bags or in bulk. Concrete in small quantities is generally made with bagged cement but, where the aggregates are delivered in bulk, the cement is handled in the same way. The bulk cement is transported in large cylindrical metal containers, about five of which fill a railroad gondola. From the railroad cars these containers are transferred to barges and floated to the job.

* * *

Ferrous metal, just as other materials, has its advantages and limitations in waterfront construction. Today, in contrast with the early days when timber was practically the only material used, it has a diversity of uses in several forms. Steel is now used occasionally for bearing piles and almost exclusively for sheet-piling. In addition it is widely used for concrete reinforcement. Cast iron, where conditions warrant it, is used for pipe piles while wrought iron is used to form the armature plates for protecting bridge fenders and the outer double pile rows of timber piers. The various mooring devices, such as cleats and bollards, are made of cast iron or cast steel. The timbers and timber piling of wooden docks are fastened together with bolts and spikes of steel, although some specifications still call for wrought iron.

Steel, generally thought of as a very indestructible material, has a limited length of useful life in water the same as timber and concrete. Although it does not decay, burn, or suffer from borers like timber, and does not spall or crumble like concrete, it does rust or corrode. Depending upon local conditions it may deteriorate more quickly than timber or concrete would in the same location.

The active agents causing corrosion are oxygen, acids, alkalines, and saline solutions. Salt spray is particularly rapid in its action on steel. In all parts of New York Harbor oxygen, both in the atmosphere and in the water, reacts with steel, while acid and alkaline conditions are caused locally by industrial waste. Either a fill of cinders or a surcharge of coal behind a sheet-piling bulkhead will generate sulphuric acid which greatly accelerates the corrosion of the steel.

Steel that is buried in mud may be expected to last indefinitely. Completely submerged steel corrodes slowly, but more quickly in salt water than in fresh. Corrosion under water is retarded by the accumulation of barnacles and other marine life on piling. The most rapid rate occurs above the low-water level.

Under ordinary harbor conditions piling of common carbon steel can be expected to last for from 10 to 25 years. By adding 0.2 percent of copper to steel this expectancy can be doubled. Other means to prolong the life of steel-piling include coatings of asphalt paint and acid-free tar, but these are not very reliable because they are marred in handling and driving. The interlocks are the weak point of sheet-piles and are particularly difficult to coat successfully.

Wrought iron is a malleable form of iron containing very little carbon. It is tough and has a high resistance to corrosion, qualities which make it very desirable where there is exposure to salt water and spray. Formerly it was used much more widely in dock work, as it was in structural ironwork, before steel became the cheaper metal.

Cast iron is not used structurally to an appreciable extent because of its weakness in tension. It has, however, been used successfully in the form of short pipe piles where, while the first cost was high, its great resistance to corrosion made it economical. In addition to mooring devices, ogee washers for bolting timbers, particularly low-water timbers, are made of cast iron.

The various articles of dock hardware such as machine bolts, washers, dock spikes, and so forth are generally made of mild steel and are used just as they are turned out from the shops. Such hardware is commonly described as black iron. Sometimes the hardware is galvanized, a process which consists of dipping it, after thoroughly removing all dirt, grease, and scale, in a bath of molten zinc. Galvanizing amounts to zinc plating and is calculated to prolong the life of hardware. This it undoubtedly does but, in the majority of instances, black iron outlasts the timbers which it holds together, so that the practical value of galvanizing is questionable.

* * *

Of a large variety of stone used in building construction a relatively small amount is incorporated in waterfront work. Its principal application is as a facing for the protection and improved appearance of concrete bridge piers, bulkhead walls, and seawalls. For this purpose it generally extends from the low-water level to the coping stone.

Granite is most widely used because of its abundance, durability, and good appearance. It is hard, resisting the erosive action of ice and the weather and, being impervious to water, it is not spalled by moisture freezing within its pores. In this type of work granite of the coarser or medium grained varieties is preferred. It may endure for from 50 years to several centuries and, as a rule, this type of stonework outlives the structure of which it is a part. For use in New York City it is quarried largely in Vermont, Massachusetts, and New York State and is transported both by rail and barge. Arriving in the city in rough blocks, it is cut and dressed for particular jobs in stonecutters' yards.

Stone is also used in waterfront construction as riprap. Riprap is broken stone loosely thrown together for a number of purposes. It is used to stiffen and give lateral support to piles, to distribute pressure on and consolidate soft mud bottoms, to prevent erosion by currents around foundations, and to provide foundations in deep water as previously (See Fig. 40) described. Riprap may vary in size from that of railroad ballast to one or two-man stone which would weigh about 40 or 100 pounds respectively. What is not commonly known is that properly shod piles can be driven through as much as a 20 foot layer of newly placed riprap, provided that the stone is not larger than 16 inches in size. Riprap, like concrete aggregate and derrick stones for breakwater construction, is quarried up the Hudson River and floated to the job on barges where it is placed with clam-shells and stone grapples.

* * *

A greater variety of material has been used for fill than for any other part of construction projects. In general it is divided into two classes, common fill and selected fill.

Common fill frequently consists of about everything imaginable, including cinders, refuse, material excavated for building foundations, debris from demolished buildings, and any other material that requires disposal. Years ago, before restrictions were imposed, much of the lands reclaimed along the North and East River fronts of Manhattan Island were filled by making them the dumping places for the ashes, refuse, and garbage from the city. This gave rise to a very offensive situation such as would not be tolerated today.

In addition to the foregoing, fill is obtained from hydraulic dredges and by using the ballast carried aboard ships inbound from Europe with insufficient cargo. A surprisingly large number of areas have been filled with material from this source. As an example, the piece of land that encloses Beard's Erie Basin, Brooklyn is filled in entirely with ships' ballast.

Selected fill is usually free from mud and clay and is placed behind bulkhead walls so that uniform earth pressures will be exerted. Such fill, usually sand and gravel, is also placed sometimes to avoid causing conditions which might be conducive to mud wave action.

# CHAPTER SIX

## CONSTRUCTION EQUIPMENT

Of the several elements which must be combined on a modern construction job in order to effect the realization of plans, probably the most important is the equipment used to handle the materials. Were it not for the introduction of modern construction plant, such waterfront facilities as are enjoyed by New York Harbor today would not exist. The demand for an expansion of the waterfront, which accompanied the rapid growth of New York City together with the rest of the nation, was so great that it could not have been met successfully by the old-fashioned dockbuilding methods.

The latter years of the last century saw major changes made both in the types and methods of construction. Piling took precedence over cribwork as a means of supporting waterfront structures and, at the same time, machinery and equipment were developed to augment hand labor and expedite the development of the harbor. Frequently special equipment was, and still is, designed and built for a particular job.

Thus it has been made possible, in the face of steadily increasing costs of labor and material, to keep the desired harbor developments and improvements within reach of both private capital and public agencies. It may be stated analogically that, as the development of better construction plant and the invention of labor-saving mechanical implements have made possible the large and numerous modern waterfront facilities now in existence, so have the erection of these facilities, together with the invention of cargo handling devices, enabled the Port of New York to attain its present proportions and importance.

The greatest single event that served to revolutionize construction methods was the introduction of steam-power. Prior to that time construction work, except for that which, in a few cases, horse-power could be harnessed, was performed by hand labor. The greatest consumer of labor has always been the moving of earth and the handling of heavy material by hand. By combining the mechanical advantages of gears and pulleys, much work of this kind has been given assistance by steam engines.

It required only a relatively short period of years for these adaptations to be made and, as more efficient rigging was devised, for derricks to evolve. Dockbuilders were not long in discovering that their particular type of construction work could most economically be carried out from the water and, as the various hoisting devices and so forth were developed, they were mounted on scows.

Modern floating derricks have some unusual and interesting forebears. One of them, built about 60 years ago and utilized by the New York Dock Department, is noteworthy (See Fig. 66). In appearance it somewhat resembled a windmill. The deckhouse was shaped like a truncated cone and was surmounted by a large mast extending axially up to a height of about 120 feet above the deck. A horizontal cross-arm was located about 70 feet high at the apex of the cone and supported by numerous guys from the top of the mast. Having a radius of about 50 feet, this could be swung about the mast. A multi-part set of falls for making the vertical lifts was hung from the cross-arm and made to travel horizontally on it by means of additional pulleys. From the opposite end of the cross-arm a number of guys were stretched to the deck. This derrick, constructed of timber, had a capacity of 100 tons and was used primarily to handle the large beton blocks in the contemporary construction

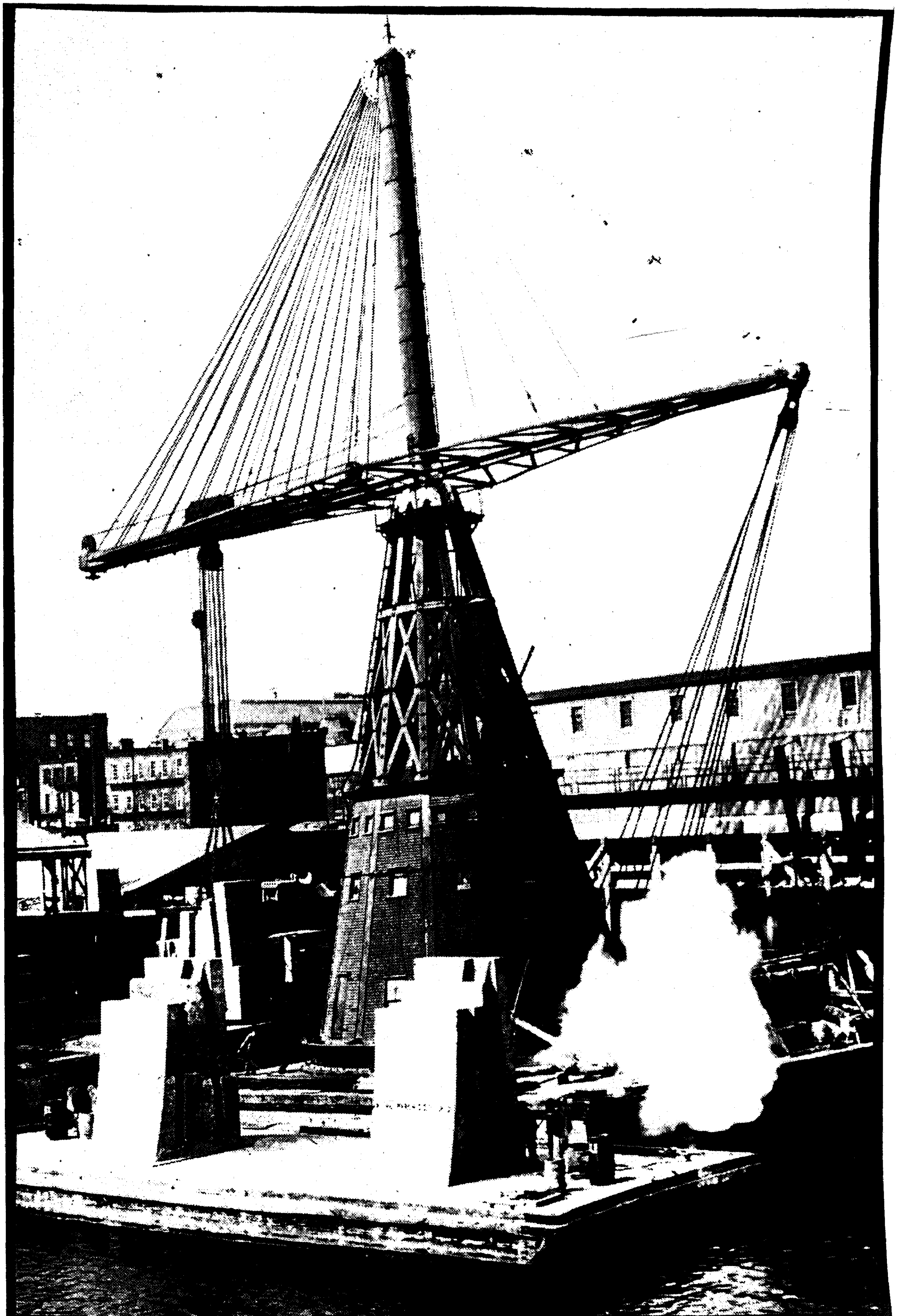


Fig. 66.- 100 Ton derrick of the Dock Department, circa 1890.

of the city bulkhead walls.

A number of the derricks still in use today are constructed of timber. Recently however, while most of the scows are still wooden, most of the superstructures have been built of steel. The A-frames are steel framed and the booms are built up with steel angles and lattice-bars. While some, designed specially for heavy marine hoisting, have capacities reaching 250 tons, the type of derrick used for dockbuilding seldom lifts more than about 15 tons, the majority having considerably less capacity.

For the convenience of the hoisting engineer and so that he can better watch the boom and falls, the operator's cab is located in an elevated position in the deckhouse overlooking the deck of the scow. The control levers are mounted in a bank in the cab and connected to the throttles, clutches, and brakes below by means of a system of cranks and rods.

In general, a floating derrick is a very handy piece of plant. Not many years ago nearly all waterfront construction and maintenance work was performed with piledrivers. Now, except for a large piledriving job or for heavy pulling, derricks have gained preference by many dockbuilders over piledrivers. A particularly good feature peculiar to floating derricks is the ability to watch the list of the scow when making a lift. The development of an excessive list serves as a warning not to be had from a land rig.

The floating derricks most widely used in dock-building today are of the guyed boom variety illustrated in Figure 67. They are equipped with two engines, one for hoisting and the other for swinging. These, with their boilers, are mounted on the after part of a scow and enclosed in a deckhouse. An A-frame, anchored with a batter brace and straddling the engines, is located just aft of amidships. The boom is pin-connected to a heavy cast steel bedplate in such a manner that it can be raised, lowered, or swung.

The rigging consists of three sets of fall lines and a pair of guys. The boom fall is a several part line reeved through one block which is secured at the top of the A-frame and another either at the tip of the boom or, in the case of long booms, suspended from it by a pennant. This line is wound on a drum of the hoisting engine and serves to lower or raise the boom.

Wound upon another drum of the hoisting engine is a single-part line led over a sheave at the tip of the boom. This is commonly known as the No. 1 fall or the single whip and is used for making light lifts.


Fig. 67.- Guyed derrick.

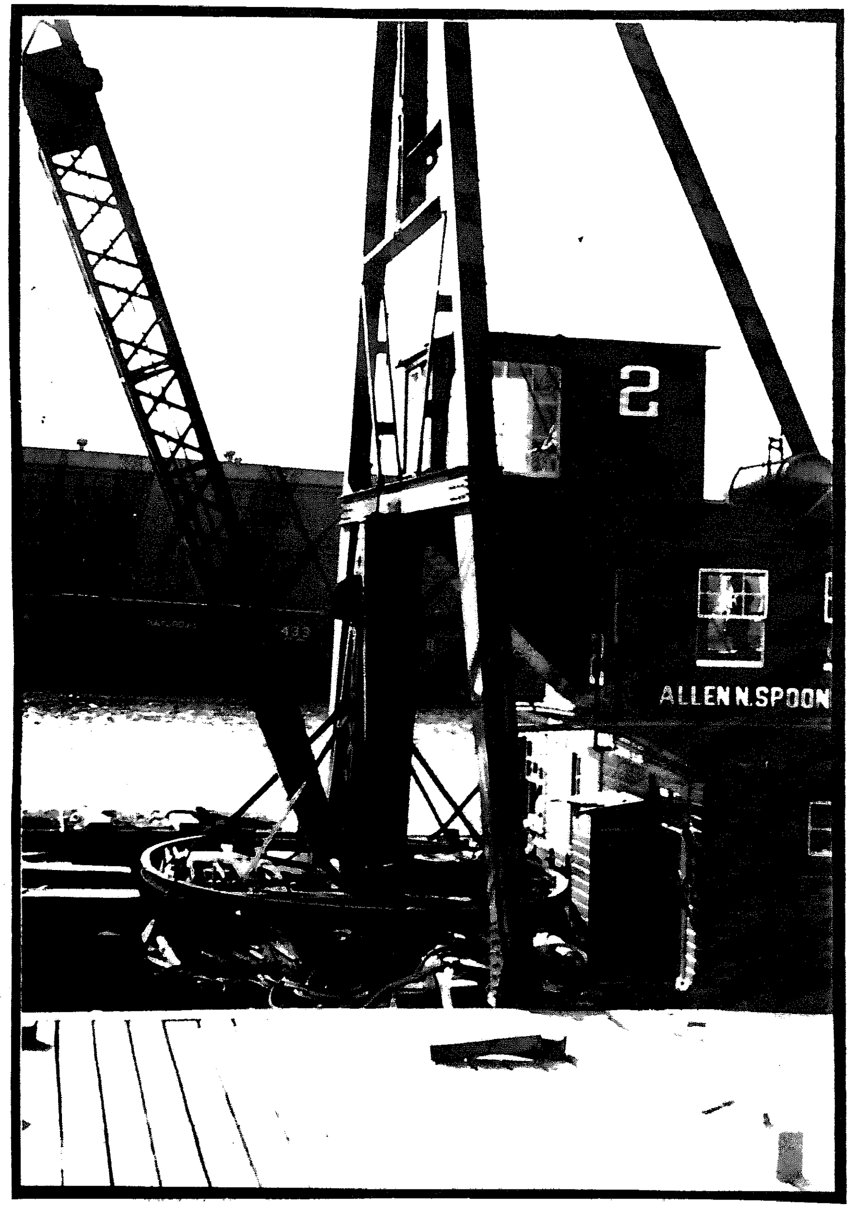



Fig. 68.- Bull wheel derrick.

The No. 2 fall is a two or more part line led over a sheave at a short distance from the end of the boom to the third drum of the hoisting engine. The hook on this fall is slower moving than on No. 1 but it has the mechanical advantage of the pulley blocks for making heavier lifts.

The guys are used for swinging the boom. From the drums of the swinging engine two lines are rigged, one to each side of the boom. Usually the guy lines are reeved through blocks suspended from the tip of the boom by pennants, and blocks secured to the gunwales of the scow near the base of the A-frame.

Bull wheel derricks are similar to guyed derricks in all respects except for the manner in which the boom is swung. The bull wheel, whence this type of derrick derives its name, is a wheel about 15 feet in diameter, depending upon the size of the rig, mounted in front of the A-frame, with its axis vertical, on a bedplate permitting free rotation. The boom is pin-connected to the wheel so that it can be raised and lowered only, swinging being accomplished by turning the wheel. Turning the bull wheel is done with two lines both of which make a turn around the wheel itself and have their other ends wound upon separate drums of the swinging engine. This arrangement permits faster slewing of the boom and is advantageous for such work as excavation or the placing of riprap and so forth where the boom is in constant motion. The bull wheel rig does not afford as positive control of the boom as do guys and is not preferred for heavy lifting.

A whirly derrick is one constructed so that, instead of the boom alone slewing, the entire derrick, engines, deckhouse, boom, and all turn together. It is mounted on a ring of pony wheels which ride on a circular track, and is turned by means of a rack and pinion gear. The fall lines are worked similarly to those of guyed and bull wheel derricks but, with a whirly, the boom can be swung in a full circle instead of only 180 degrees of arc. There is no A-frame and the lower pulley block for the boom fall is secured at the top of the deckhouse. Although there would seem to be an advantage in their ability to turn in all directions, whirly derricks, which are still a comparatively recent development, are, to date, seldom used in dockbuilding.

* * *

While it did not become prevalent in New York Harbor until the latter half of the Nineteenth Century, the art of piledriving had been practiced elsewhere for many hundreds of years. An historic example of this art in ancient times was Caesar's bridge across the Rhine and, until within the last century, the methods employed to drive piles differed but very little from those employed by the Romans. The rigging formerly used to drive piles consisted of an A-frame, supporting a set of falls, that could be moved progressively to new bents as they were completed. Successive bents were driven from the one previously constructed.

The early hammers used for driving were blocks of stone, hoisted by hand and allowed to drop upon the heads of the piles. Later, in some instances, horse-power was used to supplant hand labor to raise the hammers, while iron hammers were cast to replace those of stone.

When dockbuilders contrived to mount this equipment on scows the modern version of floating piledrivers began to take shape. Steam-power, which was introduced about the same time, was at first used for hoisting only, and all driving was done exclusively with drop-hammers. The old model depicted in Figure 69 shows that by 1870, deckhouses were already used to protect the engines and that trippers had been devised to release the hammer at

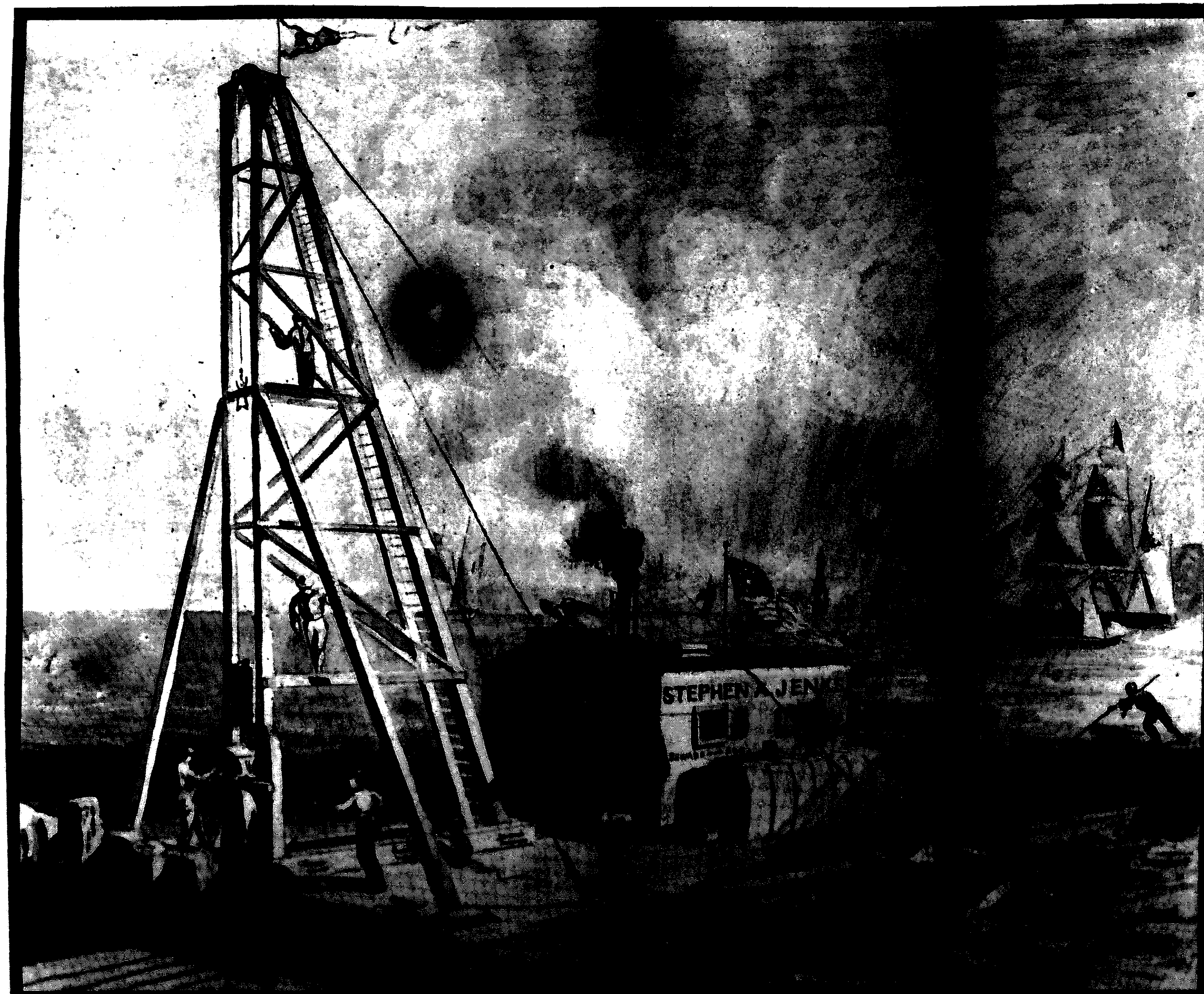



Fig. 69.- Old -fashioned piledriver, circa 1870.

the end of its upward movement.

The piledrivers used in dockbuilding today have retained the general outline of the original models. The principal changes that have been made are in the size of the scows, the height and strength of the leads, the horsepower of the engines, all of which have been greatly increased, and the addition of an assortment of auxiliary machinery. Formerly the leads were intended only to set the piles in place, to hold them while being driven, and to hoist the drop-hammers. In addition to the foregoing, leads are now designed to resist the stresses set up by pulling piles, and are guyed with cables for added resistance to overturning.

The leads consist of two vertical members, fitted with guides or conductors, between which either a drop-hammer or a steam hammer is operated. During driving, the pile is maintained in a plumb position, with its head directly beneath the hammer, by holding it between the leads. Usually a graduated scale, marked off in feet with zero at deck level, is painted on the sides of the leads so that the lengths of the piles in them can readily be noted. Several platforms, or lofts, are situated in the leads at various heights above deck so that men can conveniently hook and unhook the pile falls and assist in getting the piles ready for driving.

The standard rigging of a piledriver consists of a pile fall, for picking up piles from catamarans and holding them in place while it is plumbed and set for driving, and a hammer fall. The hammer fall is used for handling the pile hammers, and both are led over sheaves, mounted on top of the leads, to their respective drums on the hoisting engine. The hammer fall, for the larger size steam hammers, is sometimes made a two-part line by running it through a sheave on the hammer and fastening the dead end at the top of the leads. When a drop-hammer is used, a manila line is usually substituted for the wire rope commonly used with steam hammers. When not in use, the hammers are permitted to rest on a toggle so that they do not depend upon the lines to hold them.

For pulling piles, the pile fall may be used if they are not stuck too tightly. Piles that depend solely upon skin friction for their bearing capacity have approximately the same resistance to pulling as they had to driving. Clay and clayey sand cling tenaciously to piles and sometimes make pulling exceedingly difficult. Similarly, piles, about which riprap has been deposited, frequently become wedged in the rock and require a tremendous pull to break the grip on them.

Piles that are too tightly embedded to be moved by the pile fall may sometimes be pulled with the so-called monkey-purchase. This consists of making a two-part line of the pile fall. The pile fall is shackled to a 7/8 inch wire rope the other end of which is anchored about halfway up the leads. The cable is reeved through a heavy pulley block from which is suspended a $1\frac{1}{2}$ inch chain and hook. The mechanical advantage derived from this rigging can usually pull until, depending upon the engine, the forward part of the deck of the pile-driver is almost awash.

For piles that resist the efforts of the monkey-purchase, the heavy pulling purchase (See Fig. 82) is rigged. This consists of a set of blocks, making an eight-part line, to which a 2 inch pulling chain is shackled. The upper block is securely lashed between the leads with cable. The leads which, during pulling, become columns are given additional lateral support by inserting a large cast iron spreader between them to prevent their buckling. Water jets, as described later, sometimes help to break the grip on a pile.

Some piledrivers are equipped with a timber boom which is mounted close alongside the leads. The boom fall is rigged to the top of the leads while manila


Fig. 70.- Piledriver with telescopic leads.

guy lines are run by steam winches. These booms prove useful in handling material other than piles where piledriving does not constitute the entire job.

In contrast to the conventional piledrivers described above, several of which may be seen in the accompanying illustrations (See Figs. 33, 34, and 61), there are some which have been modified or specially constructed to drive a particular type of piling. The piledriver shown in Figure 70 has been equipped with telescopic leads so that the steam hammer may follow the head of the pile and continue to drive it after it has gone below the surface of the water. The moveable section of the leads is raised and lowered by means of the pile fall and fits the guides ordinarily followed by the hammer. In this particular illustration the hammer fall is rigged as a four-part line.

Shown in Figure 71 is a piledriver equipped with pendulum leads for driving batter piles. The pendulum consists of a separate set of leads, cross-braced to keep them parallel, and pivoted at a point about two-thirds up the regular leads. The pendulum is made plumb while the hammer is raised and a pile is placed in the leads. Then the desired batter is obtained by pulling the lower end of the pendulum to

Fig. 71.- Piledriver with pendulum leads.

one side with a set of falls or with a line from a steam winch. The pile, guided by the leads, maintains the proper batter and is struck squarely by the hammer all the way down.

Thus far nearly all piledrivers have been constructed of timber on a wooden scow. An outstanding example of the few exceptions is the large steel pendulum pile leads erected on the deck of a steel derrick boat (Fig. 72). This rig was designed to handle unusually long and heavy piling and, when built, was probably the largest piledriver in existence. The upper end of the steel leads are pivoted at the top of the steel tower which stands higher than the A-frame of the derrick. The lower end is swung to either side by means of blocks and tackle secured at the ends of steel struts which jut out from the gunwales at deck level. The derrick itself, mounted on the stern, is of the conventional guyed boom type and is used to facilitate the handling of material not conveniently reached and lifted by the falls of the piledriver..

* * *

Almost without exception the derricks and piledrivers used in waterfront construction are operated by steam engines. In general, the engines are built with two cylinders, one on each side, with the cranks set

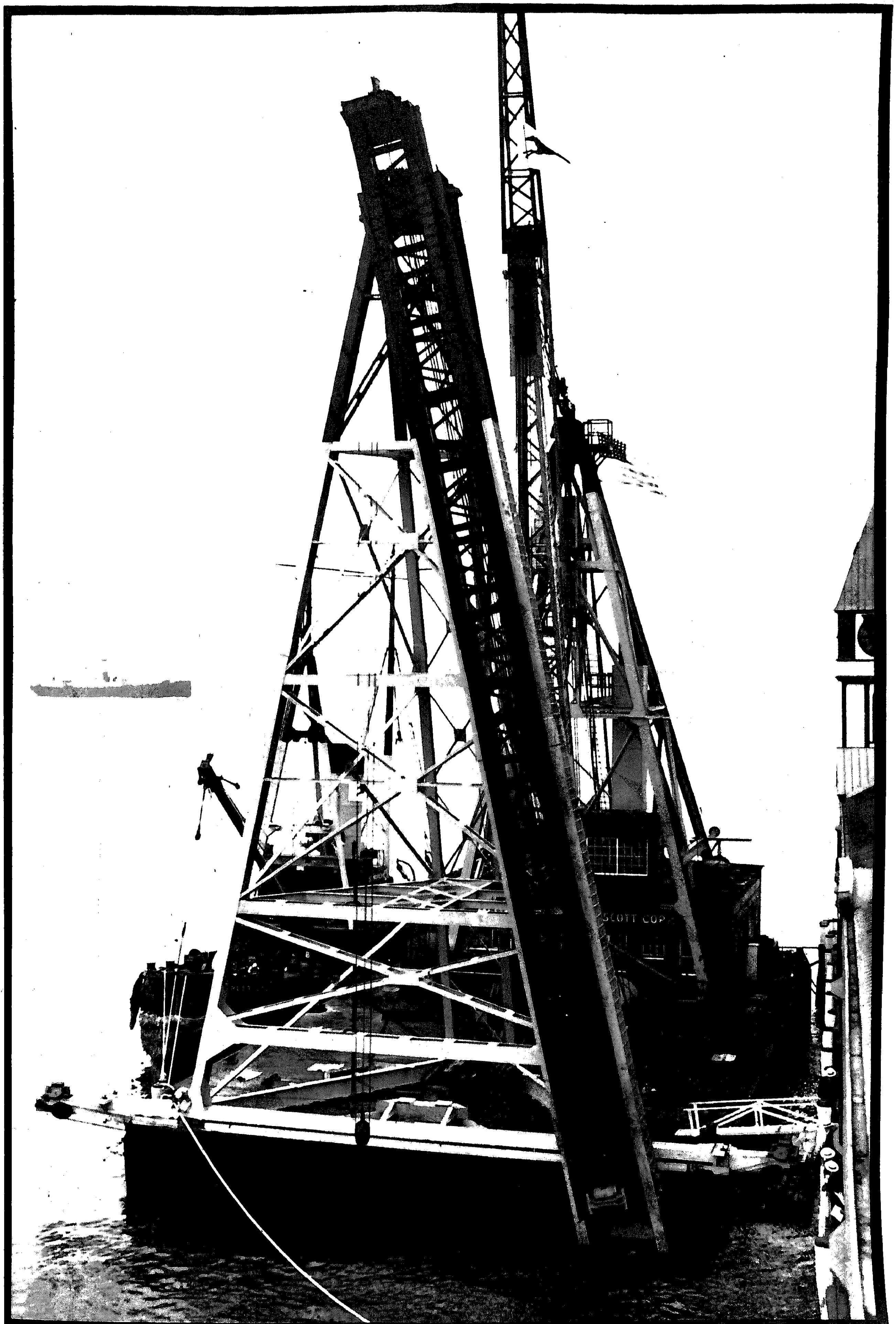


Fig. 72.- Steel tower and pile leads mounted on a derrick boat.

