Introduction to Production Processes

and Facilities in the Steel Shipbuilding

and Rpair- Industry

U.S. DEPARTMENT OF THE NAVY
DAVID TAYLOR RESEARCH CENTER

in cooperation with

National Steel and Shipbuilding Company
San Diego, California

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **FEB 1993**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE
Introduction to Production Processes and Facilities in the Steel Shipbuilding and Repair - Industry

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center CD Code 2230-Design Integration Tools Bldg 192, Room 128 9500 MacArthur Blvd, Bethesda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**87**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Introduction to Production Processes and Facilities in the Steel Shipbuilding and Repair Industry

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For:
National Shipbuilding Research Program (NSRP)
Facilities and Environmental Effects Panel SP-1

February 1993

EXECUTIVE SUMMARY

This report is provided as a supplement to the Environmental Best Management Practices project paper #0353 task #Nl-89-3 published in July 1992. The SP-I Panel, Facilities and Environmental Effects, agreed that this report would be a good addition to the Best Management Practices Project at the January 1991 Panel Meeting in New Orleans LA.

The intended purpose of this report is to serve as an introduction to the steel shipbuilding and repair industries production processes and facilities. The target audiences for this report are environmental regulators, new employees, and others not versed in shipbuilding and repair processes and facilities.

The processes and facilities described in this manual are generic in nature. The manual will provide the introductory reader a general understanding of how the facilities and production operations function in the shipyard.

Basic research for this manual was performed at NASSCO. Information about various shipbuilding facilities and processes was solicited from various shipyards throughout the nation.

FOREWORD

This report is not meant to be an extensive listing and description of shipbuilding methods and processes. Only the major facilities and processes have been included. Many shipyards will have an assortment of small facilities and processes that are not mentioned in this book. Many of the facilities and processes described in this manual may not be found at every shipyard. Also, some, of the facilities and processes that are required for shipbuilding and repair may be found at a subcontractors facility who performs the work for the shipyard.

Chapter 1 provides a generic introduction to the United States steel shipbuilding and repair industry. A basic introduction to current shipbuilding and repair processes is provided for the reader as well as a basis introduction to the facilities that help support the shipyard.

Shipyard docking facilities are introduced in chapter 2. Docking facilities are a very important aspect to any shipyard. Shipyards industrial capabilities are often evaluated based on the quantity, size, and type of docking facilities they possess. This chapter provides an introduction to the construction and operation of floating drydocks, graving docks, shipbuilding ways and other docking facilities.

Shipbuilding and ship repair have much in common, especially with its processes, facilities, support shops and support services. Chapter 3 provides an introduction the basic processes, shops and facilities found in the shipyard. A description of the current Unit and Block outfitting methods for construction ships and introduces ship repair process is also supplied.

The marine environment has detrimental effects on nearly all ships and shipboard components. Corrosion and deterioration are a continual problem in the open air salt water environment as well as in many tanks on-board ships that contain materials such as fuel oils, fuel, septic, and other corrosive substances. Therefore, proper surface preparation and coating is essential in the shipbuilding industry to preserve the life of their products. Chapter 4. describes the shipyard surface contaminants, standards, and a variety of surface preparation techniques. Chapter 4. also provides an introduction to coating systems, paint application equipment, and painting processes throughout the shipyard.

For the purpose of this report, the engineering and planning processes have not been included. Engineering and planning processes are very important to the success of any shipyard. In brief, Engineering includes designing the ship from the hull to the smokestack and assisting production with drawings and technical direction. Planning is the process of scheduling production labor, facilities, materials, engineering, and other shipyard activities to produce or repair ships.

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Introduction to Steel Shipbuilding and Repair

Introduction to Steel Shipbuilding and Repair:

The shipbuilding industry is centuries old and, like most other industries, its manufacturing techniques have changed considerably with time. Changes are the result of variables such as material types, vessel design, ship sizes, market needs, and manufacturing technology.

The shipbuilding industry provides construction and repair of ships, offshore structures, boilers, and other large steel structures that are exposed to the marine environment. The industry has undergone major changes in recent years. The changes have occurred for numerous reasons such as reduced Navy contracts, and increased competition for commercial shipbuilding. Customers of shipyards include small private owners, large companies, and the U.S. Government. Contracts for various shipyard work generally involve a project bidding process similar to those used in most major construction projects. A repair or new construction contract is put up for bid and several shipyards submit proposals to perform the work.

1.1 U.S. Shipbuilding And Repair Industry:

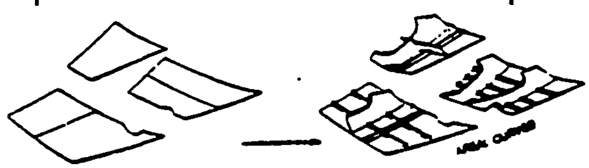
The U.S. policy towards shipbuilding and repair appears to be to maintain an industrial base capable of expansion in times of war or threat of war. In an effort to change this, several U.S. shipbuilders have embarked on a course of increasing productivity through improved management and technology. Many quality control programs have been initiated in the shipyards, with an emphasis on efficiency. Improvement in the next decade will determine the future of the American Shipbuilding and Repair Industry.

The American Shipbuilding and Repair Industry consists of approximately 250 private and eight Naval shipyards. The Naval shipyards mainly perform ship repair, conversions, and overhauls. Of the 250 private shipyards, approximately two dozen employ 70% of the shipbuilding workforce. The ship repair industry consists of more than 200 yards of varying size and capacities. Approximately 70 private repair yards are capable of drydocking vessels of 300 feet or larger. Many smaller yards exist which do not have large drydocking facilities. These yards are sometimes referred to as topside yards. These topside yards perform a variety of work on the superstructure and internal structures of ships.

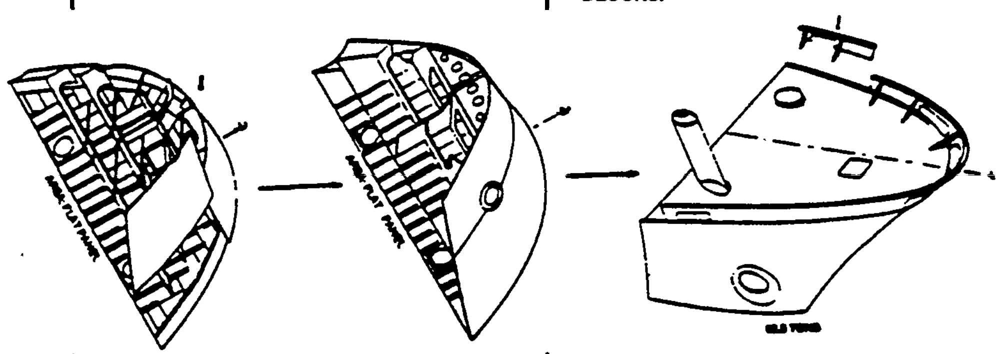
1.2 Introduction to Current Steel Shipbuilding Processes:

Once a new construction contract is awarded and most of the detailed design and production planning are performed, actual construction can begin. To understand the shipbuilding process, shipbuilding can be broken up into five general manufacturing levels. Figure 1.1 outlines the general manufacturing levels involved in the shipbuilding process. The **first level** involves transforming the raw materials (i.e. steel plates, steel bars, pipes, sheet metal, electrical, etc.) into parts. Therefore purchasing, handling, and production of these raw materials and parts comprise the first level of manufacturing ships. The **second level** involves joining the parts and steel members into subsections and sub-assemblies. The sub-assemblies of steel, pipe, venting, electrical and other outfitting are brought together to create the **third level** of ship construction. The third manufacturing level yields what are known as the hull blocks or units. These large blocks are transported through the shipyard and finally joined together onboard the ship. This procedure is the **fourth level** of ship manufacture, known as erection. Erection is performed in one of the shipyard building positions and involves assembling the blocks together to form the ship. The **fifth level** of shipbuilding involves the final installation, completion, and testing of internal mechanisms and systems before the ship can be delivered to the owner. Shipbuilding construction methods will be discussed in more detail in Chapter 3.

LEVEL #1	PURCHASING AND PRE-ASSEMBLY	A) PURCHASING OF RAW MATERIALS, B) TRANSFORMING THE MATERIALS INTO PARTS. (i.e., PLATE STEEL INTO SHAPES AND PIPE INTO PIPE SPOOLS)
LEVEL #2	SUB-ASSEMBLY	JOINING THOSE PARTS PRODUCED AT LEVEL #1 INTO LARGER SUB-ASSEMBLIES.



LEVEL #3	ASSEMBLY AND OUTFITTING	JOINING PARTS AND SUB-ASSEMBLIES TOGETHER TO FORM LARGE SECTION OF THE SHIP CALLED HULL BLOCKS.



LEVEL #4	ERECTION	INSTALLATION OF THE HULL BLOCK ONTO THE SHIP UNDER CONSTRUCTION, THUS THE SHIP IN BEING ERECTED.
LEVEL 3%	SYSTEM COMPLETION AND TEST AND TRIAL	SYSTEMS ON THE SHIP (i.e., ELECTRICAL, HEATING AND VENTILATION, PLUMBING, ETC.) ARE CONNECTED TOGETHER, TESTED, AND TESTED BEFORE DELIVERY TO THE CUSTOMER.

Figure 1.1: General Manufacturing Levels of Steel Shipbuilding

1.3 Introduction to the Steel Ship Repair Processes:

The ship repair process operates much like the shipbuilding process although, due to the variety of ship repair work, specific methods will vary from job-to-job. The ship owner sends out a Request for Proposal (RFP) and the shipyard responds with a proposal for the repair contract. Repair contracts involve overhauling engines, resurfacing the hull and superstructure, installing new electronics, and other repair and maintenance items. Ship repair contracts can last anywhere from one day to over a year, depending on the complexity of the job. Repair contracts are generally under severe time constraints and prompt delivery is very important. Failure to deliver a repair ship on time can result in expensive fines for the shipyard. Repair activities tend to be cyclic, therefore the workforce will experience surges in workload, making shipyard management difficult. Therefore, subcontractors are used for repair activities in the shipyard to help even out the manning.

1.4 U.S. Shipyard Facilities:

U.S. shipyard facilities have undergone several changes and modifications throughout their existence, therefore there is no one typical shipyard facilities layout. Most U.S. shipyards have been constructed in a piecemeal pattern, adding land and facilities as needed wherever space was available. Shops and facilities that are of major importance to the shipyard include, but are not limited to the following:

- Drydocking Facilities
- Shipbuilding Positions
- Piers and Berthing Positions
- Work Shops:
  - Sheetmetal Shop
  - Steel Assembly Shop
  - Pipe Shop
  - Machine Shop
  - Carpenter Shop
  - Maintenance Shop
  - Electric Shop
  - Boiler Shop
  - Paint and Blast Shops
- Work Areas
  - Steel Storage Area
  - Platen lines
  - On-Unit Construction
  - On-Block Construction
  - On-Board Construction
- Other Office Buildings:
  - Materials Warehouses
  - Engineering, Planning
  - Administration, Medical, Safety, Environmental
  - Security

1.5 The Shipbuilding and Repair Workforce:

The shipbuilding and repair industry requires a large reservoir of talented workers; the tradesmen are crucial to the success of a shipyard. Shipyard trades include but are not limited to the following:

- Ventilation Mechanics
- Blasters
- Boiler Makers
- Carpenters
- Chippers/Grinders
- Electricians
- Joiners
- Maintenance Mechanics
- Pattern Makers
- Pipefitters
- Riggers
- Shipwrights
- Burners/Tackers
- Sheetmetal Mechanics
- Shipfitters
- Painters

Figure 1.2: The American shipbuilding workforce is the backbone of the industry. They are highly skilled, craftsman-oriented group that provides high quality ship construction and repair.

The shipbuilding and repair industry is very labor intensive when compared to other manufacturing industries and requires a well trained and craftsmen-oriented workforce. Private shipyards experience frequent shortages of skilled labor. Labor shortages are mainly due to low wages, high labor turnover (layoffs and resignations), and instability of workload. Therefore, many shipyards have training programs for ail trades in the shipyard. These training programs are expensive to upkeep, but are an attempt by the shipyard to maintain a skilled and productive workforce. During periods when workload is reduced, shipyards are forced to lay-off skilled workers. In many cases, these workers transfer their skills to another industry or shipyard which presently has work. Many positions in the shipyard require from 3 to 6 years of training and experience. Therefore, when shipyards lose these highly skilled employees, short-term training programs cannot adequately provide the level of skills that is needed. A backlog of orders to keep skilled workers in the shipyard and continual development of newly skilled workers is necessary to keep American shipbuilding alive, and to continue its long tradition.

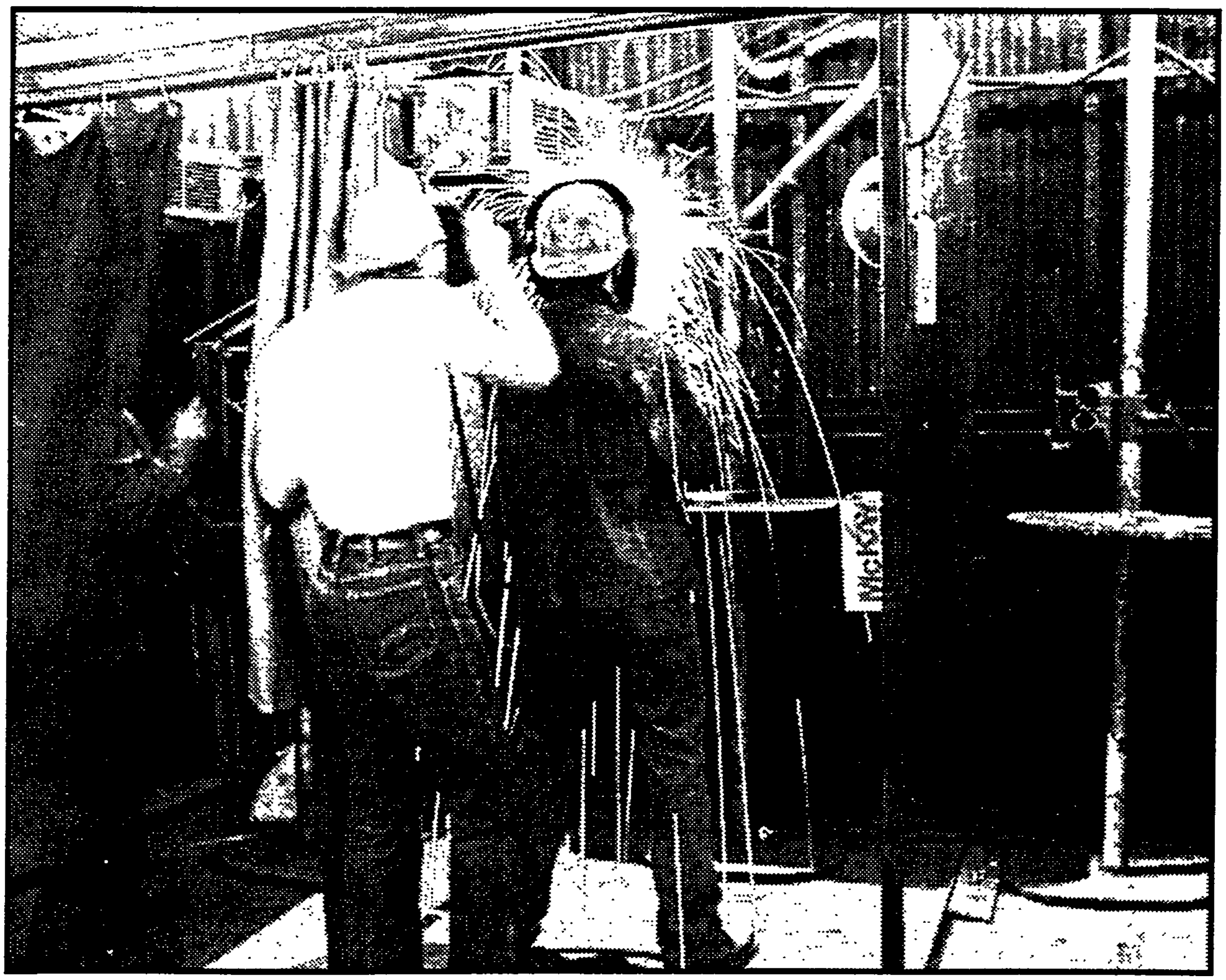


Figure 1.3.a: Trainees spend many hours in performing hand-on training, developing skills needed to build high quality ships. The figure displays a welding trainee learning how to arc weld.

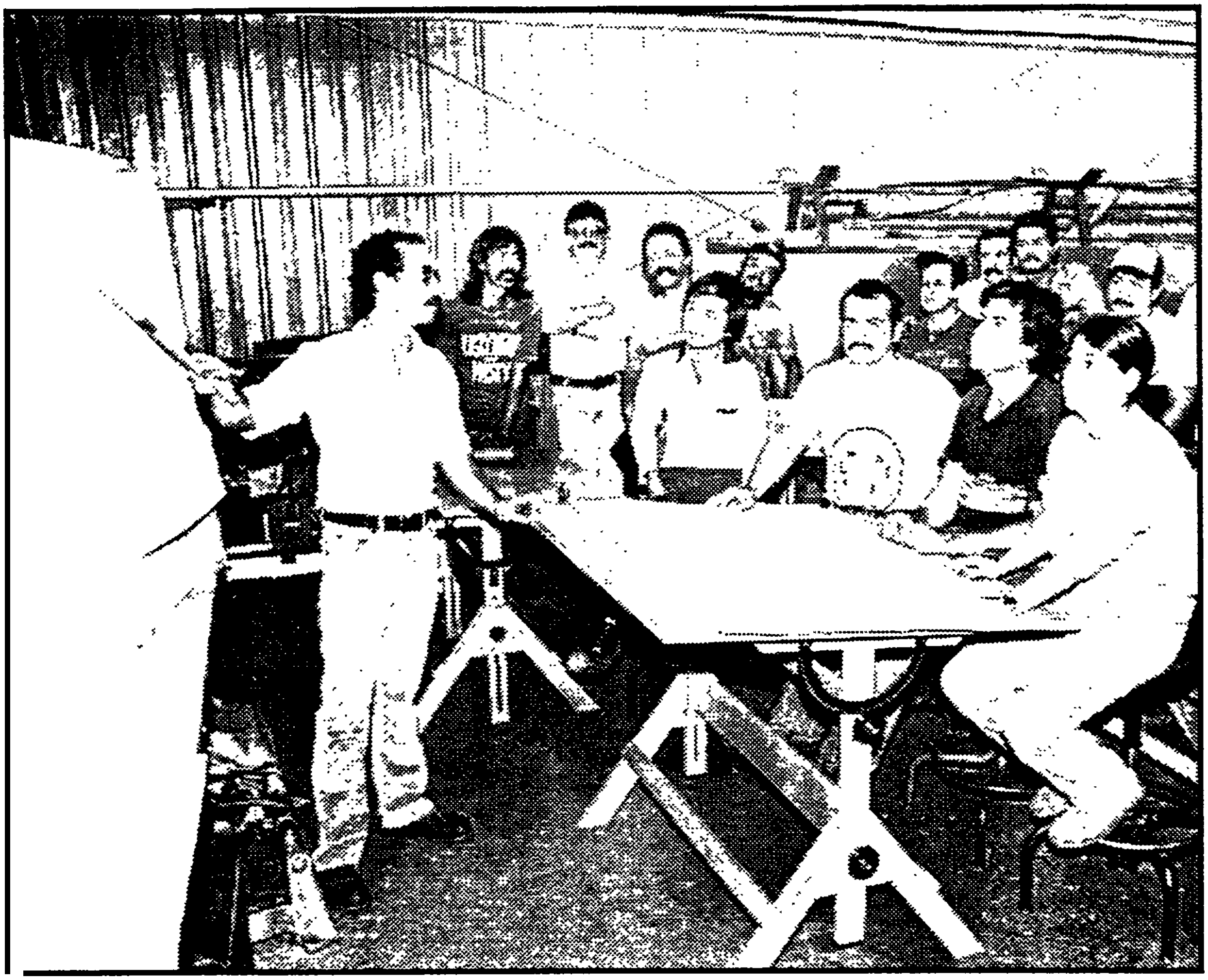


Figure **1.3.b: Training classes are required to teach shipyard workers about production practices and processes. The figure displays workers learning how to read production drawings.**

Chapter 2

Shipyard Docking Facilities

Introduction To Shipyard Docking Facilities:

Shipyards can be thought of as an integration of individual facilities and processes that are combined together to facilitate the production and/or repair of ships. Generally, the largest or most expensive facilities in the shipyard are its docking facilities. The shipbuilding and repair industries rely heavily on their docking facilities. In many cases, a shipyards' industrial capabilities are evaluated on the quantity, size, and type of docking facilities they possess. Ships can be either wet-docked or drydocked. A wet-dock or berth, as it is commonly called, is a pier or a wet slip position that a ship can dock next to and tie up. A ship that has its entire hull exposed to the atmosphere is said to be drydocked. A wide range of docking facilities exist and their construction and operation vary from shipyard to shipyard. The following sections generally describe six different types of docking and launching facilities frequently found at shipyards.