90 degrees apart to eliminate stoppage on dead center. In addition, this arrangement gives a more uniform and steady hoisting speed.

The hoisting drums of the engines, about which the fall lines are wrapped, are free to turn loosely upon their shafts and are given their motive power by a friction clutch. When the clutch is thrown in, the drum turns and winds up the fall line, thereby hoisting the load. When the clutch is released, any weight on the fall line sufficient to overcome the friction of the drum and pulleys, will overhaul it, causing the drum to spin in reverse. A single part line is usually weighted with an iron ball to overcome the friction and make it unnecessary to overhaul it by hand. In lowering, the descent of a load is slowed or stopped by means of a band brake which is able to hold any load that the engine can hoist. To hold the load, and still be free to operate other levers for booming, swinging, and so forth, the operator, by inserting a pawl in a ratchet, can dog the drum.

A hoisting engine with two drums is usually employed on piledrivers. The rear one is used for the hammer fall while the one in front is used for pulling piles, dragging piles from catamarans, setting them

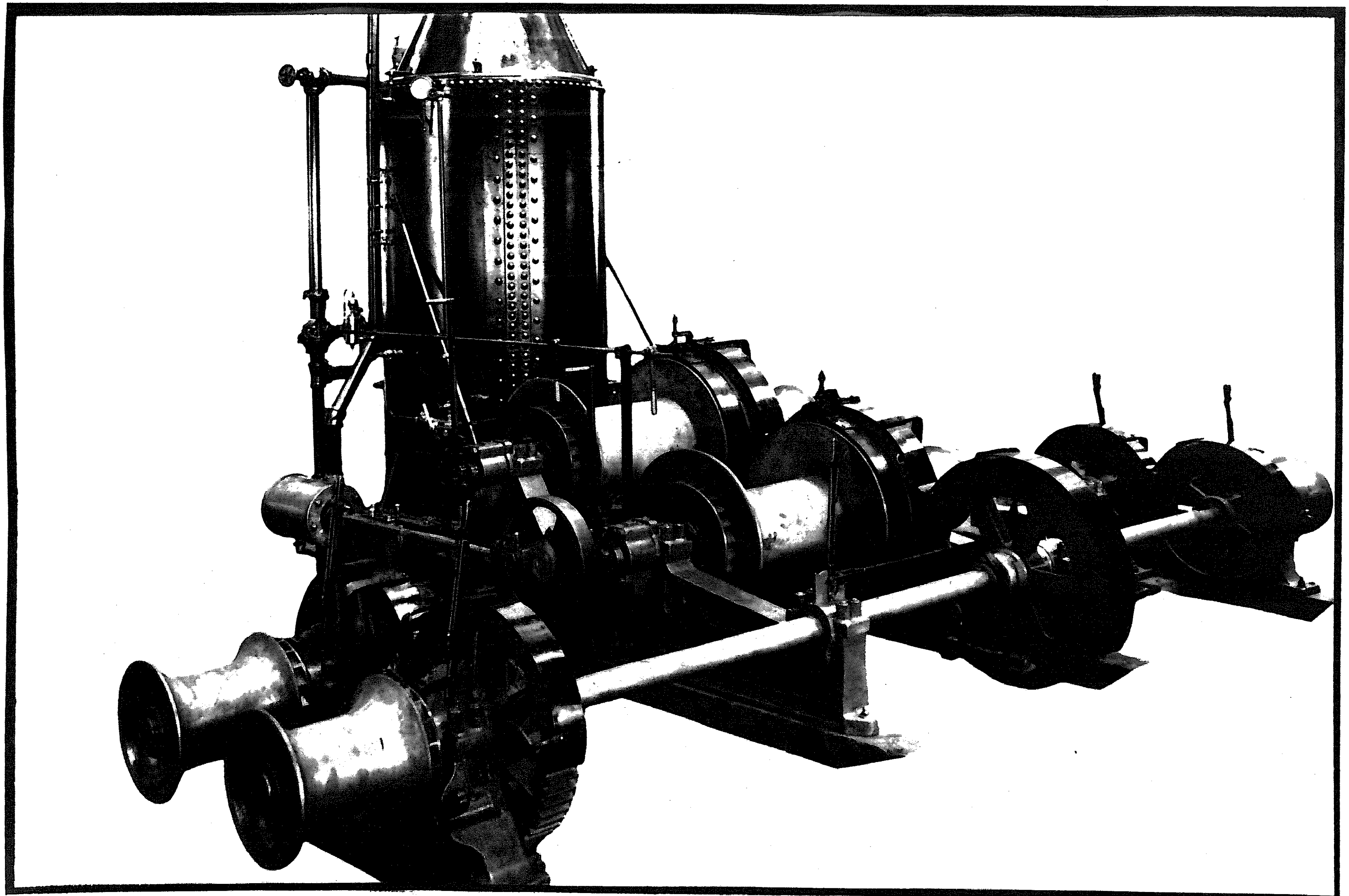


Fig. 73.- Steam boiler and hoisting engine.

in place, and hoisting. On derricks, three drum engines are most efficient. The rear drum carries the boom fall, the middle drum the No. 2 or two-part line, while the front drum carries the single whip. For swinging the boom, a separate engine with two drums is required. It is usually mounted alongside the hoisting engine and operates the guy lines or, the bull wheel cables. On both piledrivers and derricks the hoisting engines are equipped with winches, the heads of which extend outside of the deckhouse.

Small outside deck engines are mounted on some piledrivers between the leads and the deckhouse. These operate additional winches similar to those on the hoisting engines.

Nearly all of the steam engines are powered by boilers of the vertical coal-burning type. They operate at about 100 pounds pressure and vary in size, developing up to about 60 horsepower. This gives the engine a direct pull on the fall lines of up to about 8 tons. Pile driving makes the heaviest demands upon dockbuilding equipment and the boilers are frequently the first to indicate that the demands are excessive.

The average derrick, having about 10 tons capacity, is equipped with two 40 horsepower boilers. On a job both are usually kept with steam up but, where no pile driving is being done and where the boom is not kept busy, one is frequently made to suffice. Piledrivers usually have only one boiler, also about 40 horsepower, but some carry an auxiliary to assure an adequate supply of steam on jobs where the demand for it is great.

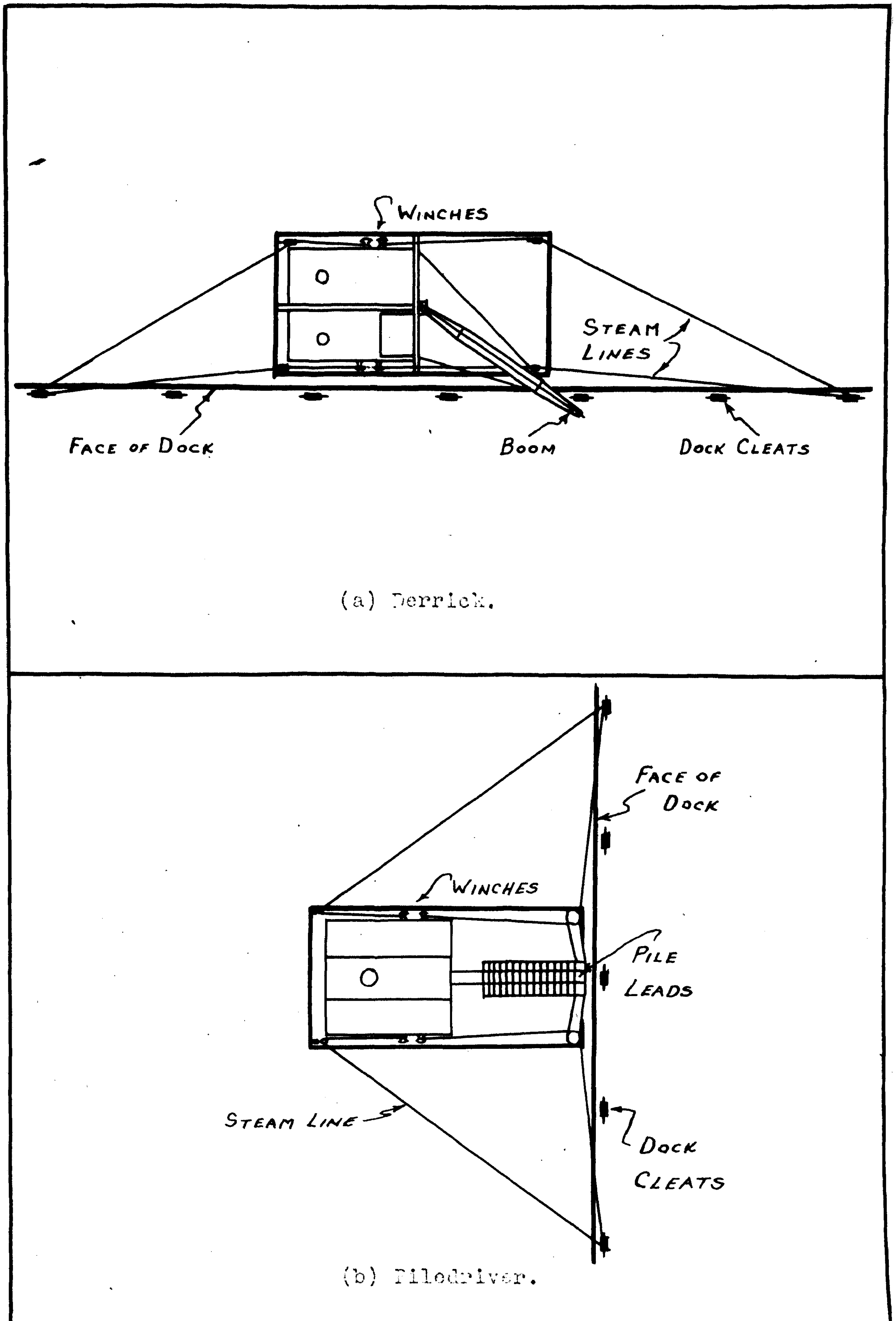
The two principal requirements for keeping a steam boiler in operation are coal and fresh water. The coal is stored in bunkers built-in at the rear of the deckhouse, while the water is stored in tanks below deck. The average rig stores approximately 15 tons of coal and from 5,000 to 10,000 gallons of water, which may last for two weeks, depending upon the type of work being done.

The winch heads (See Fig. 73), mounted on horizontal shafts extending outside of the deckhouses on derricks and piledrivers, are utilized as power take-offs for large manila lines. Power is transmitted from the winches to the lines by means of friction created by taking several turns tightly around the rotating drum. These lines, because the winches are powered by the steam engines, have obtained the name of steam lines. They serve a great many purposes, the most important of which is the maneuvering of the rigs.

In Figure 74 is shown the manner in which derricks and piledrivers are commonly moved and held in position for dock work. From the winches, the lines are passed through roller chocks or bitts mounted on the deck of the scow to cleats or bitts mounted on the dock. To move a piledriver, which is worked with the bow against the dock, the stern lines are first slacked so that the scow will clear the face of the dock. Then, to move, which is done sideways, the bow line on the side toward which movement is desired is hauled in while the other is slacked off. Meanwhile one stern line is taken in while the other is paid out until the leads are at the desired location. Then both bow lines are held fast and both stern lines are hauled in to press the scow against the dock.

In a similar manner derricks are moved, but it is customary for them to work along a dock lying sideways. To move ahead the outboard bow and stern lines are slacked and the inboard bow line is hauled in. The stern line is slacked off until the desired location is reached and then held fast. The other lines are then tightened and held.

Both piledrivers and derricks sometimes work in open water, away from docks. In such a case the steam




(a) Derrick.

(b) Piledriver.

Fig. 74.- Methods for maneuvering derricks and piledrivers.

lines are run out from each corner of the scow to anchors and the desired location is reached by adjusting them to the proper lengths.

A steam line is a versatile piece of gear and its use is not confined to the shifting of floating equipment. It is nearly always used to assist a pile-driver in loading pulled piles on a catamaran by hauling the lower end of the pile to the stern while the pile fall lowers the head. It may be used for dragging piles or timber to where it can be reached by the fall lines and is frequently used in tearing out timber to pull away pieces that have been loosened by wedges or bars. It is frequently used to pull new bearing piles under the side cap of a dock after they have been driven and cut off to the proper length. The steam line is also used to raise and lower the jet pipe when it is used for pile driving.

In addition to the hoisting engines and winches, there are other steam operated machines on board a well equipped rig. Of these, air compressors and pumps are the two most essential. All wood boring is done with air-augers, while a large percentage of timber cutting is done with air-saws. The compressors must deliver about 250 cubic feet per minute at 100 pounds pressure to operate several pneumatic tools at one time.

Pumps are usually installed, primarily on pile-drivers, for jetting piles. With the intakes extending downward through the bottom of the scows, the jet pumps are of the reciprocating type and deliver about 150 gallons per minute through a 2 or 3 inch discharge. Small feedwater pumps deliver a one inch stream from the tanks to the boilers.

On a few rigs there are electric light plants set up to provide illumination for night work, the generators being run by small steam turbines. Most rigs carry a grindstone, turned by a small steam engine, for sharpening axes and adzes.

* * *

Ever since the practice of driving piles was begun, the use of the drop-hammer has persisted for certain types of work in spite of the invention of steam operated pile hammers. A drop-hammer in its present developed form consists of a heavy iron weight, cast with an eye on top and vertical grooves in the sides which fit the guides on the pile leads. To drive a pile it is raised in the leads by the manila hammer fall, which is knotted to the eye, released by throwing out the clutch on the hoisting drum, and permitted to fall by gravity upon the pile head. A skilled operator can repeat this process in rapid succession, allowing the hammer to remain at rest for only a fraction of a second between blows. Drop-hammers are used most frequently for driving fender piles and clusters where deep penetration is not required and hard driving is not encountered. For work of this type the drop-hammer is more economical to use than a steam hammer, since the pile heads do not have to be trimmed as they do to fit a steam hammer. Drop-hammers vary in weight from one to 3 tons, depending upon the size of the piles to be driven and the leads of the piledriver.

The steam hammer, which was invented in 1845, brought about such a labor saving in driving piles, particularly where long and hard driving was required, that it was largely responsible for the abandonment of crib construction in favor of pile platforms. The first steam hammer was of the single-acting type which is still widely used today. It consists of a heavy weighted steel ram which is raised on vertical guide rods by means of steam acting against a piston. At the top of its stroke the steam is shut off by a cam-operated valve and the pressure is released through an exhaust port, allowing the piston and ram to fall by gravity. As the ram strikes, the same cam is tripped again, opening the

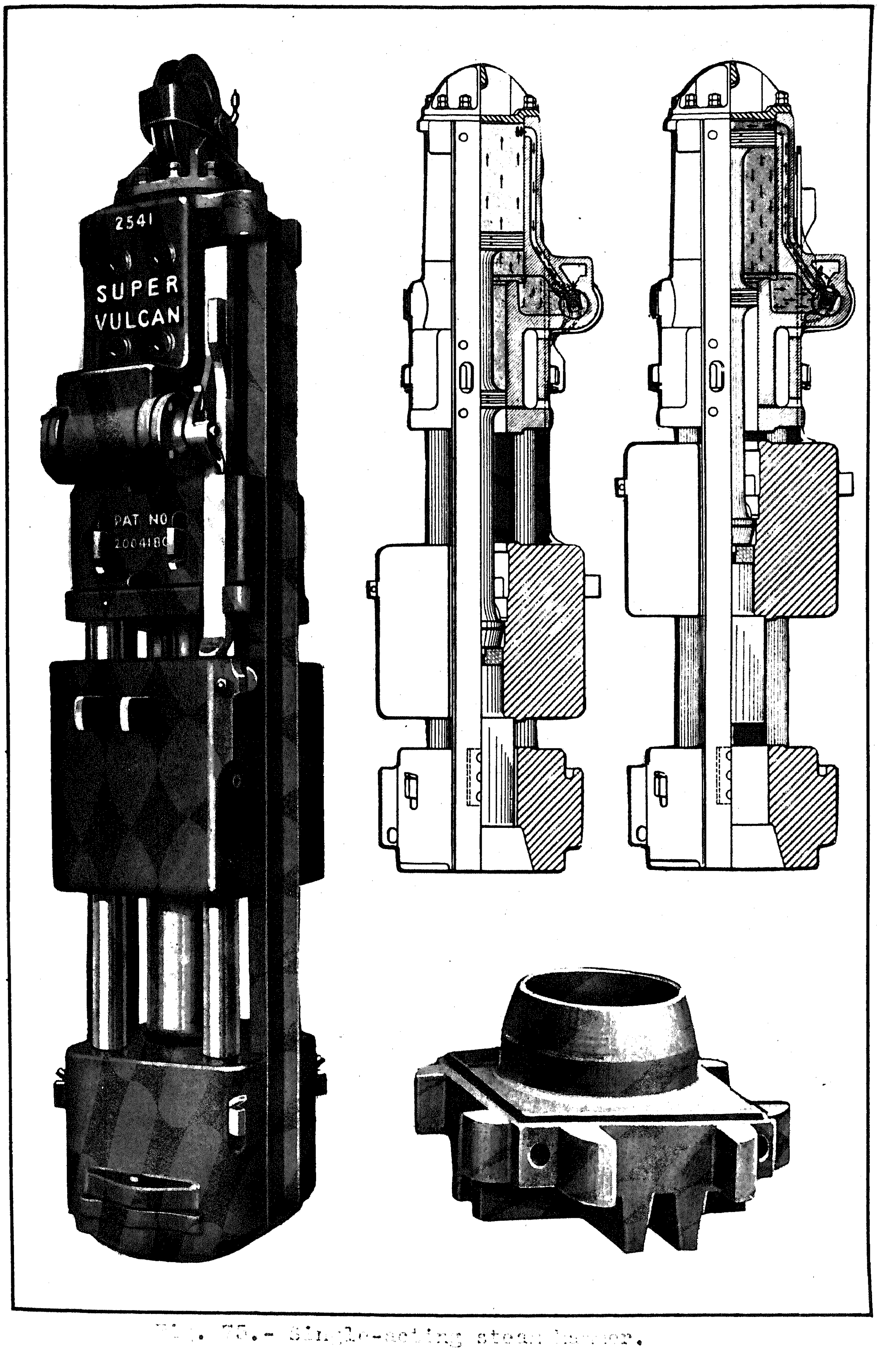



Fig. 75.- Single-acting steam hammer.

steam line, and causing the piston to be raised again, thereby completing a cycle. The rams vary in size from one to 10 tons and strike from 150 to 100 blows per minute, the speed varying inversely with the size.

The single-acting hammers are particularly adaptable for driving large and heavy piling such as long H-piles, heavy concrete piles, and for hard driving. In general, a hammer should have a ram which is equal to at least one-fourth the weight of the pile to be driven. The use of a hammer of ample weight permits piles to be driven with relatively low ram velocity, which not only utilizes more of the available energy for driving the pile into the soil, but prevents undue damage to the pile.

A more recent development is the double-acting steam hammer. This type is similar to the single-acting type in that the driving ram is raised by steam acting against a piston. It differs in that instead of being allowed to fall freely, the ram is accelerated downward by steam acting upon the upper side of the piston. The double-acting hammers, which range in weight from about 2 to 7 tons, have a faster stroke, making from 300 to 120 blows per minute, also varying inversely with the size. The rapidity of the strokes in double-acting hammers

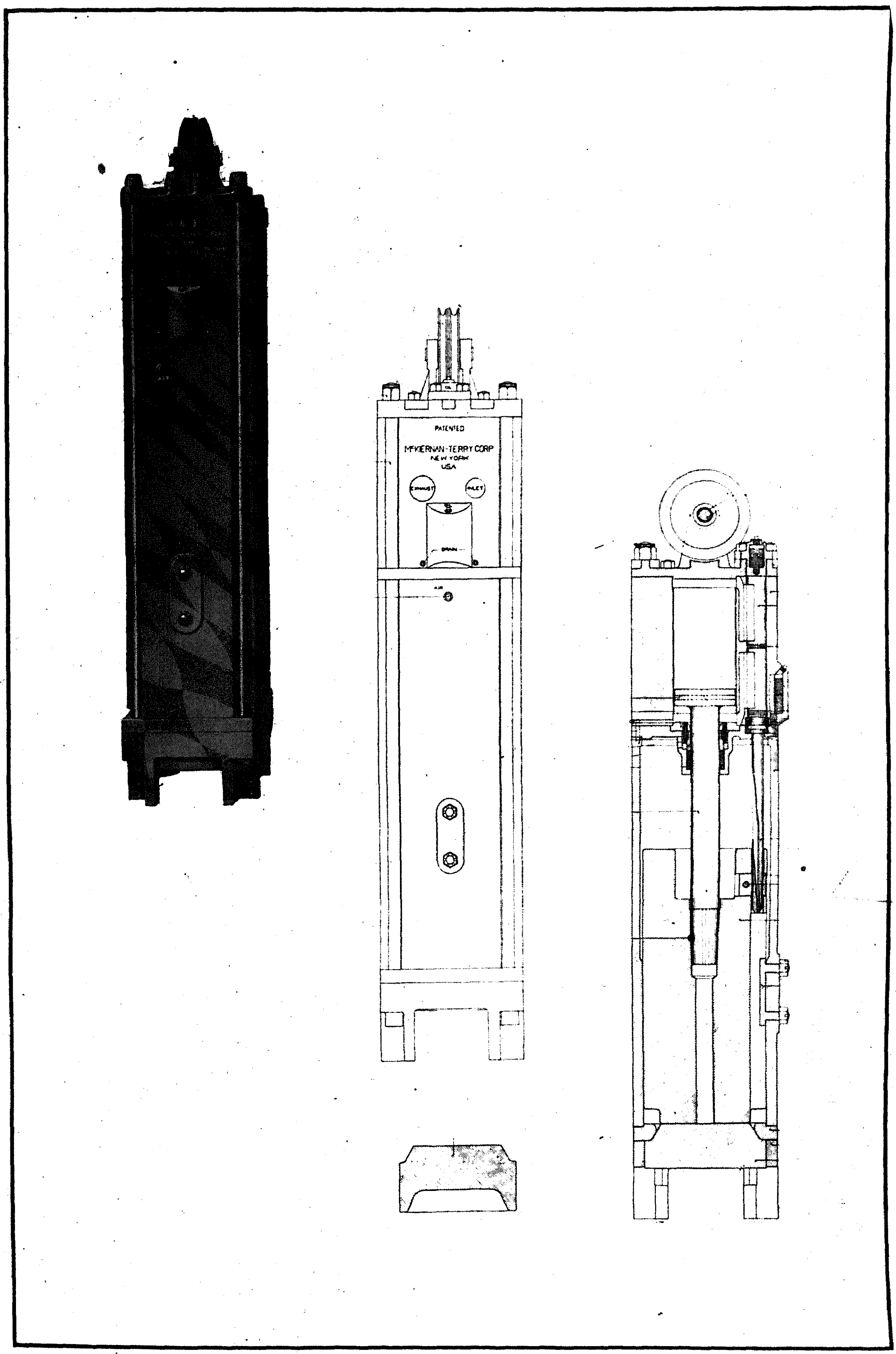



Fig.76.- Double-acting steam hammer.

is advantageous where driving is in a stiff resistant clayey material. It has a tendency to keep the pile in motion, obviating to a degree the necessity of overcoming its inertia and static friction with each blow.

With both single and double-acting hammers the reaction to lifting the ram puts a small additional load upon the pile. This, together with the dead weight of the hammer, helps to overcome the tendency to rebound which piles have when driven into certain resilient soils.

Both single and double-acting hammers can be operated with compressed air equally as well as with steam and, where an ample supply of air is available, the need of a steam boiler is precluded. Air for a hammer is most often used in conjunction with a motor-driven crane in land work. In waterfront work steam, always available on floating rigs, is used almost exclusively.

Driving caps have been devised for steam hammers to fit the various sizes and shapes of steel H-piles and sheet-piling. They serve to hold the heads of the piles in their proper place in the leads, preventing them from springing out from under the hammer and getting out of alignment during driving. For the same purpose, cylindrical steel sleeves are sometimes fastened under the hammers when concrete and timber piling is to be driven. The heads of both concrete and timber piles are usually protected against damage from impact by placing a cushion of wood or coiled manila rope between them and the hammer. Timber piles may also be chamfered at the butt or fitted with steel bands to prevent undue battering and splitting, especially where driving is hard.

It was not many years ago that driving a pile under water was both difficult and expensive. Such work was formerly accomplished by first driving the pile butt down to the water level and then completing the job by placing a follower on it and driving it to grade. In some cases extra long piles were driven, leaving the butts projecting above water to be later cut to grade by a diver. Quite recently a submarine pile hammer has been developed to facilitate such jobs by making provisions for injecting compressed air into the lower cylinder of an ordinary double-acting steam hammer. This is done by connecting an air hose to a fitting attached to the hammer for this purpose. About 60 cubic feet of air per minute is required, at a pressure of about one-half pound for each foot of depth under water, to exclude water from the cylinder and prevent it from interfering with the reciprocation of the ram. The exhausted steam from the hammer must be carried above the surface of the water in

Fig. 77.- Double-acting submarine steam hammer.

another hose.

Such a hammer has a number of advantages which includes the elimination of followers with the result that piles can be driven straighter and spaced more accurately. It enables piles to be driven very close to grade, so that the difficulty and waste of long cut-offs, made under water by a diver, are greatly reduced. It also permits foundation piles in deep cofferdams to be driven before unwatering, thereby preventing the soil from being disturbed by the combination of hydrostatic pressure and the vibration caused by hammering.

Soon after the introduction of steel sheet-piling, there arose the necessity for finding some means to salvage it after it had served its purpose. This necessity exists particulsrly in the case of cofferdams and other temporary work. Assuming that they were not distorted in driving, it may be stated that approximately the same force will be required to pull piles as was required to drive them. When the force required to pull a pile exceeds the straight pulling capacity of a derrick or piledriver, the pile must be extracted by driving it out.

One way in which this can be accomplished is to rig a double-acting steam hammer up-side down so that the force of its blows is exerted upward. This can be

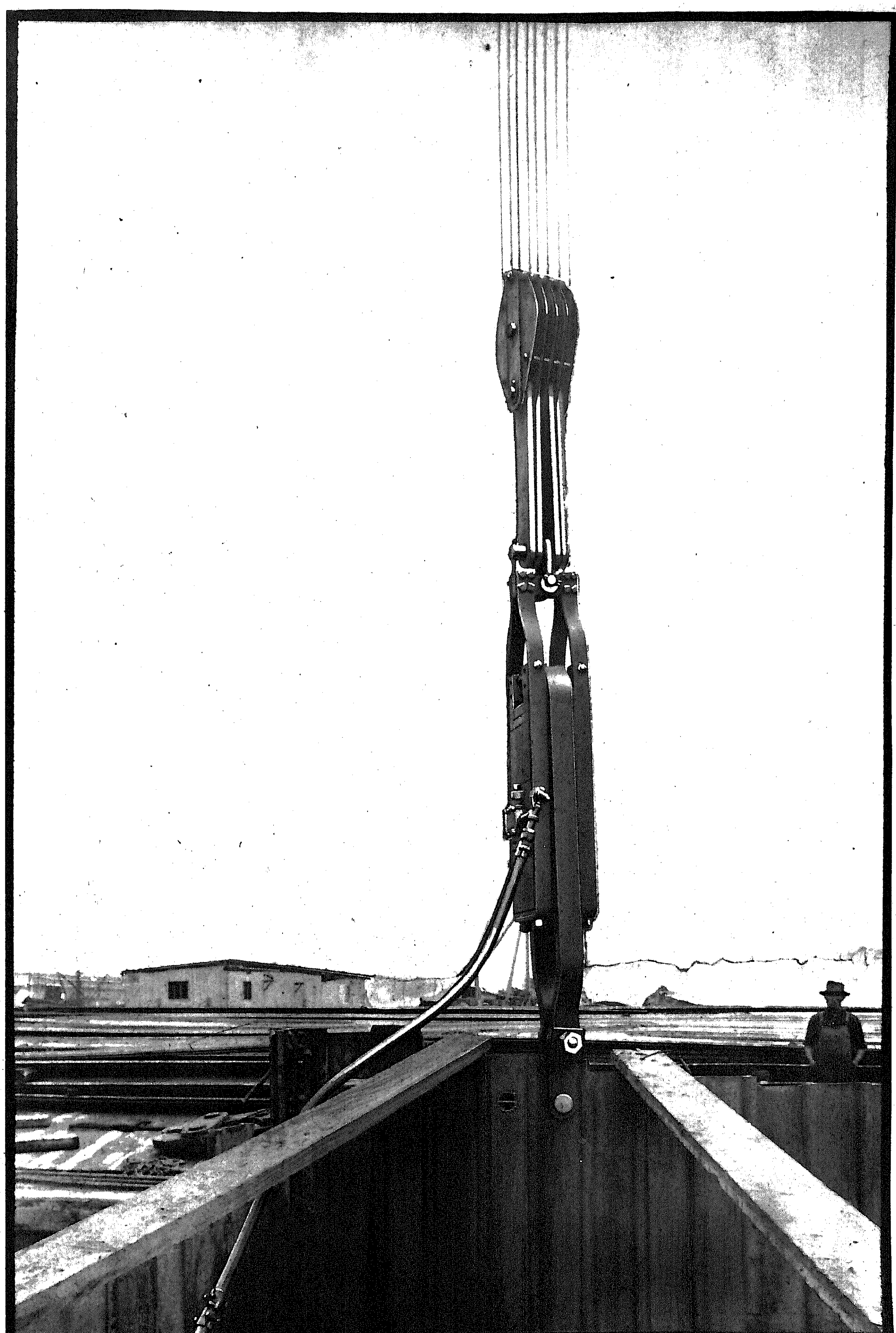


Fig. 78.- Inverted steam hammer rigged as an extractor.

done by pulling steadily upward with a fall line on the inverted hammer which is attached to the pile to be pulled. The hammer is attached to the pile by means of wire rope, steel straps (See Fig. 78), or a combination of both.

In some respects the wire rope rig is more desirable than one of rigid steel. It will not fail due to fatigue from vibration as may the rigid type, and wearing out of the wire rope may be observed with ample opportunity for renewal before it parts. Moreover, a wire rope rig which is flexible enough to permit the pile clamp or shackle to be disengaged with the pile in any position, enables the operator to land a pulled pile without first disconnecting the hammer and then taking another hitch on it.