2.1 The Floating Drydock:

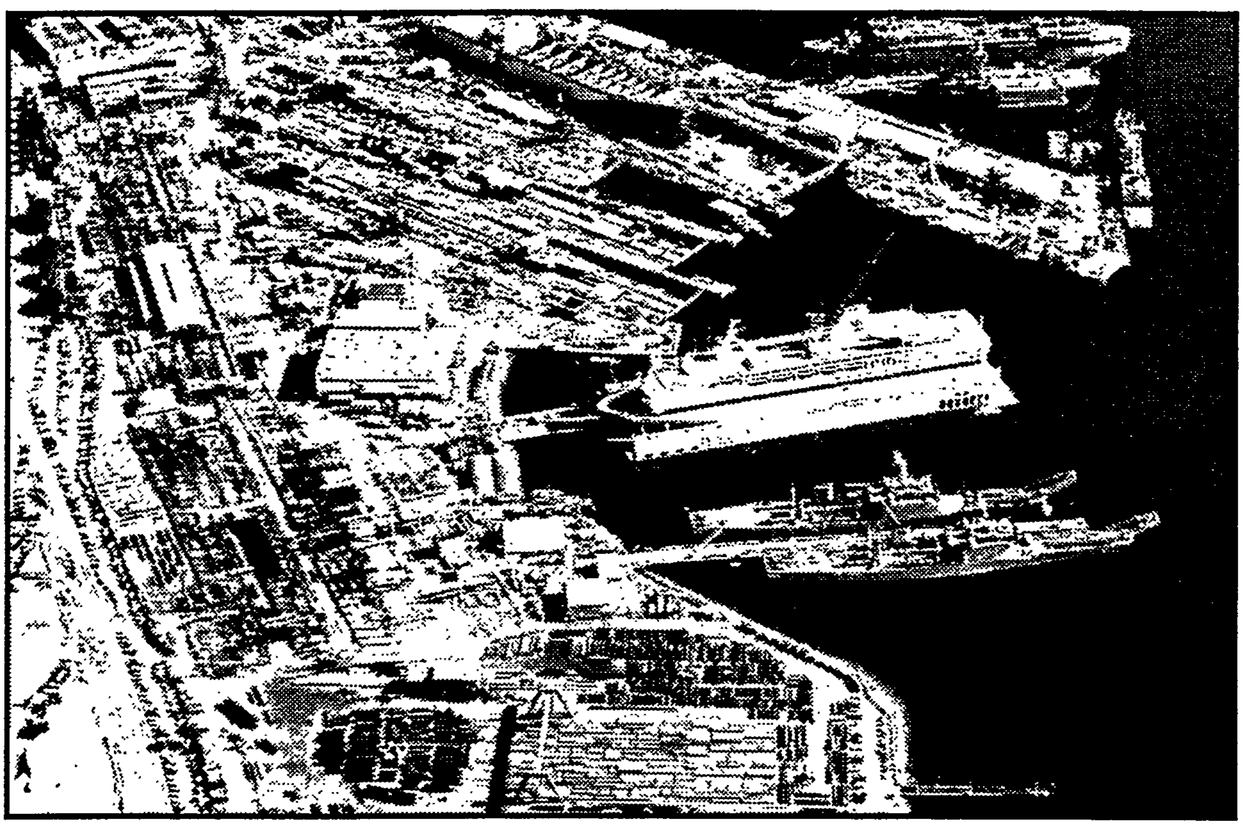


Figure 2.1.a: Aerial View of NASSCO Builder

The floating drydock is a floating vessel secured to land that has the ability to be lowered under the water's surface in order to raise ships above the water surface level. Floating drydocks are generally used for ship repair, but in some cases ship construction is performed. Drydocks range anywhere from 50 to 1000 ft. in length. Floating drydock operation and construction are like no other docking facility in the shipyard. Figure 2.1 (a) and (b) are illustrations of two typical floating drydocks.

Figure **2.1.b: Vessel drydocked at South West Marine for minor repairs. Notice the flying bridge that allows accessibility to both of the wing walls**

2.1.1 Floating Drydock Construction:

As the name implies, floating drydocks are floating vessels anchored to shore and the underlying surface. The dock is anchored to allow for rising and falling with the tides and for docking operations. Figure 2.2 is an illustration of the drydock structure and the associated terminology. Different types of floating drydocks exist in the industry and the descriptions may vary. Specific characteristics are dictated by the individual shipyard's requirements at the time the dock was commissioned. However, the basic features, terminology, and nomenclature used in the figure are widely used throughout the industry. The following sections separate the floating drydock into three main areas and describe their associated components.

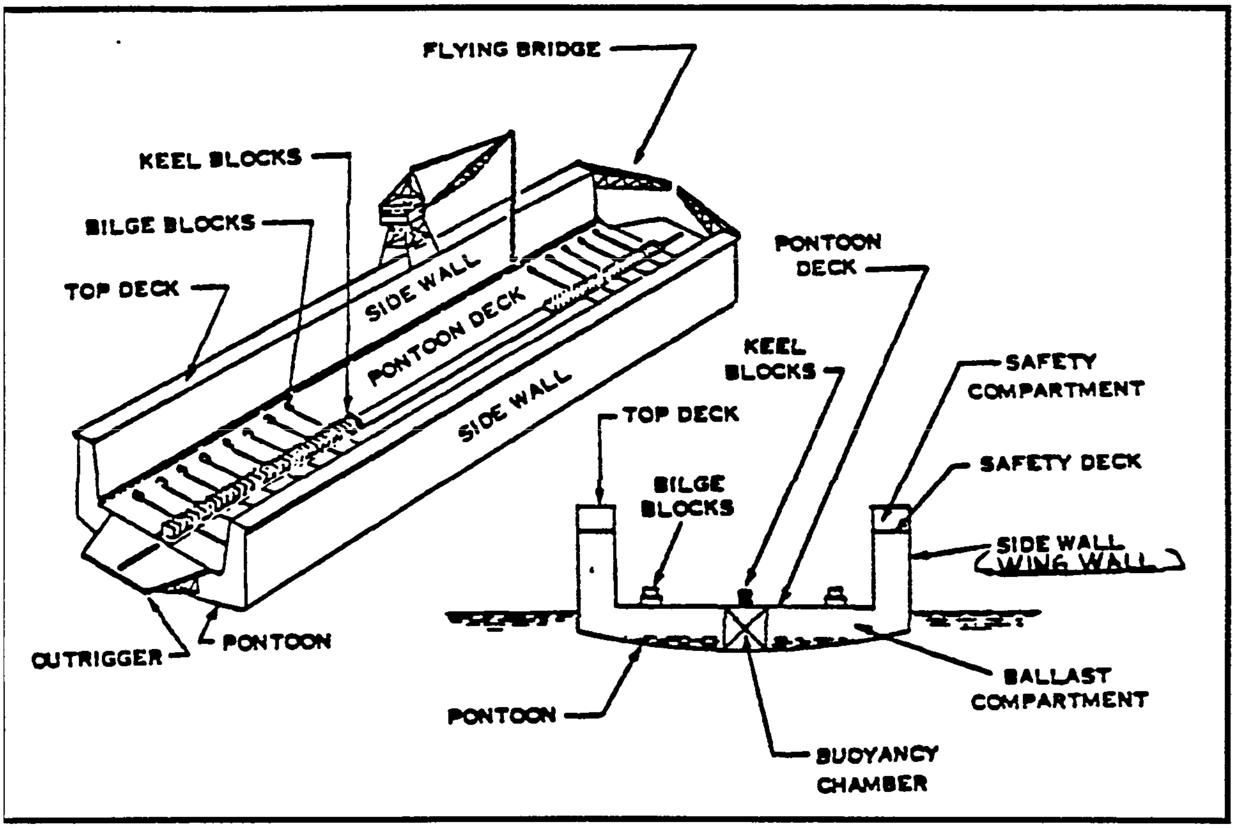


Figure **2.2: Floating Drydock and Nomenclature**

2.1.2 Pontoon Deck:

The pontoon deck, also known as the docking surface platform, is the main area of the floating drydock. Most of the repair production activities occur on the pontoon deck. When the ship is drydocked, it rests on keel and bilge blocks located on the pontoon deck. The keel and bilge blocks are shaped and strategically positioned to contour to the hull of the ship being drydocked. Most of the work performed on the ship uses supplies and equipment positioned on the pontoon deck. Many drydocks have extensions on the deck called outriggers, which are used when docked ships are longer than the pontoon deck. Outrigger extensions allow access to the overhanging bow and/or stern of the docked vessel. Another deck structure is the access bridge, not displayed in Figure 2.2. The access bridge is a steel platform that connects the pontoon deck to the shore or a pier, and allows support equipment and workers access to the dock surface area. Examples of support equipment are portable cranes, boilers, tank trucks, grit blast, and paint equipment. As shown in Figure 2.2, the pontoon deck is located between the two side walls, sometimes referred to as “wing walls”.

2.1.3 Wing Walls:

The wing walls are located on both sides of the pontoon deck and extend vertically from 25 to 100 feet above the deck's surface. Located on top of the wing walls are the top decks. The top deck can be accessed by stairs located inside the wing walls. The top deck provides space for equipment and allows access via a walking plank to the interior of the drydocked ship. Walking planks are attached to the ship and to the top deck, thus bridging the gap between the wing wall and the ship. Some drydocks use flying bridges to connect the two wing walls and provide access for foot traffic. flying bridges are installed at one or both ends of the top deck; their hinged cantilevered arm structure allows them to swing open to allow ships to enter and exit the dock. Also located on the side walls and the top deck are cranes required for the handling materials and equipment. A large crane generally operates on one or more of the deck tops and smaller cranes are usually connected to the inner side walls. The cranes are used for a variety of work. The large crane loads supplies and materials for onboard work while the small inner cranes support repairs on the hull.

2.1.4 Ballast Compartments and Buoyancy Chambers:

Most of the floating drydock structure is used as ballast tanks and buoyancy compartments for raising and lowering the dock. Most of the pontoon deck and side walls house buoyancy chambers and ballast tanks. The main difference between a ballast tank and a buoyancy chamber is that water never enters a buoyancy chamber. Water is pumped into the ballast tanks and causes the dock to submerge. The amount of water pumped into the ballast compartment determines the depth to which the drydock will submerge. When water is pumped out of the ballast tanks, the drydock returns to the water's surface. Buoyancy chambers are, as the name implies, sealed areas that maintain a certain amount of buoyancy to protect the dock from sinking too deep; they also aid in keeping the vessel level. Buoyancy chambers are located in both of the wing walls and under the pontoon deck. Since they are not subjected to flooding, many buoyancy chambers are used for machinery space, equipment storage, personnel quarters, mess rooms, workshops, and other activities. Proper functioning of the ballast compartments and the buoyancy chambers is instrumental in proper floating drydock operations. Some of the newer floating drydocks have a computer operated system that controls the raising and lowering of the dock.

2.1.5 Floating Drydock Operation:

The floating drydock consist of pumps and associated ballast tanks used to raise ships above the water level for work that requires exposure to the hull. When ballast tanks are flooded the dock begins to submerge. A ship is then strategically positioned over bilge and keel blocks located on the pontoon deck. The position is maintained while the ballast tanks are de-watered. The de-watering process raises the dock and thus the ship above the water surface level. Once the ship is drydocked, it is generally hooked up to “land based utilities” to keep systems operational during docking.

The side wall and thus the entire dock is secured to land in one or more locations to prevent the dock from floating away. Wing walls have a railway, gears, or some type of mechanical system that allows the dock to be raised and lowered. Usually one attachment is located at the shore entrance of the dock and the other is located on the outside of one of the side walls.

2.1.6 Procedures for Docking and Undocking

The specific procedures will vary from shipyard to shipyard but the general operations are as follows: (See Figure 2.3 stages A - H)

1.) Dry dock is cleaned and cleared of equipment to allow for immersion into underlying waters.

2.) Keel and bilge blocks are positioned on the pontoon deck as shown in Figure 2.3 stage A. The location, quantity, and size of keel and bilge blocks is dependent upon the size and shape of the ship being docked.

3.) Once the keel blocks are in place and the dock is ready to submerge, water is pumped into the ballast tanks. Stages B and C in Figure 2.3 displays the submerging operation.

4.) Stage D shows the dock submerged to the point where the ship can enter the docking area.

5.) The ship is positioned correctly over the keel and bilge blocks. The ship is usually secured in position by bow and stern lines from to the upper deck to the wing walls.

6.) Stages F and G in Figure 2.3 display the de-watering of the ballast tanks. Air replaces water in the ballast tanks, the dock causing to become buoyant enough to float both the dock and the ship.

7.) The final stage H displays the ship drydocked. The next step in the operation is to hook the ship up to dock/land based utilities.

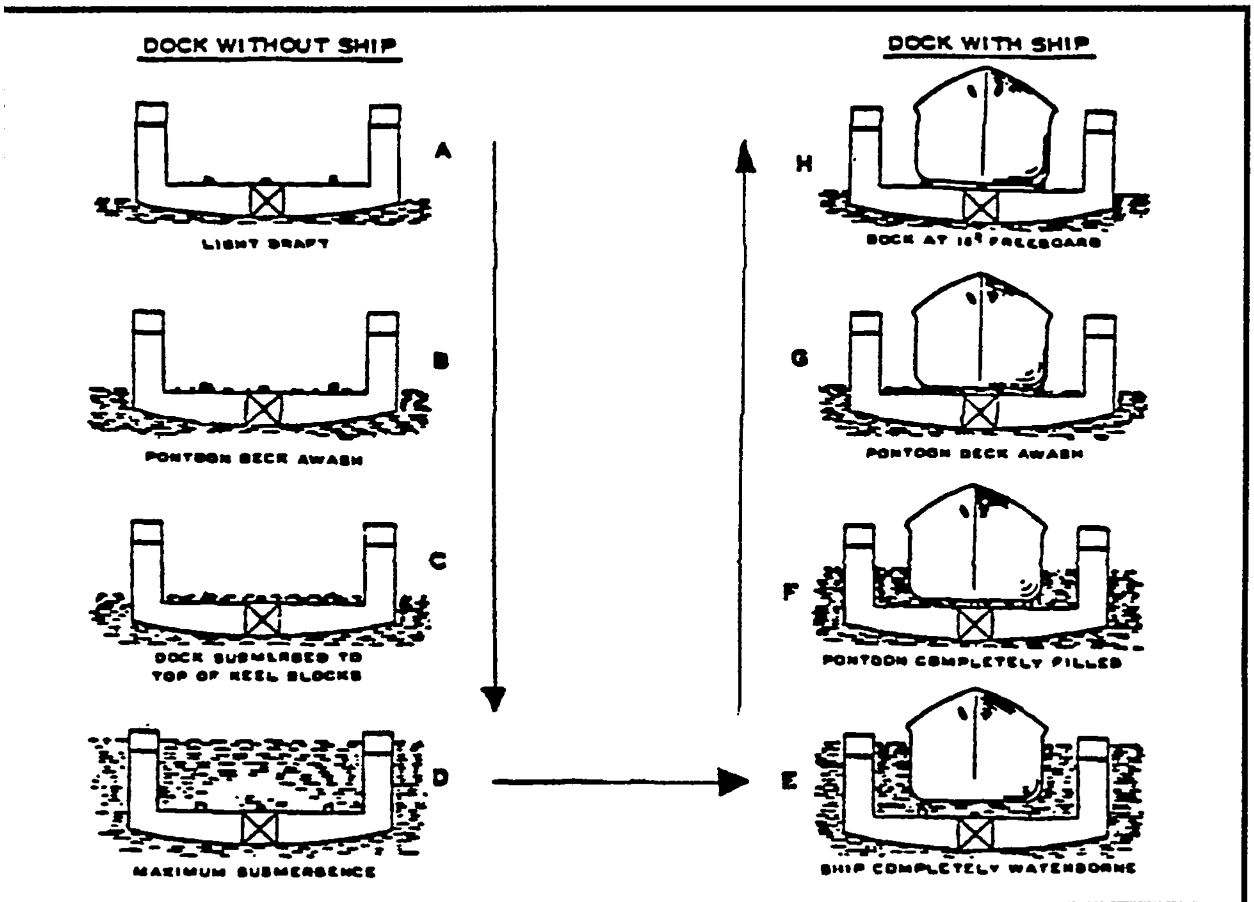


***Figure* 2.3: Floating Drydock Stages of Operation**

2.1.7 Different Types of Floating Drydocks:

Throughout the years, several types of floating drydocks have been developed. Floating drydocks are the quickest and most cost-effective facilities for drydocking sea going vessels. However, some shipyards use the floating drydocks to launch new construction ships. Launching newly constructed ships with a drydock often utilizes shipbuilding transfer facilities. The ships are built on flat ground on tracks that transport the ship to the drydock for launching. Many of the floating drydocks with transfer systems enable ships to be launched and retrieved. Figure 2.4 is an illustration of a floating drydock with a transfer system. However, transfer systems are not standard in the shipbuilding industry. Another type of floating drydock is the sectional floating drydock, which was designed to be taken apart in sections. Other types of floating drydocks exist and must be explored on a case by case basis.

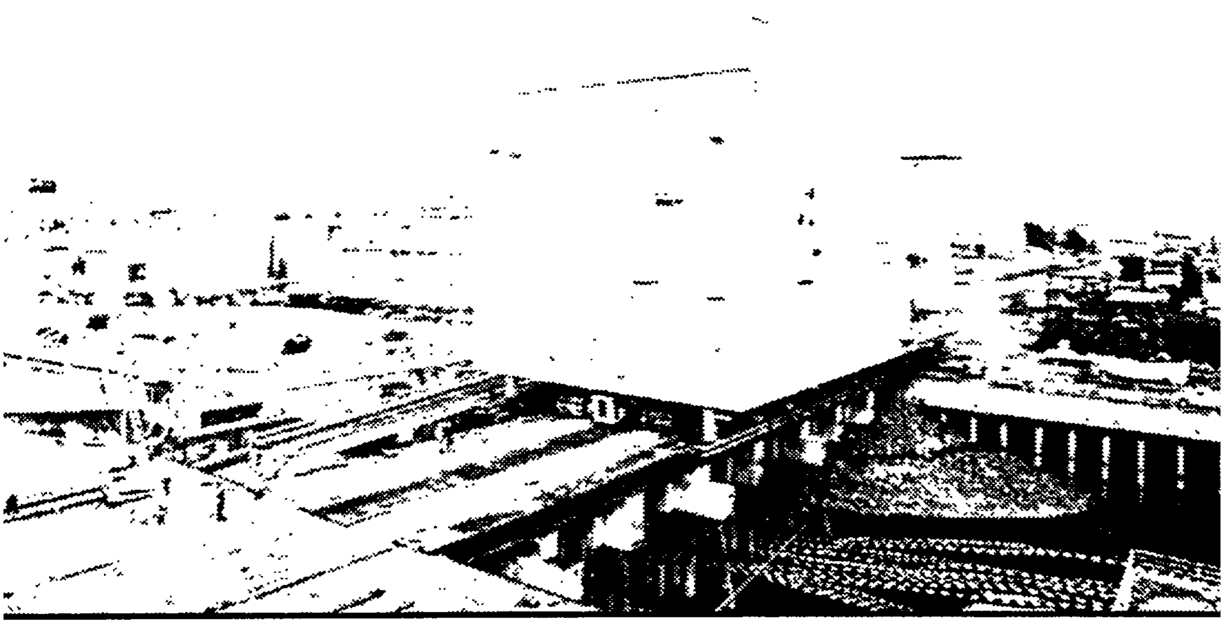
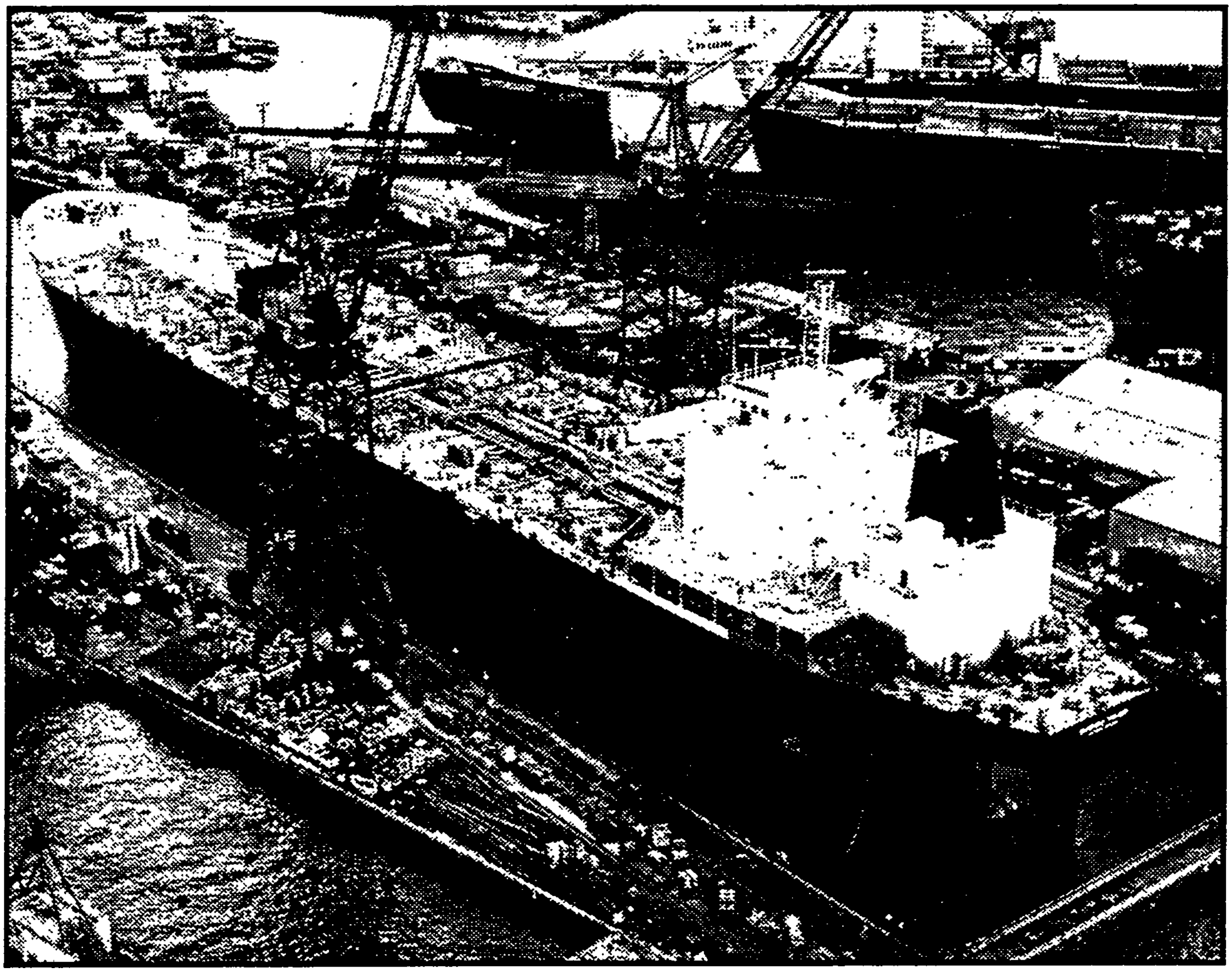


Figure 2.4: Port of Portland transfers structure from the shipyard to their floating drydock with a tractor transfer system, The structure pictured is an oil drilling platform house.

2.2 The Graving-Dock:

Graving-docks have been referred to by many different names. For example, the graving-dock is called a drydock, building dock, or building basin, depending upon what name the shipyard uses. The term "graving-dock" is derived from the fact that it looks like an uncovered grave. The graving-dock is a man-made rectangular bay where water can be let in and pumped out. Ships float into the dock area when the dock is full of water. When the water is removed and the ship rests on blocks, the ship is said to be drydocked. The graving-dock, like most drydocks in the shipyard, is used as a platform for either building or repairing ships or other marine structures. The graving-dock is unique in its construction **(See figure 2.5).**



2.2.1 Graving-Dock Construction:

Graving-docks are long rectangular cavities separated from adjacent waters by a water-tight gate and three walls. The cavity ranges from 30 to 60 ft. in depth below water level, 50 to 250 ft. in width, and 400 to 1300 ft. in length. The bottom of the dock is below the adjacent water surface level and is low enough to allow floating vessels to enter the dock cavity.

2.2.2 Graving-Dock Wall and Floor Structure:

The graving-dock walls and floor are constructed of concrete, timber, sheetpile, or a combination of the three. The walls and gates of graving-docks are below the water surface level where hydrostatic pressure and corrosion may cause problems with leaking walls, gates, and floors. Therefore, most graving-docks have sumps and pumping mechanisms to redirect hydrostatic pressure and leaking water back into the adjacent waterways. These systems are usually located within the walls or floor of the graving-dock. The floor of the graving-dock is a very important structure of the dock and must be designed to hold back hydrostatic pressures as well as provide a strong surface for ships to rest on when they are docked.

2.2.3 Graving-Dock Gate Mechanisms:

Many types of gates have been developed for graving-docks. The most frequently found gate is the floating caisson. Other types of gate closures are miter gates, flap/hinges gates, set-in-place gates, sliding caisson, and rolling caisson. The floating caisson is a gate with large water-tight tanks built into the structure. The purpose of the tanks is to float and sink the gate during removal and reinstallation. Miter gates were probably the first satisfactory gates for graving-docks. The miter system consists of two gates hinged at the dock walls. The gates swing horizontally and meet in the center to form a water-tight seal. The miter gate is generally opened and closed by means of a system of ropes and winches. A flap gate is a ridged one-piece gate which is hinged at the bottom and pivots upward and downward. Similar to the floating caisson, the flap gate uses air tanks for buoyancy to open and close the gate. Set-in-place gates are found in various forms and may be made in one piece or multiple sections. Set-in-place gates are removed and installed by a crane or some other lifting mechanism. Most of the gates described have some type of inlet valve to let water enter the graving-dock cavity. However, other configurations for flooding the docks are equally popular.

2.2.4 Flooding and De-watering System:

Generally, there are three (3) main routes for water to flow into the graving-dock. The first are large ducts built into the gate and are operated by valves at the top of the gate. The second route where water can enter the docks through culverts built in the lower part of the side walls. The culverts are connected to openings throughout the dock floor. The third route is through culverts passing transversely under the dock and directed throughout the dock floor. The previous three systems are used for flooding the dock and have nothing to do with de-watering the dock. Once the ship is properly in place in the graving-dock, de-watering will commence. De-watering is the process of pumping the water from inside of the dock area to the outside adjacent waters. Most de-watering systems have two separate pumping systems. The main pumping system consist of one or more pumps, suction passages and culverts, pump suction chambers/sumps, discharge check valves, and a backwash trash rack. In some larger shipyards with more than one graving-dock, larger pumping systems are designed to pump out more than one dock. At least two main pumps are usually required to achieve acceptable de-watering times. A secondary pumping system is sometimes designed to collect the final few inches of water blanketing the graving-dock floor. The system generally consists of a sloping dock floor which directs the water to channels on either side of the floor leading to the pump. The channels are usually covered by steel grating to let people walk on or around them. The secondary system operates to empty the final few inches of water as well as any rain or water runoff which enters the dock.

2.2.5 Graving-Dock Operations:

The graving-dock is usually only flooded when a ship is docking or undocking and is therefore dry the majority of the time. The docking and undocking procedures are an important part of the graving-dock's operation. Once the ship is docked, a variety of utilities and operations are supplied to the ship. In general, seven practices must take place before the dock can be flooded and the ship docked: (1) The dock floor below the water surface is swept broom clean and most equipment removed, (2) Keel blocks are then strategically placed on the dock floor for the ship to rest on, (3) Valves are opened for flooding to begin, (4) Once flooding is completed, the gate is opened, (5) The ship then enters the dock and is positioned over the keel blocks. (6) The gate is then closed, (7) Finally, water is pumped out of the graving-dock cavity while divers and musters insure that the ship is properly positioned over the keel blocks. Once the water is completely pumped out, the docking procedure is complete and the ship is hooked up to land-based utilities. A similar procedure occurs when the ship is launched.

2.3 Building Ways:

The traditional building positions are known as building ways in many shipyards. Building ways are also referred to as shipbuilding positions. New ships are constructed and/or launched into the water from building ways. Traditional building ways do not retrieve vessels from the waters and are usually only used for building ships and releasing them in the adjacent waters. There are two main types of building ways: the longitudinal end launch ways and the side launch ways.

2.3.1 Longitudinal End Launch Building Ways:

End launch building ways are inclined and have a rail mechanism which launches ships into the water. Sliding mechanism will vary from shipyard to shipyard, although the majority of shipyards use a slipway that the ship slides down when the vessel is launched. The ship is built on platforms that have a waxed or greased surface and is cradled within a rail structure much like a gigantic sled (See Figure 2.6). End launch building ways are generally positioned perpendicular to the adjacent water ways.

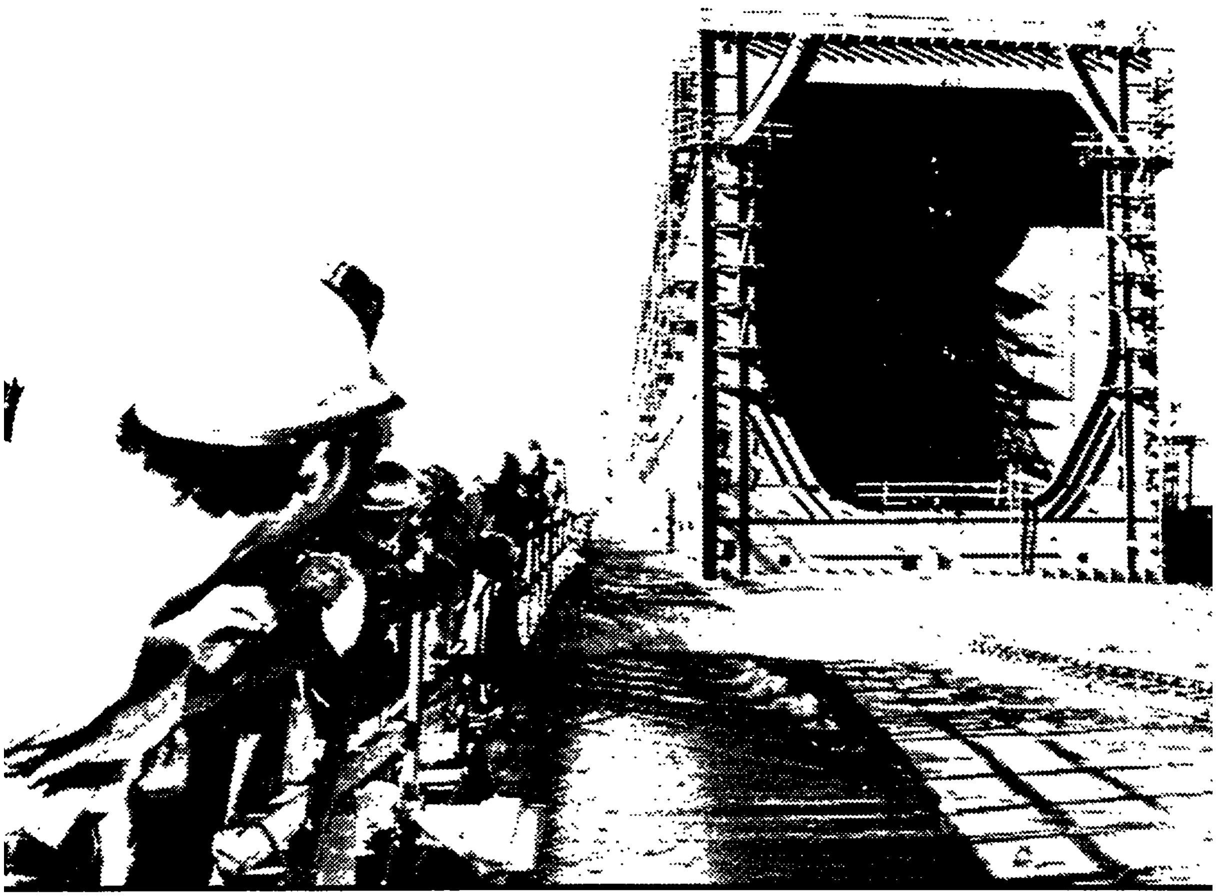


Figure 2.6: **End launch building ways launching in progress. (NASSCO)**

2.3.2 End Launch Ways Construction:

The ways walls are generally constructed of concrete, timber, and/or sheetpile cell construction. The floor of the building ways varies greatly depending on the year in which the facility was constructed. Materials used for the floor range from compacted soil to concrete. Building ways generally have a gate which keeps water from entering the docking area. Many types of gates have been developed for building ways that are similar to those used by the graving-dock, for example, miter gates, flap/hinges gates, set-in-place gates, sliding caisson, and rolling caisson (see gate description in graving dock description). The longitudinal end launch ways are constructed much like the graving dock although, the surface of the dock is sloped toward the adjacent waters.

2.3.3 End Launch Ways Operation:

The end launch operation is much like the graving-dock operation in that a section of the end launch way must be flooded like the graving dock. The section of the building ways closest to the water must be cleaned and equipment removed before the area can be flooded and the gate removed. The entire area under the ship should be cleared of all equipment that could be in the way during launching. Once the lower area of the ways is cleared, it is flooded and the gate is removed. Then the ship can be released to the water. The ship is christened and a lever is released that sends the ship sliding down into the water. Once the ship enters the water, tug boats hook up and gain control and begin to berth the ship at a designated berthing position.

2.3.4 Side Launch Ways:

Side launch ways differ from end launch ways in that they are located parallel to the adjacent waterway and are level. Ships are either moved to the side launch position and launched, or they are built at the side launch site. Therefore, shipyards with side launch ways use some type of transfer system. With a side launch ways transfer system, ships are built as they move closer to the launching position, with major sections of the ship added t each stage.

2.3.5 Side Launch Ways Operation:

Side launching of ships is one of the most exciting types of ship launches. The ship is located parallel to the waterfront and literally tipped over into the water. Figure 2.7. is an excellent illustration of how a side launch is performed. Side launch ways are generally located on rivers and other narrow waterways that make longitudinal building ways undesirable. The side launch ways are generally constructed of a series of lever arms. The ship is moved onto the secured lever arms, then the arms are locked into place until the ship is ready to launch. Once the ship is ready to launch, the lever arms are released and the ship is dumped into the waterway.

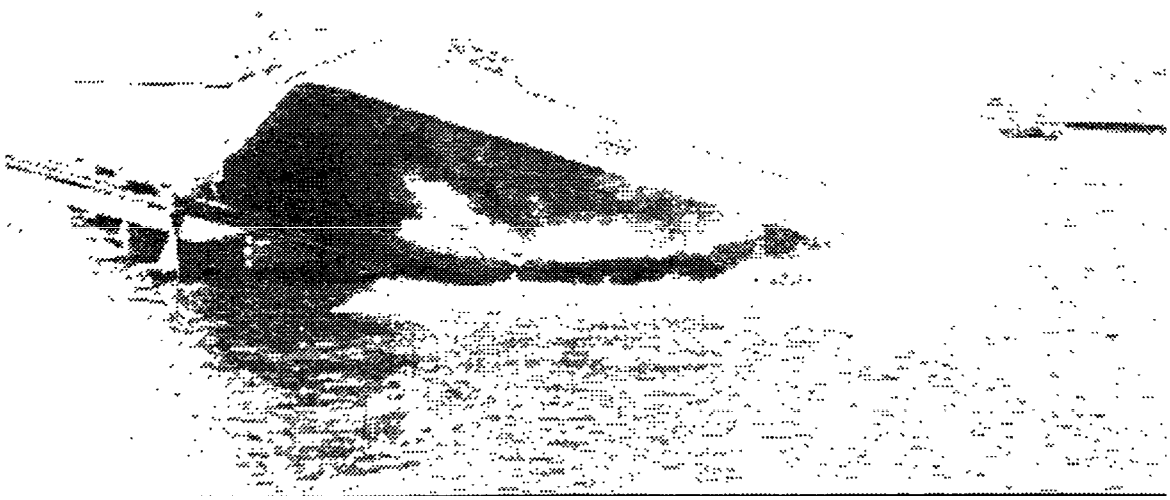


***Figure* 2.7: Side launching in action. The side launch ways literally tips the vessel up to slide into the adjacent waters**

2.4 Marine Railways:

Marine railways differ from building ways in two main characteristics; marine railways are usually much smaller and have the ability to retrieve and launch ships. Marine railways are used for drydocking ships for repair and, in some cases, small ship construction. A marine railway consists of a rail-car platform and a set of railroad tracks. The rails are secured to an inclined cement slab that runs the full length of the way and into the water to a depth necessary for docking ships. Sometimes the entire surface area is constructed of concrete or asphalt; in other cases the surface is compacted aggregate or soil. A motor and pulley system is located at the head of the marine railway to pull the rail-car platform and ship from the water. The floating vessel is loaded onto the platform much like a boat is loaded onto a trailer. The pulley system can be powered by either an electric motor or a combustion engine. The vessel is typically pulled up as far from the water as the dock will allow. Some marine railways transport the ship on rails to a transfer system while other marine railways only pull the vessel up above the high tide mark. In some repair circumstances the longer vessels will hang over the water's surface.

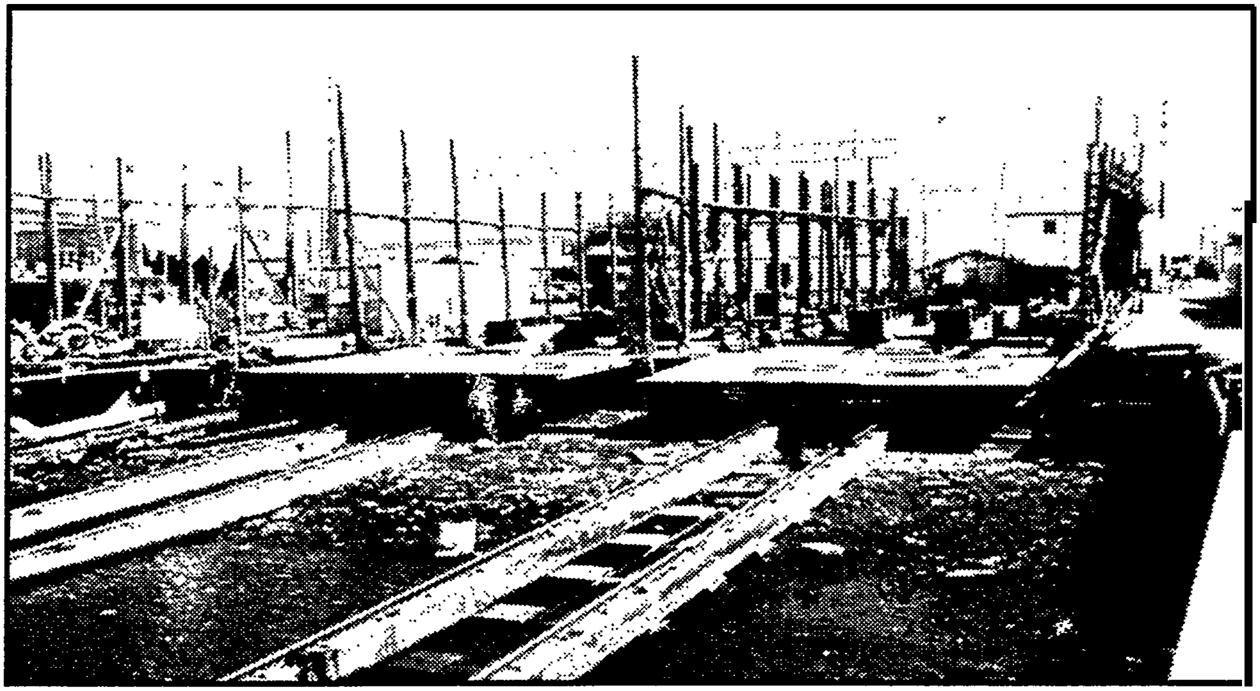


Figure 2.8: Two marine railways side-by-side at South West Marine are used for drydocking vessels ranging from 35 to 80 feet in length.

2.4.1 Marine Railway Transfer Systems:

Transfer systems are not widely used for larger marine ships, therefore most marine railway transfer systems will be located in smaller boatyards and repair facilities. A marine railway transfer system is a mechanism of railways which allows the ship on the railcar platform to be moved into several drydock positions located on land. The transfer system allows the marine railway to be a launch and recovery mechanism, as opposed to solely a ship repair position.