It was about 15 years ago, and about 15 years after it was discovered that a double-acting steam hammer could be operated in an inverted position to extract sheet-piling, that double-acting pile extractors were first manufactured. They follow the same principles that are utilized in pile hammers, but are designed to combine the advantages of rigid steel and flexible cable riggings. They have a large loop on top for engaging the fall line shackle and are connected to the pulling clamp by a

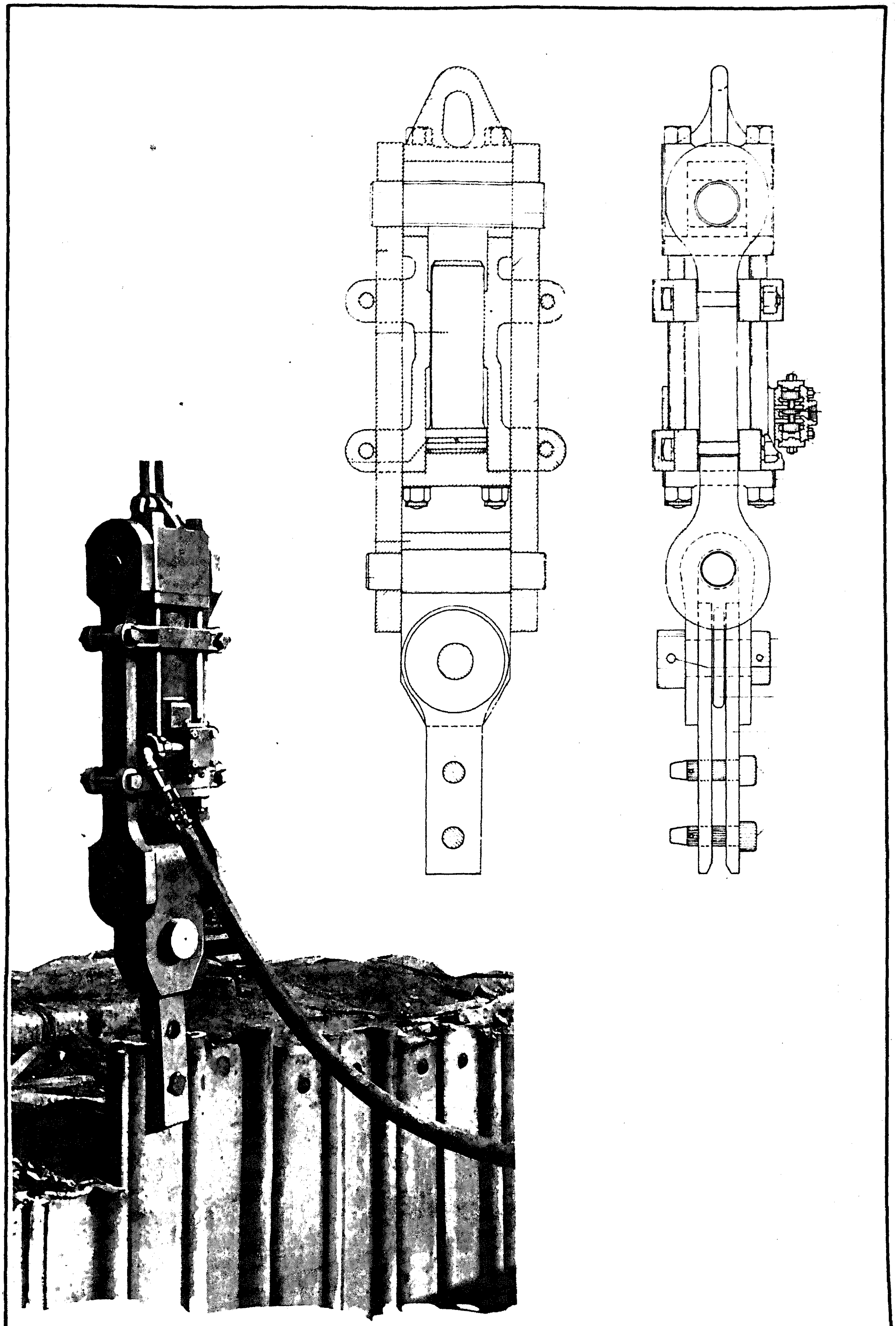


Fig. 78.- Double-acting pile extractor.

flexible combination of straps and pins which permits the pile to be pulled, landed, and disconnected from the extractor with the same ease of operation experienced with cable rigging.

Economical pile extraction depends upon both the steady strain by the fall line and the vibration caused by the heavy upward blows of the extractor. By employing such equipment as described in the foregoing paragraphs, piling that was bent, split, or crumpled so badly in driving that ordinary pulling gear could not budge it, has been withdrawn. Sheet-piling that is used for underwater forms and becomes bonded with the concrete can likewise be freed, pulled, and salvaged.

* * *

Sometimes, in piledriving, sand or gravel is encountered by the tip of the pile before the penetration desired for reasons other than bearing value alone is secured. Compacted sand or gravel offer sufficient resistance to driving to stop most piles except those of steel. Timber and concrete piles may frequently, however, be driven further with the aid of a water jet. In locations where piles are driven into sandy beach deposits, such as are found in the vicinities of Jamaica Bay, Long Island and Jersey Coast, jetting is necessary throughout the entire driving operation.

A typical jet pipe, usually about 3 inches in diameter, may be seen in Figure 46. The upper end of the pipe is curved like an inverted J so that the jet hose, which is coupled to it, will not develop a sharp bend as it is raised and lowered. The curved section also provides a suitable means for securing the manila operating rope, which is led over a sheave at the top of the leads and manipulated by means of a steam winch.

The water jet itself is forced at high pressure, 300 or more pounds per square inch, by a reciprocating steam pump through the lower section of the jet pipe which is tapered down to a one inch orifice. About 4 inches from the tip, several smaller openings are located around the perimeter of the pipe, creating smaller horizontal jets. To operate, the pipe is repeatedly raised and lowered with the main jet directed toward the tip of the pile. The effect of the jet is to loosen the compacted sand and gravel, washing some of it upward, and to create a kind of artificial quick sand. As a result, a pile frequently sinks under its own weight, but more often requires hammering to drive it deeper. Since the bearing material is loosened by jetting, the bearing capacity of jetted piles must be made certain by subsequent hammering in the conventional manner.

Water jets are also used for loosening piles that are difficult to pull. To augment the effect of the water, compressed air is sometimes injected into the jet to help break the grip of clay upon the piles.

Steam siphons, while known and utilized but little on the majority of construction jobs, are considered quite valuable by dockbuilders. Usually made of 2 inch pipe, they are made in the form of a T, the suction extending downward. As steam is introduced into one of the horizontal sections, a vacuum is created in the suction pipe, causing water to be drawn up and discharged through the opposite horizontal pipe.

Such siphons are most widely used to pump out the bilges of derrick and piledriver scows, and those so used are generally built-in as part of the rig. Others are portable and furnished steam by means of a flexible steam hose such as is used for a pile hammer. These can be used for unwatering small foundation excavations that may have become flooded or to keep down the water level in pipe piling until concrete can be placed. While theoretically water could be raised about 28 feet by such a method, it is seldom attempted to raise it more than 10 or 12 feet. The volume of discharge is not great, so that any large quantities of water are usually handled by pumps.

Another device employed to remove mud and rock fragments from the shells of piles of the tubular type is the air-lift. It may also be used in cofferdams, before unwatering, to remove the residual muck and loose rock that remains after excavation by means of a clam-shell bucket.

An air-lift consists of a vertical length of pipe, open at both ends, which can be lowered to the bottom of the water so that it is brought in contact with the material to be moved. By means of a smaller parallel pipe, compressed air is introduced into the large pipe through a number of orifices near its lower end. The compressed air rushes upward through the lift pipe, partially displacing the water in it, with the result that a differential in hydrostatic pressure is developed. The outside pressure being the greater, water is forced into the intake, to be further impelled upward by the force of the air flow. Mud, sand, and rock fragments are picked up by the rush of water and are carried upward through the pipe in much the same manner that a swiftly moving river carries detritus. The upper end of the pipe is generally curved so that the material carried can be discharged to one side.

The capacity of an air-lift is governed by the diameter of the lift pipe and the amount of air supplied. To function satisfactorily, a large volume of air must be compressed and delivered to the foot of the lift pipe, so that the velocity of the water flow, caused by the pressure differential, will be sufficient to impart motion to the material to be raised.

* * *

The majority of modern dockbuilding jobs include varying amounts of concrete work. Most modern piers have concrete decks and most modern relieving platform walls include concrete for both the platform and the wall itself. Where large quantities of concrete are to be poured, it is advantageous for the contractor to buy the necessary materials in bulk and mix it on the job.

To accomplish this, floating concrete plants, such as is shown in Figure 80, have been constructed for waterfront work. A floating plant includes storage bins for the cement and aggregates, scales for weighing batches, a large storage tank for fresh water, a concrete mixer, and a skip-bucket which may be raised in a tower to facilitate pouring, by means of inclined chutes, over a wide area. Handling aggregates, pumping water, and mixing and elevating the concrete is all performed by steam power.


Fig. 80.- Floating concrete plant.

The aggregates are loaded into the bins from deck scows by means of a derrick which in some cases is mounted on the same scow as the rest of the plant. The large metal containers, in which bulk cement is delivered by scow or lighter, are unloaded by compressed air. The air is injected into the containers where it agitates the cement, swirling it into a discharge pipe which leads to the cement bin. From the lower end of the inclined chutes, the concrete may be discharged directly into place or, if the chutes cannot reach far enough, into the familiar wheel-barrows and buggies which are used to carry concrete to the desired spot.

Ready-mix concrete, such as is commonly batched at a central plant, delivered and mixed by truck, is very frequently used either on jobs not large enough to warrant the operation of the floating plant or to augment its output. The mixer, mounted on a truck chassis, is charged with aggregates at the plant, driven to the job and there put into operation, usually just prior to pouring. Chutes and buggies are employed as before if the concrete cannot be discharged directly into place. Where a saving of labor can be realized, the concrete may be dumped from the trucks into concrete buckets of the bottom-dump variety and swung by a derrick boom, instead of wheeled into place.

Concrete from both floating plants and ready-mix trucks may sometimes be poured through a tremie pipe. A tremie pipe, or elephant trunk, as it is colloquially known, is used in pouring concrete under water to prevent the cement and fine aggregates from being washed out of the mix during the operation. To commence a pour, the lower end of the pipe, usually about 8 inches in diameter, is plugged with a bag full of concrete. The pipe is then filled with concrete and lowered to the bottom of the form, where the plug is released. Once begun, flow through the pipe, the end of which is kept buried in the wet concrete, is maintained continuously until the pour is completed. During the course of the operation, the tremie pipe must be raised slightly from time to time, as the level of the concrete rises, to reduce the hydrostatic pressure of the concrete at the discharge end, which tends to stop the flow. Concrete poured in this manner is called tremie concrete.

Bottom-dump buckets are also used to place concrete under water. These buckets are equipped with a latch which may be tripped after the bucket has been lowered and spotted at the proper location. By lowering the bucket until it rests on the bottom or in previously placed concrete before tripping, the amount of cement and fine aggregates separated from the mix is minimized.

A fairly recent development in the placing of concrete is a system whereby it is literally pumped through a pipe to the desired location. This process, powered by a gasoline engine, is known as pumpcreting. In most cases the concrete used is delivered to the job by ready-mix trucks which are discharged into a hopper. The hopper empties into a so-called remixer which serves to keep the concrete from setting before it enters the pump cylinder. A slot in the underside of the remixer is synchronized to open and shut with the stroke of a reciprocating ram. The slot opens on the back stroke, allowing concrete to flow into the cylinder by gravity. On the forward stroke, the slot closes and the ram drives the concrete ahead, through the discharge, into the delivery pipe.

The delivery pipe, about 8 inches in diameter, is made up of easily connected sections, together with bends, so that it can be run ungrade or down for hundreds of feet. Where the occasion requires it, the delivery pipe may include sections of vertical risers through which the concrete may be pumped to upper stories. At the discharge end of the pipe, the concrete may be poured directly into place by swinging the last section about on a flexible joint and by substituting longer or shorter lengths for the last section.

In order to readily chute the concrete into the receiving hopper, ready-mix trucks must be able to back in at a level higher than the pumpcrete machine. For this reason the pumpcrete machine is usually set up at the end of a ramp or under a trestle. In the event that this is not done, it may be necessary to empty the ready-mix trucks into buckets which in turn must be raised by a crane and dumped into the hopper.

* * *

Very frequently a job will occur on which it is economical, by reason of time and labor saved, to construct a piece of equipment designed specifically for some particular operation. An example of such a piece of plant is the subaqueous pipe laying apparatus (See Fig. 93) used for the construction of the Narrows siphon, which is described in Chapter Eight.

On another job, the construction of a railroad bridge over a wide expanse of water, there was a great number of timber piles driven. These piles had to be cut off below the low-water level to form the foundations for a series of masonry piers. To cut off these many piles, an under water pile cutter was devised. It was assembled on a piledriver scow and consisted of a large circular saw blade mounted horizontally on a vertical shaft. The bearings for the shaft where secured between the leads of the piledriver and, by means of bevel gears and horizontal shafting, was turned by the steam engine. By means of this rig it was possible to cut off the piles, well under water, at a rate greatly in excess of what could have been accomplished by a diver with an air saw.

During the construction of the Trans-Atlantic Steamship Terminal at West 48th Street, a unique rig was designed and built for the express purpose of loosening the steel sheet-piling of the cofferdam prior to its removal (See Fig. 81). It consists of a steel tower, somewhat similar to that of a piledriver, 75 feet in height, mounted on one-half of a railroad carfloat, about 40 x 140 feet in size. From the top of the tower, which overhangs the bow by 12 feet, is rigged a fall line with nineteen parts of 1-1/8 inch wire rope. This main fall is operated by steam from a 150 horse-power boiler. Designed to exert a pull of 300 tons, it has started any pile that it has thus far encountered. Since the largest marine derrick in New York Harbor has a capacity of 250 tons, this machine has, on occasions,

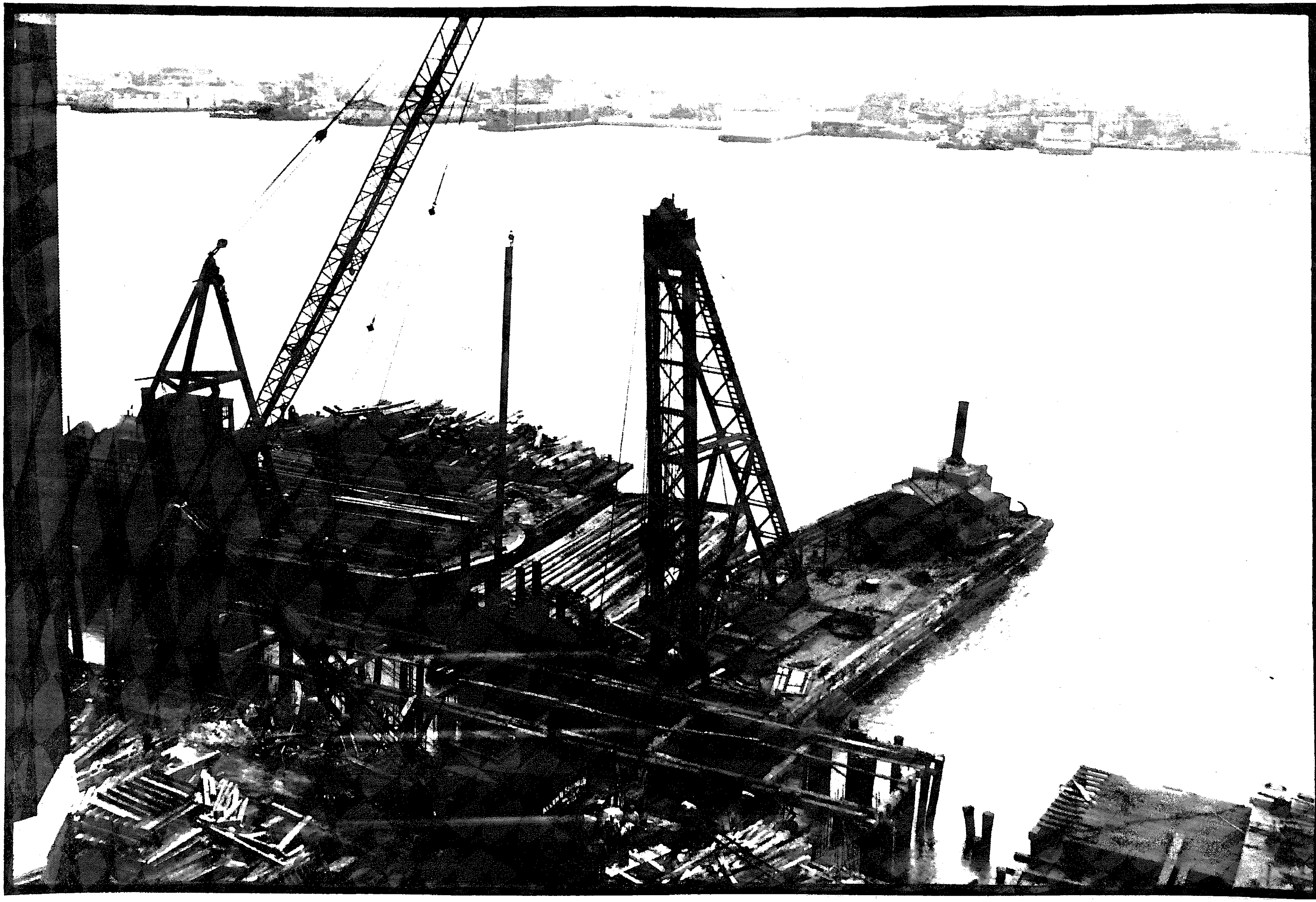


Fig. 81.- 300 Ton pile puller.

been able to make straight lifts that no other rig could attempt. Where ordinary pulling holes for shackles and clamps are used for withdrawing sheet-piling, and the resistance of the piling is sufficient, the sockets will be ripped from the ends of the pile.

To overcome this problem, special pulling grips for sheet-piling have been devised (See Fig. 82). These engage a greater area of the web of the pile, giving a wider distribution of the stress. They are so designed that, once engaged, the harder the pull exerted, the more tightly they take hold.

On another job, also described in Chapter Eight, a saving was realized by mounting a multiple set of thirteen pile leads on a scow (See Fig. 35). The advantage gained by this device was that only one shift of the scow was required to set an entire bent of piles in place. Shifting the piledriver consumes a sizeable percentage of the time in driving operations, so that this arrangement, which reduced this time by more than 90 percent, represented a material reduction in the cost of the job.

Batter piles, although sometimes handled by a piledriver having adjustable leads, such as the pendulum type, are usually driven with a double-acting steam hammer suspended from the boom of a derrick. Where the piles

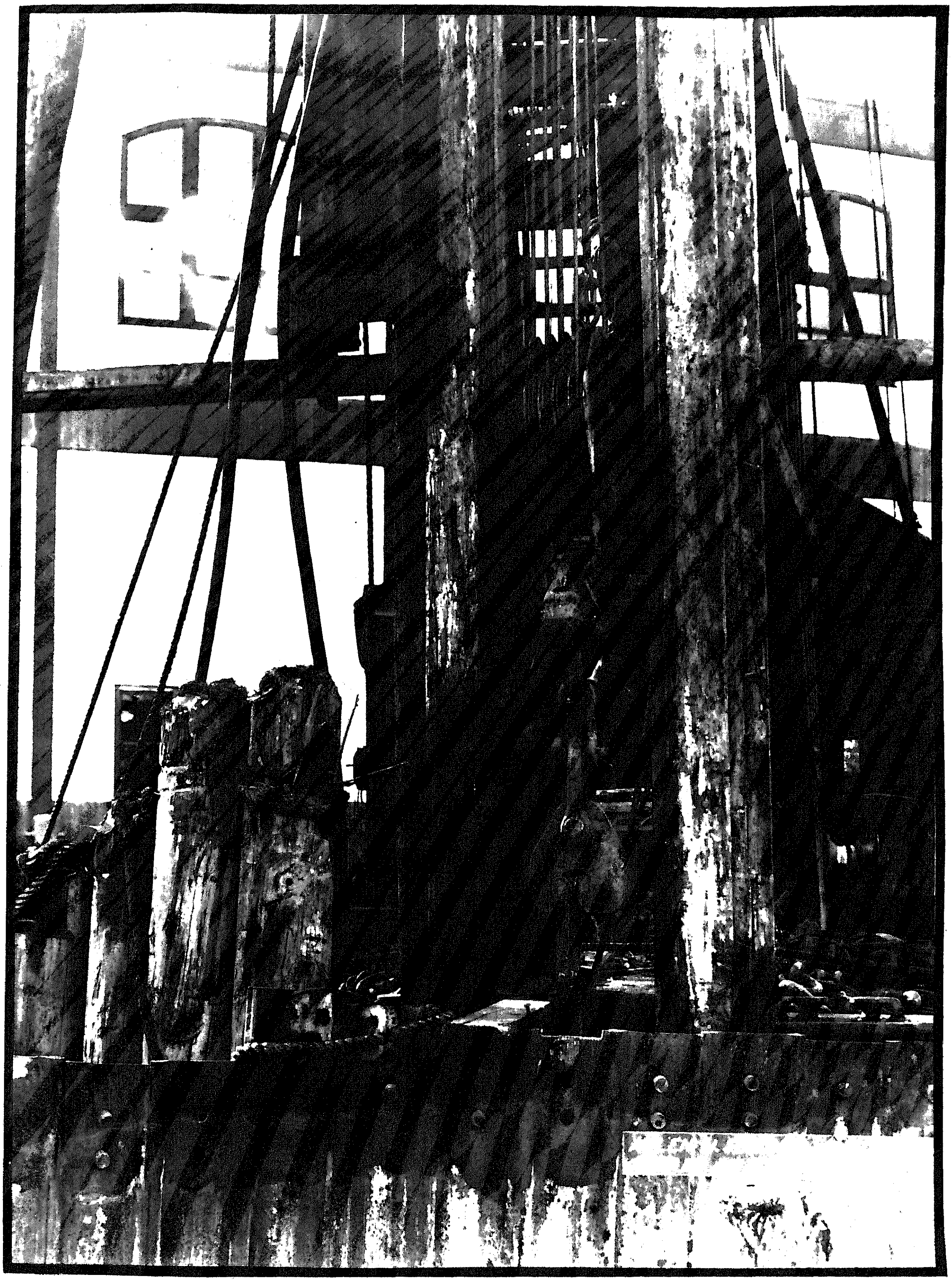


Fig. 82.- Special heavy pulling grips for steel sheet-piling.

can be set so that they stand at the proper batter or are braced in place with timbers, the hammer may be fitted with a cylindrical steel sleeve which is fastened to the lower portion around the striking piece. After the piles are set up, the hammer is lowered so that the sleeve slips over the butt of the pile, holding the hammer in place and aligning it axially. While driving, as the pile goes down, the operating engineer lets out just enough slack in the hammer fall so that there is practically no strain on it.

Another arrangement for driving batter piles is the set of swinging leads shown in Figure 83. Instead of having a steel sleeve, which is limited in use to piles of comparatively small diameter, the hammer is mounted in a timber frame. The two parallel side timbers extend below the hammer for about 6 feet and are fastened together with two cross struts, one at the bottom of the hammer and one at their lower extremity. When the hammer is set up for driving, the lower strut bears against the underside of the pile. This prevents the hammer from tipping over and also aligns it with the pile. The manila line looped about the pile and the hammer frame is used to hold the pile at the proper batter, should it have a tendency to fall over during driving.

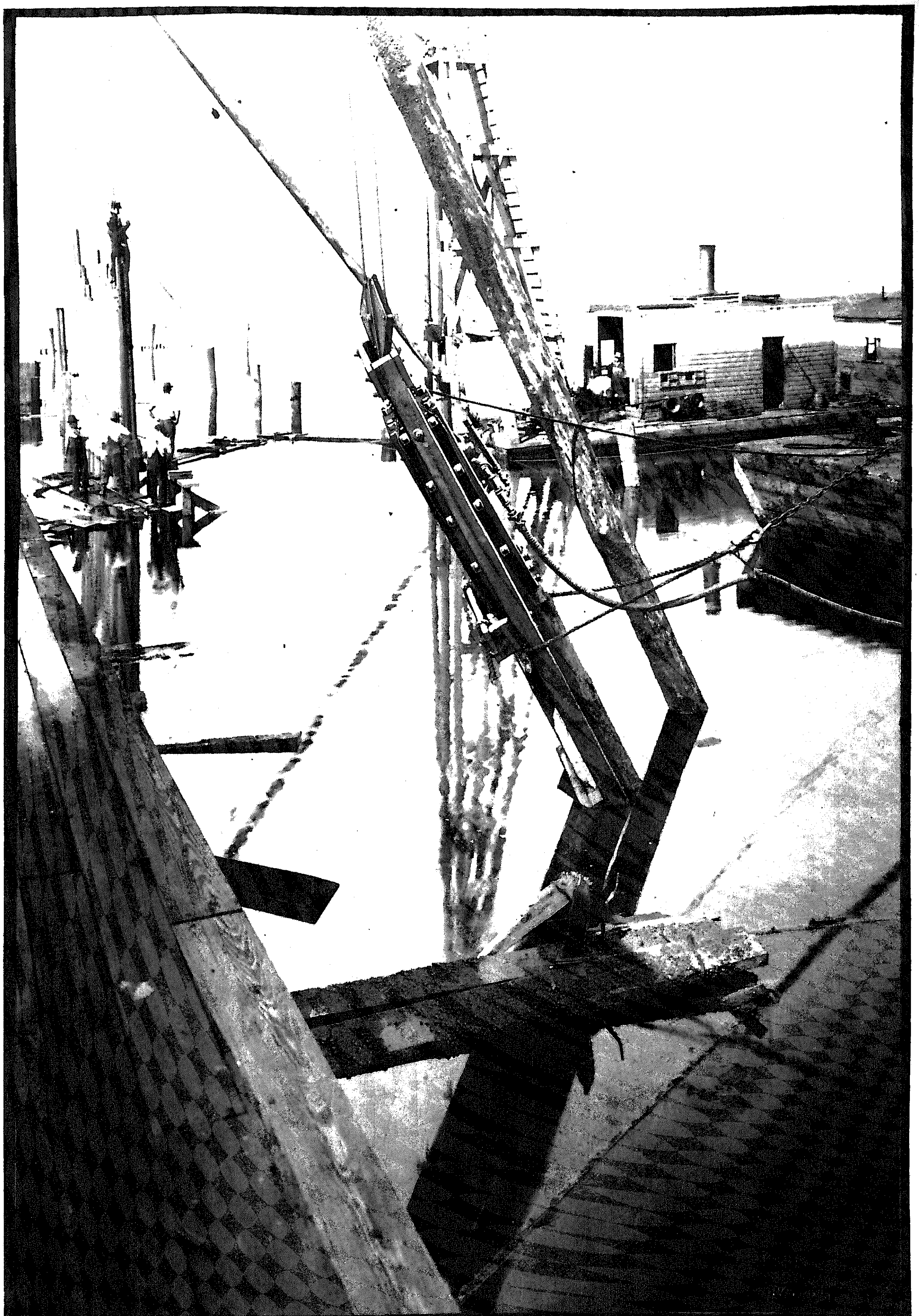


Fig. 83.- Swinging pile leads.

Scows are frequently equipped to augment floating plant in various ways. For example, on a cofferdam job, a battery of pumps for unwatering, complete with steam boilers to operate them, have been mounted on the deck of a scow and towed to the site. Similarly, on a job where no fire hydrant is conveniently located for supplying the rigs with boiler water, scows that have been converted into water tankers may be used. This saves the time that would otherwise be lost were it necessary to shift inshore and lay a hose line every time water is needed for the boilers.

* * *

For the purpose of performing underwater excavation or providing material to fill-in areas for land reclamation, a special variety of plant, known as dredges, has been developed. To be classified as a dredge, a floating excavation machine must be particularly designed to perform three functions. They are the removal of subaqueous material, the handling and shifting of dump-scows, and the moving of the dredge itself.

The principal methods of excavation are four in number, each requiring a distinctly different type of machinery. The various types of dredges are as follows: grapple, dipper, hydraulic, and ladder types. The names are derived from the manner in which they operate.

The dump scows are shifted by means of cables turned about steam operated winches and capstans, while the dredges themselves move themselves about by means of spuds, anchors, or a combination of both.

Spuds are long heavy timbers, shod with iron, which are suspended by gallows frames mounted on the dredge scow. They move vertically through holes in the hull and, when dropped, they anchor the dredge in position. Spuds provide the desirable features of fast operation and non-interference with harbor traffic. They are operated in different ways, depending upon the type of dredge on which they are used. Where the water is deep or swift, however, cables and anchors are necessary.

When anchors are utilized, it is common practice to set out four, one off each corner of the dredge. To minimize interference with digging operations, the forward anchor cables are frequently run from the stern corners of the scow while the aft anchor cables are run from the bow. With either arrangement, the cables must clear the dump-scow which is customarily held forward on the starboard side. Sheaves are mounted at the tops of the spuds on the starboard side, so that the anchor cables, led through them, clear the scow by passing over it. On

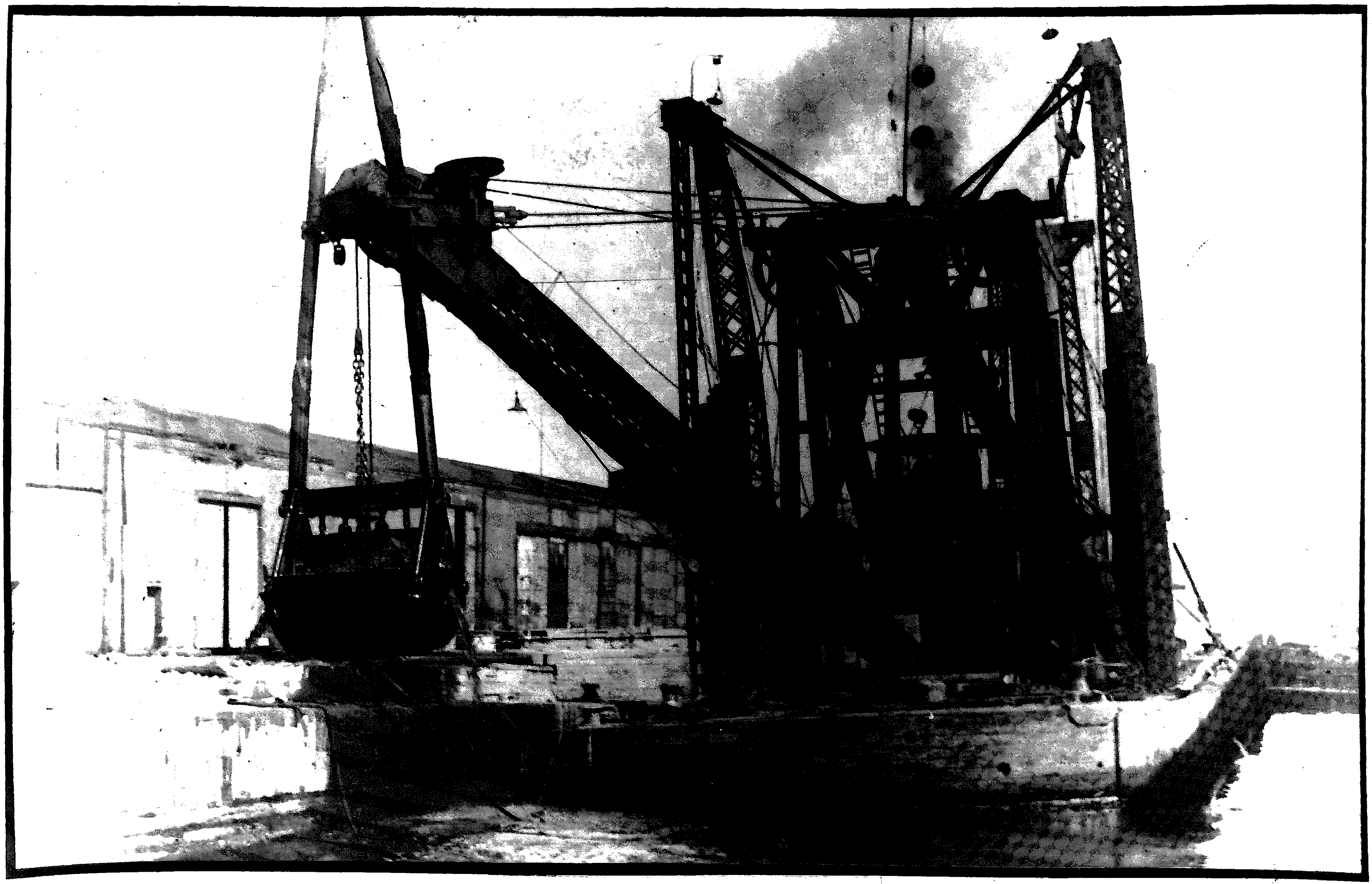


Fig. 84.- Clam-shell dredge.

some dredges, all of the anchor cables are so elevated to avoid the formation of an overturning couple. Another method of anchoring, whereby interference with navigation, as well as with the dump-scow, is avoided, is to run the cables through sheaves mounted near the lower ends of the spuds. By taking up and slacking off on the proper anchor cables, the location and position of a dredge can be closely controlled.