2.5 Wharfs and Piers:

During a ship’s stay at a shipyard, it is usually docked at a pier or wharf. These docking positions are referred to as berthing positions and berths and are generally numbered for easy identification. Shipyards have a variety of berthing positions depending on the shipyard’s size and configuration. Repairs and final outfitting of newly constructed ships are performed at berth.

2.5.1 Wharf and Pier Construction:

Piers and wharfs provide a place for ships to wet-dock or berth and in many cases are constructed differently. Piers are constructed of wood, steel, concrete, or a combination. Piers extend longitudinally into the nearby waters and are supported by columns which are driven down into the underlying soil. Piers are set up to berth ships on either side of the pier. The depth of the water surrounding the piers is dependent on the requirements for draft of docking ships. Frequent dredging may be required to maintain the desired depth of surrounding waters. Piers range in size from 100 feet to over 1000 feet long. Wharfs are positioned parallel to the adjacent waters and can only berth ships from one side. Throughout the years, construction material for wharfs has been similar to that used for piers: steel sheetpile, cement retaining walls, and wood pillars.

2.6 Utilities Supplied by the Docking Facilities:

When a ship is docked for repairs or is under construction in a drydock, many utilities need to be supplied to the ship, shipyard workers, and the ship's force. The ship needs utilities to support production/repairs and supply shipboard systems. System support utilities include: fresh water, power, steam boilers, grey and black water discharges, and sea water for cooling and fire system. Production support utilities include: power, compressed air, oxygen, and argon. Ships docked at shipyards are hooked up to "land based utilities". Those utilities which are generally supplied are as follows:

- Fresh Water
- Sea Water
- Boilers for Steam
- Disposal Receptacles for Sanitary Waste Water
- Disposal Receptacles for Solid Waste
- Tanks and Pumps
- Compressed Air
- Power
- Various Welding Gasses
- Crane Service
- Fire Systems
- Telephone
- Wastewater Removal

Chapter 3

New Construction and Repair Processes in the Shipyard

Introduction to Steel Shipbuilding and Ship Repair:

Shipbuilding and ship repair facilities and processes are very similar in nature. Both processes require the same basic types of facilities, equipment, and skilled labor force. In general, new construction shipbuilding requires a larger and more complex facility than ship repair facilities. The higher complexity of the shipbuilding shipyard centers around the assembly line and hull block construction methods. As one would imagine, shipbuilding is a process that involves ground-up construction of ships, while ship repair involves refurbishment and conversion of ships. Current shipbuilding methods utilize a modular "building block" type of strategy. Large steel "blocks" are outfitted with parts and assemblies (i.e., piping, venting, electrical, lighting, etc.) throughout the shipyard and the blocks are joined together at a building position where the ship is erected. Ship repair and new ship construction facilities have many support shops, support services, and various industrial facilities to support shipyard activities. Many shipyards throughout the country perform both shipbuilding and repair in their shipyard. As of 1992, there are approximately 200 ship repair facilities in the United States; but only about 70 are capable of drydocking ships 300 ft. or longer. Therefore, approximately 130 of the ship repair yards are referred to as "topside" yards. The topside repair yards mainly perform repair work to ships at pierside, or drydock smaller vessels.

3.1 Introduction to Steel Ship Construction:

Shipbuilding techniques have progressed through the years to the current method of "block" and "unit" construction and outfitting. Modern steel ships are constructed by producing manageable-sized "blocks" and "units". These blocks are built and transported through the shipyard and joined together at the shipbuilding position. In other words, ships are built with "building blocks" which are stacked on one another and welded together to form a ship. The size of the blocks that the shipyard can build is dependent on the shipyard capacity to build, transport, and lift the blocks onto the ship under construction. The blocks are built in varying shapes (e.g., curved shell, orthogonal, wing side shell, and bilge/ballast blocks) and sizes (i.e. grand blocks, super units, and house blocks). Units are assemblies that form major machinery spaces onboard the ship (i.e. auxiliary machinery spaces, pump rooms, engine rooms, etc.). All of the blocks and units are joined together to construct the new ship.

3.1.1 Parts Fabrication and Assembly:

Before the blocks are erected (i.e., stacked and welded together at shipbuilding position), they must first go through several stages of construction. The “assembly line” of the shipyard starts in the steel storage area. The steel is blasted and primed with a construction primer which preserves the steel during construction. Then the steel is fabricated into the parts needed to construct the steel structure of the block. The size and shape of the parts is determined from engineering design. Fabricated parts are then brought together to form sub-assemblies. At this stage, most of the parts are steel sections and plates. The sub-assemblies are brought together to form construction blocks. This stage of construction is known as parts fabrication and assembly. Please

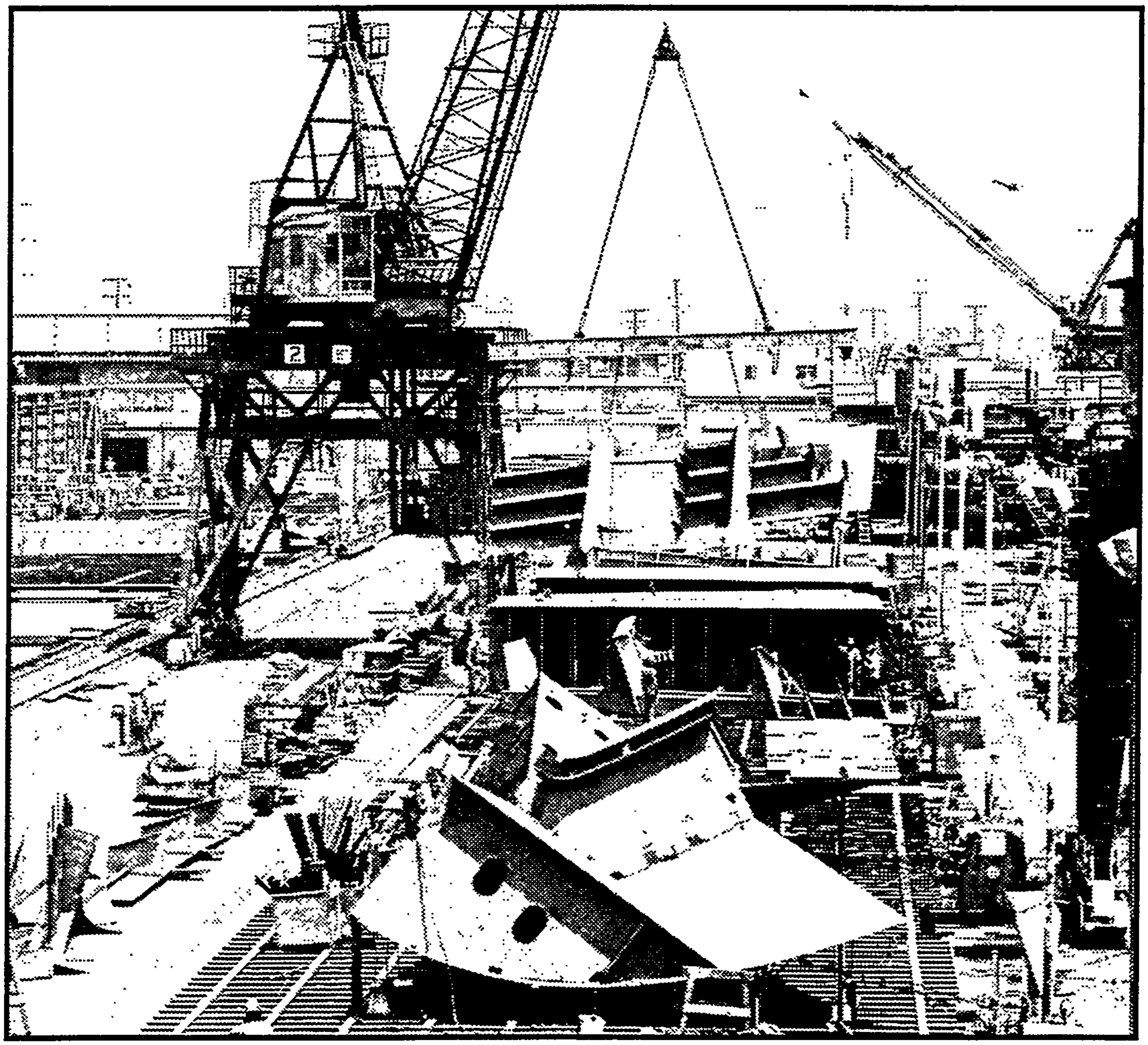


Figure 3.1: The outside platen line at NASSCO illustrates the assembly line approach to block production. Notice the curved block in the foreground is placed on a pin jig structure.

refer to the manufacturing levels presented in Chapter 1. Figure 1.1 displays a major block sub-assembly constructed on the platen line.

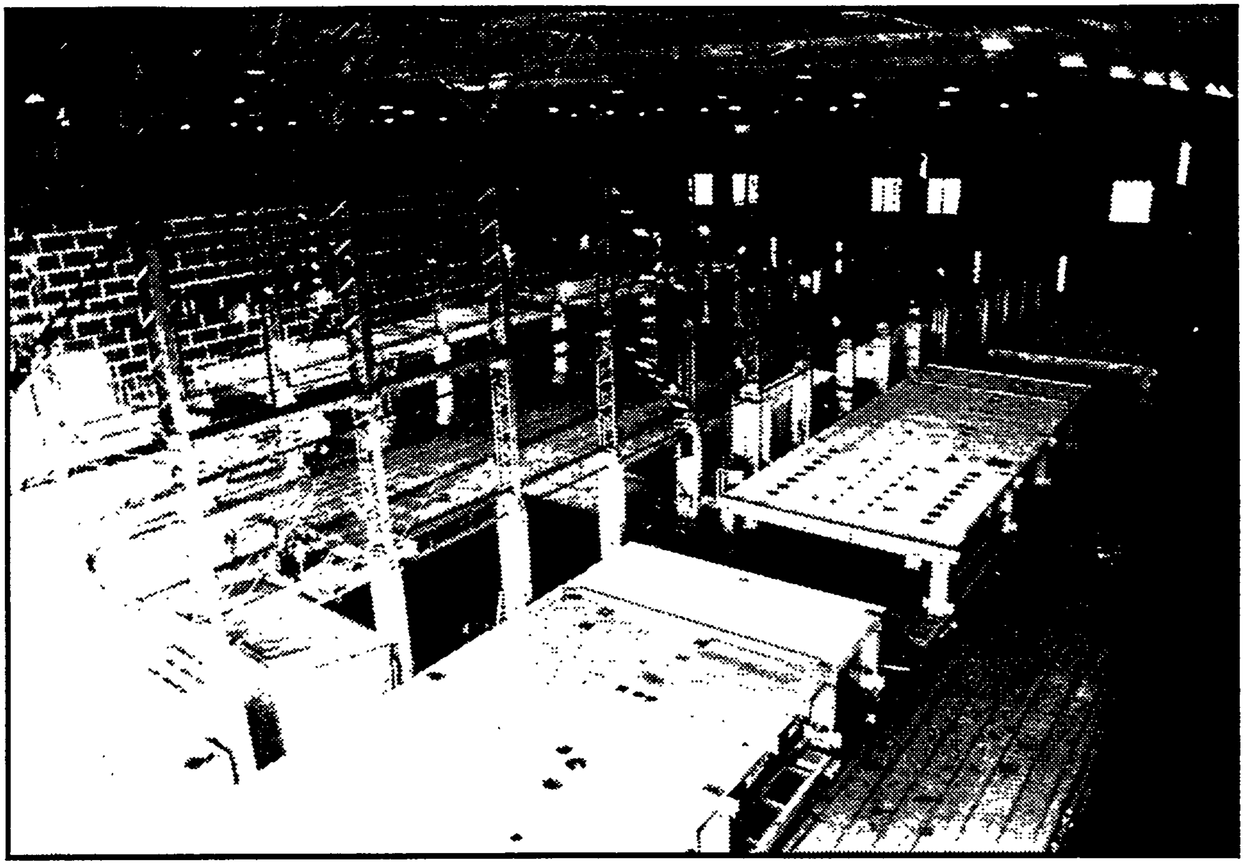


Figure **3.2: indoor production facilities at the Port of Portland Shipyard. Pictured are blocks used to construct an oil drilling platform.**

3.1.2 Surface Preparation and Painting:

Surface preparation and painting operations can occur at nearly all stages of construction. However, the majority of blasting and painting on the block structure occurs prior to outfitting. Much of the blast and paint that occurs after outfitting is touch-up. Units are usually painted prior to assembly and installation. The main constraint with blast and paint is when too much material is installed on the block prior to blast and paint, making the process more difficult. Much of the outfitting material that is installed at assembly will need to be masked of blasters and painters will have to work around outfitted material. This is an important consideration because of the increased cost of outfitting at later stages of construction. It is desirable to outfit materials onto the construction blocks as soon as possible. Surface preparation and coating for ship construction is described further in Chapter 4 of this manual.

3.1.3 New Construction Outfitting:

Pre-erection outfitting of construction blocks is the current shipbuilding method used by all competitive shipbuilders worldwide. Outfitting is the process of installing parts and various sub-assemblies (i.e. piping systems, ventilation equipment, electrical components, etc.) on the block prior to joining the blocks together at erection. The outfitting of blocks throughout the shipyard lends itself to forming an assembly line approach to shipbuilding. Figure 1.3 Displays outfitted materials on a construction block.

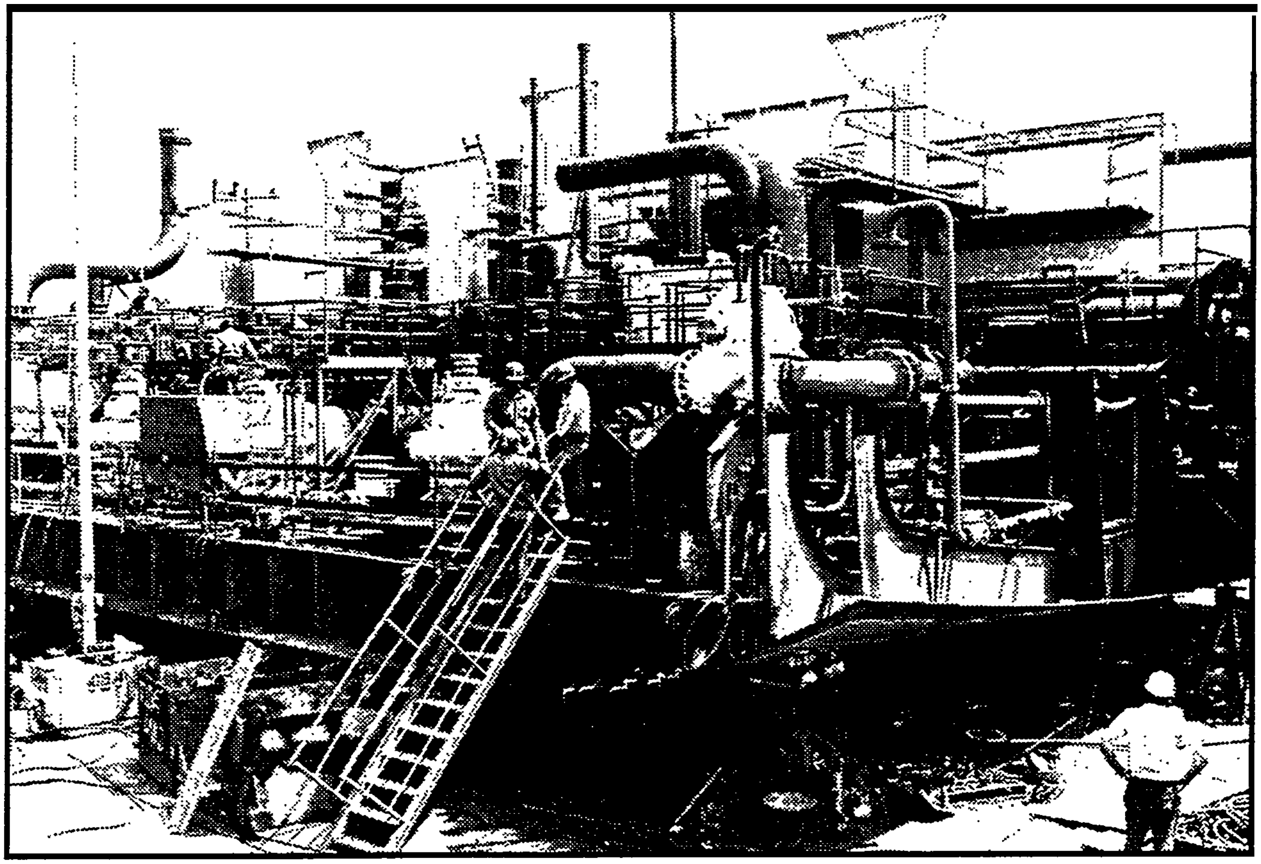


***Figure* 3.3: On-block outfitting, notice the amount of outfitting materials that are installed (e.g., pumps, pipes, ladders, walkways, etc.) and notice the access to the equipment at this stage in the construction process.**

Outfitting processes divide the shipbuilding process into stages of construction. Outfitting at each stage is planned to make the construction process flow smoothly throughout the shipyard. For simplicity, the outfitting can be divided into three main stages of construction once the steel structure of the block has been assembled. The three stages are as follows: 1) Unit Outfitting, 2) On-Block Outfitting, and 3) Onboard Outfitting.

3.1.4 Unit Outfitting:

Unit outfitting is the outfitting stage where fittings, parts, foundations, machinery, and other outfitting material are assembled independent of the hull block (i.e. units are assembled separate from steel structural blocks). Assembly of such units is called unit outfitting. Unit outfitting is important because it allow workers to assemble shipboard components and systems on the ground where they have easy access to the machinery and workshops. Units are either installed at the onboard or on-block stage of construction. Units come in varying sizes, shapes, and complexities. In some cases, units are as simple as a fan motor connected to a plenum and coil. Large complex units are mainly composed of components in machinery spaces, boilers, pump rooms, and other complex areas of the ship. Unit outfitting involves assembling piping spools and other components together, then connecting the components into units. Machinery spaces are areas on the ship where machinery is located (i.e. engine rooms, pump stations, and generators) and outfitting is intensive. Outfitting units on the ground increases safety and efficiency by reducing the manhours that would otherwise be allocated to on-block or onboard in more confined spaces, where work conditions are more difficult,

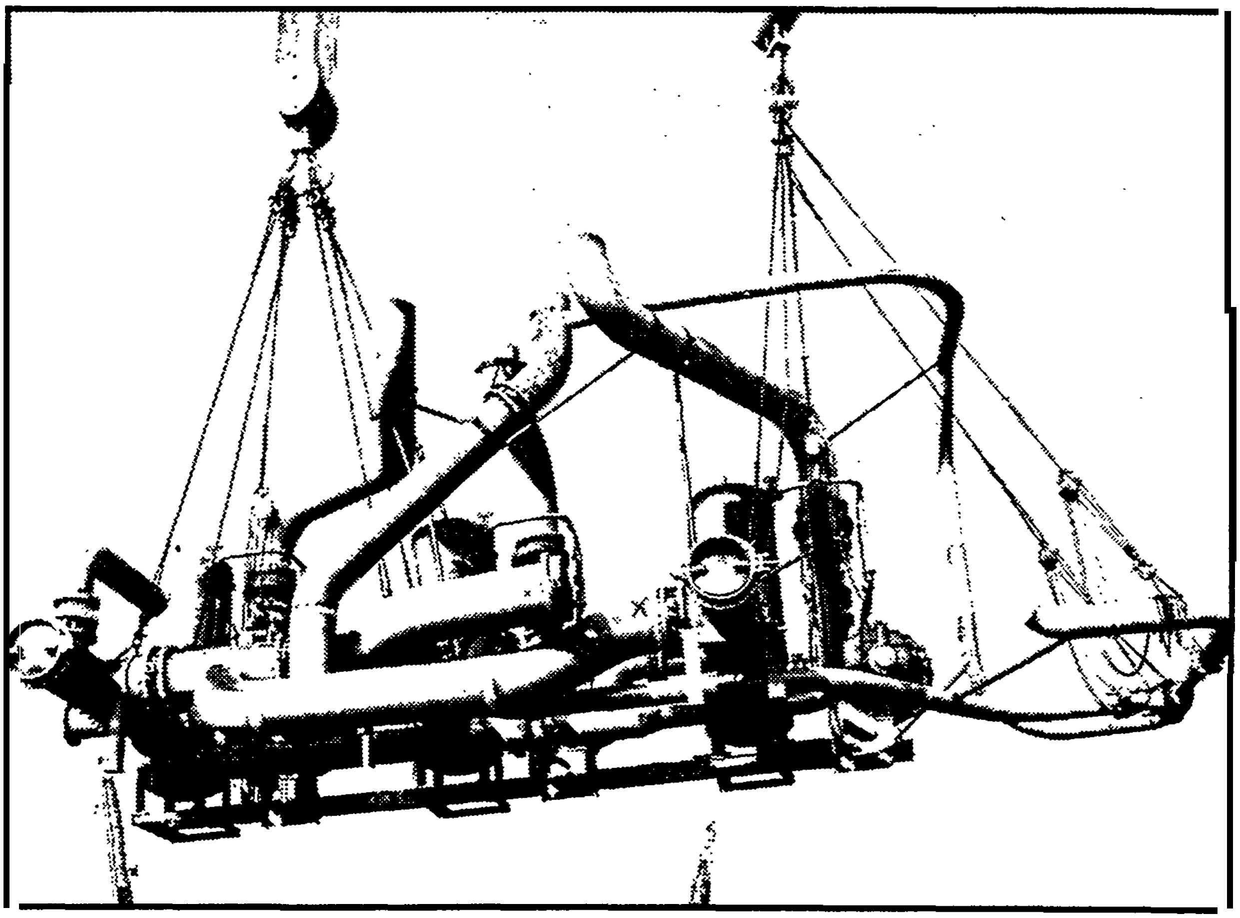


Figure 3.4.a; **The figure displays unit outfitting. The unit consists of pumps, valves, pressure vessels, and piping systems.**

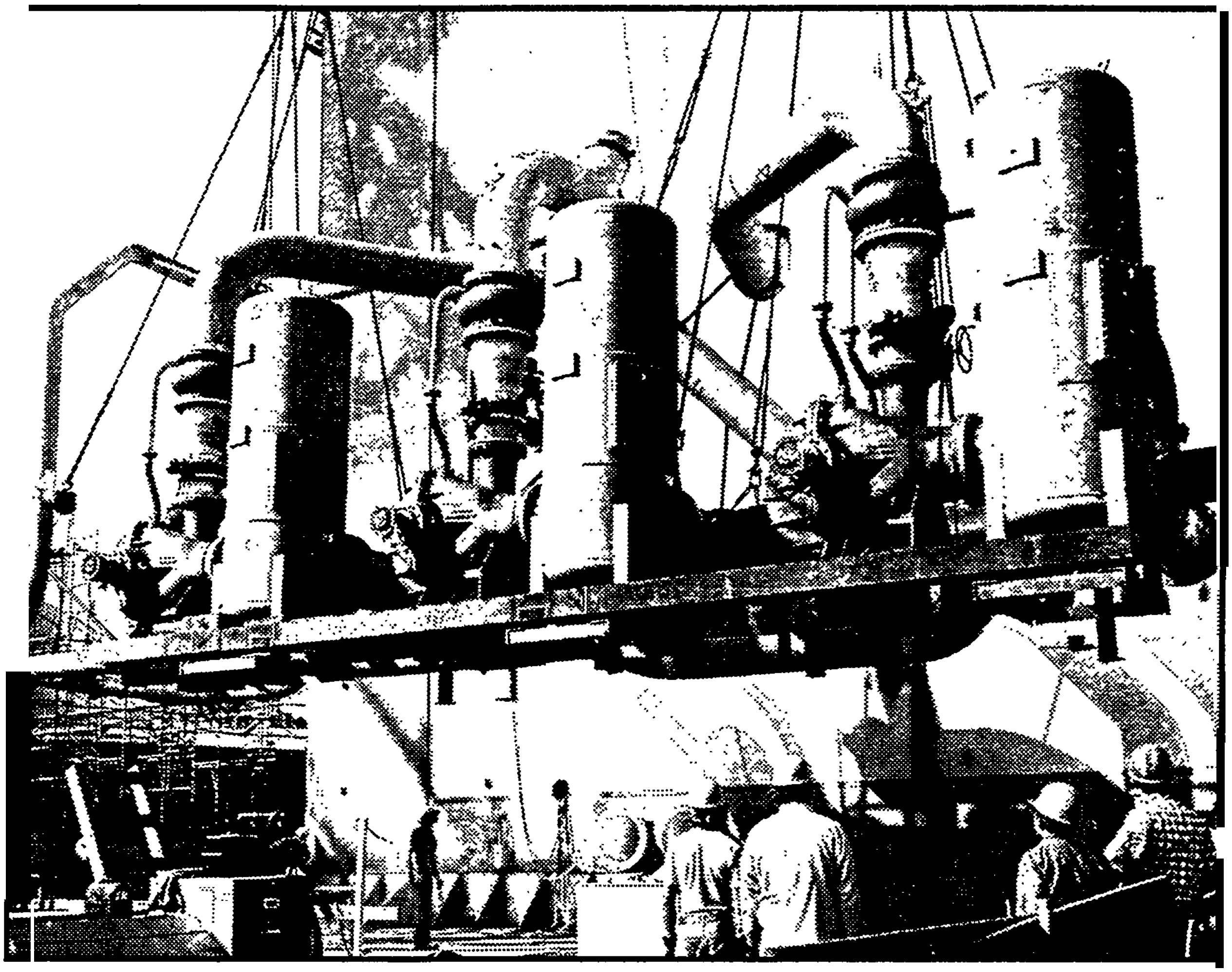


Figure 3.4.b: Figure (b) displays the unit being installed onboard the ship under construction.

3.1.5 On-Block Outfitting:

On-block outfitting is the stage of construction where most of the outfitting material is installed onto the blocks. Outfitting materials are installed on-block consist of ventilation systems, piping systems, doors, lights, ladders, railings, electrical assemblies, and many others. Many units are also installed at the on-block stage. Throughout the on-block outfitting stage, the block can be lifted, rotated, and moved to efficiently facilitate installing outfitting materials on the ceilings, walls, and floors. All of the shops and services in the shipyard must be in communication with the on-block stage to ensure that materials are installed at the right time and place. If materials are not installed at this stage, it will cost 3 to 5 times to install it at a later stage. Figure 3.5 displays the amount of outfitting materials that are installed on-block.

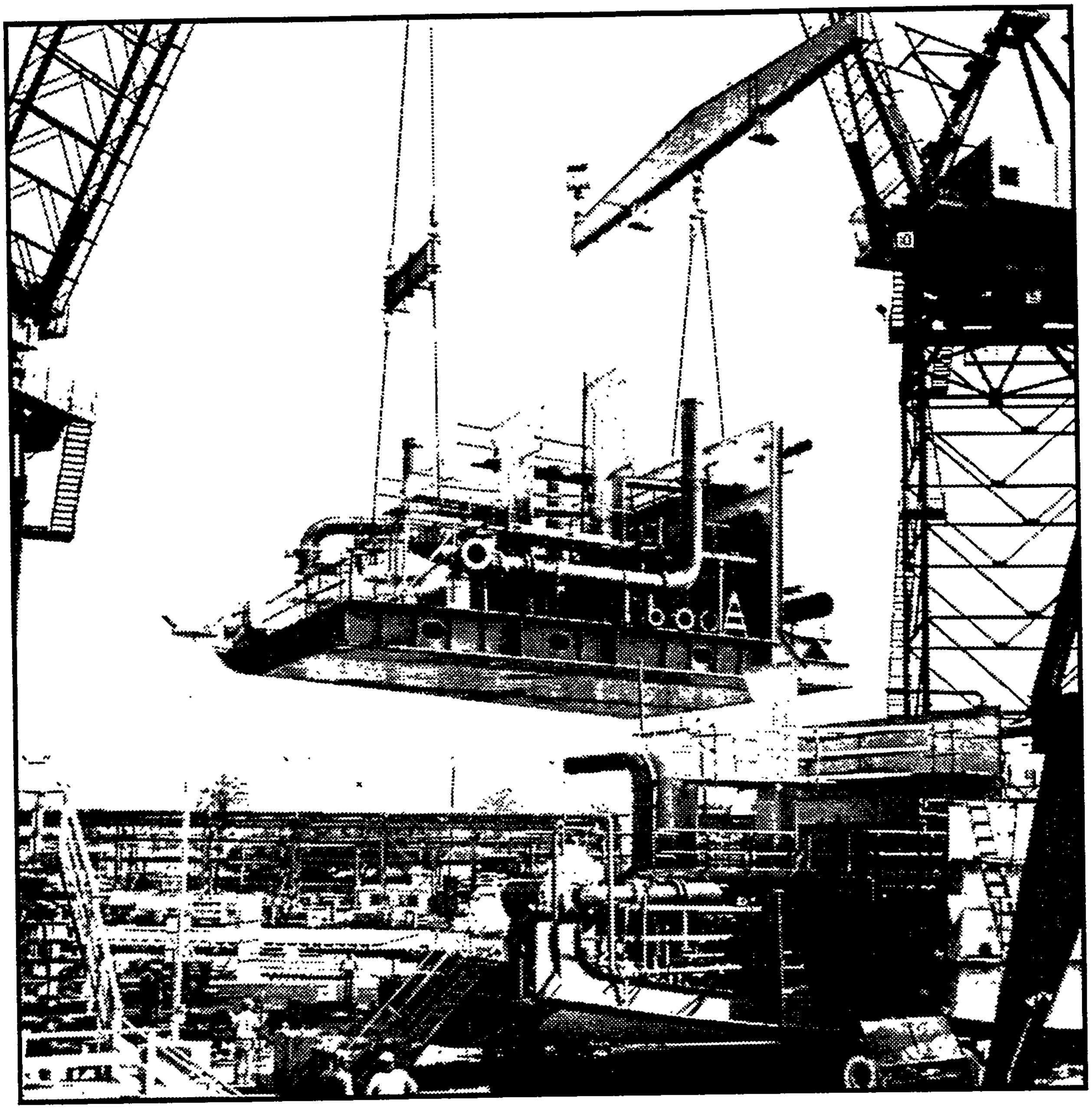


Figure 3.5: **Grand blocking is accomplished by joining blocks together on the ground and then joining the larger block at erection. The figure displays a block being lowered into a position for grand blocking. After the grand block is outfitted, it will be erected onto the ship.**

3.1.6 Onboard Outfitting:

Onboard outfitting is performed after the blocks are lifted onto the ship under construction (eg. after erection). At this time, the ship is either at a building position (building ways or building dock), or the ships could be berthed at pierside. The blocks are already outfitted to a large extent from the work performed at assembly, on-unit, and on-block, although much more work is still needed before the ship is ready to operate. Onboard outfitting involves the process of installing large units and blocks onboard the ship. Installation includes lifting the large blocks and units onboard the new ship and welding or bolting them into place. Onboard outfitting also involves connecting the shipboard systems together (i.e. piping system, ventilation system, and electrical system). All of the wiring systems are pulled throughout the ship at the onboard stage. Figure 3.6 displays the onboard stage of construction on the building ways at NASSCO. The onboard outfitting stage is not only the last stage, it is the most expensive, difficult, dangerous, and time consuming.

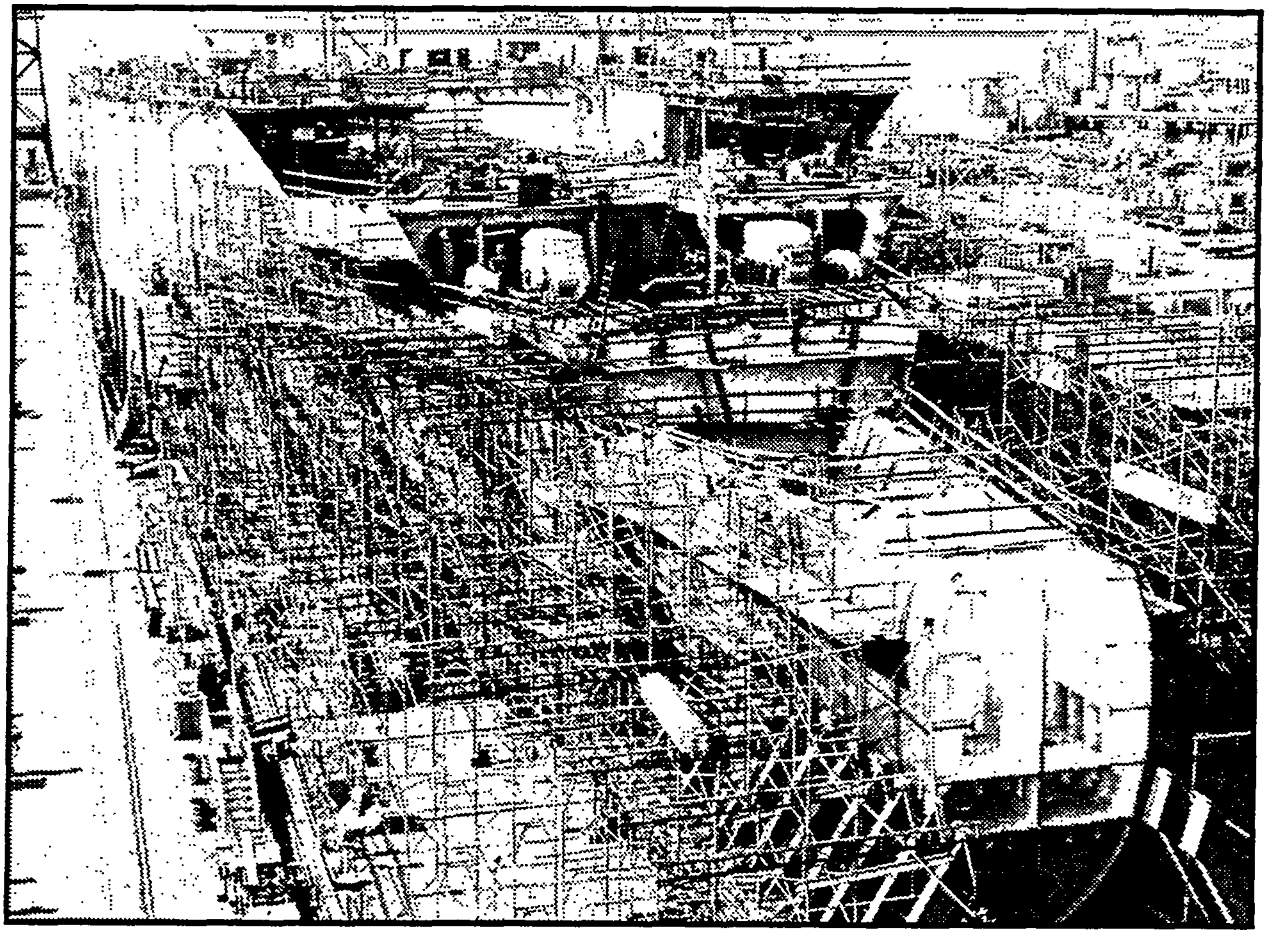


Figure 3.6: **At erection, scaffolding is essential to construct the ship. Pictured is the bow of a Navy vessel under construction at NASSCO.**

3.1.7 Testing and Trial Operation of Systems:

The operation and test stage of construction assesses the functionality of installed components and systems. At this stage, systems are operated, inspected, and tested. If the systems fail the tests for any reason, the system must be repaired and retested until it is fully operational. All piping systems onboard the ship are pressurized to locate leaks that may exist in the system. Tanks also need structural testing, which is accomplished by filling the tanks with fluids (i.e. salt water or fresh water) and inspecting for structural stability. Ventilation, electrical, and many other mechanical and electrical systems are tested for performance factors. Most system testing and operations occur while the ship is docked at pier side. However, there is an increasing trend to perform testing at earlier stages of construction (e.g., preliminary testing in the Production Shops). Performing tests at earlier stages of construction makes it easier to fix failures because of the increased accessibility to the systems, although complete systems test will always be tested onboard. Once all preliminary pierside testing is performed, the ship is sent to sea for a series of fully operational test and sea trials before the ship is delivered to its owner.

3.2 **Steel Ship Repair Practices and Processes:**

Ship repair generally includes all ship conversions, overhauls, maintenance programs, major damage repairs, and minor equipment repairs. Ship repair is a very important part of the shipping and shipbuilding industry. Repair and conversion work consists of approximately 25 percent of the labor force in most private shipbuilding shipyards. Currently there are many ships that need updating and/or conversions to meet safety and environmental requirements. With U.S. fleets becoming old and inefficient and the high cost of new ships, the situation is putting a strain on U.S. shipping companies. In general, conversion and repair work in American shipyards are more profitable than new construction. In new-construction shipyards, repairs contracts, overhauls, and conversions also help to stabilize the workforce during times of limited new construction and new construction augments repair labor workload. The ship repair process is much like the new construction process, except that it is generally on a smaller scale and performed at a faster pace. The repair process requires a more timely coordination and an aggressive bidding process for ship repair contracts. Repair work customers are generally the Navy, commercial ship owners and other marine structure owners.

3.2.1 The Repair Contract:

The customer usually provides contract specifications, drawings, and standard items. Contracts can be Firm Fixed Price (FFP), Firm Fixed Price Award Fee (FFPAF), Cost Plus Fixed Fee (CPFF), Cost Plus Award Fee (CPAF), or urgent repair contracts. The process starts in the marketing area when the shipyard is asked for a Request for Proposal (RFP) or an invitation for Bid (IFB). The lowest price usually wins an IFB contract while a RFP award can be based on factors other than price. The repair estimating group prepares the cost estimate and the proposal for the repair contract. Bid estimates generally include manhours/rates, materials, overhead, special service costs, subcontractor dollars, overtime/shift premium, other fees, facilities cost of money, and thus the estimated price of the contract. Once the contract is awarded, a production plan must be developed.

3.2.2 Repair Planning, Engineering, and Production:

Although some preliminary planning is performed at the proposal stage of the contract, much work is still needed to plan and execute the contract in a timely manner. The following steps should be accomplished: read and understand all contract specification, categorize the work, integrate the work into a logical production plan, and determine the critical path. Planning, Engineering, Materials, Subcontracts, and Repair Production must work closely together to perform the repair in the most timely and cost effective manner. Prefabrication of piping, ventilation, electrical, and other machinery is performed, in many cases, prior to the ship’s arrival. Pre-outfitting and prepackaging of repair units takes cooperation with the production shops to perform work in a timely manner.

3.2.3 Common Types of Repair Work:

Ships are similar to other types of machinery in that they require frequent maintenance and, sometimes, complete overhauls to remain operational. Many shipyards have maintenance contracts with shipping companies, ships, and/or ship classes that identify frequent maintenance work. Examples of maintenance and repair duties consist of the following:

- **Blasting and repainting** the ship's hull, freeboard, superstructure, and interior tanks and work areas
- **Major machinery rebuilding and installation** (i.e., diesel engines, turbines, generators, pump stations, etc.)
- **Systems overhauls, maintenance, and installation** (i.e., piping system flushing, testing, and installation)
- **New system installation,** either new equipment added to the ship or replacement systems that are in need of replacement (i.e., navigational systems, combat systems, communication systems, updated piping systems, etc.)
- **Propeller and rudder repairs, modification, and alignment**
- **Creation of new machinery spaces on the ship** (i.e. cut-out of existing steel structure and adding new walls, stiffeners, vertical, webbing, etc.)

In many cases, repair contracts are an emergency situation with very little warning, which makes ship repair a fast moving and unpredictable environment. Normal repair ships will stay in the shipyard from 3 days to 2 months, while major repairs and conversions can last over one year.