The first type of dredge to be developed, and the type most widely used for digging in confined places, such as in slips, is the grapple dredge. A grapple dredge is, in principle, a derrick mounted on a scow and equipped with a grab-bucket. In fact any floating derrick with a bucket on its fall lines can perform dredging operations. Such an arrangement, however, is only a makeshift, since it lacks the other features of a dredge which are incorporated specially for digging.

The type of bucket employed on a grapple dredge varies. For digging soft river muck and clays, the clamshell buckets, such as those illustrated, are most commonly used. They vary in size, depending upon the power available for operation. The largest of this type, depicted in Figure 85, has a capacity of 30 cubic yards when the side-boards are in place. Side-boards are used to increase the

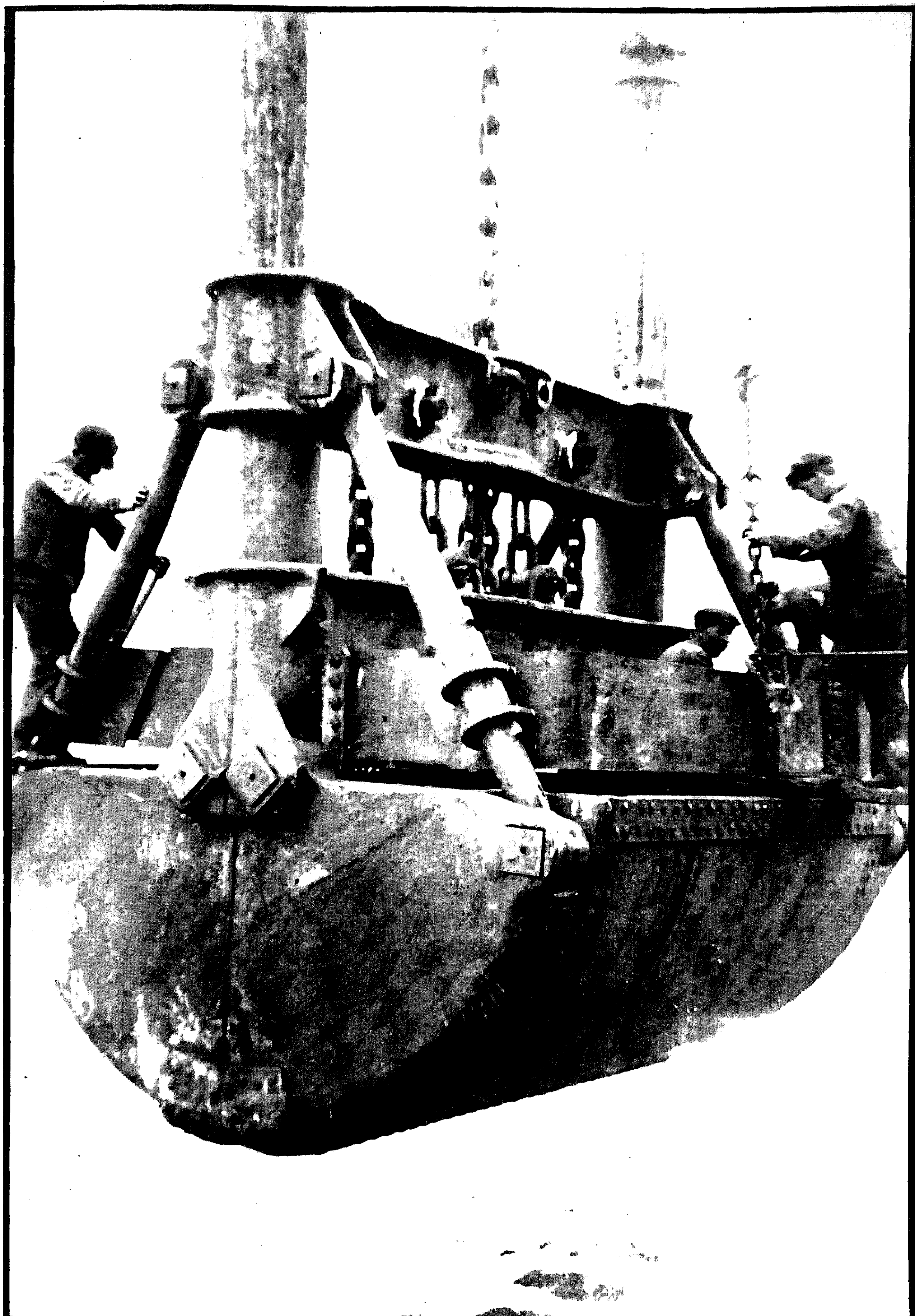


Fig. 85.- 30 Cubic yard clam-shell bucket.

bucket capacity where the material being dug is not too heavy to be handled by the rig. The two poles, which extend upward from the sides of the bucket through guides at the end of the boom, serve a dual purpose. Primarily, they prevent the bucket from spinning and the bucket lines from twisting. Secondly, they prevent the bucket from tipping over when it hits bottom, assuring that the jaws will get a good bite as the bucket is closed. Clam-shells may be provided with teeth where stiff clay and compacted sand is encountered.

When a grapple type dredge is used to excavate harder bottoms which may contain gravel and rock fragments, buckets of the orange-peel type are used to advantage. The pointed segments of this type of bucket are better able to dig into the harder material and scrape up a load. The orange-peel bucket is particularly adaptable for the excavation of riprap and work within cofferdams.

Stone grapples are also used on dredges of the grapple type. They closely resemble a number of ice tongs, mounted on the same fulcrum and opening and closing simultaneously. They are well adapted to dredging loose boulders and fragments blasted from ledge rock that would be too large and cumbersome for buckets.

The boom of a grapple dredge is swung by means of the bucket lines, requiring neither guys nor a bull wheel as in the case of derricks. This is accomplished by locating the fair-lead sheaves for the bucket lines as widely apart as possible (See Fig. 84).

For maneuvering a grapple dredge there are three spuds, two forward, at each corner, and one aft at the center of the scow. In order to "walk on spuds", the bucket is grounded while the rear spud and one bow spud is raised. The bucket line which would swing the boom toward the side of the raised spud is then stressed, causing the dredge to pivot on the third spud. When the free bow corner has swung forward far enough, the spud is dropped. This operation is then repeated on the opposite side to advance the other corner. The rear spud is then dropped and digging is resumed.

While adaptable to other kinds of work by changing buckets, the grapple dredge is primarily a mud digger. With a heavy bucket, it can actually excavate soft rock, although of course not economically, and in soft material it can outdig a dipper dredge.

By means of an extra large hoisting drum and an exceptionally long bucket line, this type can be used to dig at great depths. One such rig is equipped to reach 120 feet deep, which is far beyond the reach of dredges of other types.

A dipper dredge is very similar in operation to the familiar steam shovel. The bucket, fitted with large teeth, and a hinged bottom which is opened by pulling a latch, is attached to the end of a so-called dipper stick or handle. The boom may be swung in the same manner as on a grapple type dredge, but more commonly a large bull wheel is employed. The spuds are usually heavier than those for other types, to resist the thrust of the dipper when digging resistant materials.

Dipper dredges are moved forward by raising the bow spuds, grounding the dipper stick, and taking up on the bucket backing chain. As the scow moves ahead, the aft spud, which stands in a slotted hold, inclines forward, preventing the stern from swinging about. This aft spud has obtained the name of walking or trailing spud.

In order to keep on an even keel while the boom is swung, dipper dredges are usually operated with so-called "pin up" rigging. By this it is meant that the displacement of the scow is slightly decreased by hoisting it up on the spuds, thereby putting part of the weight of the dredge upon them. Dippers are particularly good at digging hard bottoms, blasted rock, boulders, riprap, old foundations, cribwork, piling, stumps, and sunken hulks. For harbor improvement work they range in size

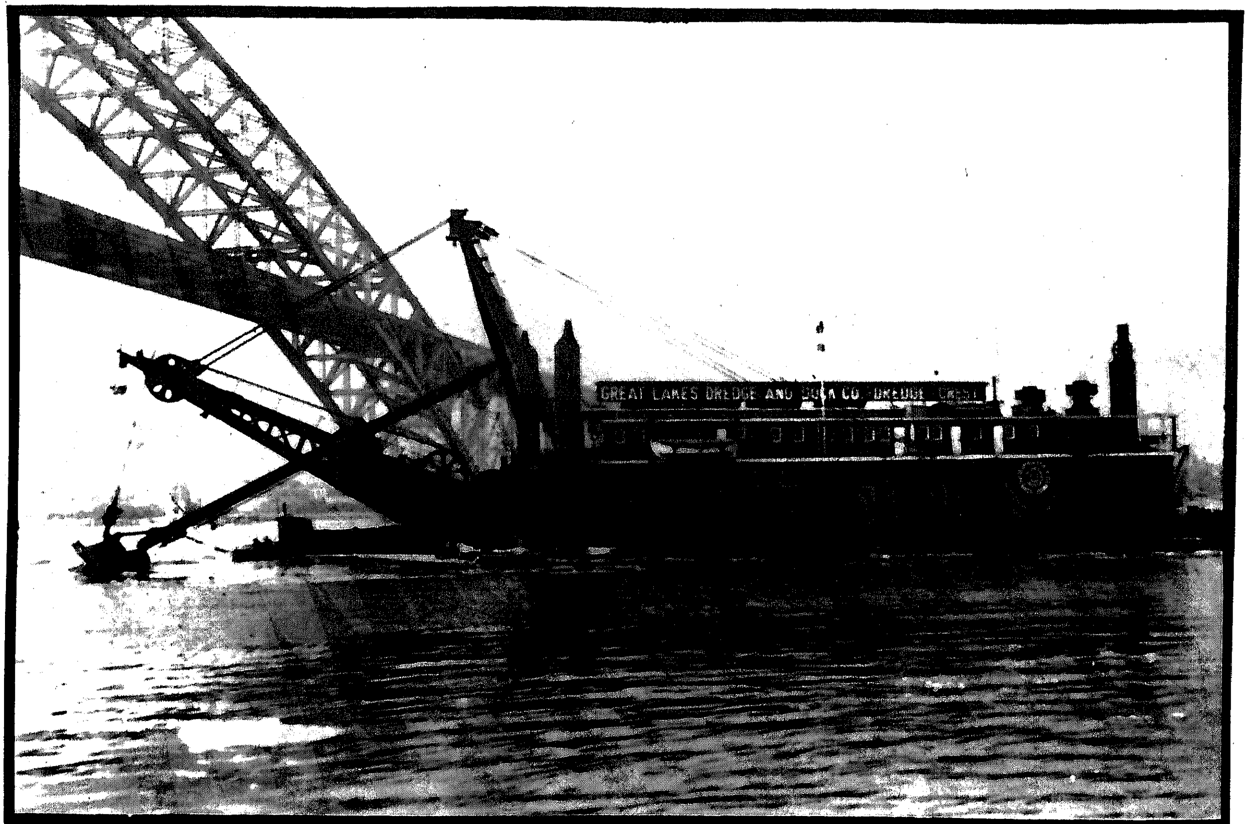



Fig. 86.- Dipper dredge.

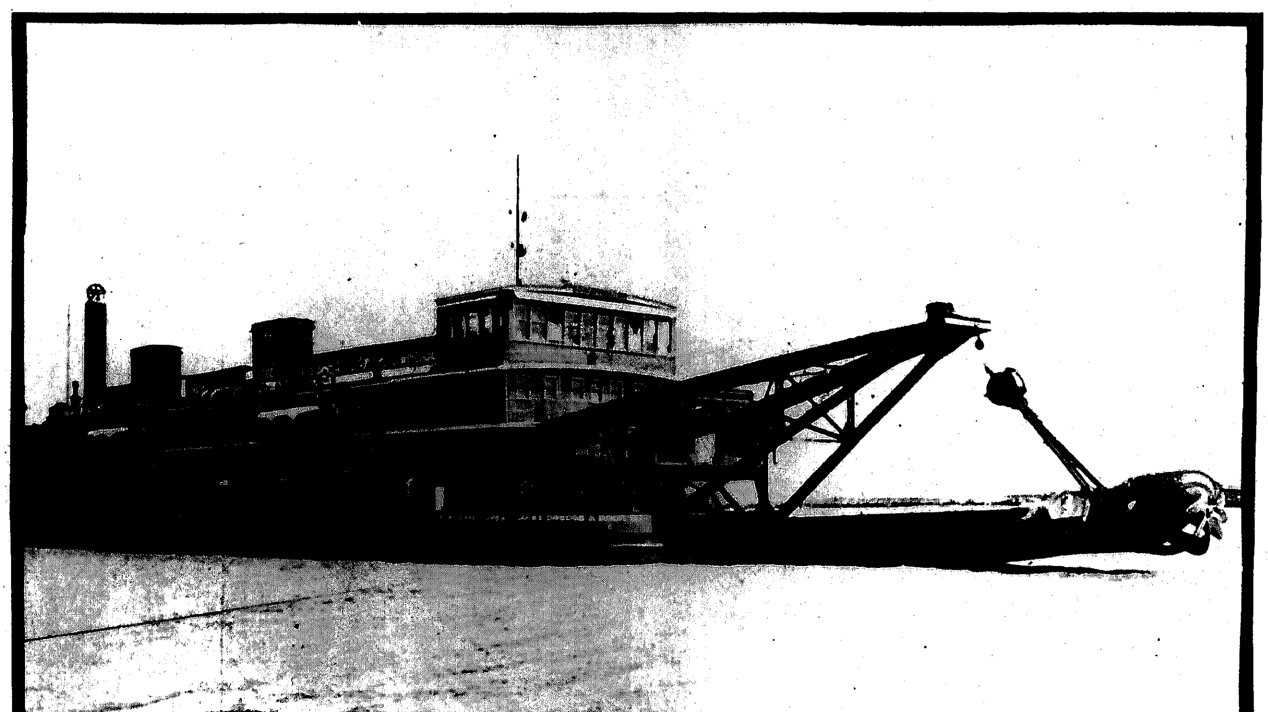


Fig. 87.- Hydraulic dredge.

up to such proportions as are shown in Figure 86. That particular plant is a diesel-electric dredge having 1440 horsepower. Its buckets are interchangeable, ranging in capacity from 9 to 20 cubic yards depending upon the material to be dredged.

A hydraulic dredge consists primarily of a large centrifugal pump which is used to suck up material from the bottom and pump it to the desired disposal point. To constitute a dredge, however, the pump must be mounted on a scow together with several essential accessories.

The suction pipe is mounted on a so-called ladder, which is pivoted at the bow of the dredge so that, in its lowered position, it places the intake in proximity to the bottom. At the lower end of the ladder, which is raised and lowered by means of a boom or an A-frame, is a cutter which is rotated just ahead of the intake by a heavy shaft which is also mounted on the ladder. The cutter either churns up mud and clay so that the pump can pick it up or, where the bottom is hard, it loosens up compacted sand, gravel, or actually cuts into soft rock. For digging rock, the cutter is fitted with teeth, like the cutting tools for a metal-turning lathe.

There are two principal methods by which hydraulic dredges are operated. The first method requires two stern spuds and two bow anchors. The anchor lines are lead through sheaves fixed at the end of the ladder so that they cannot accidentally foul the cutter. Dredging is performed with one spud up, while the anchor lines are used to swing the entire dredge, pivoted upon the other spud. When the cutter has described an arc, the limits of which are established by the position of the anchors and the length of the dredge, the first spud is dropped, the second raised, and the dredge is swung back, making another cut. This procedure advances the dredge, but, should it be necessary, the dredge is swung back and forth several times, pivoting on the same spud, while the ladder is lowered with the cutter until the desired depth is attained.

The other method requires four spuds but no anchors. The four spuds, which operate through slotted holes, are dropped to hold the dredge in position while it is pumping as the ladder alone is swung back and forth sideways by cables from sheaves mounted at the forward corners of the scow. There are sheaves fixed at the toes of the forward spuds from which cables run to the stern corners of the hull. To move the dredge ahead, these cables are hauled in, causing the spuds to incline forward with the forward motion of the scow. These "walking spuds" are then raised, one at a time, and dropped again plumb. The stern spuds may either be raised or allowed to trail. This system has the advantage of requiring no anchor lines but the swing of the ladder covers less area at each setup.

From the discharge end of the pump the excavated material is carried away in a large pipe to the point of disposal. The pipeline method of disposal introduces some features peculiar to this type of dredging. Whether operations are carried on to widen or deepen channels or to fill in an area, the pipeline must be run ashore and emptied into an impounding basin where the solids carried by the water can settle out. The impounding basins are constructed by throwing up dikes around the disposal areas.

The dikes present several maintenance problems. Rains cause erosion, freezing and thawing open cracks, the river currents or waves tend to scour, and in some places muskrats dig burrows in them. To prevent rills from developing into major leaks that would necessitate shutting down the dredge until they could be repaired, the dikes must be constantly patrolled and kept in shape.

The pipeline between the dredge and the settling basin may be divided into three distinct parts. The first portion, built-in as part of the dredge from the pump to the side of the scow, is a heavy casting. Between the dredge and the shore it is composed of sections of lap or spiral riveted pipe, varying from 10 gauge to 3/8 inch in thickness and from 20 to 50 feet in length. These sections are supported by pontoons and are floated into position. The shore sections are made smaller and lighter so that men can more easily handle them. In some instances, where the pipeline must traverse a swamp where the water is too shallow for floating sections but where there is no support for the type used on land, a pile bent trestle must be built to support it. The pipe sections, both floating and on land, are connected by flexible couplings to facilitate their assembly and to enable the dredge to move about freely.

Hydraulic dredges not only excavate material from the bottom, but they deliver it to the point desired all in one operation. This feature is responsible for the low unit costs obtainable with plant of this type. The capacity of such dredges depends upon the character of the material to be excavated and the distance and elevation to which it must be pumped. Modern hydraulic dredges may operate with as high as 6,000 horsepower on the main pump and with 1,500 horsepower on the cutter. On the larger dredges, power for the pump is frequently a geared steam turbine, although many operate on electrical power from shore.

The suctions of these dredges vary in diameter up to 34 inches and the discharges up to 30 inches. The large plants are capable of delivering material, without the aid of boosters, for distances up to 15,000 feet and are designed to excavate to depths up to 60 feet. The plant illustrated in Figure 87 is a 30 inch diesel-electric dredge with a power plant consisting of four 1,150 horsepower engines driving direct current generators.

A variation of the hydraulic dredging principle is utilized in the operation of so-called hopper dredges. They consist of large pumps which are used to suck up the soft and soupy mud and silt that accumulates in navigable channels. Since the material is not solid, but semi-fluid, no cutters are required, and only the intake end of the suction pipes are lowered to the bottom.

Hopper dredges also differ from hydraulic dredges in that they do not dispose of material by pumping it ashore. Instead, it is loaded into hoppers contained within the hull of the dredge itself. Lastly, hopper dredges are primarily a ship, self-propelled in the conventional manner. The pumps are operated and the hoppers are filled as the ship cruises slowly up and down the area to be dredged. When loaded, the ship sails out to sea, the hoppers are opened, and the material is dumped.

The Goethals, built in 1937, is the largest and most powerful of this type of dredge (See Fig. 88). It has a displacement of 15,500 tons loaded, with a capacity of 5,000 cubic yards. It is equipped with turbo-generators and two 1,300 horsepower electric motors, each of which operates a 30 inch pump capable of dredging to a depth of 50 feet.

Ladder dredges, or elevator dredges as they are sometimes called, resemble in appearance and method of operation the ditch digging machines of the bucket-elevator type such as are used on land. The principal difference is that the machines used in dredging are much larger and mounted on scows. They are a European product and are little used in the United States. The qualities of this type of machine are not responsible for its unuse however. The main reason it has not been adapted here more widely is that contractors, for the most part, build their own plant and, since their contracts are likely to be varied in both location and conditions, they do not construct a specialized plant, nor one that will represent more capital than their

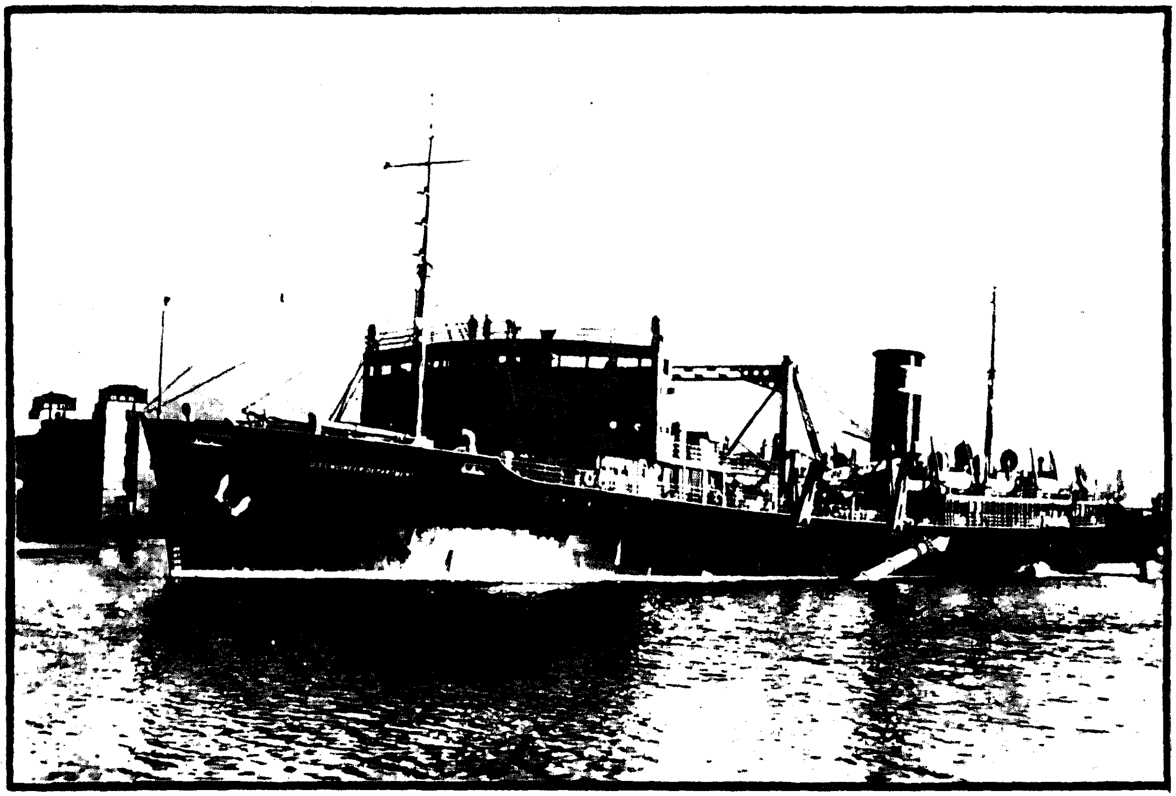


Fig. 88.- Hopper dredge.

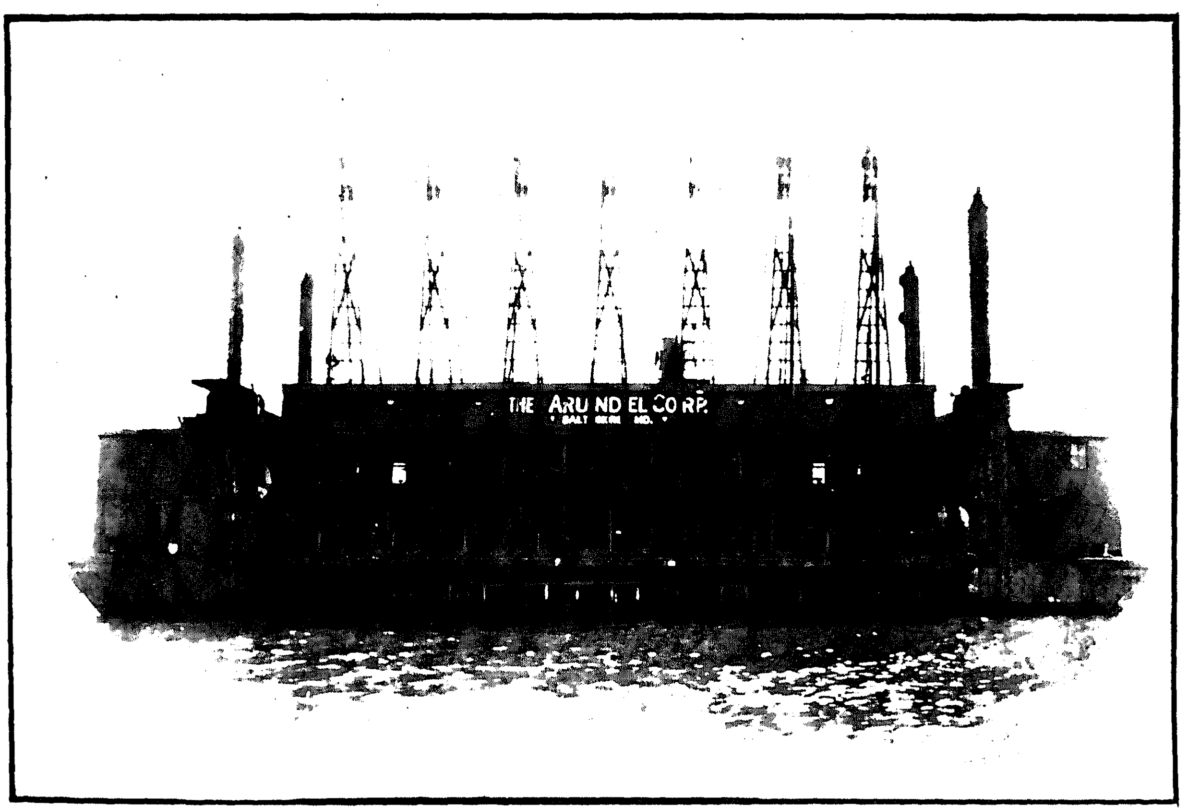



Fig. 89.- Drill scow.

contracts will warrant. The ladder dredges built in Europe, which attain great proportions, are financed by some governmental agency such as a Board of Harbor Trustees, which can plan work and provide for steady employment of the plant over a period of years.

Such dredges may be designed so that the buckets are changeable. A set of 2 cubic yard buckets might be used for easy digging, while another set, of perhaps $\frac{1}{4}$ cubic yard, might be substituted for hard digging. They are particularly good for excavating hardpan, including hard clay, shale, and other unblasted soft rocks. There are some dredges of this type located in or near the metropolitan area, but their operation is confined to the excavation of gravel banks for the procurement of road building material and concrete aggregates.

Considering the three types of dredges commonly used within the harbor, the following table will indicate which are the more preferable for handling various materials. The types are listed in the order of their preference.

| | | | |
|---|---|---|---|
| Mud | Hydraulic | Grapple | Dipper |
| Fine sand | Hydraulic | Dipper | Grapple |
| Coarse sand | Hydraulic | Dipper | Grapple |
| Sand and gravel | Dipper | Hydraulic | Grapple |
| Gravel | Dipper | Grapple | Hydraulic |
| Stiff clay | Dipper | Grapple | Hydraulic |
| Hard clay and hardpan | Dipper | Grapple | Hydraulic |

The foregoing is based upon large quantities to be handled, with no obstructions and all other things equal. It would not necessarily apply in cramped spaces where large plants could not operate.

At times it is desired to remove ledge rock from underwater locations. The usual procedure is to drill holes in the rock, load them with powder, and blast. The fragments are best picked up by means of a dipper dredge. If a large dipper is used, large pieces of rock can be handled, which decreases the number of holes required to be drilled. Since drilling represents a large percentage of the job, large rigs are more economical if the size of the job warrants their use.

To perform the operation of drilling, scows are equipped with a battery of vertical drills (See Fig. 89). They are mounted on steel towers and usually operated by steam. To keep them plumb, they are guided by vertical leads which are lowered downward from the towers. If the drills must penetrate soft strata or obstructions, they are driven through a pipe casing which conducts them down to rock. When the holes, usually 4 to 8 feet apart, are drilled, they are loaded from the deck by means of a charging pipe. Using this device, the powder is rammed through the pipe, inserted in the holes, and tamped, preparatory shooting.

During drilling operations a drill rig is set up on four spuds, one at each corner of the scow, raising it somewhat above the line of normal flotation. This is done to avoid disturbance from currents and wave action.

As a substitute for drilling and shooting rock, rock-breaking machines have, on occasions, been employed. One such machine, made by a New York company, consisted of a massive chisel the shank of which projected from the lower end of a hollow cylinder. A hammer or ram operated in the upper portion of the cylinder, in much the same manner as a steam pile hammer, striking the chisel shank. This machine, the counterpart of the pneumatic road-breakers that are mounted on truck chasses for the demolition of concrete pavement, was successful in breaking up stratified rock.

Another machine was designed for the same purpose in Scotland. It consisted of a very large and heavy projectile-shaped cutting ram which was raised and dropped a distance of 15 feet at a rate of four strokes per minute. Its heavy concentrated impact was able to break pieces from the hardest of rock.

Except in the case of hydraulic dredges, where excavation and disposal is accomplished in one operation, a means of conveyance to the dumping grounds is required in conjunction with dredging operations. The standard method of disposal is towing to sea in bottom-dump scows and dumping.

Practically all such scows are constructed of timber along similar lines. They vary in size up to about 120 feet in length, and about 1,000 cubic yards capacity. They are rectangular in shape and contain from three to six partitioned sections. Each section, called a pocket, is in effect a hopper bin.