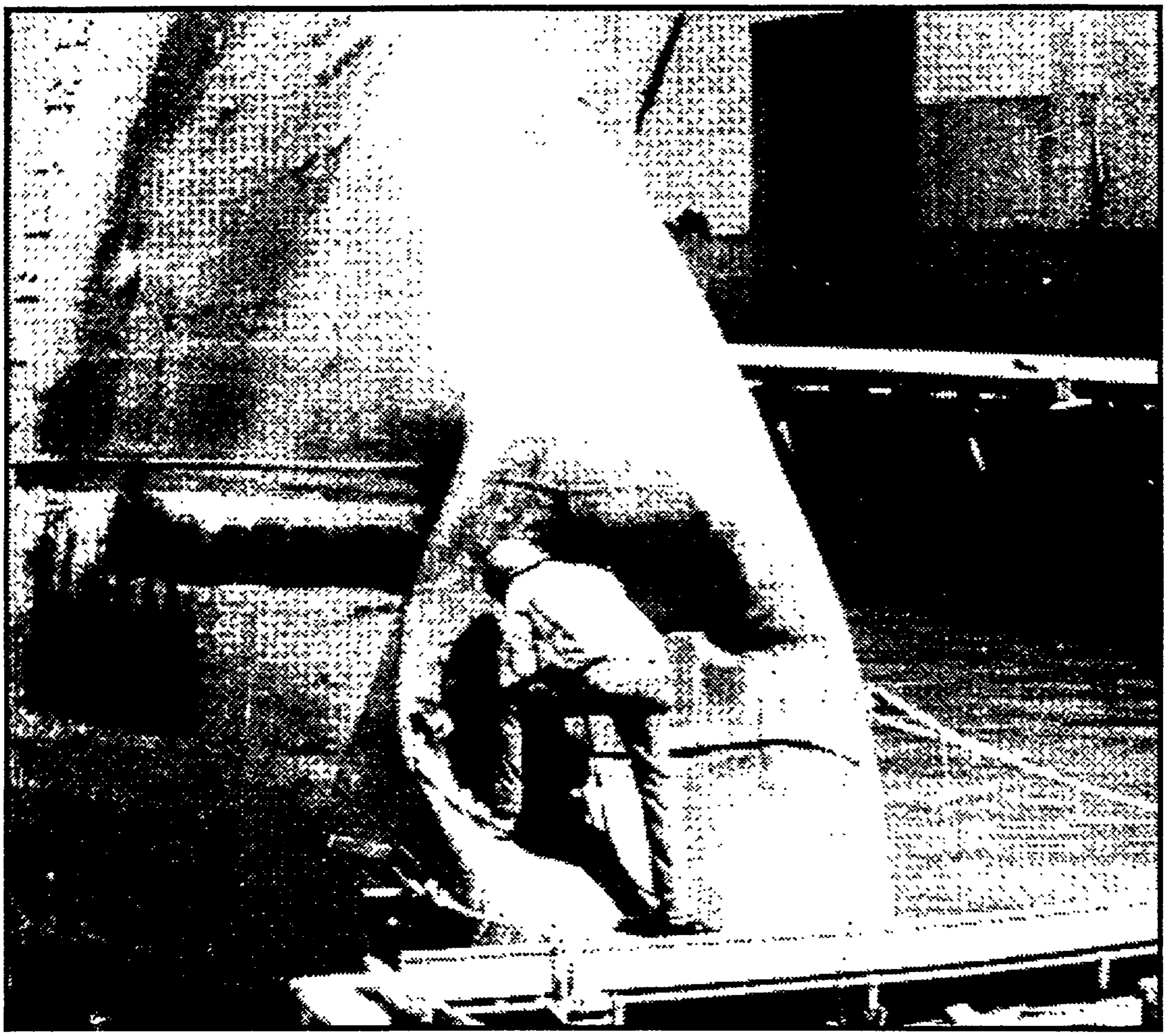


Figure 3.7: **Minor repair work on the bulbous bow of a small product carrier at General Ship Repair, Baltimore, Maryland.**

3.2.4 Large Repairs and Conversion Projects:

Large repair contracts and major conversions are common in the ship repair industry. Most of these large repair contracts are performed by shipyards that have the ability to construct ships, although some primarily ship repair yards will perform extensive repairs and conversions.

Examples of major repair contracts are as follows:

- Conversion of supply ships to hospital ships (See figure 3.8)
- Cutting a ship in half and installing a new section to lengthen the ship
- Replacing segments of a ship that has run aground
- Complete rip-out, structural reconfiguration and outfitting of combat systems
- Major remodeling of ship's interior or exterior (e.g., complete overhauls of passenger cruise ships)

Most major repairs and conversions require a large planning, engineering, and production effort. In many cases, a large quantity of steel work will need to be accomplished (i.e., major cut-out of existing ship structure and installation of new configurations). These projects can be divided into four major stages; 1) Removal, 2) Building new structure, 3) Equipment installation, and 4) Testing. Subcontractors are required for most major and minor repairs and conversions. The subcontractors provide expertise in certain areas and help to even the manload in the shipyard. Some of the work that subcontractors perform are as follows:

- Support of ship repair
- Major combat systems installations (technical)
- Boiler Retubing and Rebuilding
- Air Compressor Overhauls
- Asbestos Removal and Disposal
- Tank Cleaning
- Blasting and Painting
- Pump System Overhauls
- Small Structural Fabrication
- Winch Overhauls
- Main Steam System Modifications
- System fabrications (i.e. piping, ventilation, foundations, etc.)

As with new construction, all installed systems must be tested and operational before the ship is delivered back to its owner. Testing requirements generally originate from the contract, although other sources of testing requirements do exist (e.g., NAVSEA standard items, reference memos, etc.). The tests must be scheduled, tracked for proper completion, and checked off by the proper groups (i.e. shipyard internal quality, SUPSHIP, Ships Force, government agencies, ship owners, etc.). Once systems are in place and properly tested, the area, compartment, and/or system can be considered sold to the ship (i.e. completed).

Figure 3.8: **Pictured is a major conversion of an oil product carrier to a hospital ship for the Navy. Notice the ship is in a graving dock and a floating dry dock is in the background. Photo is courtesy of National Steel and Shipbuilding Company.**

3.2.5 Similarities Among Shipbuilding and Repair Processes:

There are many similarities between new construction and repair processes. The primary similarities are that they both use the application of essentially the same manufacturing practices, processes, facilities, and support shops. Ship repair and new construction work require highly skilled labor because many of the operations have limited potential for automation (especially ship repair). Both require excellent planning, engineering, and interdepartmental communications. The repair process flow is generally as follows: estimate job, plan and engineer the job, rip-out work, refitting of steel structures, repair production, test and trials, and deliver the ship. In many ways the ship repair process is similar to shipbuilding although new construction requires a greater amount of organization because of the size of the workforce, size of the workload, number of parts, and the complexity of the communications (i.e. production plans and schedules) surrounding the shipbuilding work-flow.

3.3 Support Shops For Shipbuilding and Ship Repair:

Support shops are an important part of the shipyard's overall success. In some cases, the support shops are small manufacturers producing goods to support the production effort. Other support shops mainly provide services to the shipyard that support production (e.g., maintenance and carpenter shops). Communications between the support shops, the stages of construction, planning, and engineering are the key to efficient shipbuilding and repair.

3.3.1 Pipe Shop:

The pipe shop is responsible for manufacturing and assembling piping systems. Piping systems are the largest outfitting task in shipbuilding. Small pipe sections known as “pipe spools” are assembled in the pipe shop and transported to the stages of construction (i.e. assembly, on-block, on-unit, and on-boa-d). Pipe spools are shaped and manufactured per engineering design, are scheduled for construction, and sent to the various stages for installation. Many pipe shops will tag the spools to identify the location for installation on the block and ship ship. A typical ship may have anywhere from 10,000 to 25,000 pipe spools. Some of the processes in the pipe shop include: pipe welding (arc, MIG, TIG, pulse arc), pipe bending, flux removal, grit-blast, pickling, painting, galvanizing, and pressure testing. Some of the equipment used by the pipe shop are as follows: pipe welders, lathes, pipe cutting saws, shears, grinders, chippers, hole cutters, pipe benders, pickling tanks, transportation equipment, and many more.

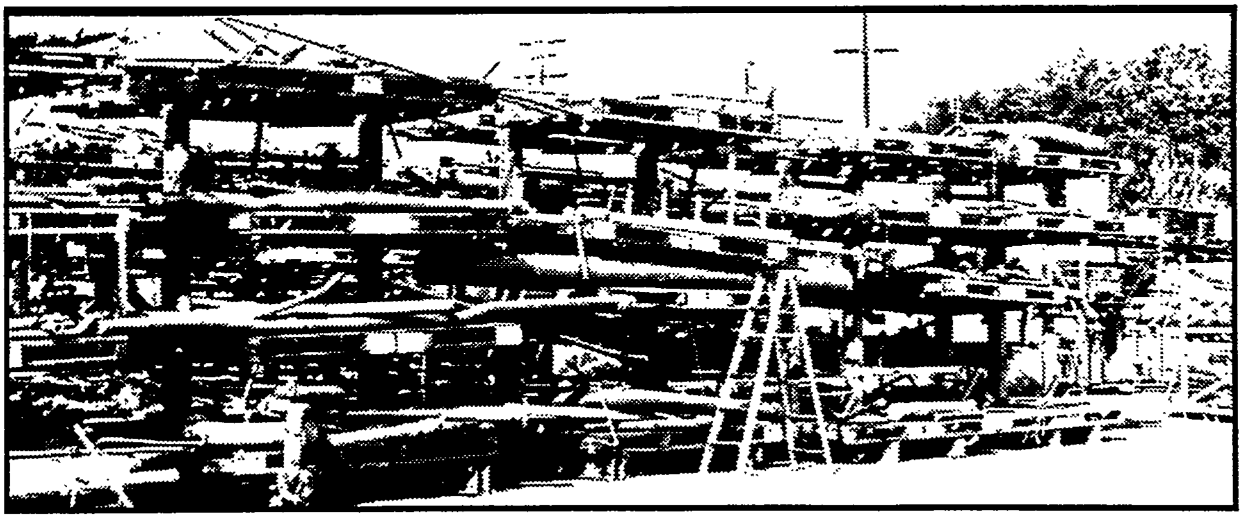


Figure 3.9: Pipe spools are kitted and organized on pallets for identification and installation at the stages of construction

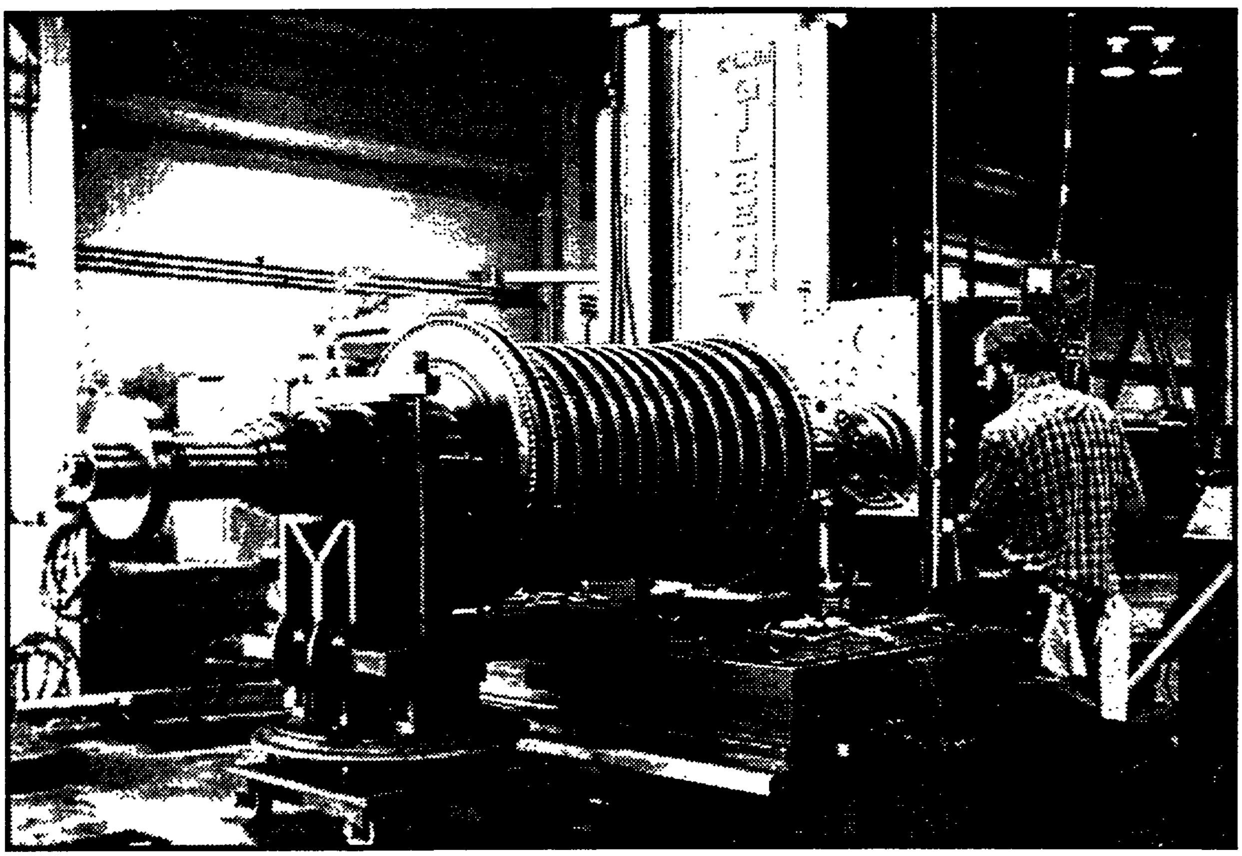


Figure 3.10: Shipyards have the capacity to perform the variety of machine work required by shipbuilding and repair. Displayed is a gas turbine being turned on a lathe.

3.3.2 Machine Shop:

The machining shop serves the entire shipyard's machining needs though the exact functions of the shipyard machine shops vary throughout the shipbuilding industry. Shipyard machine shops perform functions ranging from rebuilding pumps to turning 25 foot long propeller drive shafts on lathes. Equipment in the machine shop consists of end mills, lathes, drill presses, CNC milling machines, band saws, large presses, work tables, cleaning tanks, and other machining equipment.

3.3.3 Sheet Metal Shop:

The sheet metal shop is generally responsible for fabricating and installing ventilation ducting and vent spools. Using engineering drawings and special sheet metal tools this shop produces ventilation systems for new construction, as well as repair work. The shop cuts, shapes, bends, welds, stamps, paints, and performs a variety of manufacturing operations for ship ventilation systems. Many sheet metal shops are also responsible for assembling large ducting fans and heating and air conditioning components. Sheet metal workers perform the installation of the ducting in various stages of construction (i.e. on-block, on-unit, onboard).

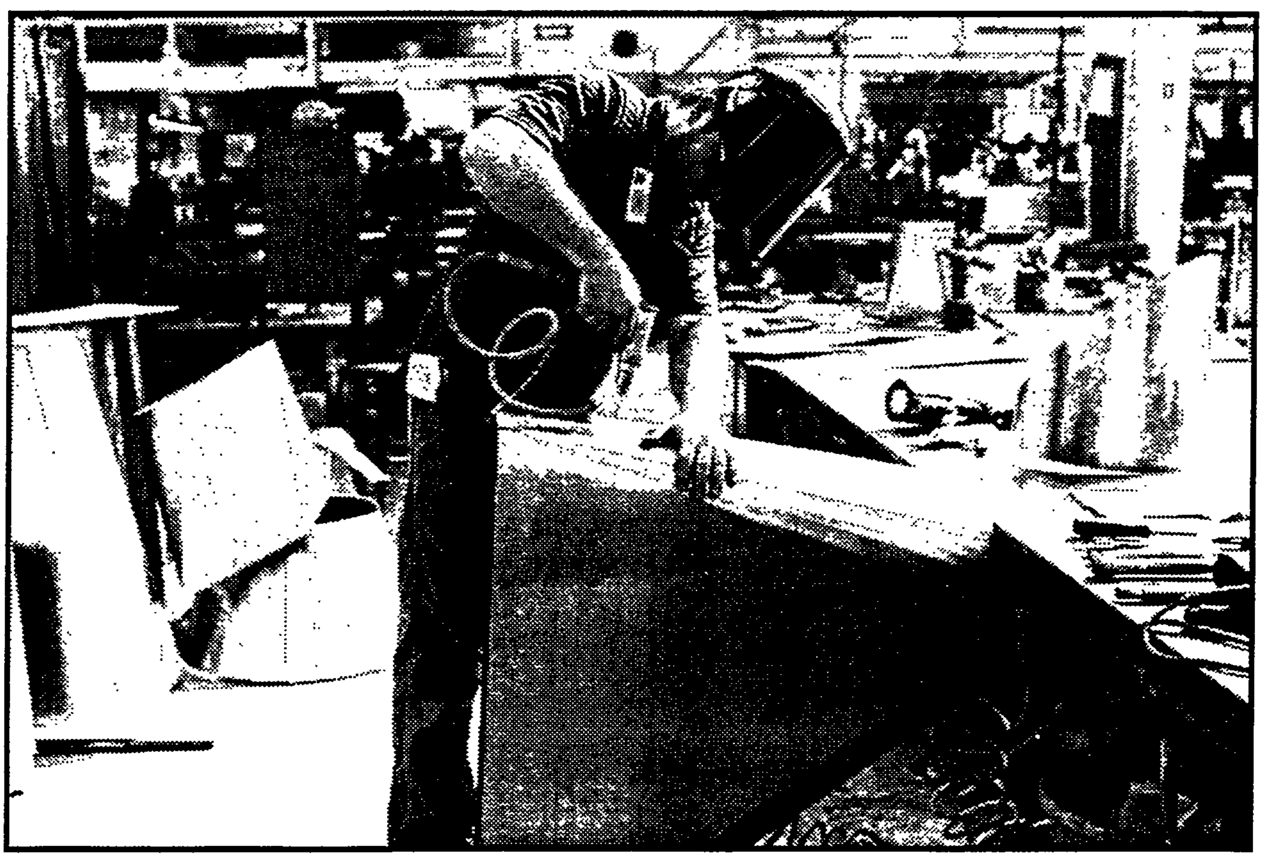


Figure 3.11: The **sheetmetal shop constructs and repairs ventilation systems. Displayed is a sheet metal worker at the final assembly stage of construction in the shop.**

3.3.4 Electrical Shop:

Electrical shops in the shipyard perform a variety of functions throughout the industry. In many cases, the electrical shop installs, rebuilds, builds, and tests electrical components (i.e., motors, lights, transformers, gauges, etc.). The electrical shop electricians also install the electrical equipment on the ship either on-block or onboard. On-block is where the electrical parts are installed and onboard is where cables are routed throughout the ship connecting the electrical systems together. The electric shop requires highly skilled workers. Electric shops generally have plating tanks, dip tanks for lacquer coatings, electrical testing equipment, and much more specialized equipment.

3.3.5 Blacksmith Shop:

The blacksmith shop is an older term used for the shipyard shop that performs forging or castings. Shipyard forging and casting are somewhat rare in U.S. shipyards. Over the years, forging and casting functions have been shifted to subcontractors. The subcontractors are usually foundries whose primary function is forging and casting. Shipyards that have black smith shops maintain large furnaces and other foundry equipment.

3.3.6 Plate Shop:

The plate shop is a generic term used for the area and process in the shipyard that provides steel parts cutting, bending, and sub-assembly. The plate shop uses information from engineering drawings to produce plate shapes. The shapes are cut and formed as needed. The plate shop has manual and computer controlled machinery. The types of machinery commonly found in the plate shop are cutting machines, steel bending machines and plate bending rolls, shearing machines, presses, hole punching equipment, and furnaces for heat treatment. The plate shop sends the parts and sub-assemblies that they manufacture to the stages of construction, or the platen area for installation.

3.4 Support Services For Shipbuilding and Ship Repair:

Support services are important to the shipbuilding operation. They perform functions ranging from general yard cleanup to rigging cranes, and support and facilitate production with their knowledge and labor. A general list of services needed in the shipyard are as follows:

3.4.1 Production Services:

The production services shops are sometimes grouped into one department. The services they provide are instrumental in the overall operation of the shipyard. Services provided by this department include: carpentry, scaffolding installation, crane operations, rigging, facility and equipment maintenance, and other production support activities. As the name implies, these departments are designed to service production in the effort to build and repair ships. It is crucial that these groups react efficiently to the needs of the support shops and stages of construction.