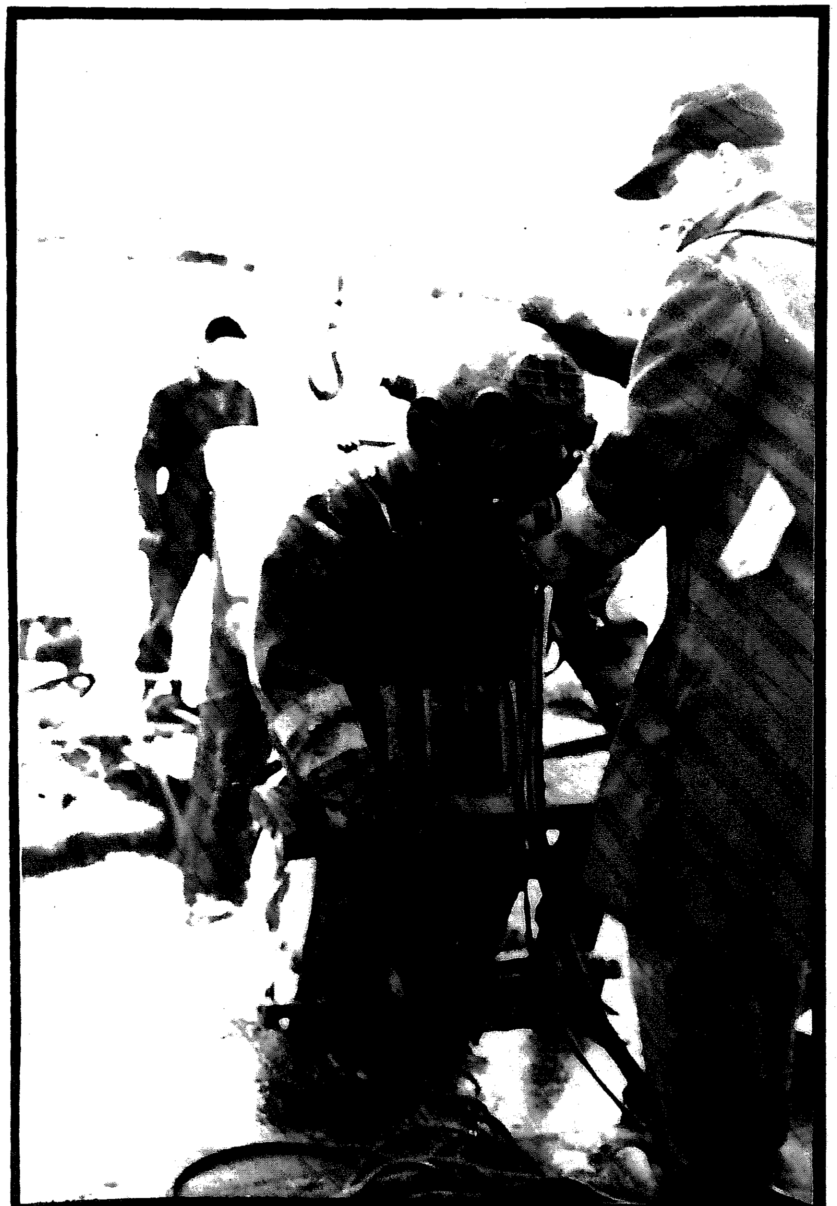
Each hopper bottom is closed by a pair of hinged flaps which are hoisted into place with chains by a hand operated ratchet windlass. When sandy material is to be dredged, the hopper flaps must be closed tightly to prevent the sand from leaking out. Occasionally, when the flaps do not close perfectly, it is necessary to calk the spaces around them before loading the scow.

* * *

The equipment necessary to put divers down for underwater work is comparatively small and simple. The diver himself requires a rubber suit, around the shoulders of which are fitted stud bolts and a gasket. A bronze collar, the top of which is threaded, is bolted fast to the top of the suit. The diving helmet, to which the air-line is connected, is screwed onto the collar just prior to making the dive.

To facilitate the descent and help the diver to keep his feet on the bottom, additional weight is carried in the form of a lead weighted belt and a pair of weighted shoes. In addition to the air-line, which is made of rubber and feeds fresh air into the helmet, the diver also has looped around him a life-line of manila rope. The life-line is used to send and receive signals between the diver and his tender. A prearranged code is employed to translate jerks on the line. The life-line is also used by the diver to orient himself and to be hauled to the surface should it become necessary. Both the air-line and the life-line are bound together at short intervals to prevent them from fouling.

Air is pumped through the air-line by means of a portable hand operated compressor. Hand operation


(a) Diving suit.

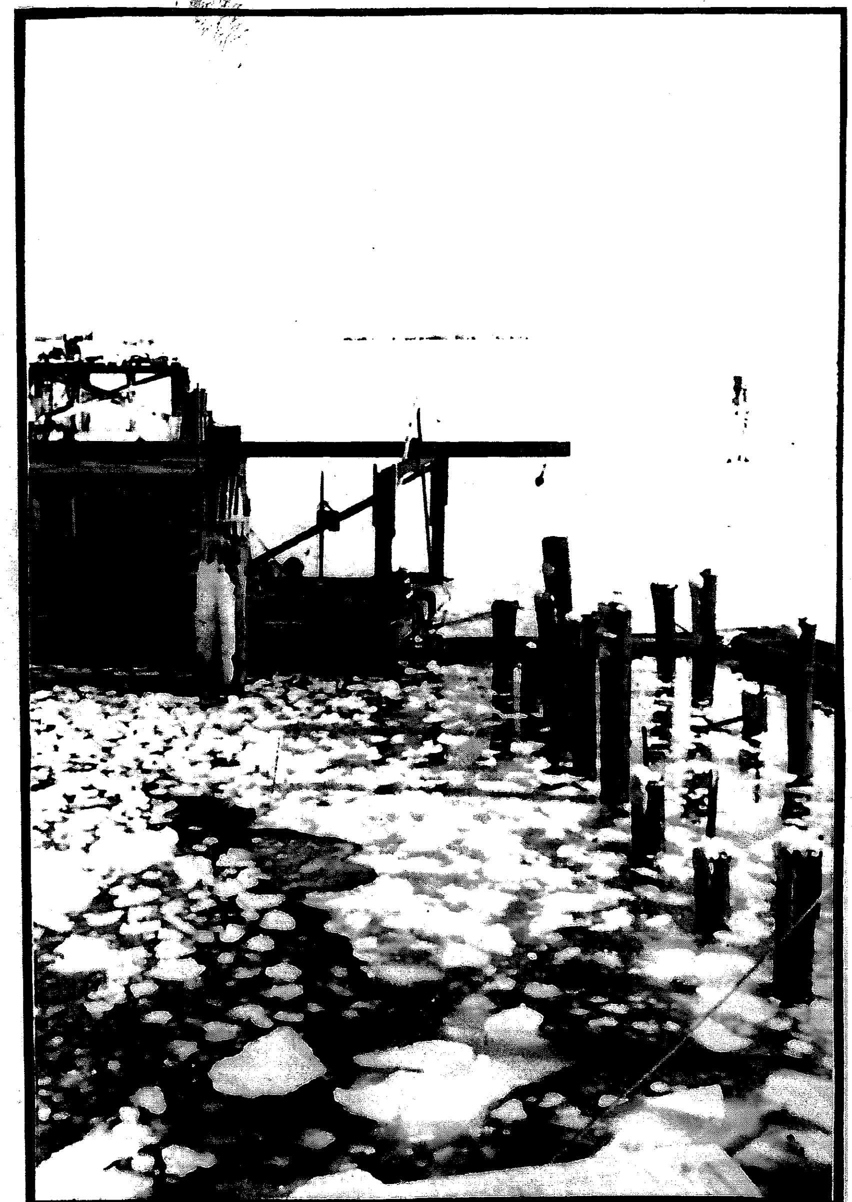

(b) Diving scow.

Fig. 90.- Diving gear.

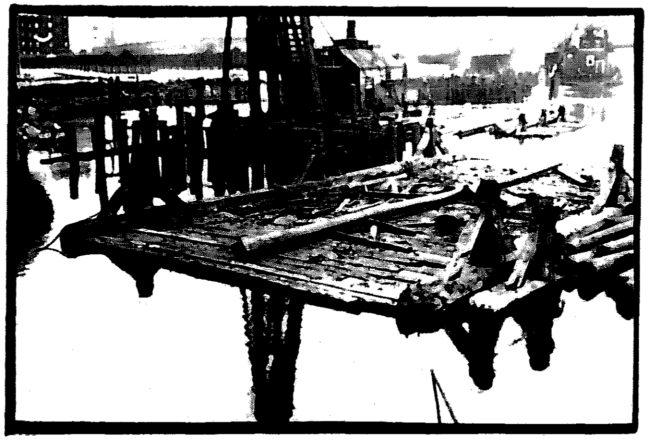
takes preference over mechanical compressors for two principal reasons. The first is that there is no possibility of interruption due to mechanical difficulties and secondly, there is no disagreeable smell or vapor in the air such as there is from a mechanical compressor. The compressor, consisting of bronze cylinders and working parts is operated by slowly turning the handles of large crank wheels. One man can operate the so-called air pump.

The diver may make his descent from a dock or pier, in which case all that is required is a ladder hung over the side. In the event that the site of the work is not located near a waterfront structure, the diving gear may be carried on a specially constructed diving scow. It consists of a small rectangular hull, a cabin to house the air pump and the men who turn it, and a recess in one end through which the ladder for the diver is lowered. The ladder, in no case, must necessarily reach to the bottom, its main function being to help the diver out of the water. Once completely submerged the diver can raise and lower himself by regulating with a valve the amount of air in his suit. Where no diving scow is used, the diver may operate from the deck of a derrick, piledriver, or tow boat, whichever is most convenient.

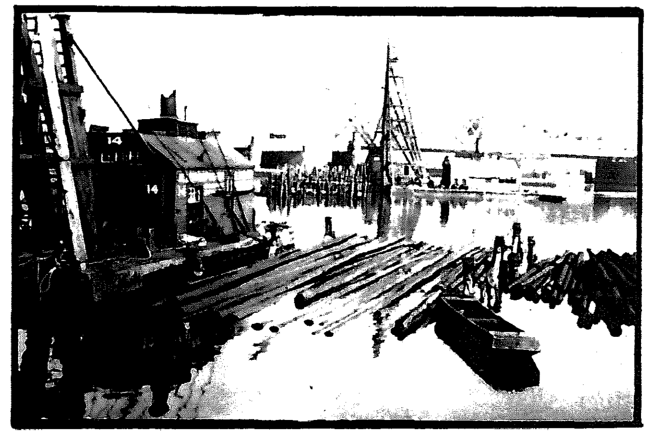
* * *

In addition to the various types of floating plant already described, there are miscellaneous smaller items used in connection with waterfront work. Catamarans serve two functions: to carry timber piling to the job sites and to carry junk timber and second hand piling and timber away from jobs. A catamaran consists of a floating framework floored with timbers or unhewn logs. Fir is the lumber preferred for their construction because it is light and floats high in the water for a long time without becoming water-logged. The ends of the flooring logs, which are laid transversely, are fastened to longitudinal timbers. At each corner, and at one or two intermediate points on each side, there are stoutly braced timber stanchions. They serve to retain the load and to provide means for securing towing lines. Catamarans vary in size up to about 30 by 60 feet and may carry as many as 150 to 200 piles depending upon their size, the lower layers sinking below the surface.

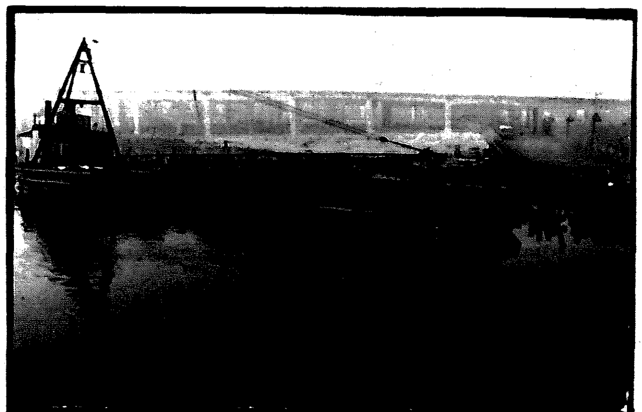
Deck scows are used to transport materials such as may be desired to be kept dry together with those which are too heavy to put on a catamaran. Sawn timbers, steel piling, concrete aggregates, and so forth come



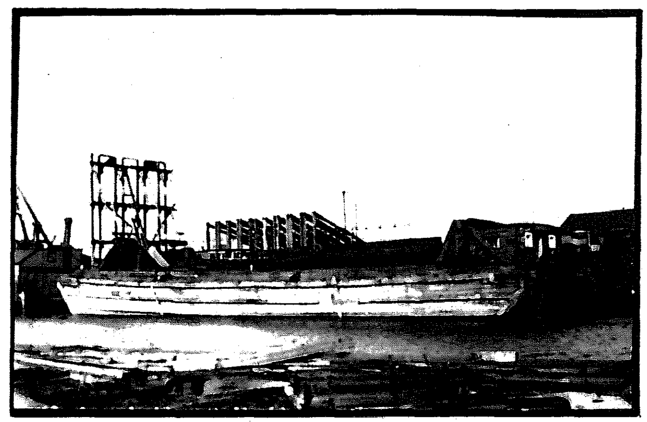
(a) Catamaran (light).



(b) Catamaran (with piling).



(c) Deck scow (with sheet piling).



(d) Deck scow (with timbers).

Fig. 91.- Catamarans and deck scows.

in this category. Most of the scows are constructed of wood with a deck built strong enough to carry a load equal to its allowable displacement. Deck scows may be moored at a job site and used for temporary storage space or they may be held alongside floating plant as the material is used (See Figs. 61 and 95).

In order to enable dockbuilders to work beneath piers and other waterfront structures between the pile bents, and to work alongside of such structures at a low level, float stages are used. They consist of several timbers bolted together longitudinally with spreaders between them and decked with planking. The stages are usually about 3 feet wide and 30 or more feet in length. They can be slid between pile rows or held alongside a derrick between it and the dock. The timbers, which do not sink entirely below the water will satisfactorily support several men at a time.

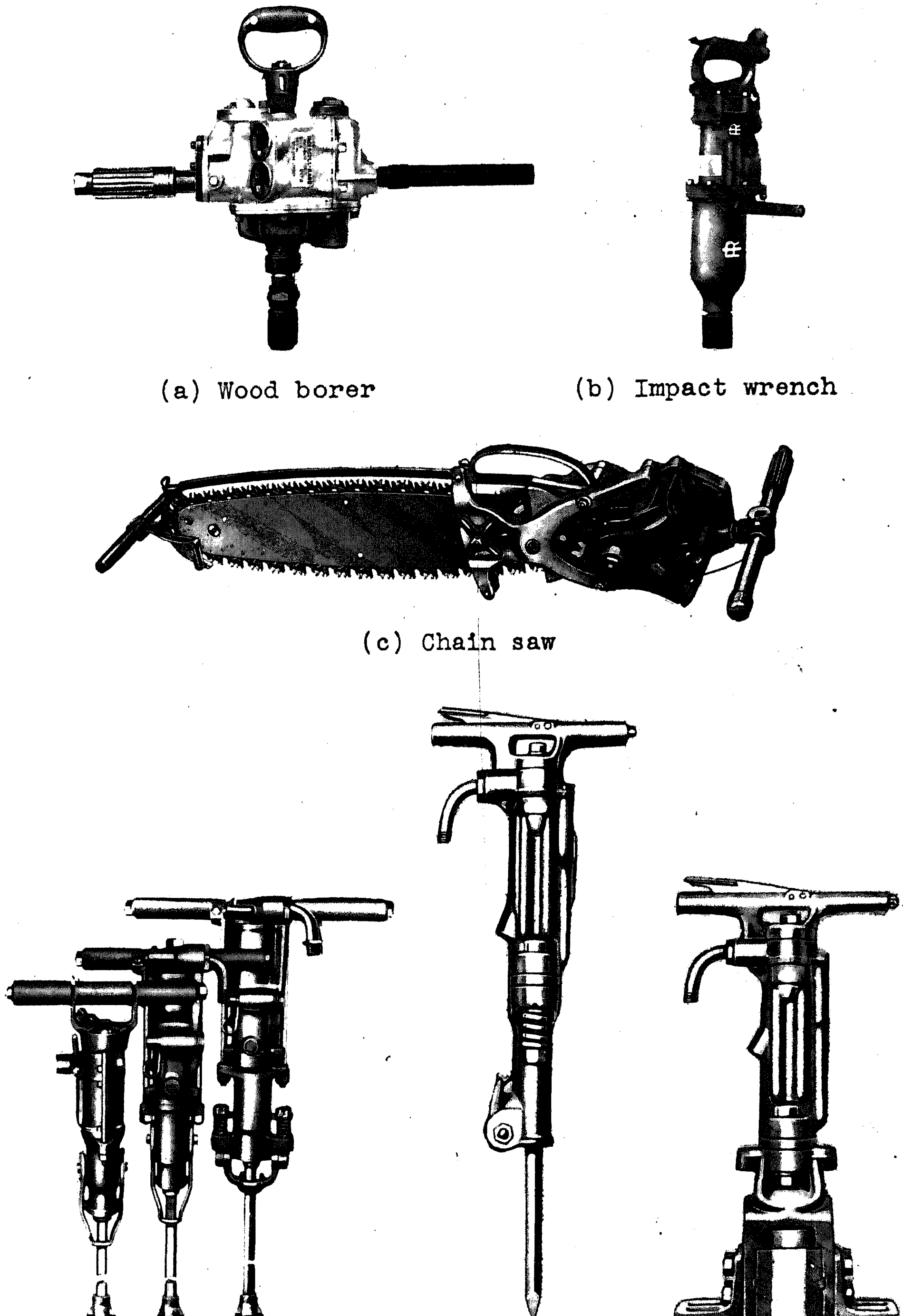
No dockbuilding rig would be completely equipped without a scull boat. A scull boat differs from the common row boat both in shape and manner of propulsion. It has square ends and the bottom slopes upward at both ends. To propel it, by means of sculling, a man stands in the stern with a single long oar resting in a notch in the stern plank. The oar is manipulated with one hand, giving it a motion similar to that of the tail of a fish. These boats are indispensable for shifting the lines of derricks, piledrivers, and all other plant that is moved by means of winches and steam lines.

* * *

There is a wide variety of tools used in the heavy construction industry; some of them, it will be seen, are peculiar to dockbuilding. The advent of compressed air tools resulted in a great labor saving in many branches of the building trades, including that of the dockbuilders. Timber construction requires a great number of bolt holes to be bored, and the slow hand auger method of boring has been superseded by rapid air guns.

Where many nuts are to be tightened up, air impact wrenches may be used. In the majority of cases, hand wrenches are still used for putting nuts on bolts but, where lag screws are installed, impact wrenches are such a great saving in labor that they are utilized when they are available.

The air saw is also a great labor saver in framing timbers. The teeth of the saw must be kept well filed and set however, or the dockbuilders may be able to make good a common contention that they can saw through



(a) Wood borer

(b) Impact wrench

(c) Chain saw

(d) Jackhammers

(e) Concrete buster

(f) Sheeting driver

Fig. 92.- Compressed air tools.

a 12 x 12 just as fast with a cross-cut saw.

Modern structures with concrete foundations, deck, and so forth have made jackhammers an indispensable implement. Frequently holes must be drilled into foundations to set anchor bolts and through deck slabs to secure the various types of mooring devices. The old-fashioned method, employing a star-drill and a maul, requires many times the effort exerted for the same purpose with a jackhammer. Breaking concrete, soft rock, pavement, and compacted earth is accomplished with comparative ease when using a similar air tool with a bull point which is known as a buster.

Another air tool, which is used on occasions where many heavy spikes must be driven, is the spike driver. It is similar in shape and operation to a buster, but the shank of the tool is shaped to fit over the head of a spike.

To eliminate driving light timber sheeting by hand, an air driver has been developed. The driving head is shaped to fit over square-end sheeting. It may also be utilized to drive light steel-sheeting.

In concrete construction, the use of a vibrator has become a requirement in most specifications. Compressed air vibrators are light and easy to operate, giving highly satisfactory results.

Air operated sump pumps are sometimes found useful. They are of the impeller type centrifugal pump and, with 80 pounds of air, can lift 150 gallons per minute against a head of 100 feet, or 100 gallons per minute against a head of 150 feet. They are light enough to be carried by one man and can handle dirty water, polluted with mud and oil.

All of the foregoing tools can be operated, several at one time, with the volume of air supplied by the steam-operated compressors commonly mounted on dockbuilding rigs. Compressed air power is safe power, eliminating the hazard incurred by the use of electrically operated tools such as drills and saws. This hazard is particularly great in waterfront work where the operators are frequently standing in brackish water or, at best, on a wet footing.

Oxy-acetylene burning outfits are an essential part of dockbuilding equipment. In repair work it is necessary to remove existing timbers and their metal fastenings, namely bolts and spikes. Bending and corrosion makes it impractical to remove bolts by unscrewing the nuts and backing them out, while spikes cannot be readily pulled even when new. Instead, the heads of the bolts are first burned off and the timbers are forced apart with oak wedges. Then, the bolts, or spikes as the case may be, may be cut and the timbers removed.

The burning torch, which mixes a combination of oxygen and acetylene, is fed from the familiar cylindrical gas tanks by means of long lengths of flexible hose, so that it may be used in places remote from the deck of the rig. The oxy-acetylene flame, using a small amount of oxygen, is used to heat the iron to its melting point, then the oxygen valve is opened wider, creating a jet which burns the molten metal away, thus making the cut. The burning outfit is also used for cutting off steel sheet-piling and H-piles and for performing numerous other tasks where cutting or heating of ferrous metal is required.

Besides the mechanical labor saving devices described in the foregoing paragraphs, the dockbuilders use a number of heavy hand tools, several of which are unknown on land jobs. Those most often used are the long handled axe, the adze, and the cross-cut saw. Use for these tools is found both in framing new timbers and preparing timber piles for driving and in ripping out old timbers.

Hand spikes are tools used only in pile driving. They consist of barked oak or hickory poles, 4 inches thick by about 12 feet long, which are jammed, one from each side, between the pile and the hammer guides. Used as levers, they hold the lower section of the pile in its proper place between the leads until the bottom material has been sufficiently penetrated to maintain it, during the balance of the driving, in a plumb position.

Pike poles also are used only around water work. They consist of long wooden poles with iron tips. The tips are similar to a boat-hook, differing in that, instead of having rounded knobs, pike poles have sharp points. Their uses are numerous, a few being to shove floating timber and piling around, to fish for lines laying under water, to propel rafts, float stages, and boats either where the water is shallow or where there is conveniently located piling and timber on which to hook on. They are also used to steady swinging loads, to reach for the hook when the load to be raised lies partially submerged and the hoisting chain must be passed around it under water, and to spear floating debris and cut off pile butts, for which there is a fine by the Supervisor of the Harbor if allowed to go adrift.

Cant hooks, which are similar to the peaveys of the lumberjacks, are widely used in land work for rolling timbers and piling. They are also used for handling dock timbers, rolling piles on catamarans, and turning them as they hang in the leads so that they may be dropped plumb. They may also be used, with the aid of a sharp pointed hook on a chain, as levers to pull timbers and the heads of piles into place. To do this, the chain is passed around the timber or pile with the hook fast in a fixed timber, while the cant hook, with its hook in a link of the chain, is braced against the same or another stationary timber and used to exert a pull.

On derricks and piledrivers there are a number of hoisting aids commonly employed to facilitate work. For handling timbers and piling, a chain with a hook is attached to the end of the fall line. For ordinary work a 3/4 inch chain, 10 feet long, and a slip hook are used. A slip hook is designed to permit the chain to reave through the hook, tightening itself as the strain is taken.

When it is desired that the chain should not tighten, a grab hook is employed. The opening of a grab hook is a slot just wide enough to slip over one link, between the round ends of adjoining links, thus being prevented from sliding.

A sling hook is used where iron rings and chain or steel wire rope is used to sling loads. The opening in the hook is rounded, being larger than that of a grab hook, so that a ring or cable may easily be hooked, but smaller than that of a slip hook.

The foregoing hooks are made of drop forged steel and, while most often used at the end of a chain, they are sometimes shackled to an eye spliced in the end of the fall line.

Still another hook, employed in dock repairs and demolition, is known as a ripping hook. It is usually a home-made affair cut from steel plate, perhaps an inch thick. It is in the shape of a large L, about 2 feet long and a foot wide at the bottom. At the end of the horizontal leg of the L is a triangular point, part of the same plate. A hole is provided at the top for inserting a heavy ring so it can be shackled to a fall line. This hook is used for tearing up fender chocks, rangers, caps, and whatever other timber which may be held by only spikes or bolts, the heads of which have been cut off.

The chains themselves are of wrought iron and similar for all types of work, differing only in size.

The common pile fall chain is about 3/4 inch, while when piles are pulled with the pile fall a 7/8 or an inch chain is substituted. For harder pulling, where the monkey purchase is required, a 1½ inch chain is used, and for very hard pulling, where the heavy pulling purchase is needed, a 2 inch chain is used.

When unloading piles, either from cars or lighters, onto catamarans, ten or more are picked up at a time. A pair of wire rope slings are generally used for this purpose. A sling has an eye with a thimble spliced in each end. The eyes are hooked to the fall line while the slings pass under the load. The sling does not slip, tightening around the lead in this arrangement.

A choker consists of a single piece of wire rope, with eyes at both ends like a sling, that is permitted to tighten upon the object being lifted. One eye is passed through the other and placed on the hook while the loop is passed around the load. As a strain is taken the loop tightens, getting a secure hold. Chokers are commonly used for handling steel piles and such objects as are desired to hang nearly vertically rather than horizontally as they are hoisted.

Tongs are frequently used in handling piles on catamarans. Sometimes it is impossible to hook the desired pile with the pile chain. This may be because it is partly covered by other piles and cannot be raised by hand to pass the chain around it. The tongs, which resemble ice tongs, with rings instead of handles, are hung on the hook of the pile fall and used to grasp the pile and drag or shake it free.

# CHAPTER SEVEN

## WATERFRONT CONSTRUCTION PERSONNEL

In order that the elements of material and equipment may be properly combined to produce the consummation of plans, a third element, labor, is required. Within the province of waterfront construction, the chief type of labor is that performed by a group of men known as dockbuilders. They must be able to operate floating derricks and piledrivers, be skilled in the use of carpenter tools for framing timbers and building forms for concrete construction, and be proficient in the use of mechanical labor saving devices.

The background of this class of labor and the evolution through which it has come is of interest. Years ago, when the waterfront of New York was first being expanded, the majority of the dockbuilders were either Dutch or of Dutch descent. During the latter part of the 19th Century, there entered the group a number of immigrants from Ireland which increased until, by the year 1900, a look at the New York Dock Department payrolls would show that dockbuilders were predominantly

Irish. Nor at this point was the situation stable. Commencing near the turn of the century, still another element began to grow in the group. This time the source of new dockbuilders was the Scandanavian countries. For 25 years the trend continued, until the ranks were filled almost entirely with immigrants from Finland, Sweden, Norway, and Denmark. As the situation stands at the present time, a preponderance of the dockbuilders are Finns.

After several unsuccessful attempts in the early years of this century, a labor union of dockbuilders was formed. They are joined together with pier carpenters, building shorers, and foundation workers in Local Union No. 1456, affiliated with the American Federation of Labor. This union claims jurisdiction over all work involving piledriving, pier carpentry, caisson and cofferdam work, timber trestle work, shoring, underpinning, breakwater and jetty construction, concrete form work for all types of foundations, and, in general, all work on waterfront structures from the top of the backing log down and, on inland foundation work, from the column base down.

While all members of the union are at liberty to work on any job in the foregoing category, there is a large degree of specialization among them. Certain men become proficient with floating equipment just as others become proficient in the use of land rigs or at underpinning. A good foreman and his gang are usually kept working by the same contractor from one job to the next. Thus a group of men becomes familiar with a specific type of work and skilled at using a particular variety of equipment. Well organized gangs under good foremen enable certain contractors to become specialists in a field and consistently underbid, to obtain work, would-be competitors who do not possess the necessary competent personnel. Such is very much the case in waterfront work, much more so that in some other phases of construction where an entire force of workmen may be hired for a particular project and laid-off upon its completion.

Dockbuilding is an arduous type of work, probably more so than any of the other branches of the building trades. Frequently, for instance, in the winter, when other jobs are shut down because of ice and snow, dock-builders are able to work through because their floating equipment does not become snowbound and the jobs, because they are usually located in busy districts, are nearly always accessible for both men and materials.

There are times however, when ice jams in the harbor make the maneuvering of floating equipment very difficult, but the jams seldom last much longer than a change of wind and tide.

To make their winter work more difficult, catamarans of piling and rafts of lumber frequently become frozen and caked with ice so badly that individual pieces must be chopped free with axes. After sleet storms, the rigging of piledrivers and derricks may be frozen and sheaves may have to be thawed out before the fall lines can be worked. In addition, much of the work to be performed is located either under the piers or close to the water alongside. In either case, the dockbuilders must stand on rafted lumber or on float stages over which break swells and the wash from passing boats. For this reason, rubber boots are an important part of each man's gear, along with his set of wood-working tools. In the summertime, however, many dock-builders disdain the use of boots and frequently work in water up above their knees. Likewise, where low-water work, such as braces and so forth, is required and the available time is short, holes are bored and bolts are placed under water, sometimes a foot deep. Taken collectively, the dockbuilders are an unusually steady working and conscientious group, giving a good account of themselves for each day that they work.

The principal change in the membership currently taking place within their union is the gradual replacement of the older foreign-born members by younger Americans, mostly of Scandanavian ancestry. In an effort to keep its membership small, the union is admitting very few newcomers, additions at present being restricted to sons and relatives of members.

In conjunction with all dockbuilding work performed with the aid of floating plant another class of labor is required, namely the operating engineers. The International Union of Operating Engineers Local No. 14, affiliated with the American Federation of Labor, and one of the oldest in the construction game, claims jurisdiction over the operation of all power-driven equipment, whether floating or ashore. As in Local No. 1456, the dockbuilders union, any member in good standing of Local No. 14 may operate any piece of equipment which he is capable of handling. However, what applies to the dockbuilders applies likewise to the operating engineers with regard to special skill. It takes a lot of practice to handle loads with floating rigs, making the proper allowances for settling as loads are picked up and for listing as they are swung. These elements are foreign to an operator brought up on rigidly fixed or travelling land rigs.

Most of the men who operate the piledrivers and derricks for dockbuilding contractors get their start and serve their so-called apprenticeship in contractors' yards where they more or less grow up with floating equipment. The operating engineer, like the foreman, can make or break a job, depending upon his individual skill and reliability.

On all derricks except the smallest, where he stands on the main deck, and on some piledrivers, the operating engineer is assisted by a fireman. Where a fireman is employed, it is his duty to fire the boilers, maintain steam and air pressure, turning on the compressors when necessary, and to periodically siphon out the bilges of the scow. The firemen's union, while maintaining a separate identity, is closely allied to that of the operating engineers.

On jobs where under water work or inspection must be performed, the services of divers are required. These men are members of the Marine Divers and Tenders Union, Local No. 2205. This union is a branch of the United Brotherhood of Carpenters and Joiners of America and is also affiliated with the American Federation of Labor. Four men, a diver and his tender who generally work together from job to job, plus two deckhands or laborers to man the air pump, constitute a unit in this type of work. Sometimes they work alone, when the operation is primarily a job for a diver, while at other times they work in conjunction with a regular construction crew, performing their part as required.

A diver must be a jack-of-all-trades, since his underwater tasks may include the work of nearly all of the many building trade specialties. For instance, he may be required to perform carpentry work, such as sawing off piles, spiking timbers, and building forms for concrete, or he may be required to fit pipe and calk the joints. Inspection jobs may require him to examine piling and cribwork or to see that subaqueous cable is properly laid in a trench. In the latter cases he must be able to intelligently report his findings to topside.

This type of work is considered hazardous, and only men with cool heads and steady nerves are suitable for it. During the winter months, a diving job becomes very unattractive; cold water and ice make the duration of dives necessarily short. The membership in the union of this group is very small, including only several dozen divers and an approximately equal number of tenders, some of whom may be called upon for deep sea diving and miscellaneous salvage work as well as the work described in previous paragraphs.

* * *

Nearly 100 percent of the construction work done in New York Harbor is performed by plant and labor organized by contractors. The exceptions to this generality are the comparatively small amounts of repair work carried on by a few agencies owning and operating a sufficient number of piers to warrant keeping a private maintenance force. These agencies include the New York City Department of Docks and several of the railroads having terminal facilities in the harbor.

Specializing in dockbuilding work, there are only about a dozen contracting concerns actively engaged in competitive bidding for both public and private work. Of these, only about one-half are capable of handling jobs of magnitude. These contractors, by virtue of the fact that they have their own floating equipment and have at their disposal the best dockbuilders in the union, succeed, to a large degree, in keeping additional competition from entering the field. Would-be competitors must either rent or purchase plant and obtain a crew of men who can work together efficiently. Renting plant and breaking in new gangs means higher costs, so that it is difficult for them to turn in a winning bid.