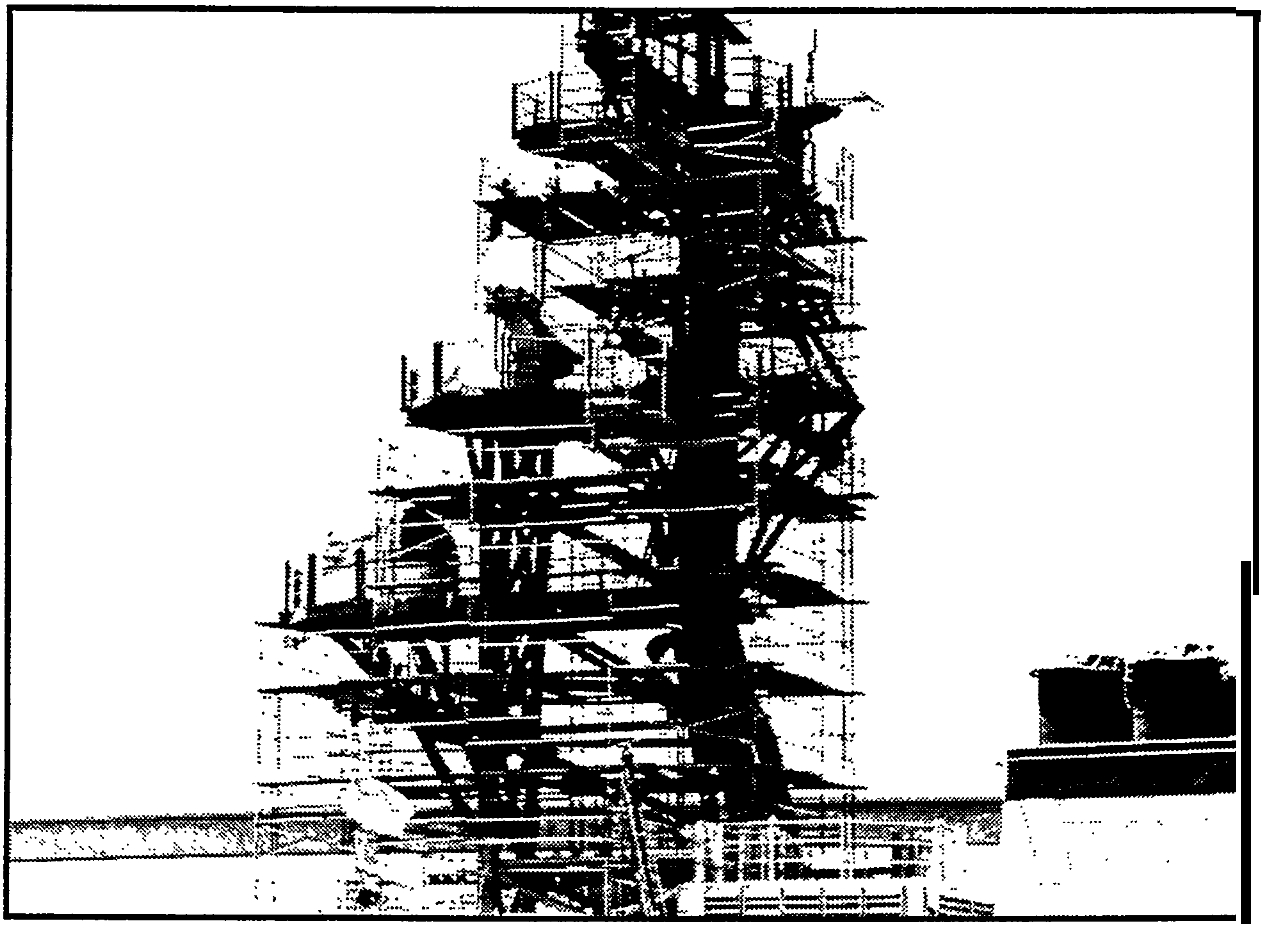


Figure **3.12: The figure illustrates the scaffolding requirements for performing superstructure repair.** Photo is courtesy of South West Marine, San Diego, California.

3.4.2 Materials Transportation and Warehousing:

Material control is one of the most important aspects in efficient shipbuilding. Materials throughout the shipyard are generally controlled by a transportation and materials department. The materials (e.g., pipes, lights, venting) need to be delivered to the proper location in the shipyard to be installed on the construction blocks. Forklifts, trucks, cranes, carts, carriers, and other materials transport equipment are used by this department. Materials received through the materials department are checked for quality, quantity, and proper invoicing before they are sent to the warehouse. The materials are then packaged in work packages and prepared for shipment to production at the various stages.

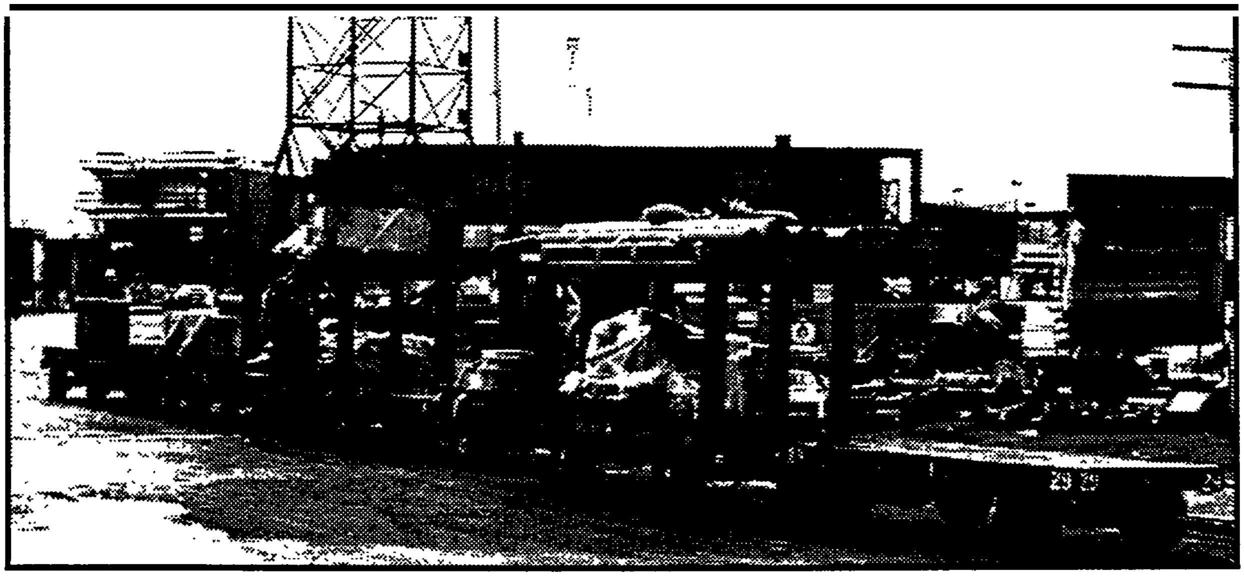


Figure **3.13: The mule train is used in conjunction with a forklift and serves as a valuable tool for material movement in the shipyard.**

3.4.3 Subcontractors in the Shipyard:

Subcontractors are frequently used in the shipbuilding industry. They perform many of the functions the production workers and support shops in the shipyard perform. Subcontractors perform painting, blasting, ventilation production and installation, piping system installation, electrical installation, and many others. Shipyards use subcontractors for their expertise in a particular area (e.g., special combat systems) and to even the manning load of the shipyard at times when there are load peaks. Using subcontractors in times when there is a large amount of work in the shipyard reduces the need for shipyards to lay-off workers in times of reduced work-load.

3.5 Major Production Facilities For Shipbuilding and Ship Repair:

3.5.1 Prime Line

The prime line is a large machine that blasts and primes raw steel sheets, preparing them for production. Steel sheets, parts, and shapes enter one end of the prime line, go through a blasting section, then through a priming section. The primer is referred to a construction primer, and is used to prevent corrosion during the production processes. Chapter **4** of this manual discusses the prime line in more detail.

3.5.2 Panel Lines:

The increasing need to produce ships more efficiently and increasing steel throughput in the late 1960's resulted in the development of panel lines. The panel line was a way to introduce manufacturing flow line techniques into the steel shipbuilding industry. The majority of panel lines installed in shipyards were primarily designed to construct units for large tankers (i.e. large rectangular blocks). The panel line generally consists of motor driven conveyors with fixed rollers used to move large plates together for joining (welding). Plates are tacked together with magnetic aids and seam welded. Seam welding can be performed by either one sided or two sided welding. Two sided welding requires the steel to be turned over. Vertical stiffeners are also welded on the panel line, and is performed using gravity welding machines or twin-fillet submerged arc machines. Gas cutting equipment is usually incorporated in the lines to cut off "excess" material after the seam weld. A panel line could consist of the following stations: plate storage, alignment/tack, machine weld (side one), turnover, machine weld (side two), trim excess, layout/tack stiffeners, weld stiffeners, and inspection. The assembly line moves with the aid of magnetic cranes (bridge, overhead, etc.). Welding machines are accessible throughout the panel line for productivity.

3.5.3 Platen Lines (Assembly):

The platen lines are the area in the shipyard where blocks are assembled. Therefore, platens are the areas in the shipyard that form assembly lines where the steel structure of construction blocks is fabricated. Sub-assemblies from the panel line and plate shop are brought together at the platen and assembled into blocks. The platen mainly provides locations for sub-assembly construction, block layout, tack-welding, and final weld out. The platen lines are serviced by various cranes for materials movement as well as welding and steel cutting equipment.

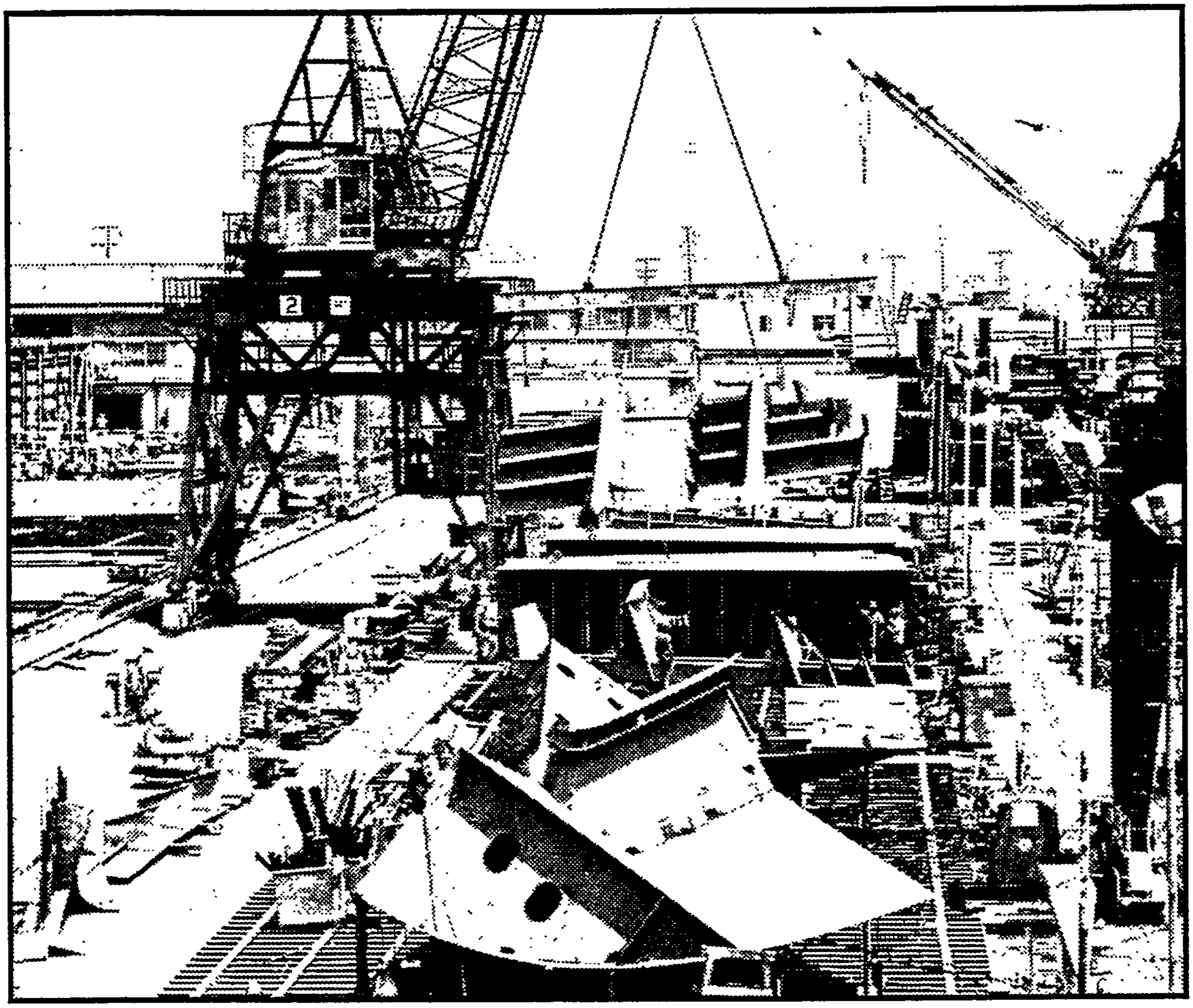


Figure 3.14: **The outside platen line at NASSCO illustrates the assembly line approach to block production. Notice the curved block in the foreground is placed on a pin jig structure.**

3.5.4 **Rolls:**

Rolls are large facilities that bend and shape steel plates. The rolls frequently consist of three large cylindrical steel shafts and a motor drive, and are used to form the curved surface plates for the curved portion of the hull. Rolls vary greatly in size and technology from shipyard to shipyard. Some of the newer rolls are computer controlled, while the older machines are manually positioned and operated.

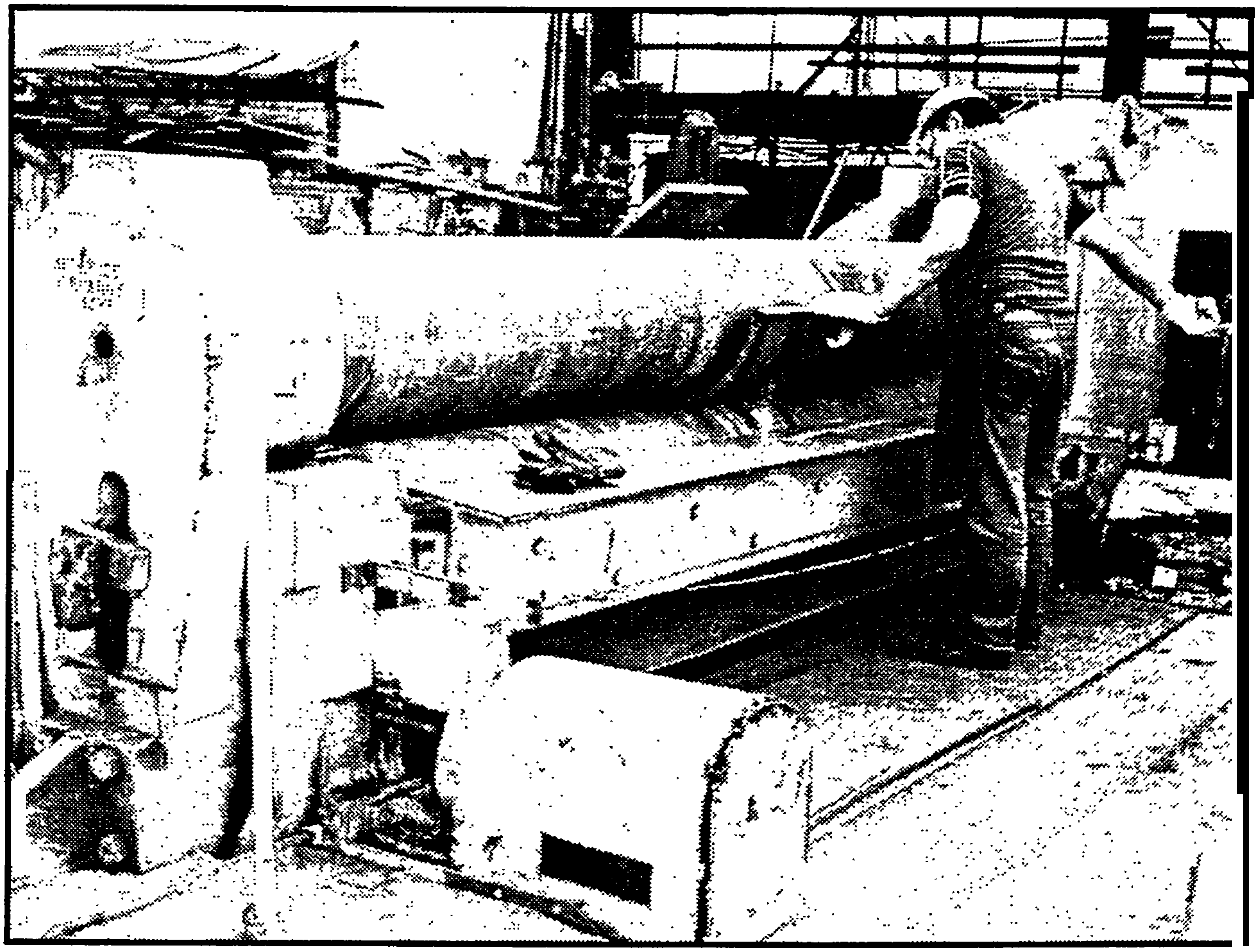


Figure **3.15: Displayed is a 20 foot roll used to bend plate steel in, to Curved shape required for ship construction. Larger 40 foot rolls are used to bend the steel plates that form the hull's curved surfaces.**

3.5.5 Pin Jigs:

Pin jigs are platen lines used to assemble curved blocks, and are situated throughout the shipyard into process lanes. The pin jig is one of the simplest and most effective facilities developed by the modern shipbuilder. A pin jig is simply a series of vertical screw jacks that support curved blocks during construction. The jacks can be adjusted to attain the desired curvature. Curved blocks form the outside of the hull's curved surface; mechanizing the production of curved blocks is much more difficult than that of rectangular blocks. Curved blocks are three dimensional panels consisting of:

- Rolled plates
- Shaped sections
- Profiled plates
- Shell plates
- Shell longitudinales
- Webbed frames and stringers

The most common method to assemble these blocks is on a pin jig set up specifically for the curved block. The legs of the jig are telescopic and therefore easily adjustable for different curved blocks. The jig heights are usually determined from the engineering drawings and production information. See foreground in Figure 3.14.

3.5.6 Rotary Turntables:

Rotary tables are a facility that hull blocks are set into and have the ability to rotate the block mechanically. The ability to rotate a block in a single location reduces the number of time-consuming crane lifts needed to rotate the block, thereby reducing expenses. Rotary tables are used to exploit the increased efficiencies experienced when workers are able to weld and assemble blocks down hand. Down-hand welding provides a higher quality weld with higher efficiency rates. Turntables are also used for outfitting materials on the block because of easier access to outfitting locations. Turntables come in a variety of forms, although their primary function remains the same.

3.5.7 Materials Handling Equipment:

Material handling equipment can be subdivided into four major categories, including conveyors, cranes, industrial vehicles, and containers. Materials handling is an important aspect of shipbuilding and repair. Extreme coordination is needed between materials delivery and the production schedule.

Conveyors:

Conveyors in the shipyard are mainly used to move materials in process lanes for efficient movement. The primary conveyors are roller type and can be found on the panel line and the platen lines. They are usually a roller and chain assembly that pulls the material from one station to the other. Conveyor systems are also used in the pipe shop area to help with automation of material flow. In many cases, conveyor systems take up more shop floor space, although the overall improvements in material flow more than compensate for the loss in work space.

Cranes:

Cranes are the most popular type of material handling equipment used in shipbuilding. In many cases, they are the only method for moving large materials around the shipyard. In new construction, cranes are used to move blocks throughout the stages of construction and other material movements. In repair operations, cranes are primarily used to load materials onto the ship. Crane types come in a variety of sizes and shapes, depending on the shipyard and its associated applications. The four main types of cranes used in the shipyard are bridge cranes, jib cranes, gantry cranes, and mobile cranes. Bridge cranes require support much like a bridge. The bridge crane travels on two wall-type structures with rails on top see Figure 3.16. Small bridge cranes are used to move parts throughout shops for material movement, production, and assembly. Most large bridge cranes are used to move heavy steel plates from one work area of a platen to another and are used to assemble sub-assemblies and blocks. Most bridge cranes have electromagnets or clamps to attach steel plates being transported and/or assembled.