Established concerns retain, insofar as is possible, several key gangs which work continuously from job to job, as long as the company has work in progress. When work is plentiful, and more gangs are required, the most capable dockbuilders in the regular gangs are made foremen and delegated to pick up gangs of their own. Thus the gangs consist of men known to the foremen, which results in more harmonious and efficient work and precludes random hiring direct from the union hall.

When work slacks up and the number of jobs decreases, the extra gangs are laid off and the foremen return to their old gangs. In this way, a contractor may expand and contract his organization in accordance with his requirements while keeping the nucleus intact.

In addition to organizing plant and labor, the contractor must procure and regulate the flow of materials and supplies with which the jobs are kept running. There are purchase orders to be placed and delivery schedules to be made up. The latter are as changeable as the weather and are usually revised as the jobs progress. Next to securing the job itself, a contractor's most important function is to see that the proper materials are delivered at the most opportune time. With the cost of labor as high as it is, time lost on account of a lack of needed material is an expense that cannot well be afforded.

The local contractors who engage in large scale construction operations have formed an organization known as the General Contractors Association. This was formed for two reasons: to provide a collective bargaining agency for dealing with the various labor organizations and to establish standards of fair practice among themselves. The members of the association are divided into various groups, depending upon the nature of their work specialty. The members engaged in dockbuilding and foundation work constitute one of these groups.

* * *

The Dockbuilding and Foundation Contractors Group of the General Contractors Association have entered into agreements with the several unions to which the various classes of their labor belong. To quote from the preambles of these agreements, they have been made in order "to prevent strikes and lockouts; to facilitate peaceful adjustment of grievances and disputes between employer and employee; to prevent waste, unnecessary and avoidable delays and the results through them, to the employer of cost and expense and to the employee of loss of wages; to enable the employer to secure at all times sufficient forces of skilled workmen; to provide as far as possible for the continuous employment of labor; to provide that employment hereunder shall be in accordance with conditions and at wages herein agreed upon, and by reason of this agreement and the purposes and intent thereof, to bring about stable conditions in the industry, keep costs of work in the industry as low as possible consistent with fair wages and proper working conditions, as provided for hereunder; and further, to establish and setup the necessary procedure for amicable adjustment of all disputes of questions that may arise between the parties, so that the foregoing purposes may be brought about and accomplished."

The primary principles agreed to apply to any work performed within a 25 mile radius from the New York City Hall. It is agreed that workmen shall not be limited in the amount of work they may perform during the working day, with the understanding that men shall turn in a fair and honest day's work. This item eliminates featherbedding. Machinery and labor saving devices may be used to a maximum advantage, and any, except prison made, materials or manufactured articles may be utilized.

It is further agreed that the contractors may hire and fire as they deem fit, they being the sole judges concerning the men and their work. The men may work for whomever they please, but they must be paid the prevailing wage rates for their services. Union representatives may visit jobs during working hours but shall not interrupt or interfere with the progress of work.

In return, the contractors have agreed to employ only men who are in good standing with the unions so long as the unions are able to furnish a sufficient number of competent men. In the event that the unions cannot produce such men within 48 hours, the contractors may employ non-union men who, if they so desire, may be enrolled in the union and be permitted to continue to work as regular union members.

In order that there may be no strikes or lockouts resulting from disputes and so forth, both the unions and the contractors have agreed to settle their differences in a prescribed manner. First, an amicable solution will be sought by a conference of the employer and the union. Should this fail, the matter will be submitted to an arbitration board of four members. Two members shall be from the General Contractors Association, being unassociated with the contending employer. The other two shall be members of the Joint Labor Committee of Heavy Construction, being unassociated with the union in question.

Should the four-man board fail to reach a decision, they shall choose a fifth member who is identified with neither the construction industry nor labor. The chairman of the American Arbitration Association shall designate the fifth member in the event that the first four cannot agree upon an individual.

Until a decision is reached neither the contractor nor the union involved shall take any action on the matter in dispute and any decision made under one of the foregoing plans shall be final and binding upon both parties to the dispute.

The unions have agreed that, should a jurisdictional dispute arise there shall be no work stoppage and that the trade in possession of the work may proceed with the job pending settlement of the dispute by the Building and Construction Department of the American Federation of Labor.

While the unions have agreed not to participate in jurisdictional disputes with other trades affiliated with the Joint Labor Committee of Heavy Construction, should a work stoppage occur in spite of everything done to prevent it, the contractor may pay off his straight-time men at the end of the day on which it occurs and need not pay them for its duration. The unions agree to require acceptance of the terms of their agreements with the General Contractors Association by all trades which enter and are employed in heavy construction work.

The wages and rules governing their payment differ among the dockbuilders, operating engineers, and divers. Taking the dockbuilders first, the daily wage for 8 hours is $23.00, while the foremen receive $25.00. Any work in excess of 8 hours per day or 40 hours per week, and work on Sunday is paid for at double time. Single shift work is normally confined between 8 A.M. and 5 P.M. When low-water construction necessitates working with the tide, the period may be between 6 A.M. and 6 P.M. Dockbuilders are paid only for the number of hours they work per week, but the foremen are paid for 40 hours regardless of time lost on account of weather or the length of the job. There are eleven holidays during the year for which, if work is performed, the rate is double time. Six of these in New York, and eight in New Jersey, are paid holidays. On paid holidays also, the men are paid double time if they are required to work. To be eligible for holiday pay a man must have worked at least one day of the payroll week in which the holiday occurs.

Where five or more gangs are employed on a job in one shift, a general dockbuilder foreman is required. He is selected by the contractor and must be paid at least $1.00 per day more than the dockbuilder foreman rate.

Where three shifts per day are worked, each shift works only 7½ hours, allowing ½ hour for meal time, but is paid for 8 hours. Should a contractor request men to report on a job and then fail to hire them, such men receive 2 hour's pay for reporting. Should failure to provide work result from conditions beyond the contractor's control, such as bad weather or failure of materials to reach the job, such payment need not be made.

Each dockbuilder is expected to furnish his own hand tools for framing timbers, and the contractor must provide a suitable place for storing them, together with work clothes, overnight. Loss of tools or clothes by theft, fire, or sinking is the liability of the contractor who must pay claims for such losses.

The rules governing the working hours of the operating engineers and firemen are the same as those which apply to the dockbuilders with whom they work. The daily wage of an engineer for 8 hours is $25.00, the same as a dockbuilder foreman, while that of the fireman is $16.00. Both engineers and firemen are paid for 40 hours per week, like the foremen, regardless of the number of hours that the gang may work.

Where five or more operating engineers are employed per shift on one job, a master mechanic must be employed. He may operate machines in an emergency, but only until an engineer can be obtained. A master mechanic is appointed by the contractor and, like a general dockbuilder foreman, his rate, a minimum of $26.00 per day, may be determined by the contractor.

The working hours of divers and their tenders are similar to those of dockbuilders and operating engineers, except that they do not receive pay for holidays unless they work, in which case they receive double time. However, where a diver is not employed during the regular hours of a single shift job, and is ordered to work at the end of the single shift, he is paid at the overtime rate. No diver may be required to work more than 10 hours per day at the double time rate.

Divers receive a daily wage of $27.00 for 8 hours, while their tenders receive $14.40. For stand-by time both receive $12.00 per day. Stand-by time is paid when a diver is called upon for consultation but does not dive and when a diver is called out but for some reason, no fault of his, he makes no descent. A diver and a tender constitute a diving unit, and a tender may attend only one diver on any one shift.

When required to work at depths in excess of 10 fathoms, divers receive additional compensation. For working between 60 and 75 feet a premium of 15 cents per foot per day is paid. From 75 to 100 feet, the premium is 20 cents per foot per day and from 100 to 125 feet it is 60 cents per foot per day. In depths over 125 feet the rate is agreed upon between the diver and the employer.

The wage rates of the building trades, which have always been comparatively high, have recently been raised along with those of other industries. To illustrate how they have risen since the start of the century and steadily increased during recent years, it may be stated that about 40 years ago dockbuilders were earning about $4.00 per day. The rate 10 years ago was $1.75 per hour; just prior to World War II it was $1.85 per hour. During the war it was raised to $2.10 per hour and in 1947 it was jumped 40 cents an hour to $2.50. In 1948 it was again increased, this time to $2.75, with no assurance that further increases will not be sought.

The net effect of these recent increases, together with higher material costs, has been to nearly double the cost of construction over a 15 year period. While the volume of public and private construction now in progress is fairly large, the increased costs may, in the future result in a curtailment of new work and strengthen the tendency to defer maintenance.

# CHAPTER EIGHT

## NOTABLE PROJECTS WITHIN THE HARBOR

The volume of waterfront construction in New York Harbor has, through the years, fluctuated between periods of great activity and those of near idleness. Neither condition is normal and, since New York City was founded, the process of expanding and improving its principal asset has persistently been sustained.

By far the great majority of these projects were commonplace and attracted no undue attention. Occasionally however, even as in other fields of endeavor, there have been times when something out of the ordinary has been undertaken. By virtue of either unique designs, unusual magnitude, or novel methods of construction, jobs sometimes become landmarks both in the harbor and in construction annals. The jobs briefly described in the following paragraphs are some that belong in this category.

* * *

The first, in chronological order, of such outstanding jobs is the removal of Flood Rock at Hell Gate. To navigate the East River, from the time it was first used as a waterway by ships, was always a comparatively hazardous voyage. This was due to the fact that the tidal currents which run through it attain high velocities and the natural channel was marred by rocky shoals and pinnacle rocks. The passage through the Hell Gate was particularly difficult because, due to the constriction of the channel, the current ran even more strongly and because the currents had a tendency to carry ships onto the rocks.

As early as 1853 the federal government undertook to make improvements in the vicinity of Hell Gate by removing some of the obstacles to navigation. At that time the work was confined to dredging and small rock removal but the worst offender among them was a sizable rocky islet called Flood Rock. Because of its size and the fact that there was no precedent to follow in the removal of such obstacles, this rock was left to menace mariners for over thirty more years before a workable plan was devised for its removal.

The project, both planned and executed by General John Newton, was accomplished about 1885. It consisted of sinking two shafts through the exposed portion of the rock to a depth slightly in excess of the desired 26 feet below mean low water. From the bottom of each of these shafts a series of horizontal galleries were driven at right angles to each other. These galleries were 10 feet wide and 10 feet high on 25 foot centers, so that there were left between them columns of rock 15 feet square. From the roofs of the galleries to the river bottom above measured from 8 to 15 feet. Next the columns and the roof were drilled and loaded with dynamite. Up to this point the shafts and galleries had been worked in the dry, the excavating being accomplished in free air through solid rock. Then the entire excavation was flooded and all of the charges were fired simultaneously. As a result of the explosion the rock was so completely shattered that it could be removed from the surface by grapple dredges.

In the course of this work nearly 22,000 feet of tunnels were driven, over 80,000 cubic yards of rock were excavated, and approximately half a million pounds of explosives were used. The final blast required about 285,000 pounds of explosives, but there was not a loud report nor a severe earth shock and only a few windows were broken as a result of it.

* * *

The early improvement of channels through Sandy Hook Bar was a pioneer project, developing a method of dredging new to New York Harbor. During the latter part of the Nineteenth Century the natural channel which entered Lower Bay from the sea became inadequate to accommodate the newer and larger ships that were being built. In response to an increasing demand for an improved entrance, the River and Harbor Act of July 5, 1884 appropriated federal funds for the deepening of Gedney Channel through Sandy Hook Bar.

Up to this time there had been no experience in the removal of ocean sand bars in this vicinity and, as a result, the dredging project that followed was somewhat an experiment. The first attempt was made in February 1885 by Mr. Roy Stone of New York who agreed to provide a channel, 200 feet wide and 28 feet deep at mean low water, through the natural Gedney Channel. The contract was awarded with the stipulation that the government would pay a lump sum upon the completion of the work but would incur no expense if the channel was not opened to the specified dimensions.

To remove the shoal, Stone proposed to employ an operation called hydraulic plowing. His plant was a self-propelled steamboat, 120 feet long and equipped with four 1250 gallon per minute pumps. The pumps were placed in pairs on each side of the boat where they discharged into two 10 inch pipes 54 feet in length. The two discharge pipes could be lowered to the bottom where the end of each was fitted with two 2 inch nozzles, one of which was directed forward, the other upward. The nozzle pressure was about 150 pounds per square inch.

The plowing operation consisted of moving up and down the channel with the jets of water cutting furrows in the sand and forcing some of it upward into the water. This apparatus was employed only during ebb tide and, in theory, the agitated material would be carried out to sea by the current. After working for about one month, soundings indicated that no progress was being made. Apparently any material carried seaward by the ebb tides was later returned by the flood tides.

Before giving up, Stone modified his plant to make a second attempt. He installed on his boat a 30 inch induction pipe which was open at both ends, the bottom end being bell-mouthed. At its lower end a 2 inch nozzle was placed to provide an agitating jet. Seven feet above the bell two more nozzles were placed to inject jets directed upward inside the large pipe. The upper end of the induction pipe was held close to the surface of the water. The theory advanced for this arrangement was that the material agitated by the lower jet would be drawn by the upward jets, through the induction pipe, and discharged near the surface where the ebb currents would have a greater opportunity to carry it away. Less than a month was required to demonstrate that this method was no better than the first and Mr. Stone, abandoning the project, withdrew from the contract.

After subsequent readvertisement the project was undertaken in September 1885 by a Mr. Elijah Brainard. To accomplish the desired results he proposed to utilize pumps that would suck up the sand from the bottom and discharge it into scows. Since pumps of the type required for this work were not on the market at that time, he found it necessary to first specially construct his own equipment for the job. The first plant to be operated by Brainard was a bottom-dump scow with a centrifugal pump mounted at one end. A winch and boom were rigged to raise and lower the suction pipe which was 16 inches in diameter. The discharge pipe was so fitted that it could be diverted into any one of the scow pockets. The scow, 40 feet wide by 120 feet long, with a draft of 12 feet loaded and a capacity of about 700 cubic yards, was maneuvered by means of a towboat. This method of dredging proved successful enough to warrant the outfitting of another scow, similar but larger. The new piece of equipment had a more powerful pump with a 22 inch suction and a capacity of over 1,000 cubic yards.

In May 1886 the plant on the job was further increased by the addition of a self-propelled scow carrying two 9 inch suctions, one on each side, and having a capacity of 175 cubic yards. The load carried in the bins was dumped at sea through side doors. With the combined efforts of these three rigs, Brainard's contract was carried to completion in November 1886 and, while the rate of work attained by them did not come fully up to expectations, the practicability of this method of dredging was demonstrated.

Even before Brainard completed his contract, the River and Harbor Act of August 5, 1886 appropriated $750,000 to secure a 30 foot channel, 1,000 feet wide, between the Narrows and the sea. This project, and later modifications of it, which included dredging in Gedney, Main (Bayside), and Main Ship Channels, were responsible for the rapid development and improvement of self-propelled hopper dredges.

In January 1901 a contract was let for the improvement of East Channel, under which an estimated 42,500,000 cubic yards were to be dredged to provide a channel 40 feet deep and 2,000 feet wide. The contractor assembled equipment similar to that used on the Gedney project but attempted to operate it in a different manner. He had heard of the method employed in Liverpool, England where the dredges worked while at anchor, digging large holes in the area to be deepened. Into these holes the material from the adjacent areas flowed, thereby lowering the elevation of the surrounding bottom. Two dredges similar to those employed in Liverpool were built for and put to work on the Ambrose Channel project.

They were partially successful at the outer end of the channel but, throughout the rest of it, the material at the bottom was so compacted that, although holes were dug to depths of 55 feet, it would not flow as did the soft, semi-fluid material encountered in Liverpool. Since the contractor received no compensation for excavation below the 40 foot mark, his method of operation proved to be a losing proposition and he finally abandoned it in October 1906.

The River and Harbor Act of March 3, 1903 provided for two government owned seagoing hopper dredges to be constructed to supplement the contract work on the Ambrose Channel job which was far behind schedule. These dredges were of the type previously used on the Gedney job, and they completed the project between 1907 and 1914 after the contractor had given up. At the close of the job it was estimated that a total of 66,000,000 cubic yards had been removed and the government was convinced that seagoing hopper dredges were the answer to harbor channel problems.

That the government still held such esteem for this type of dredge was indicated in 1937 when the Goethals was built. The Goethals is the world's largest and most powerful dredge of this type. It has a capacity of 5,000 cubic yards with two 1300 horsepower motors, each of which operates a 30 inch suction pipe which can dredge to a depth of 50 feet.

* * *

Outstanding among the submarine pipelines constructed in New York Harbor are the two Narrows siphons. The Narrows siphons are subaqueous water mains laid under the waters of Lower New York Bay, between Brooklyn and Tomkinsville, Staten Island. The second is the larger of the two, being a 42 inch pipe of the flexible joint type (e) shown in Figure 58. While it is 6 inches larger in diameter, it is somewhat shorter than the first, being 9,400 feet in length, including 600 feet of shore connections. The principal features of the flexible joint are the gib-screw holes drilled in the circumference of the bell, the inside of which is machined to a spherical surface. Pellets of lead and a lubricant were forced through them into the joint to fill the space left by shrinkage after molten lead was poured in the conventional way.

Prior to the pipe laying operations, experiments were conducted to determine in advance what size and location of gib-screw holes and what quantities of lead and lubricant would give the best results. The joints were deflected under pressure to determine their stiffness and leakage, if any. Tests made with high internal pressure indicated that the joint had a longitudinal strength of 130 tons. To flex a joint, after calking and pouring, required a force of 13 tons applied at the end of a 12 foot length of pipe.

The sloping shore ends of the line were placed in sheeted trenches by pulling them down grade on tracks built by divers. The center section of the subaqueous

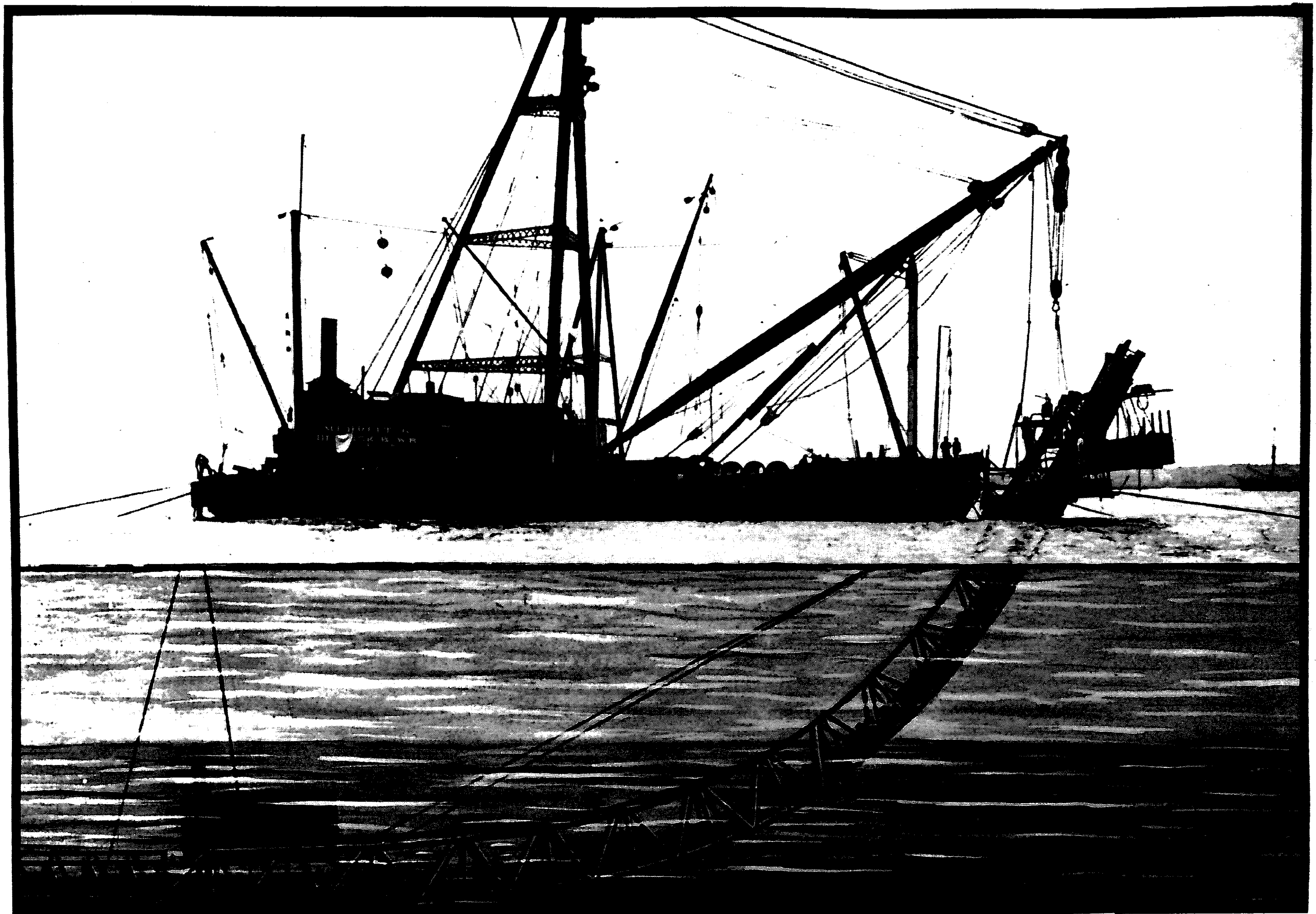


Fig. 93.- Laying the Narrows siphon, a subaqueous water main.

pipe was laid in a trench excavated by a clam-shell dredge. The laying operation was performed by means of a very unique launching-way rigged on a large derrick boat (See Fig. 93).

The way itself consisted of a pair of steel Warren trusses totaling 148 feet in length. The curvature was obtained by making some of the top chords shorter than the rest so that, in seven panels, the panel points were given a deflection of 8 degrees. The upper end of the trusses were supported by a heavy cable sling, while the lower end rested on the bottom of the trench. The trailing three panels of the trusses were floored with timber and steel plate to reduce their tendency to sink into the soft mud. To further reduce the weight, an air tank was fastened to the trusses.

The alignment of the pipe, established by top, bottom, and side guides in the launching-way, was maintained by a "trailer", consisting of two timber Howe trusses which received the pipe as it left the way. The trailer served to straighten out the deflections in the joints and prevented them from following irregularities in the bottom of the trench. The derrick boat was held in place and shifted by taking up and slacking off on ten anchor lines. When it was to be moved, a strain was taken on cables secured to the trailing end of the way and additional air was pumped into the tank to reduce the drag on the mud bottom to a minimum.

Scaffolding was constructed so that the joints could be made up at the upper end of the way. Upon the completion of each joint, the entire plant was pulled ahead, permitting the pipe to slide down and make room for the next length. In each joint 370 pounds of lead were poured hot and 30 pounds of lead pellets were forced into the joint by gib-screws turned by five pneumatic wrenches mounted on a steel ring which rode on the band at the end of the bell. An oil and graphite lubricant was painted on the inside of the bell before pouring and injected into the gib-screw holes after the pellets were inserted. The gib-screw holes were then filled by means of screw plugs with copper gaskets and the joint was completed.

The rate of pipe laying was governed by the speed of the dredge and from 6 to 8 lengths of pipe were laid per 8-hour shift. Joints were occasionally tested on the scow but no leaks ever developed. Before back-filling the trench, the entire line was subjected to 50 pounds of air pressure and bubbles indicated only two leaks which were calked by a diver. Across the greatest portion of the Narrows the pipe was covered with an 8 foot layer of sand to keep anchors off it, while under the Staten Island slip 2 feet of sand over the pipe was covered with 8 feet of riprap to protect it from the spuds of dredges.

* * *

The construction of Pier 34, North River, because it presented some problems seldom encountered in an ordinary pier, is deserving of notice. This pier serves a dual purpose. First, and most apparently, it is a dock whereat ships take and discharge cargoes. Its second purpose, which is less obvious, is to act as a fender both for the Holland Tunnel itself and for its outshore ventilation shaft.

Before the tunnel and shaft were built, the existing waterfront structures in the vicinity were removed and a clay blanket was placed on the river bottom over the site of the tunnel as a construction aid. Upon the completion of the tunnel, the first step in the construction of the pier was to build a fender system around the ventilation shaft (See Fig. 34). This fender, together with the shaft from which it is completely separated by about 10 feet on all sides, stood for a

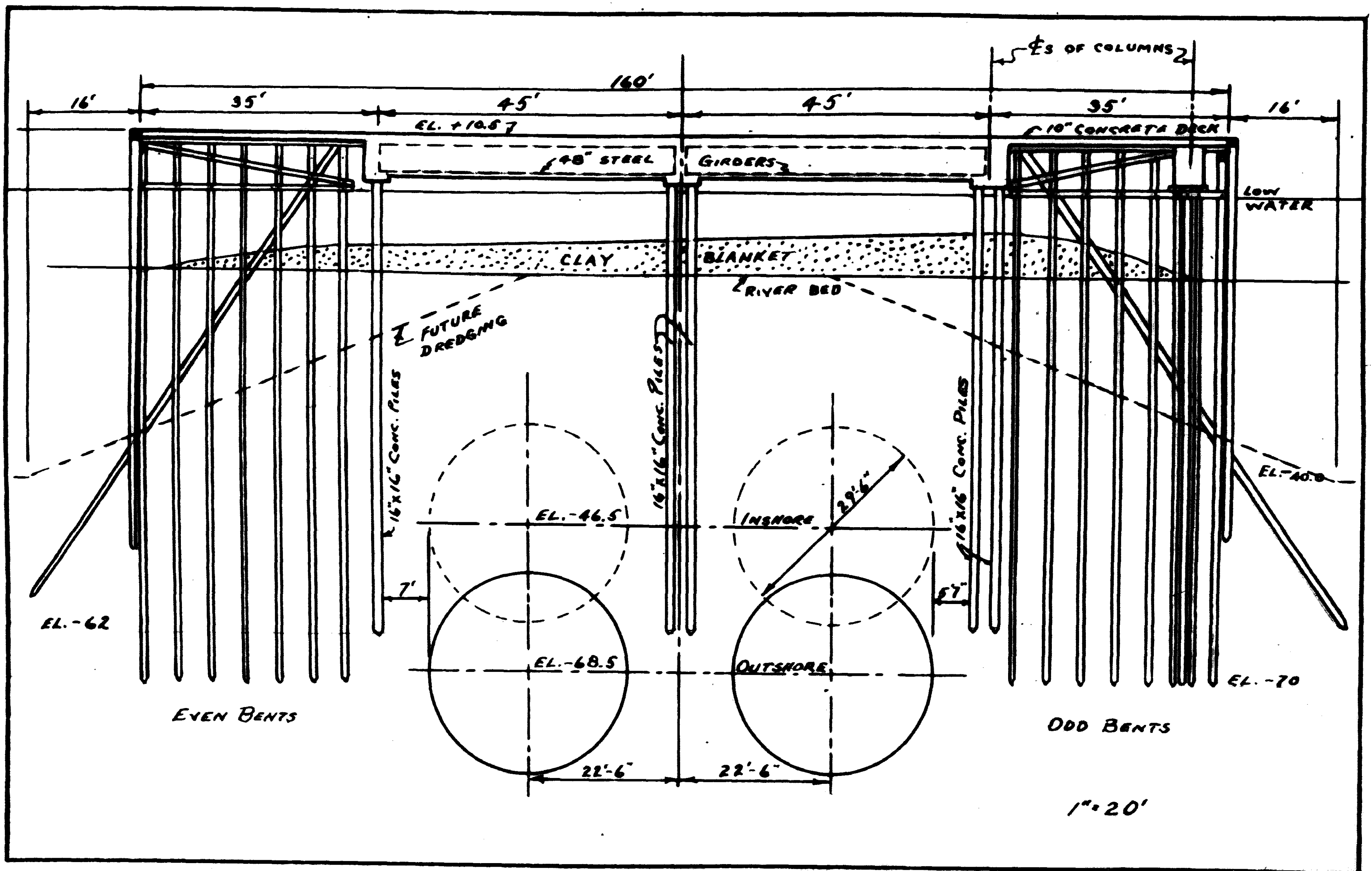



Fig. 34.- Section through Pier 34 and Holland Tunnel, North River.

while like an island at the pierhead line. It served to protect the shaft from collisions by vessels operating in the vicinity and later became the outshore end of Pier 34.

Pier 34 is built directly over the Holland Tunnel, in fact on a plan their centerlines coincide. The reason for this superimposition is that it provides a safety measure. Were the tunnel under a slip, where a ship could sink as did the Normandie, serious damage might be suffered from the tremendous weight lying in the mud over it. Being located under a pier however, this contingency can never arise.

Straddling the two tubes of the tunnel as it does, the pier is of very unusual design. No piles are driven directly over the tubes because, to reach firm bearing, they have to penetrate to an elevation lower than that of the tubes themselves. Instead, this space is spanned by 48 inch steel girders encased in concrete. The ends of the girders are carried by three longitudinal reinforced concrete beams which are in turn supported by precast concrete piles.

The concrete piles are 16 x 16 inch square and 65 feet long. Two rows, 3 feet apart, support the center beam while single rows support the outside beams. The deck, a 10 inch reinforced concrete slab, extends to each side for an additional 35 feet which is supported on timber piles and caps, braced and fendered in the conventional manner for timber substructures. Where steel columns for the superstructure occur, over odd bents, 4 foot square concrete pedestals, supported by a few additional piles, are provided.

Both the line and grade of the tubes change under the pier. At the outshore end their axes are at El. -68.5, while near the inshore end they are at El. -46.5. From the shaft shoreward, the tubes run in a straight line symmetrically under the pier to a point approximately where the axes reach El. -46.5. From this point eastward, the tubes curve to the south toward the approach and exit plazas. To conform to this curvature the alignment of the concrete piles was altered. As a result, the bents closer to the bulkhead have more timber piles on the north side of the pier and fewer on the south side. At the bulkhead the southerly concrete beam is almost at the south edge of the pier.

Extreme care was exercised in driving the concrete piles since it was desired that they should not be driven against the tubes. Since the tubes are 29 feet 6 inches in diameter, and their axes are 45 feet on centers, there is 15 feet 6 inches clearance between them. In this space two rows of 16 inch piles, 3 feet apart, were to be driven. This meant that between the shell of the tubes and the piling there was theoretically 5 feet 7 inches of river muck. While it is fairly easy to set and drive piles so that their heads conform to the dimensions shown on a plan, it is quite another proposition to control their tips. Frequently a submerged or buried obstacle will cause them to be deflected. Such a deviation from plumbness will usually not affect the bearing capacity of the pile but, in this case, the 5 feet 7 inch space represented close clearance for pile driving.

During the driving operations a listening post was set up within the tunnel so that, should a pile happen to get out of line enough to touch the tubes, the listener would hear it ring against the shell and communicate by telephone a signal to the piledriver to stop driving. This signal was necessitated several times and the hammer was stopped and the pile was withdrawn and reset. As mentioned in a previous chapter, as a result of so many large piles being driven in a confined space, lateral pressure was exerted against the tubes by mud wave action and a perceptible distortion in their alignment was detected in subsequent checks. The deformations were so slight however that no ill effects ever resulted.

* * *

The Trans-Atlantic Steamship Terminal, as Piers 88, 90, and 92 are called, was planned and built in anticipation of the arrival in New York Harbor of two new ships, the Queen Mary of the Cunard Line and the Normandie of the French Line. Both of these ships were to be over 1,000 feet in length and so large that there was no pier suitable to accommodate them. Since it was desired that these ships should find adequate docking facilities, it was proposed to construct piers 125 feet wide and 1,100 feet long, with slips 400 feet wide between them.

Nowhere in the waterways surrounding Manhattan Island would the War Department grant a relocation of the pierhead line that would provide the required space for the desired length of pier. It was therefore determined to find a suitable location where the pierhead line could be moved outshore as far as possible and where the slips could be extended inland until the necessary length was obtained.

The site deemed most desirable for this construction, considering property values and proximity to midtown New York, together with the foregoing, was on the North River between 47th and 56th Streets. At this point, the extension of the slips involved the excavation of solid rock for a minimum of 300 feet in each. It was proposed to construct the portions of the piers between the excavated slips on solid rock and rock fill behind concrete retaining walls. These portions represented about one-third of the total lengths of the piers while the remaining two-thirds were to be constructed upon timber substructures of the conventional type.

In order to perform the rock excavation and concrete construction in the dry, it was decided to surround the area with a huge cofferdam. While the piers were the largest in the harbor and the excavation was a tremendous job in itself, the construction of the cofferdam was probably the most remarkable part of the project.

The initial phase of the job was the demolition and removal of the existing structures in the area. Two of the old piers were only partially demolished. Their entire superstructures were razed and those portions of the substructure, including the piling, that came within the line of the cofferdam were removed. The outboard portions of these piers, which were outside the limits of the cofferdam, were temporarily left in


Fig. 95.- Piers 88, 90, and 92, North River under construction.

place as two small islands which served as tie-up racks for the contractor's plant and storage yards for material.

The next operation consisted of dredging the area that was to be enclosed to a depth of about 46 feet below mean low water. As the large dipper dredges that were used moved shoreward, they encountered the underlying bed rock which sloped downward to the West. From that point the dredges continued eastward to the existing bulkhead walls, following the contour of the rock and stripping the overburden of silt and unconsolidated material from it.

Upon completion of the dredging, construction of the cofferdam was commenced. This cofferdam, of the cellular steel sheet-piling type, was 2,079 feet long, the largest of its kind ever attempted in the Metropolitan area. The steel sheet-piling was of the straight-web variety and averaged about 75 feet in length. Inside the cells, timber pile bents were constructed to form a trestle over which trucks could travel.

When the last cell was closed, pumping operations were begun to unwater the enclosed area. The water level was lowered in gradual stages and, as the rock surface was exposed it was drilled with jackhammers, blasted, and excavated with power shovels. The excavated material was loaded into dump-trucks which were then driven over the timber trestle and emptied into the cells of the cofferdam. Thus, by filling the cells with excavated material as fast as it was removed, the stability of the cofferdam was increased sufficiently to withstand the subsequent increases in pressure caused by further lowering of the interior water level. The quantities of excavation were great, totaling 140,000 cubic yards of overburden and 648,000 cubic yards of rock. The difficulty of excavation was increased by the nature of the rock in the vicinity. At the bulkhead line of the slips, the vertical surfaces of the older Manhattan Schist was intruded by granite pegmatites which formed wedge-shaped masses of rock that had a tendency to slide. On several occasions they did slide, causing some damage and considerable extra work.

At the time, there were differences of opinion regarding the stability of such a cofferdam upon rock that sloped as it did in this location. It was theorized by some that there was insufficient toe-hold for the sheet-piling and that the dam would either move laterally or tip upon its inner edge. As the water was lowered by stages, the alignment of the dam was checked by repeated surveys and it was found that movement was developing.

To overcome this hazard, additional material was dumped to form an embankment against the inner side. The movement was arrested and the unwatering process was successfully carried to completion. Approximately 200,000,000 gallons had to be pumped out of the cofferdam to expose an area of about 15 acres for work in the dry.

During the same time that the area within the cofferdam was being excavated, the piles for the outboard portions of the piers, outside the cofferdam, were driven (See Fig. 61). Half-lagged piles were used for approximately the outer thirds of the piers, while fully lagged piles were used at the pierheads. The timber substructures were also completed in these outside portions and reinforced concrete decks were placed upon them.

Following the completion of the unwatering process and the rock excavation, the concrete walls for the inboard portions of the piers and the bulkheads were formed and poured. The rock was placed for the rock fill portion of the piers and the concrete decks were poured. Meanwhile a siphon was started to reflood the area within the cofferdam.

When the normal water level was restored the next problem was to withdraw the steel sheet-piling. To do this, the pile puller, which is described in Chapter Six, was bought on the job. The tremendous pulling capacity of this rig was utilized to start the piling and raise it until it could be picked out by a derrick.

Following the removal of the steel sheet-piling and the trestle within it, together with the remaining portions of the old existing piers, the dipper dredges were recalled to the job. They took out all of the material that had been used to fill the cells and form the embankment, and brought the water in the slips to the desired depth. The final phase of the project consisted of driving the piles and completing the platforms in the gaps between the inboard and outboard sections. This done, the piers were completed so far as the dock-builders were concerned. Although the resulting structures are both uncommonly large and expensive, to the casual observer there is perhaps nothing remarkable about them. To the construction men who worked there however, this project is still referred to as "the big job".

* * *

The construction of the George Washington Bridge between the island of Manhattan and Fort Lee, New Jersey required that the tower on the Jersey side be founded on solid rock many feet below the surface of the Hudson River. The location of the tower was established after several variable factors were considered. Test borings indicated that solid rock for the foundations could be reached inside the government pierhead line at depths of less than 100 feet below the water level. Since it was desired to keep the main span at a minimum and the approached spans of equal length for the sake of symmetry, the tower had to be located as far from the shore as was feasible. This distance was restricted by the sloping surface of the underlying rock which rapidly sank to great depths under an increasingly thick layer of overburden.

At the site determined for the tower, rock was encountered at elevations varying from 30 to 76 feet below water level. The rock itself, according to the borings, was composed of strata of coarse sandstone, fine sandstone, sandy shale, and fine red shale. These gradually merged into one another, often with no line of demarcation between them. While the surface of the rock sloped downward sharply to the East, the dip of the strata was westward. Above the rock was an overburden of river silt, 30 to 60 feet in thickness, the lower portion of which contained some boulders, disintegrated rock, and shells. The water at this point was about 12 feet deep.

The tower of the bridge stands upon two legs which are founded on rectangular concrete piers 153.5 feet apart, center to center. From El. -15.0 to rock they measure 89 by 98 feet and, from El. -15.0 upward, they measure 76 x 34.5 feet. Starting at 9 feet below high water, and extending for 24 feet to their tops, the piers are faced with granite, both for the sake of appearance and to protect the concrete against the salt water and frost.

To construct these piers the use of pneumatic caissons was weighed against that of an open cofferdam. It was found that, in view of the cost and other considerations, the cofferdam method was the more desirable. It was also found that two small cofferdams, one for each pier, were cheaper than one large enough for both. The advantages enjoyed by the cofferdam method were the ability to work in free air and the ability to fully uncover and examine the rock, and to clean and prepare it thoroughly prior to concreting.

The twin cofferdams which were proposed for this job, while not particularly large in area, were the deepest yet attempted. Consequently greater than usual consideration was given to their design. The walls were formed by interlocking steel sheet-piling. The east

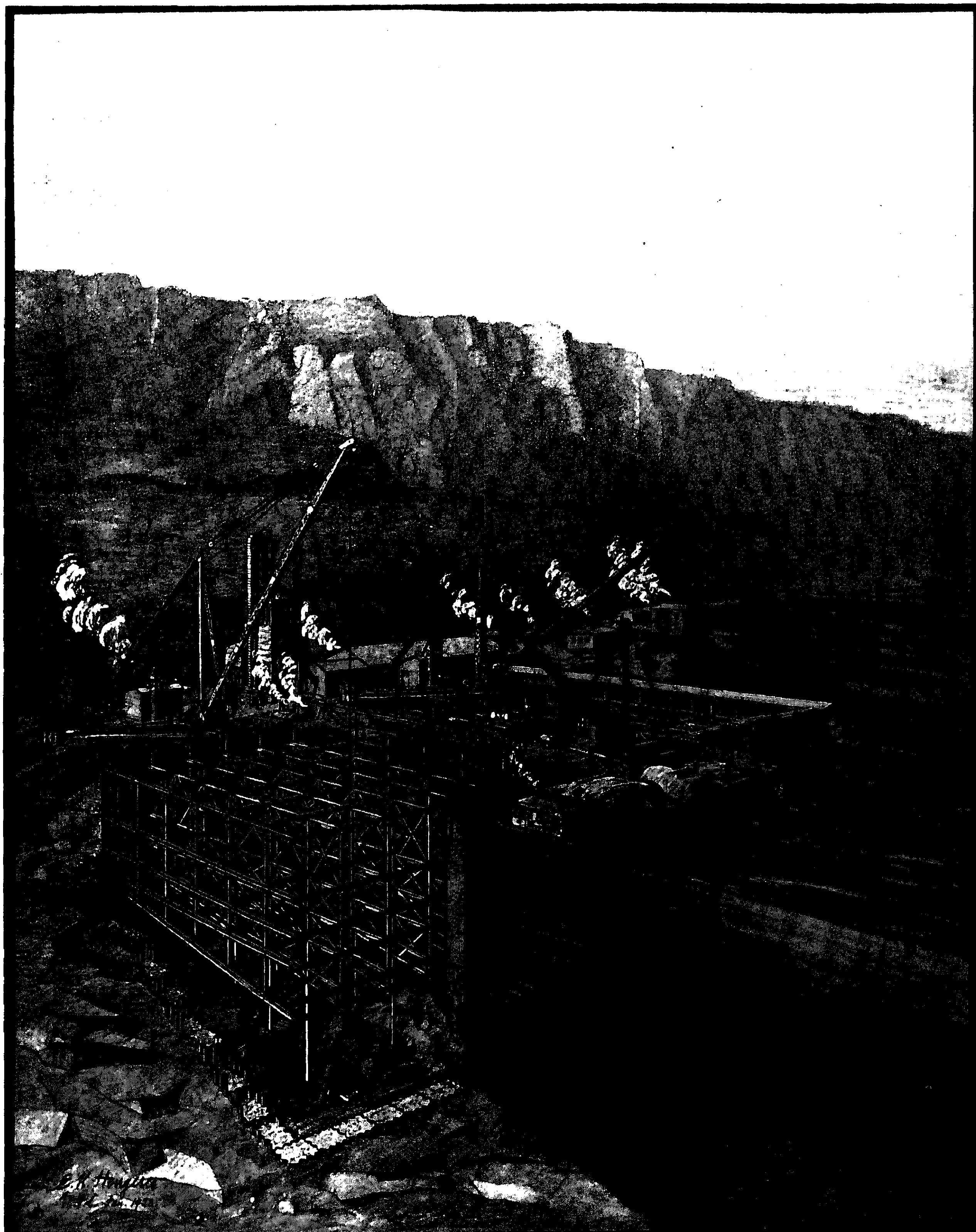


Fig. 96.- Cofferdam for the west pier of George Washington Bridge.

walls, where the rock was deepest, consisted of a double row of sheet-piling, divided into 8 x 10 feet rectangular cells. The deeper portions of the north and south walls were similarly constructed, while the remainder of the walls consisted of a single row. Each cofferdam was to be braced internally by heavy steel girders placed as wales against the sheet-piling at six different levels. These wales were supported by a series of horizontally and vertically braced timber frameworks.

To facilitate the work, a platform was erected between the pier sites upon which a portion of the contractor's plant was located. Two stiff-leg derricks with 125 foot booms were located so that, between them, they could cover the entire job. The batching plant and concrete mixer were located on the shore and the aggregates, all of which were delivered to the platform by barge, were unloaded by one of the derricks and transferred to storage bins by means of a hopper and a belt conveyor. The cement was similarly delivered and handled, but was transferred to the shore on a covered conveyor. Concrete was mixed in a 2 yard mixer, dropped into 2 yard bottom-dump buckets that were carried on flat-bed trucks, and hauled out onto the platform. From there the bucket was lowered down into the cofferdams by the derricks.

The construction of the cofferdams and the piers themselves took place in the following sequence. The river silt at the site of the piers was first dredged to El. -45.0 below high water by means of a large dipper dredge. Then piles were driven to support the wales and bracing frameworks, both during and after construction. The braces were framed and assembled one tier at a time and suspended from the piles. As each section of framework was completed it was lowered, so that the next section could be constructed upon it. The last frame built was left just about at the high water level, while the bottom one was located just above the line of dredging. The steel sheet-piling was driven around this submerged framework close to the steel wales. The tips were driven hard against the rock surface and in some instances the comparatively soft sandstone and shale was penetrated. The rectangular cells were dredged out by means of a clam-shell dredge having an unusually long bucket line and an extra large hoisting drum. Then, after divers were sent down to clean the rock surface within the cells and examine the tips of the sheet-piling, concrete was poured into the cells, as a seal, up to the level of the bottom wale. The remaining parts of the cells cofferdam was again unwatered, and concreting was resumed, this time without mishap.

In both cofferdams, with the exception of the one big leak which developed, the sheet-piling served well in excluding water. The average leakage was small, and no effort was made to stop it since it could be handled easily by pumping. The surface of the rock exposed was particularly well suited for receiving concrete. There were natural benches formed in the sandstone which precluded the necessity of drilling and blasting within the cofferdams to provide good bond.

The remaining wales and braces located above the third wale, which was buried and left in place, were removed as the level of the concrete reached them. From an elevation of 9 feet below high water, where the granite facing commenced, the concrete was poured behind each course as it was laid, until the piers were completed.

* * *

The site selected by Seatrain Lines, Incorporated for their new terminal is located in Edgewater, New Jersey where the rock, underlying a 90 x 600 foot pier (See Fig. 19), is encountered approximately at El. -90.0 inshore and El. -186.0 outshore. Over the rock, a silt and clay overburden varies from 90 to 190 feet in thick-were filled to the high water level with sand.

The southerly cofferdam was successfully unwatered first to a depth of 45 feet. This exposed the southwestern corner, where the rock was shallowest. It was found that the undredged remainder of the overburden consisted of boulders, shells, and rotten rock, as mentioned before. This material was excavated and loaded by hand into skip-buckets and hoisted out by the derricks. The exposed rock was then flushed clean with a stream of water and a block of concrete was placed in forms up to an elevation such that the lower three frames were buried. Subsequently the water level was reduced by stages, exposing deeper portions of the rock. These were cleaned in turn and concrete was poured until a level even with the top of the first block was reached.

The northerly cofferdam was similarly unwatered and a substantial block of concrete was placed in the southwest corner, which was the shallowest. Then, the northwest corner, which had just been cleaned in preparation for concreting, developed a leak under the sheet-piling. Water and silt entered the cofferdam without warning and filled it so suddenly that several men were unable to escape. The leak was repaired by placing concrete against the bottom of the sheet-piling; the ness.

Departing from the usual procedure of driving sufficient timber friction piles to support the superstructure, which usually results in some settlement, it was determined to drive steel H-piles all the way to rock, which necessitated pile lengths of up to 200 feet. The piling, arranged in 35 bents of 13 piles each, are 14 inch H-sections, weighing 89 pounds per foot. Each bent is braced by two batter piles and capped with a 3 x 3 foot section of reinforced concrete. The distance between bents, which averages about 20 feet, is spanned by reinforced concrete girders poured monolithically with a 10 inch deck slab.

Near the center of the pier is located a large hoisting device, resembling a hammerhead crane. It cantilevers out beyond each side of the pier for 75 feet, and its purpose is to hoist loaded railroad cars to and from ship and shore. The foundations of this crane consist of eight concrete pedestals, four of which are supported by thirteen plumb piles and six batter piles spread at 60 degrees apart, and four of which are supported by six plumb piles and four batter piles spread 90 degrees apart. These eight pedestals are constructed independently from the pile platform of the pier and there is 9 inches of clear space around them. They are, however, tied together by means of reinforced concrete struts which extend below the pier proper. This feature of the construction is to prevent the possible shock from a ship colliding with the pier from being transmitted to the crane structure.

The steel piling in the outer half of the pier is encased in cylindrical concrete jackets which extend downward from the concrete caps to 3 feet below mean low water. The cylinders are 28 inches in diameter, giving a minimum cover of 4 inches for the steel. The piles in each of the 3 pedestals for the steel superstructure are encased in a common concrete cap which also extends to El. -3.0, mean low water. The remaining steel piles were left without this type of protection to save on the cost. It possibly was figured that the protective concrete placed can be observed over a period of years to see whether it is a worthwhile investment. Should it deteriorate and fall apart in 10 or 15 years, while the unprotected steel suffers no appreciable damage, the matter may be dropped. If on the other hand, the concrete should endure, then the unprotected steel might be similarly encased if its rate of corrosion should make it seem prudent. The fender system for the pier consists of the conventional oak piles, caps, and chocks, while around the rounded corners are driven close rows of piles.

The retaining wall at the bulkhead line consists of steel sheet-piling supported by pairs of piles, one plumb and one batter, at 5.5 foot centers. The heads of all this piling is cased in a heavy reinforced concrete wall. This bulkhead wall is, in effect, a bridge abutment since it was necessary to place new fill behind it to provide an access embankment from the shore to the pier across a marginal strip of soft muck. This strip, even after filling in, was not stable enough to support the railroad, and the tracks are still supported by a temporary timber trestle of friction pile bents. Several years will be required before the filled approach becomes sufficiently consolidated by the periodic addition of new fill where settlement takes place.

The bearing piles were driven with the aid of a scow mounting 13 pile leads (See Fig. 35). The leads were spaced in conformance with the spacing of the piles in the bents. Thus it was necessary to line up the scow once for each bent and all 13 piles were spotted. The leads were 45 feet high and built of timber. The scow carried a boiler to supply steam for the pile hammer while the hammer itself was suspended from the boom of a derrick during driving operations. The same derrick, with a 103 foot boom, was able to handle piles up to 130 feet in length and set them up in place in the leads.

Where lengths in excess of 130 feet were required, the additional section was spliced on by welding, while the first section was held with its top about at deck level. While the majority of such spliced piles had to be held up in place, some had to be pushed down to deck level by setting the hammer on them.

The batter piles too were driven with the aid of a specially constructed piece of equipment. It consisted of a timber framework which, except for being wider and not as high, roughly resembled the tower of a piledriver. The piles however were placed for driving on the sloping side. It was lightly constructed so that it could be shifted with the floating derrick, and the desired batter for the piles could be obtained by tilting the entire framework with wedges and blocks. The framework, when in use, was supported upon the previously driven bearing piles. The piles, laid upon the sloping face, were permitted to slide under their own weight as far as they would go and were then shoved down by adding the weight of the hammer. During driving the hammer was allowed to slide down the sloping side, following the pile. Driving of the piles was done with a minimum of effort required, since the soft silt offered but little resistance to the H-piles. After fetching up on rock, a few additional blows caused the steel to penetrate the soft rock sufficiently to provide full end-bearing, without requiring that the tips be reinforced as they usually are.

Concrete was mixed and placed by a floating plant which is similar in appearance and operation to the one depicted in Figure 80. The aggregates and cement were, as usual, delivered to the site on barges. The concrete which was placed about the piling was formed by steel cylinders having bolted vertical joints to facilitate removal.

The use of steel H-piles with concrete caps, rangers, and deck was decided upon in spite of the fact that the cost was estimated to be five percent higher than alternate proposals. The deciding factors were that the structure would be incombustible and have a high degree of permanence, that the maintenance would be low, that no settlement was anticipated, and that the time required for construction would be a minimum. It yet remains to be seen whether the permanence and low maintenance will come up to expectations.

* * *

One of the ventilator shafts for the Brooklyn-Battery vehicular tunnel was founded upon bed rock by employing a novel method to sink a caisson. The method permitted such a saving in cost that, when the bids for the contract were opened, there was such a great difference between the lowest bid and the next higher that the bonding companies were reluctant to cover the job. In addition, the Tri-Borough Bridge and Tunnel Authority was reluctant to award the contract. The reason for this reluctance apparently was that they could not understand how the job could be done for so much less than the figures estimated by other well known contractors.

The result of this uncertainty was that the contract was not awarded and the job was readvertised. This time the original low bidder, using a different firm name, submitted another bid which, while it was about $500,000 higher, was still the lowest bid. After a considerable amount of conferences and rechecking, the contract was awarded.

The scheme which made this job so unusual was that, instead of floating the caisson to the site and sinking it in place, with the use of compressed air during the greater part of the time, it was sunk as an open caisson by open dredging through an artificial island. How this was done is described in the progressive order of the operations.

To prepare the site, just off Governors Island, where rock is encountered at about 70 feet below high water, the area was dredged to within 12 feet of the rock. The dredging, which included some hardpan, was performed by a large dipper dredge. The area, in the shape of an octagon 200 feet across, was then surrounded by a system of piling, both plumb and battered, which were secured together with wales and braces. Just inside of this timber piling, about 6 feet apart, a row of H-piles were driven vertically to support horizontal sheeting planks which were to be placed later. Next, around the timber piles was deposited 25,000 cubic yards of riprap, to increase their stability and to help counteract the outward pressure of the fill which was to be placed inside.

The bottom of this enclosure was then blanketed with a 10 foot layer of clay which was to serve later as a water seal for the caisson. On top of the clay, 46,000 cubic yards of sand was deposited, filling the area up to a few feet above high water. The sand itself was obtained from all over the world, since most of it came into New York Harbor as ballast in the holds of ships.

When the level of the sand attained the elevation of the top of the riprap embankment, the horizontal sheeting planks were inserted between the H-beams to serve as flash-boards and retain the sand fill.

For handling materials and for the erection of the caisson, two stiff-legged derricks were mounted on pile foundations at opposite corners of the island. Having 115 foot booms and about 30 tons capacity, they were able to cover the entire job.

The caisson itself is 51 x 111 feet, 85 feet in height, and constructed of steel bulkheads filled with 6.5 feet of concrete. It is divided into three compartments separated by two 4 foot thick concrete walls. The 6.5 foot walls extend from the cutting edge upward for 51 feet, at which point their thickness is stepped in by 18 inches. The top 10 feet of the caisson walls consist of an outer steel plate braced by steel columns and beams. The outside dimensions of the walls are kept uniform to the height of 75 feet by pouring an 18 inch layer of concrete, with welded-in-place reinforcing, around the section with the reduced wall thickness. The steel of the caisson was erected by riveting, but all of the seams in the skin plates were made water-tight by welding. Completed, the caisson weighed

2,635 tons.

To commence assembly of the caisson, the girders to which the cutting edge is fixed were set up on a system of 24-200 ton wedge jacks. The first 27 feet, weighing nearly 1,000 tons, was erected before the cutting edge was jacked down onto the sand. Water jets, to facilitate sinking, were directed at the cutting edge by 56 nozzles located around its inside perimeter.

Riveting, the limiting factor in progress, was done during the daylight hours, while excavation was carried on during the night shift. The excavation by clam-shell buckets was performed as an open dredging operation, no effort being made to pump the water level all the way down. The excavated material was deposited in bottom-dump scows for removal. Concrete, of which 80 cubic yards was required per vertical foot of caisson, was also placed during the day shift. To furnish and place the concrete, a one-yard mixer was mounted with an 8 inch pumpcrete machine on their own pile supported platform.

An old ferry-boat was obtained and utilized as a floating shop, powerplant, and supply base. On it were mounted 18-500 cubic foot compressors for riveting, and later for pneumatic caisson operations, 10-60 kilowatt generators for illuminating the night shift, and fuel oil tanks for the diesel engines operating them. Water for the jets was delivered to a 6 inch header, at 300 feet head, by 4-550 gallons per minute gas-driven centrifugal pumps mounted on the island.

The caisson was erected, concreted, and, by excavating the enclosed material, was sunk with the aid of jetting through 70 feet of sand to the surface of the underlying rock. At this point, the air deck was placed over the top of it, and thus the caisson was transformed from the open to the pneumatic type. Entering it under compressed air, the caisson was sunk an additional 7 feet into the rock where it was landed and sealed with concrete. Below the sealed caisson, the shaft is extended downward for another 63 feet, intercepting the tunnel, the axis of which is located in solid rock 115 feet below high water. This work however was part of another project.

The great cost reduction on this job was made possible by sinking a caisson of the open type for about 90 percent of the way, resorting to the expensive compressed air method for only the last 7 feet. The additional cost of creating the artificial island and excavating through it was more than counterbalanced by the great saving in labor costs.

# CHAPTER NINE

## A PROSPECTUS OF FUTURE HARBOR DEVELOPMENT

In order to successfully compete with other ports for maritime business, New York must keep abreast of the times with its harbor facilities. Criticism has been voiced in the past because business was lost by failure to do so. For example, a large percentage of the grain formerly handled by New York is now shipped, due to a lack of proper facilities in the past, out of Montreal. The Port of New York has since constructed a fine modern grain terminal, but such losses are exceedingly difficult to recover, since gains made by rival ports are zealously guarded.

Public concern has again developed during recent years lest further losses be suffered. With approximately ten percent of the population dependent, either directly or indirectly, upon the port for a livelihood, the people of the metropolitan area cannot afford to hazard their economy by risking further neglect of their prime asset, the harbor. The modern conception of a pier includes widths ranging up to 300 feet. In comparison to this, piers have been built during the past 40 years from 100 to 150 feet wide, while prior to that, piers as narrow as 40 feet were common. The congestion of present day traffic on such antiquated piers as these may well be imagined. Lack of space for the free movement of vehicles creates a bad condition that is further aggravated by insufficient cargo storage space and inadequate cargo handling machinery. The net result is a traffic jam of trucks, waiting their turn to load or unload, which extends up and down the marginal streets. The amount of time lost by trucking companies is tremendous, and the turn-around time of ships is similarly increased. The cost of these delays, incurred by both steamship lines and trucking companies, must be borne, together with a high stevedoring cost, by the shippers. These are the expenses which are sought to be avoided by discovering more accommodating port facilities.

Therefore, to protect their own interests, the various governmental agencies in the area have caused plans to be drawn up whereby the port facilities would be both rehabilitated and modernized. The task of completely overhauling the waterfront will be a tremendous undertaking. Of the city owned piers in New York, some are still in service although 70 years old. Thirty-nine piers are over 50 years old, while eighty-nine are over 40 years old. More than half of these piers are in poor physical condition in addition to being obsolete from an operating point of view. These old piers were built in the days of horse-drawn wagons and were never intended for motor vehicles at all, much less the large tractor-trailer units which now transport a large percentage of the freight to and from the docks.

In general, the harbor improvements will result in the total number of piers being reduced, the new ones being wider and farther apart. The present plans include the construction in New York of six new steamship piers, 200 to 300 feet wide, with U-shaped truck driveways, and the reconstruction of Pier 57, North River, one of the Chelsea Docks, which was destroyed by fire. In addition, four union carfloat stations and a new waterfront union produce terminal will be constructed. Approximately seventy of the existing piers will be rehabilitated and modernized. In New Jersey, four new piers are planned in Hoboken, while facilities at Port Newark will be made operative. The plans, when implemented, will require an estimated 12 years to carry out.

Work has already been commenced at Port Newark by the Port of New York Authority and, as soon as it is decided which agency of the government will carry out the program, the various projects in the overall plan will be advertised and bids will be solicited for their construction.

In order to alleviate the congested condition of street traffic and to reduce the cost of handling freight, primarily of the perishable variety, in the vicinity of the present Washington Produce Market, it is proposed to construct a large union produce terminal in Lower Manhattan. The building will be located on the North River waterfront between Piers 21 and 30. It will be 625 feet wide and 2,320 feet long, having a shedded area of 32 acres for the handling of between 500 and 600 carloads of fresh fruit and vegetables per day.

Unique in the plan for this terminal is the provision for creating the necessary space for operations outshore from the existing bulkhead line. By so doing, the acquisition of real estate, which would result in a large tax loss to the city, will be made unnecessary. Moreover, the space will be made available at a cost of about $4.30 per square foot, which is nearly one-fourth the purchase price of adjacent inland property. For space, the terminal will utilize the inboard portions

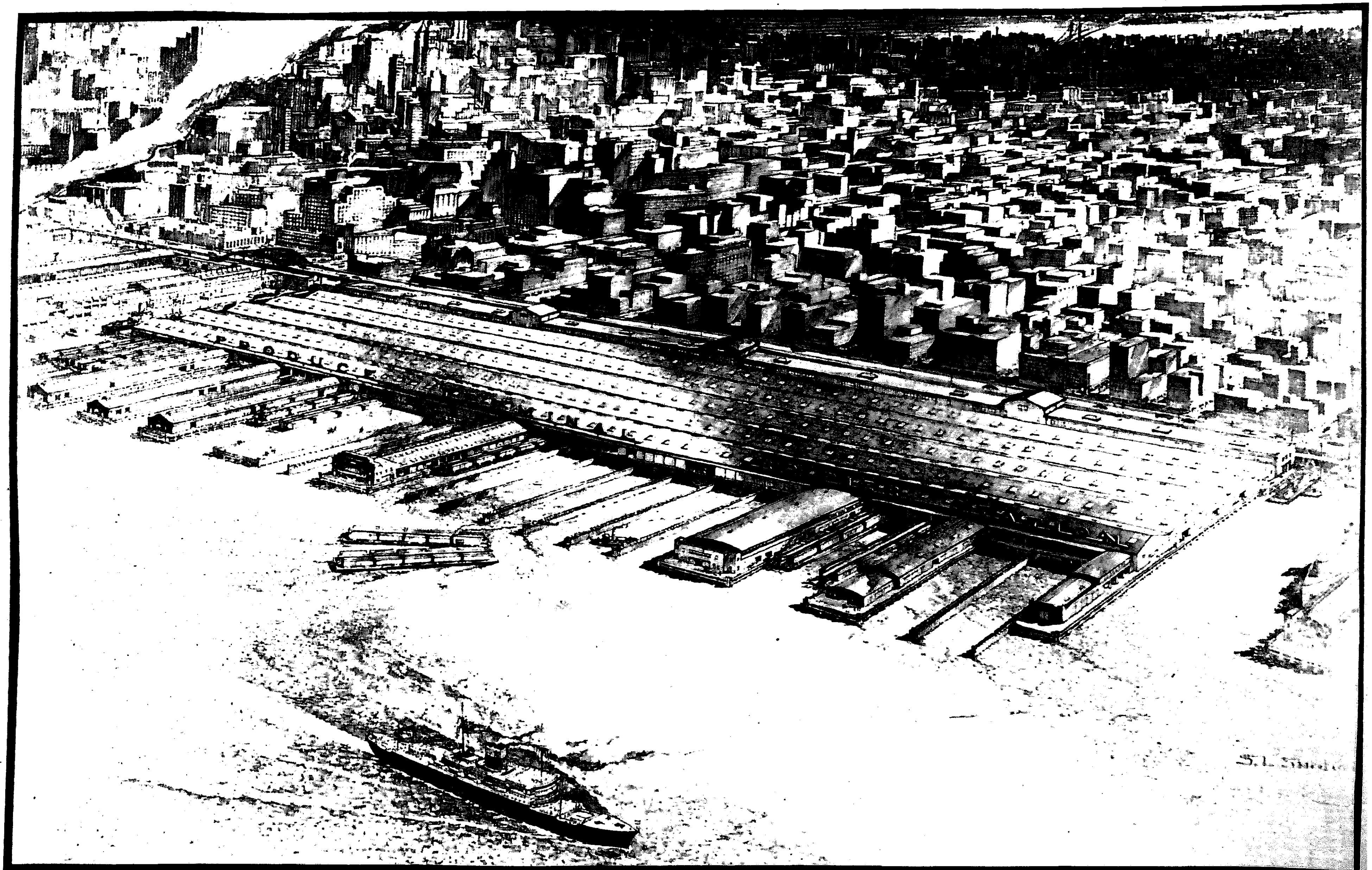


Fig. 97.- Proposed union produce terminal, Piers 22 to 30, North River.

of the piers in the area, together with additional pile supported platforms constructed in the slips between them. The outboard ends of Piers 22 and 23 will be removed, since these piers are old, narrow, and in poor condition. The outboard ends of the remaining piers, which average about 400 feet in length and are in fairly good condition, will be retained and furnished with new superstructures to serve as transit sheds.

The spaces between these outboard ends will be subdivided by pile racks to form slips for thirty-six railroad carfloats berthed head-on to the new bulkhead. The street side of the entire building will be located 40 feet west of the existing bulkhead line, thus widening the marginal street and providing off-street parking space for trucks backed up to the cargo doors of the bulkhead shed. The anticipated results of this project are more efficient and economical means for receiving and distributing great quantities of foodstuffs and relief for the most congested street traffic in the port. The estimated cost of constructing this produce terminal is $27,500,000.

Of the four proposed union railroad carfloat stations, three will be located on the North River and one on the East River. It has been estimated that, by the construction of these stations and the abandonment of the numerous other carfloat terminals operated individually by the several railroads, nearly a million square feet of waterfront space will be made available for desired pier improvements.

One will be located immediately south of the proposed produce terminal in the area now occupied by Piers 19, 20, and 21, and the Erie Railroad ferry terminal. It will extend out over the water for 625 feet and front on West Street for almost 600 feet. The projecting outboard sections of the existing structures will be retained as finger piers. From the end of Pier 19, which is shorter than the rest, a pile rack will be built 90 feet long out to the pierhead line. A rack will also be constructed in the slip between Piers 19 and 20, thereby providing berths for eight carfloats.

The shedded area, totalling 427,000 square feet, will be located 25 feet back from the existing bulkhead line, to keep parked trucks off the street, similar to the produce terminal. Office space will be provided for by a second story portion which will be 70 feet wide and 535 feet long parallel to the street. This facility, capable of handling 2,000 tons of freight per day, is estimated to require $7,000,000 for construction.

Another will be located at West Twenty-third street, occupying the space where Pier 62 and the abandoned Lackawanna Railroad ferry terminal are located. One of the old ferry slips is at present used for docking the LST's of the Trailer Ship Corporation. It will consist of a pier, 300 feet wide by 350 feet long, with two tie-up racks on each side to form four slips, or berths for a total of eight carfloats. The accompanying bulkhead shed will be an irregularly shaped structure 375 feet long, varying from 75 to 200 feet in width.

A second deck, 40 x 250 feet, for office space, will be centrally located over the bulkhead platform. This station also will have a capacity of 2,000 tons per day and provide off-street truck parking. The estimated cost of construction is $5,815,000.

A third station will be located at Thirty-third Street, replacing the two old and obsolete North River Piers 72 and 73. It will consist of a central pier 113 feet wide by 350 feet long, with two tie-up racks forming two slips on each side. Similar to the others, it will accommodate eight carfloats with a capacity of 2,000 tons per day. The bulkhead shed will be 300 feet wide and 573 feet long with second story office space 40 x 267 feet. The new bulkhead line will be 50 feet out-


Fig. 98.- Proposed union carfloat station, foot of 33rd St., North River.

shore from the existing one to keep parked trucks off the marginal street. The estimated construction cost of this station is $5,380,000.

The fourth station, on the East River, will be located at Coenties Slip, replacing Piers 4 to 8 inclusive. The construction will be similar to that of the three on the North River, having a center pier flanked on either side by two tie-up racks. The center pier will extend 350 feet from the bulkhead and for 330 feet parallel to it. The bulkhead shed will be 950 feet long, varying from 125 to 160 feet in width. The two story portion will be 40 x 250 feet and the face of the new shed will be 100 feet outshore from the existing bulkhead line.

While similar in layout, berthing eight carfloats and having a capacity of 2,000 tons per day, this station will occupy a greater area and will be able to accommodate more trucks than any of the North River stations. Its cost is estimated at $9,215,000.

Three of the new piers to be constructed will be located on the North River. The largest of these will be Pier 79, a single-deck, two-berth general cargo pier for large steamships. It will be located at West Thirty-ninth Street and will be so constructed that it will

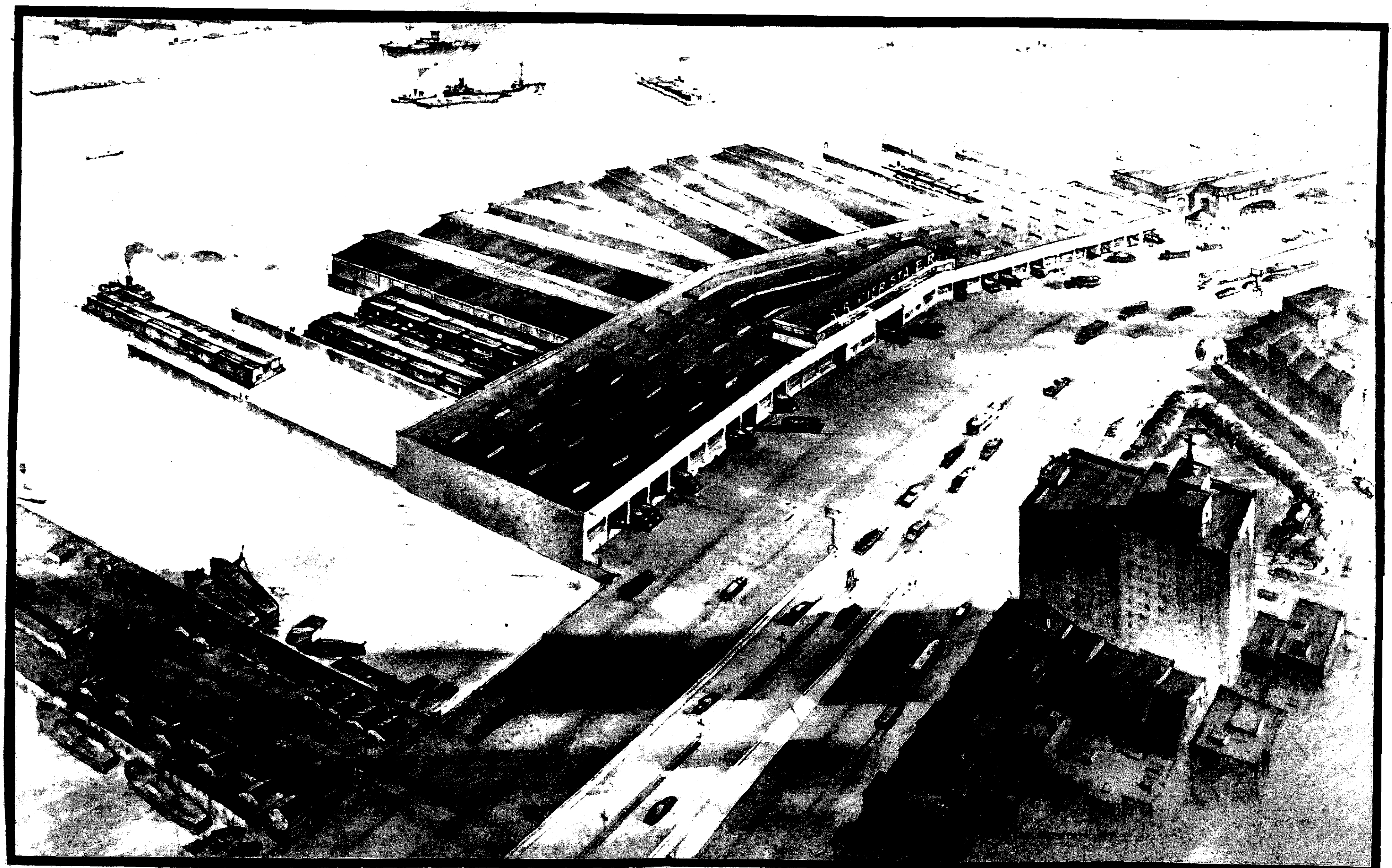


Fig. 99.- Proposed union carfloat station, foot of Coenties Slip, East River.

straddle the Lincoln Tunnel in a manner similar to that of Pier 34 over the Holland Tunnel. It will be 310 feet wide and 650 feet long, with a 280 foot wide transit shed, traversed by a 20 foot U-shaped roadway. Open platforms 15 feet wide, will extend for the length of the pier on both sides, while the pierhead will be 100 feet short of the pierhead line to permit berthing of extra lighters.

Bulkhead sheds will extend along the street on both the north and the south sides. They will be 125 x 175 feet and 85 x 112 feet respectively and a second story portion, 70 feet wide, will extend over the entire length. The slips to the north and south will be 515 and 505 feet long respectively, and to obtain the necessary space, the old Piers 78 and 80 will be removed. This pier will cost an estimated $6,354,000 to construct.

Two more old piers, 40 and 41, will be removed to make way for new Pier 40, North River. This pier also will be a single-deck two-berth pier, designed for coastwise shipping. It will be 200 feet wide by 945 feet long and, like new Pier 79, will have 15 foot open platforms for the full length on both sides. The bulkhead sheds will be set back from the front of existing buildings for the relief of street traffic, while a wide roadway will traverse the pier itself. Bulkhead sheds on either side of the pier will be 100 feet wide by 140 feet long, parallel to the street. A second deck, 70 feet wide will extend the full 480 feet across the bulkhead sheds. To construct this facility will cost an estimated $5,715,000.

By removing two more old piers, 36, and 37, the necessary space for new Pier 36, North River will be obtained. This will be a double-deck pier for large steamships. It will be 200 feet wide by 1,025 feet long and will have accompanying bulkhead sheds, 65 feet wide, extending 95 feet to the north and 145 feet to the south. These sheds will also have a second story for office space. Open platforms, 15 feet wide, will extend along both sides, as on the other piers, and a 20 foot wide roadway, with a separate entrance and exit, will accommodate trucking. This pier is estimated to cost $8,473,000.

Two of the proposed new piers will be located on the East River. Pier 37 will be a single-deck pier, 240 feet wide by 373 feet long, and old Pier 36 will have to be removed to make room for the slip on the west side. Similar to the new North River piers, 15 foot platforms will extend full length on both sides and 20 foot roadways will serve the truck traffic. The bulkhead sheds, two story and 50 feet wide, will extend 100 feet to the west and 225 to the east. This pier, designed for medium-sized cargo ships, will cost an estimated $1,903,000 to construct.

At Old Slip, on the East River, new Pier 9 will be constructed. It will be a single-deck general cargo pier, 338 feet wide by 550 feet long. Old Pier 11 will be removed to clear the way for the slip on the east side, and the new bulkhead line will be 75 feet outshore from the existing one. The marginal platforms and truck roadways will be similar to those of the other new piers and the bulkhead shed will have a second deck. The estimated cost of this pier is $3,540,000.

The sixth new pier will be constructed on the site of the old ferry slips at Atlantic Avenue in Brooklyn. It will be 170 feet wide by 945 feet in length, having two decks and berthing space for three ships. A ramp will provide truck access direct to the upper deck. Like the rest, a 15 foot platform will extend along the sides while a 20 foot U-shaped roadway will traverse the lower deck. This pier, a combination passenger and general cargo pier, is estimated to cost $6,662,000.

In order to facilitate cargo handling and relieve street traffic congestion, it is further proposed to

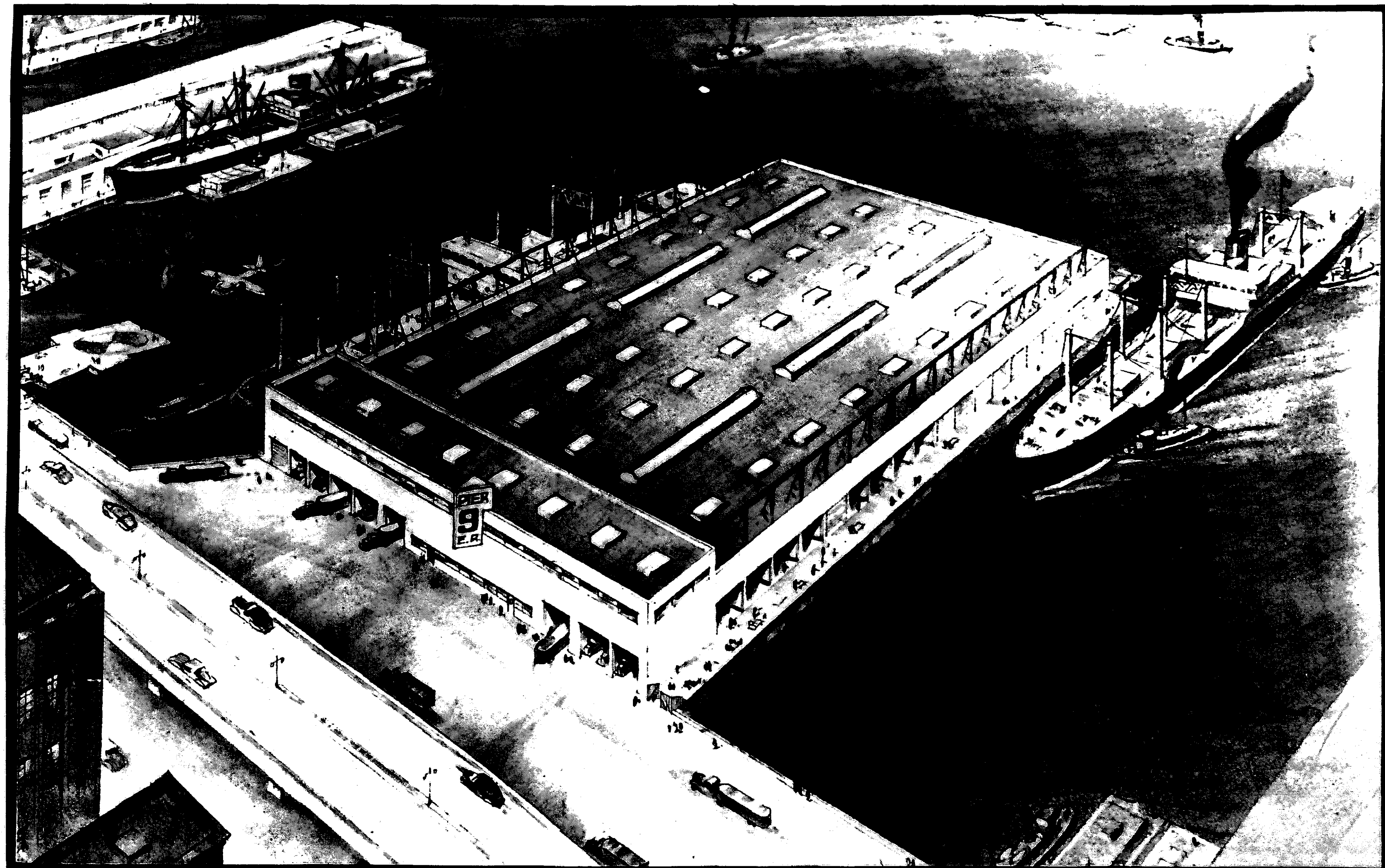



Fig. 100.- Proposed new Pier 9, foot of Old Slip, East River.

rehabilitate and modernize certain other piers, fourteen in number. Substantial improvements will be made in cargo handling equipment, including the installation of new hoists and hatches. Up to date freight elevators and passenger escalators will be installed, and entrances and stairways will be remodeled. Bulkhead sheds will also be remodeled to permit truck parking inside the building line thereby leaving the streets free.

In addition, a program of repair will be commenced. Deteriorated substructures and fender systems will be restored, while roofing, paint work, electrical facilities, and plumbing will be overhauled. Particular emphasis will be placed on fire fighting facilities such as standpipes, sprinkler systems, roof monitors, hose reels, and openings in the deck to insert revolving nozzles for substructure fires beneath the deck. Fire protection measures will also be included. Fire-stops will be located at regular intervals, extending from the deck to low-water. Fire-stops will also be located, at 100 foot intervals, on the roof trusses, extending from the lower chords to the roof itself.

The program anticipates that, in the future, the trend will be from the use of timber to that of steel and concrete for substructures. This trend, it is believed, will result not only because of the fire resistant qualities of the materials, but in recognition of the possibility that marine borers may some day invade the harbor. The foregoing rehabilitation and modernization involves thirty-seven Manhattan piers on the North River, twelve on the East River, six in Brooklyn, thirteen on Staten Island, one in the Bronx, and one in Queens, with an estimated expenditure of $27,152,000.

In New Jersey it is proposed to construct four modern piers for large steamships on the Hoboken waterfront. Each will be 300 x 1,000 feet, double-deck, and provided with ramps for direct truck access to the upper levels. They will be located north of the Lackawanna Railroad terminal, extending over the area formerly occupied by Pier 4 which was destroyed by fire.

At Port Newark, it is proposed to construct two new transit sheds, 200 x 400 feet, reconstruct 525 lineal feet of marginal relieving platform, to restore the fender system, and to renew and reset the necessary mooring devices around the entire channel bulkhead.

* * *

In a plan of longer range other improvements are contemplated, especially on the Manhattan waterfront. On the North River alone it is probable that eventually many of the older piers will be removed to make way for fewer and wider piers and wider slips. The numerous privately owned carfloat stations, which by then should be abandoned, will also be removed, as will most of the float bridges now in operation. According to tentative schemes, about twenty-eight old North River piers will be replaced by about fourteen new ones. This will be in addition to those already described in previous paragraphs. Similarly on the East River, about twenty old piers will give way to ten new ones, while at Thirty-ninth Street, Brooklyn, an old pier and adjacent ferry slips will give way to a large modern pier.

Future plans for the Port of New York also include the removal and modification of all bridge obstructions, to provide a clearance of 135 feet above high-water through all of the harbor waterways. It is also planned that ultimately all ferry terminals and float bridges will be eliminated, making room for additional piers. To accomplish this, it is contemplated that all traffic, both passenger and freight, will be transported to the various parts of the harbor, separated by water, by means of tunnels. The Hudson and Manhattan Railroad and the Pennsylvania Railroad tunnels together with the Holland and Lincoln vehicular tunnels, are the pioneers toward this end under the North River.

Railroad freight may some day be carried between New Jersey and New York, without the use of carfloats and float bridges, by means of a deep tunnel which would reach Manhattan near the Battery. This line would be a branch of a marginal belt railroad which would run parallel to the Jersey waterfront, intercepting the various trunk lines and carrying their freight southward to the tunnel and to Staten Island. From the Battery, at a deep elevation, the tunnel would run parallel to the North River, with sidings and elevators for moving freight to the surface, and connections with the New York Central freight lines. Another branch, would extend under the East River to Long Island, where the line would emerge from underground. Thus the New Jersey waterfront, which is largely occupied by railroad terminal yards, could be made available for steamship piers or such industrial plants as might find a tidewater location desirable for receiving raw materials and exporting by ship.

Another remotely possible development of the harbor concerns an area of shoal water located south of Governors Island and west of Long Island, together with a similar area east of the Jersey shore, extending southward from Bedloes Island. It is conceivable that, with additional increases in the already high values of real estate in Manhattan and Jersey City, it might become economically possible to reclaim these areas by creating artificial land. This could be done easily enough by filling in behind a retaining bulkhead wall, as has already been accomplished in numerous locations on a smaller scale.

Other than the proposed projects which will benefit the port when constructed, there are factors which may have an adverse effect upon it. There is the possibility that the St. Lawrence Seaway, which has been urged by upstate interests, may some day be constructed. This would enable seagoing ships to enter the Great Lakes area and bypass the New York docks.

Another factor affecting the economy of the port is labor. Should the time come, when the cost of handling freight in the metropolitan area becomes excessive, shippers and shipping lines will divert their traffic and find another port where better facilities and cheaper operation costs are to be found. This last item is a most important one, and the purpose of the program previously outlined is to reduce to the lowest practical point the costs of port operations.

# GLOSSARY

Alluvium - Gravel, sand, or silt deposited during flood stages by a stream which has overflowed its banks.

Armature plate - Protective metal plate, usually half inch wrought iron, placed at the corners of bridge pier fenders and around the outboard pile bents of timber piers.

Archeozoic Era - Era of ancient life, derived from Greek: archaios meaning ancient and zoe meaning life.

Basalt - Dark, basic lava containing a predominance of iron, magnesium, and lime.

Batter - Deviation from vertical. Descriptive of piles driven at a slant.

Berm - An artificial bank of earth or riprap, usually level on top and having a sloping side.

Beton - The French word for concrete, hence concrete made with lime and cement after the French manner.

Beton en masse - Mass concrete, poured into a wet caisson and sunk to rest upon a prepared foundation.

Biotite - Black mica, a silicate containing potassium, magnesium, iron, and aluminum.

Boil - Water flowing upward through sand as in a spring or quicksand.

Boom - The timber or steel mast of a derrick which, pivoted at its base, may be raised, lowered, or swung, having the fall lines for hoisting reeved at its upper end.

Bulkhead - When referring to a waterfront structure, a retaining wall constructed parallel to navigable waters which may be used also as a quay.

Bulkhead line - The line established by the Federal Government beyond which bulkheads and solid-filled piers may not extend.

Burn - To cut iron or steel with an oxy-acetylene torch.

Cambrian Period - Period during which rocks of the series first studied in Cambria, the Roman name for Wales, were formed.

Carboniferous Age - Age of great coal forming, namely the Pennsylvanian and Mississippian Periods.

Cenozoic Era - Era of recent life, derived from Greek: kainos meaning recent and zoe meaning life.

Cleavage - The manner in which certain rocks and minerals fracture along plane surfaces.

Combing - Vertical side boards constructed around hatches and the pockets of dump scows, in the latter case to increase the capacity of the scow.

Conformity - Parallel rock strata formed in an uninterrupted series having no intervening period of erosion.

Conglomerate - Rock composed of firmly cemented particles of sand and gravel.

Coniferous - Descriptive of trees of the cone bearing variety.

Cornbury Charter - Charter granted to the City of New York in 1708, named after Lord Cornbury, the governor of New York from 1702 to 1708.

Cretaceous Period - Period of great chalk making, derived from Latin: creta meaning chalk.

Cryptozoic Eon - Eon of hidden (with reference to fossils) life, derived from Greek: kryptos meaning hidden and zoe meaning life.

Deciduous - Descriptive of trees of the broad leaved variety.

Derrick - A machine, including engines, boom, and rigging necessary for hoisting.

Devonian Period - Period during which rocks of the series first studied in Devonshire, southwest England, were formed.

Diabase - Basalt of a decidedly basic character.

Dike - A tabular mass of igneous rock that fills a crevice in older rocks, cutting the strata, where stratification exists, at an angle.

Diorite - Igneous rock of feldspar and dark minerals but without quartz.

Dip - The angle of inclination of a rock stratum measured from the horizontal.

Disconformity - A series of parallel strata the formation of which was interrupted by a period of erosion.

Dolomite - A variety of limestone composed chiefly of calcium-magnesium carbonates.

Dolphin - A group of piles, the heads of which are fastened together.

Dongan Charter - Charter granted to the City of New York in 1686, named after Col. Thomas Dongan, the governor of New York from 1683 to 1688.

Draft - With reference to ships and other vessels, the distance from the waterline to the under side of the keel.

Eocene Epoch - Dawn period of the recent era, derived from Greek: eos meaning dawn and kainos meaning recent.

Erosion - Weathering or wearing away of rock or soil due to the action of wind, water, frost, or other natural elements.

Fair-lead - Guide for a fall line located between the hoisting engine and the boom sheaves.

Fall - Line wound around the drum of a hoisting engine and reeved through pulleys for the purpose of making heavy lifts.

Falsework - Temporary construction required to facilitate the erection of a permanent structure.

Fault - A fracture of rock where displacement parallel to the plane of the break has taken place.

Feldspar - A mineral containing silicon, aluminum, and either potassium and sodium and calcium.

Ferrous - Pertaining to iron or steel and their alloys.

Fill - To bring an area up to a desired elevation by introducing material transported from another location, or the material so used.

Foliation - Parallel arrangement of minerals within rock formations.

Fossil - Petrified form of a plant or an animal, especially one of prehistoric origin preserved in rock.

Free air - Uncompressed air at its natural pressure.

Free board - Distance measured on a ship or other vessel from the deck to the water line.

Gantry - A structure supporting a crane and capable of moving about while straddling roadways, railroad tracks, and so forth.

Gib-screw - Screw that is used to hold an object in place.

Glaciation - The act or result of overspreading with or erosion by glacial ice.

Gneiss - (Pronounced nice) A type of rock resulting from the metamorphosis of granite or conglomerate.

Granite - A hard rock composed of feldspar, quartz, and mica.

Granodiorite - Metamorphic diorite of granitic nature.

Groin - Short jetty built out from the shore, usually perpendicular to the flow of the littoral currents, for the purpose of preventing beach erosion.

Harbor - A sheltered expanse of water in which ships may be launched, repaired, or anchored in refuge from a storm.

Hardpan - A firm stratum of rock, gravel, or compacted sand or clay lying underneath a soft penetrable stratum.

Hatch - An opening in a deck or roof.

Igneous - Formed by the melting or fusing action of subterranean heat.

Interlocks - Ball and socket joints extending along the edges of steel sheet-pile units for the purpose of holding one pile to another.

Jurassic Period - Period during which rocks of the series first studied in the Jura Mountains of France and Switzerland were formed.

Littoral - Pertaining to the shore or beach.

LST - Abbreviated designation of a naval landing craft known as a landing ship, tank.

Marl - A clayey soil containing a considerable amount of calcium carbonate.

Mean - Average.

Mesozoic Era - Era of middle life, derived from Greek; mesos meaning middle and zoe meaning life.

Metamorphic - Descriptive of rocks that have had their original character greatly changed by temperature, pressure, or other factors acting within the Earth.

Mica - A mineral having perfect cleavage, the flakes of which are elastic. It is composed of silicon, aluminum, potassium, and sometimes also iron and magnesium.

Miocene Epoch - A less recent period of the recent era, derived from Greek: meion meaning less and kainos meaning recent.

Mole - A breakwater so constructed that its inner side may be utilized as a wharf.

Monitor - A nozzle for fire fighting mounted on the roof of a pier shed so that a stream of water may be turned in any direction.

Monolithic - Descriptive of concrete that is poured in one block without construction joints.

Montgomerie Charter - Charter granted to the City of New York in 1730, named after John Montgomerie, the governor of New York from 1729 to 1731.

Oligocene Epoch - An early period of the recent era, derived from Greek: oligos meaning little and kainos meaning recent.

Ordovician Period - A period of the Paleozoic Era, derived from Latin: ordino meaning order and vix meaning change.

Outcrop - Rock exposed to view by the process of erosion.

Overburden - Rock fragments, gravel, sand, clay, or silt that may lie superimposed upon bedrock.

Paleocene Epoch - The oldest period of the recent era, derived from Greek: palaios meaning ancient and kainos meaning recent.

Paleozoic Era - Era of ancient life, derived from Greek: palaios meaning ancient and zoe meaning life.

Pegmatite - Granite having very large crystals.

Peneplain - A formerly mountainous region eroded down to low relief.

Pennant - A cable extending from the tip of the boom of a derrick, and terminating with a sheave or sheaves, to shorten the length of wire rope required for the boom fall or guys.

Permian Period - Period during which rocks of the series first studied in Perm, a province on the western slope of the Ural Mountains, were formed.

Phanerozoic Eon - Eon of visible (referring to fossils) life, derived from Greek: phaneros meaning visible and zoe meaning life.

Pier - A wharf which projects from the into navigable waters.

Pierhead - The outshore end of a pier.

Pierhead line - The line established in navigable waters by the Federal Government beyond which waterfront structures may not extend.

Plant - General term for construction equipment.

Pleistocene Epoch - The most recent period of the Cenozoic Era during which the great glaciers appeared, derived from Greek: pleion meaning most and kainos meaning recent.

Pliocene Epoch - A recent period of the Cenozoic Era, derived from Greek: pleion meaning more and kainos meaning recent.

Plumb - Perpendicular to the horizontal.

Point - To repair masonry by removing loose mortar from joints and refilling them with new.

Port - A harbor which has been improved by the construction of terminal facilities.

Proterozoic Era - Era of first life, derived from Greek: proto meaning first and zoe meaning life.

Quartz - A mineral composed of silicon dioxide.

Quartzite - A metamorphic rock, originally sandstone, in which the quartz grains are so firmly cemented that fracture takes place through them rather than around them.

Quay - A marginal wharf constructed parallel to the shore.

Rack - A structure against which vessels may be moored but across which no cargo or passengers are transferred.

Riprap - Broken stone, in pieces varying from 10 to 150 pounds each, placed upon earth surfaces for protection against erosion, to improve the footing for piles, and so forth.

Sandstone - A sedimentary rock formed by the cementation of grains of sand.

Schist - A metamorphic rock having well developed and closely spaced foliation. Manhattan Schist is a mica schist transformed from shale into a dark crystalline rock containing flakes of mica.

Section modulus - Index to the strength of a beam; the ratio of its moment of inertia to the distance from its neutral axis to its extreme fiber.

Sedimentary rock - Rock formed by the compression and cementation of the sediment carried by streams and deposited upon the floor of the ocean or upon that of their own flood plain.

Serpentine - A soft metamorphic rock with a dark greenish hue and without cleavage.

Shackle - A U-shaped piece of steel having eyes at each end through which is passed a bolt.

Shaft - A well-like excavation connected with a tunnel both to ventilate it and to facilitate the removal of material during its construction.

Shale - A sedimentary rock of laminated structure formed by the compression and hardening of silts and clays.

Sheave - Grooved pulley wheel for changing the direction of the pull of a rope.

Sheathing - (Sometimes also called sheeting) Timbers fastened to the sides of wharves as part of their fender systems.

Sheeting - Vertical pieces of timber, steel, or concrete placed to retain material as in a cofferdam or in a bulkhead wall.

Shore - A prop or temporary support for a structure.

Silicon - A chemical common to a large percentage of the minerals composing the Earth.

Sill - A tabular mass of igneous rock lying between the parallel strata of older sedimentary rock.

Silt - Very fine earthy sediment carried and deposited by water.

Silurian Period - Period during which rocks of the series first studied in the region occupied by the Silures, a name for the ancient Celts, were formed.

Skip-bucket - A bucket which can be overturned and dumped by tripping a lever.

Slip - The area of water between two adjacent piers.

Strain - To put tension in a rope or cable.

Striated - Scratched and grooved. Said rocks so marked by the passage of a glacier.

Strongback - A device employed in hoisting a non-rigid load, consisting of a beam suspended from the fall line and having supports for the load spaced along its full length.

Subsoil - The soil upon which foundations rest and into which piles are driven.

Substructure - That portion of a structure below and including the deck.

Superstructure - That portion of a structure above and excluding the deck.

Surcharge - Additional load, such as railroad tracks or piles of coal, upon the earth fill behind a bulkhead wall.

Tackle - The lines, pulley-blocks, and rigging necessary for hoisting.

Till - Material, both heterogeneous and unstratified, deposited by a receding glacier.

Toggle - A pin or bar used to engage a hole or a slot for the purpose of securing two objects together.

Tongue and groove - Desciptive of the edges of certain timber sheeting and form lumber which is made with a projecting strip on one side which fits into a corresponding groove in the edge of the adjoining piece.

Transit shed - The superstructure of a wharf built to shelter merchandise and passengers during transit.

Treenail - A wooden dowel, usually of oak or locust and varying in size up to 3 by 48 inches, formerly used as fasteners in timber wharf construction.

Tremolite - A mineral composed of calcium and magnesium silicates, often occurring where dolomites have been altered by metamorphism.

Triassic Period - Period during which rocks of a three-fold series first studied in Germany were formed.

Truss - A structure composed of straight members arranged to form a series of adjoining triangles lying in the same plane.

Unconformity - Two series of rock the formation of which was interrupted not only by a period of erosion, but also by a movement of the Earth's crust, so that the strata are not parallel.

Varved - Banded. A varved clay is one formed by seasonal deposits over many years, so that seasons are indicated by the horizontal bands.

Wale - A horizontal beam braced against piling, sheeting, or form studs to hold them in place. In the former cases a wale may serve as a medium for holding bolts and spikes.

Wharf - Any landing place or platform, built either parallel to the shore or projecting out into the water, at which vessels can transfer cargo or passengers.

Whip - A single part hoisting line of a derrick or a piledriver.

Winch - A machine employed to create tension in a rope or line.

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