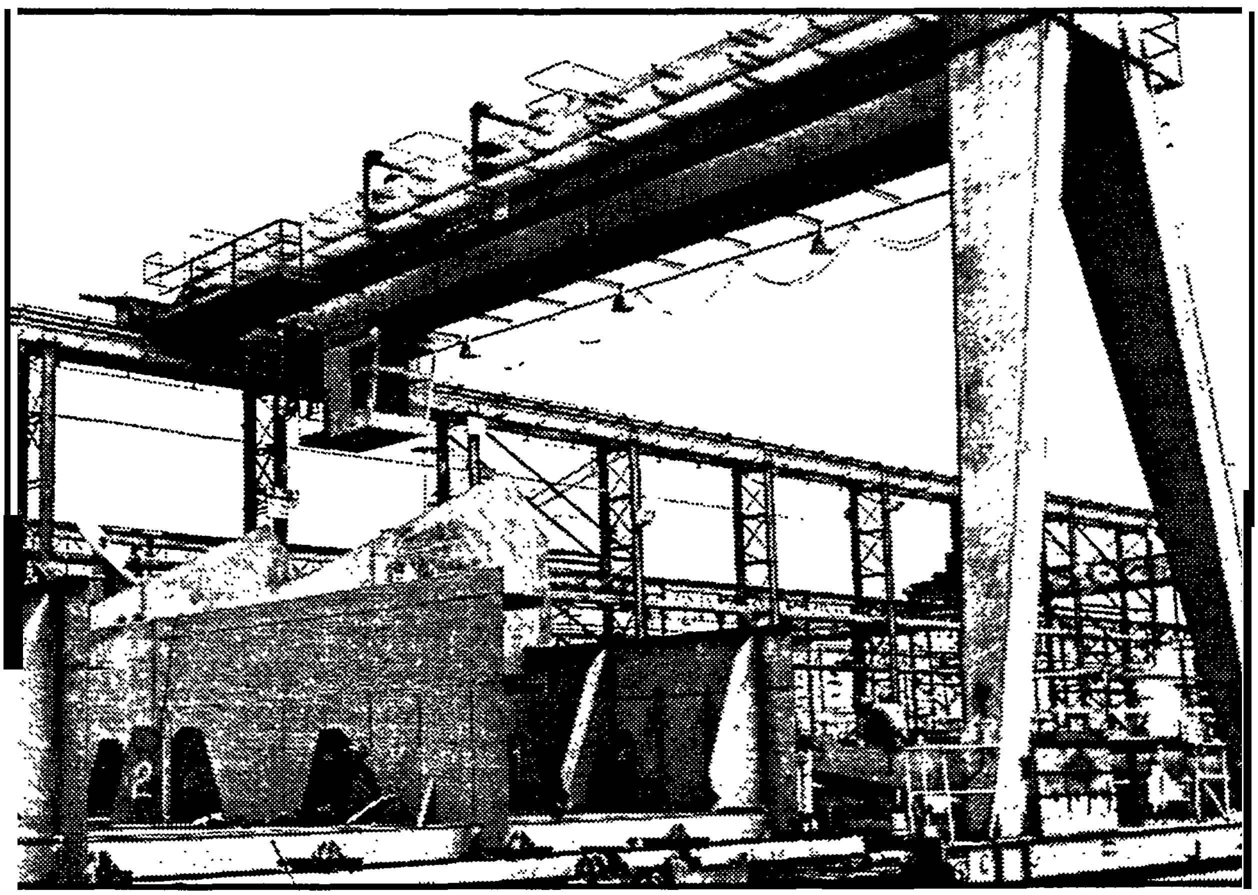


***Figure* 3.16: Building Cranes are frequently used at the assembly stage of construction. They are essential in assembling large steel structures.**

Gantry cranes are similar to bridge cranes except that they are self supporting and run along rail tracks on the ground. Figure 3.15 displays a gantry crane used in the steel storage area. Similarly, jib cranes are self supporting and run along rail tracks on the ground. They can revolve about their base and extend to reach out over work areas. Their lifting and reaching abilities vary from crane to crane, depending on size and geometry. Jib cranes are the most popular type of crane found in ship-building and repair. For heavy lifting, shipyards will use two or even three jib cranes to lift and transport one large structure. Figure 3.18 shows a multiple lift using jib cranes. The stationary hammerhead crane or tower crane is similar to a jib crane, but stationary. The stationary cane allows for 360 degree movement about its base. When there are many small movements in a centralized area, a tower crane may be the best alternative for materials movement. On the other hand, mobile cranes are used for smaller materials that are not located in a centralized area. The mobile cranes have rubber tires and can drive to nearly all locations in the shipyard. As expected, the mobile cranes have lower limits with respect to the size, shape, weight, and height to which material can be transported.

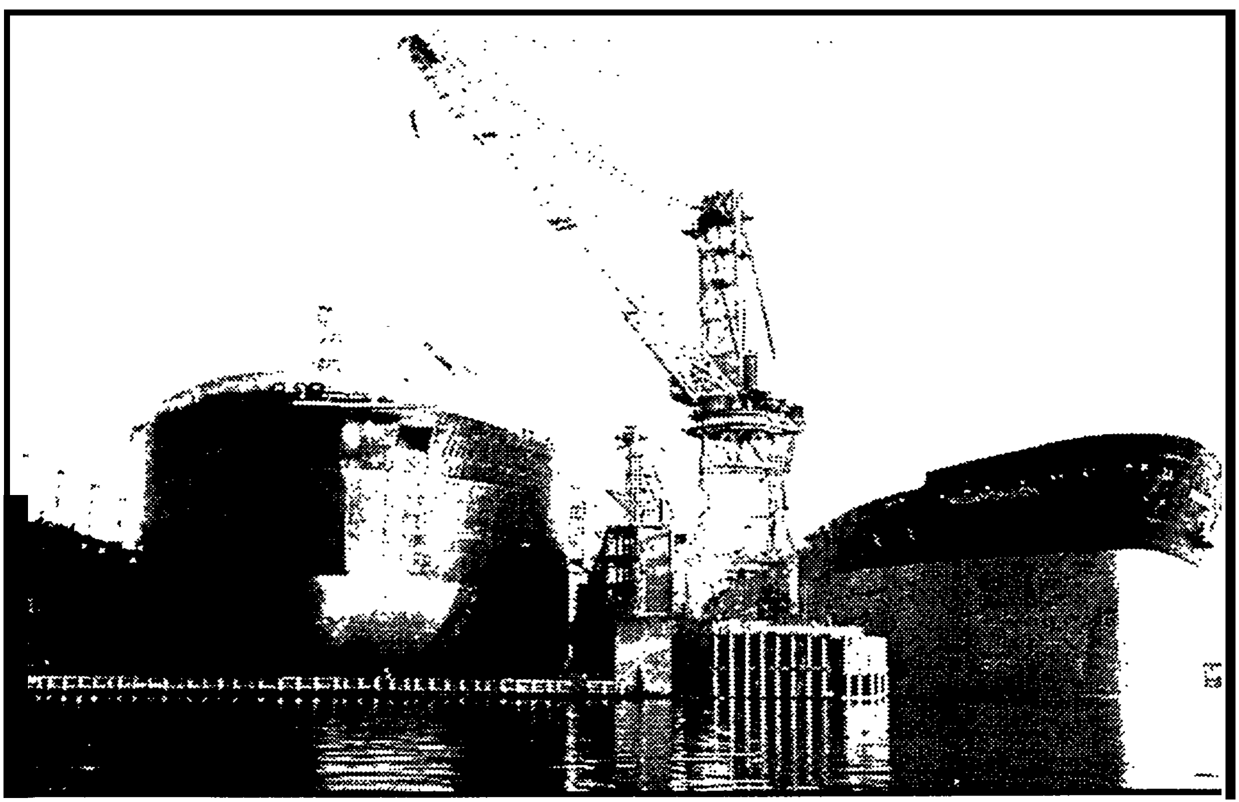


Figure 3.17: **A large jib crane at Port of Portland used to service the ship in the floating dry dock (left) and the ship at berth (right).**

Figure 3.18: A three jib crane lift is required a NASSCO to lift the crankshaft for the Matson commercial container ship under construction.

Containers and Container Movers:

Containers in the shipyard consist primarily of boxes, pallets, drums, tanks, etc. Containers are important for consolidation of like material to facilitate more productive materials movement. Containers are used to transport small units, packages of piping, steel foundations, paint, trash, etc. Movement of these containers is performed by fork lifts, small cranes, transport flatbeds, mule trains, and special lift vehicles.

Chapter 4

Surface Preparation and Coating for Shipbuilding and Repair

The marine environment has detrimental effects on nearly all ships and shipboard components. Corrosion and deterioration are a continual problem in the open air, salt water environment as well as in tanks onboard ships that contain materials such as fuel oils, fuel, septic, and other corrosive substances. Maintaining the ship's structural integrity is the main purpose of shipboard paint system. Therefore, proper surface preparation and coating system application is essential in the shipbuilding industry to preserve the life of the ship's products.

4.1 Introduction to Surface Preparation:

The steel structure must be protected from the environment to maintain it's structural integrity. Coating systems serve the purpose of corrosion protection and surface preparation is the interface for coating system adhesion. To a large extent, the effectiveness of the surface coating relies on the quality of surface preparation. In shipbuilding and repair, over half of the money estimated for application of coating systems is for surface preparation. This helps to illustrate the importance of surface preparation in shipbuilding construction and repair. All paints will fail eventually, but the majority of premature failures of paint systems is due to loss of adhesion caused by improper surface preparation.

In order to remove surface contaminants for application of coating systems, some type of abrasion or chemical action needs to occur. Abrasion is usually accomplished mechanically, using air pressure, centrifugal action, abrasion (sanding), and/or direct contact (chipping and scraping). Chemical cleaning of surfaces with paint removers, alkaline cleaners, and metal etching also occurs in the shipyard. The choice of surface preparation methods involves the following considerations: surface contaminants, paint type, required surface profile, cost, safety, pollution, available equipment, and other production related constraints.

4.1.1 Surface Contaminants:

Surface preparation techniques are used to remove surface contaminants such as mill scale, rust, flash rust, dirt, salts, old paint, grease, and flux. Contaminants that remain on the surface are the primary causes of premature failure of coating systems. The following is a brief discussion of five common surface contaminants:

(1) Mill Scale:
Mill scale is a residue which forms on the surface of new steel that is hot rolled. As the steel cools, a residue of iron oxides forms a "tight skin" or "crust" called mill scale over the entire surface. Mill scale is bluish, shiny, and smooth. In many cases, mill scale is difficult to detect. The main problem with mill scale is that rust may form under the scale after a paint system has been applied.

(2) Rust:
Rust is the major disease which plagues most ships. When it is time to apply coating systems to the ship, the rust should be removed from the surface. Painting over rust will lead to uneven coating and will cause premature failure of the coating system. However, in some surface preparation techniques small quantities of rust are painted over. In those cases major portions of the rust are blasted off and the surface made smooth and uniform.

(3) Dirt and Dust:
Excess particles of dirt and dust on surfaces to be painted prevent the application of a uniform coat of paint. Loose dirt particles should be brushed, vacuumed, or washed off the surface prior to coating to assure adherence of the paint.

(4) Salts:
Salts accelerate corrosion. If paint is applied over salts, corrosion cells develops and rust forms rapidly. Salts can become trapped in pits and crevasses. Therefore, when there is risk that salts are present, particular attention must be given to cleaning these areas. Since most shipyards are in a salt air environment, this is always an issue when applying coating systems.

(5) **Oil, Grease, and other Shipyard Contaminants:**
Oil or grease on a surface will prevent good paint adhesion, therefore it must be removed completely from the surface. Smoke from welding and inspection/construction markings on the steel must also be cleaned from the surface prior to paint application.

4.1.2 Standards for Surface Preparation:

Standards for surface preparation have been developed by many organizations and in several countries. Standards simply determine the level to which the surface needs to be cleaned. The specific standards for surface preparation are stated in the ship repair or new construction contract. Standards of importance to U.S. shipbuilding are as follows:

> **Steel Structures Painting Council:** SP-1 Solvent Cleaning, SP-2 Hand Tool Cleaning, SP-3 Power Tool Cleaning, SP-5 White Metal Blast Cleaning, SP-6 Commercial Blast Cleaning, SP-7 Brush off Blast Cleaning, SP-10 Near White Metal Cleaning, SP-11 Power Tool Cleaning to Bare Metal. National **Association of Corrosion Engineers:** NACE Standards; Grade 1 “White Metal Surface”, Grade 2 “Near White Metal Surface” Grade 3 “Commercial finish”, Grade 4 “Brush Off Blasting”. **Various U.S. Government Specifications** also exist for shipbuilding. For example, Fed-Spec TT-490, “Cleaning Methods and Pretreatment of Ferrous Surfaces Of Organic Coatings” and Department of the Navy, Naval Sea Systems Command: Chapter 631, “Preservation of Ships in Service”.

4.2 Surface Preparation Techniques:

4.2.1 Solvent, Detergent, and Steam Cleaning Surface Preparation:

The process of removing grease, oil and other contaminants with the aid of solvents, emulsions, detergents, and other cleaning compounds is frequently used for surface preparation in the shipbuilding industry. Solvent cleaning involves wiping, scrubbing, immersion in solvent, spraying, vapor decreasing, and emulsion cleaning the surface with rags or brushes until the surface is cleaned. The final wipe down must be performed with a clean rag, brush, and solvent. The major problems with solvent cleaning is the fact that many solvents are regulated by OSHA and EPA, which limit their use. Many solvents are hazardous and care must be taken when using such substances for cleaning. Users should follow all safety precautions regarding ventilation, smoking, static electricity, respirators, eye protection, and skin protection. Environmentally, many solvents can have excessive Volatile Organic Compounds (VOC’S), which lead to local smog. Inorganic compounds such as chlorides, sulfates, weld flux, rust and mill scale cannot be removed with organic solvents. In many cases steam cleaning is a better alternative to solvent wipe down. Steam cleaning or high pressure washing is used to remove dirt and grime that is present on top of existing paint and bare steel. Many hot steam cleaners with detergents will remove most petroleum products and sometimes, old chipping paint. After steam cleaning the part should be rinsed with fresh water and allowed to dry. In many cases the surface is ready to prime although, many items will require further surface preparation before painting.

4.2.2 Abrasive Blasting:

Abrasive blasting is the most common method for paint removal and surface preparation. In recent years, concerns have been raised regarding the amount of waste associated with blasting operations and the amount of fugitive dust released into the surrounding areas. Therefore, shipyards are performing waste minimization and recycling of abrasive. Copper slag grit is generally only used once or twice, although it is in many cases recycled into Portland Cement. On the other hand, steel grit is reused at the shipyard more than fifty times. Local air quality regulations now make it difficult to perform blasting operations in the open atmosphere. Therefore shipyards are performing blasting operations in more confined spaces. Shrouding systems and structures are being utilized to control fugitive abrasive dust.

4.2.3 Centrifugal Blasting Machines:

Centrifugal blasting machines are one of the more popular methods for meeting steel fabrication blasting requirements. Many companies refer to centrifugal blasting as roto-blasting, automatic blasting, or “Wheelabrator” blasting (“Wheelabrator” is a popular blasting machine company). Generally, centrifugal blasting is performed with metallic shot or grit in enclosed cabinets or blast rooms. Metallic shot are small round balls; grit is triangular with sharp edges. Both are sold in varying ranges of hardness and size. The abrasive is propelled to the surface to be prepared by a spinning wheel. Many centrifugal blasting machines recirculate metallic grit and shot anywhere from 50 to 5,000 times before the material becomes too small to be effective. Therefore, centrifugal blasting is very cost efficient because the blasting material is easily recovered and recycled.

Centrifugal blasting has many advantages and disadvantages in the shipyard. Its use in small parts applications and sheet steel preparation has proven quite efficient. However, centrifugal blasting equipment is not applicable to all shipyard blasting needs because the machines are limited in size. Another disadvantage is that the material must be brought to the blasting machine and passed through on a conveyer or rotary table. Therefore, the machine is not very flexible. The centrifugal blasting machine produces uniform blasting on flat surfaces; it takes more time to prepare surfaces that are hard to reach. Any oil on the surface, to be prepared will contaminate the grit that is recycled which, inturn, will contaminate future blasted surfaces. Therefore, surfaces contaminated by oil or grease should be steam cleaned, wiped with solvent, or washed prior to blasting. The advantage of centrifugal blasting are high production rates on flat surfaces, even surface preparation, and is easy recovery and recycling of the abrasive. The original investment is high for centrifugal blasting machines. However, in many cases the investment return is good because of the ability to recycle grit blast material and increase productivity.

There are two centrifugal blasting machines which are most common in shipyards; the “small parts” machine and the “Prime Line” machine. Small parts blasting machines generally have a maximum size of 5 ft. X 4 ft. Small parts centrifugal blasting machines are usually located near small parts painting areas and are used for pipe spools and small steel sub-assemblies. The “Prime Line” blasting machine is used to prepare “raw” steel sheets or shapes for production. Steel sheets are brought from the steel storage area and placed on a conveyer which carries them to the “Prime Line” machine. The first stage of the prime line is the centrifugal blasting, which is performed on both sides of the plate steel. The second stage sprays a pre-construction primer on the steel. The sheet of steel is then ready to continue onto further stages of construction with a properly prepared surface and a construction primer system.

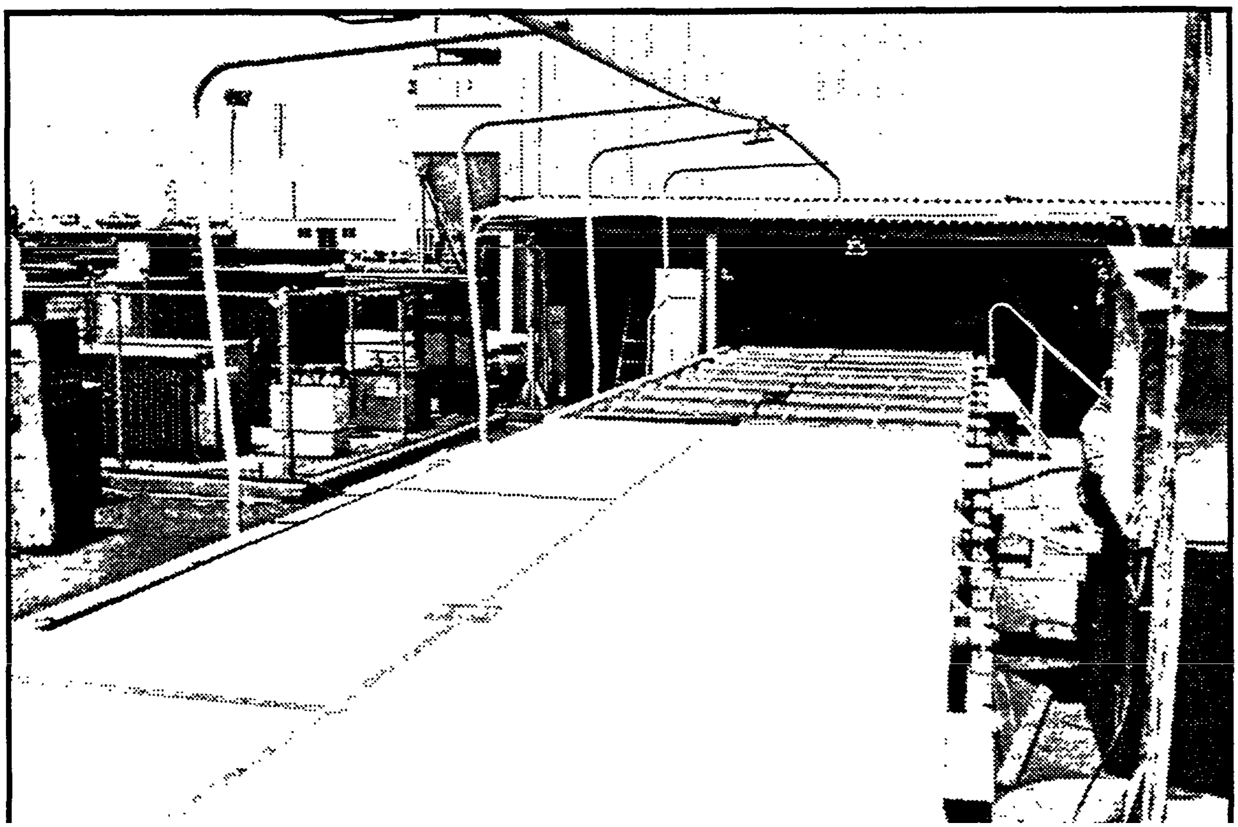


***Figure* 4.1:** The figure displays a primed sheet of plate steel after it has gone through the prime line. The date was blasted and primed automatically on a conveyor system and is now ready to continue though the production’ process.

4.2.4 Dry Abrasive Air Nozzle Blasting:

Dry abrasive blasting is also referred to as air nozzle blasting. Air nozzle blasting is probably the most common type of blasting found in the shipbuilding and repair industry. Dry abrasive blasting is used for nearly all interior tank preparation and exterior hull preparation. Dry abrasive blasting is a process by which the blasting abrasive is conveyed in a medium of high pressure air (approximately 100 PSI) through a nozzle at velocities approaching 450 feet per second. The grit impinges the surface, causing abrasion. Originally sand was used as the blast medium, but due to health problems caused by silica dust, coal, copper slag, and other metallic mineral, abrasive have replaced sand. Depending on the type of abrasive used and the surface condition, it can take between 4 to 12 lbs. of abrasive to blast 1 square foot of steel. Air nozzle blasting is generally accomplished manually by shipyard blasters. Dry abrasive blasting can either be performed within a building or in the open air, depending on the application. Open air blasting is usually performed in an identified location within the shipyard. However, through the use of portable blasting units, blasting occurs at almost every location of the shipyard. In most states, open air blasting is regulated to special abrasive types. Air blasting can also be performed in blast booths, although this has limited application in the shipbuilding industry because booths are limited in size.

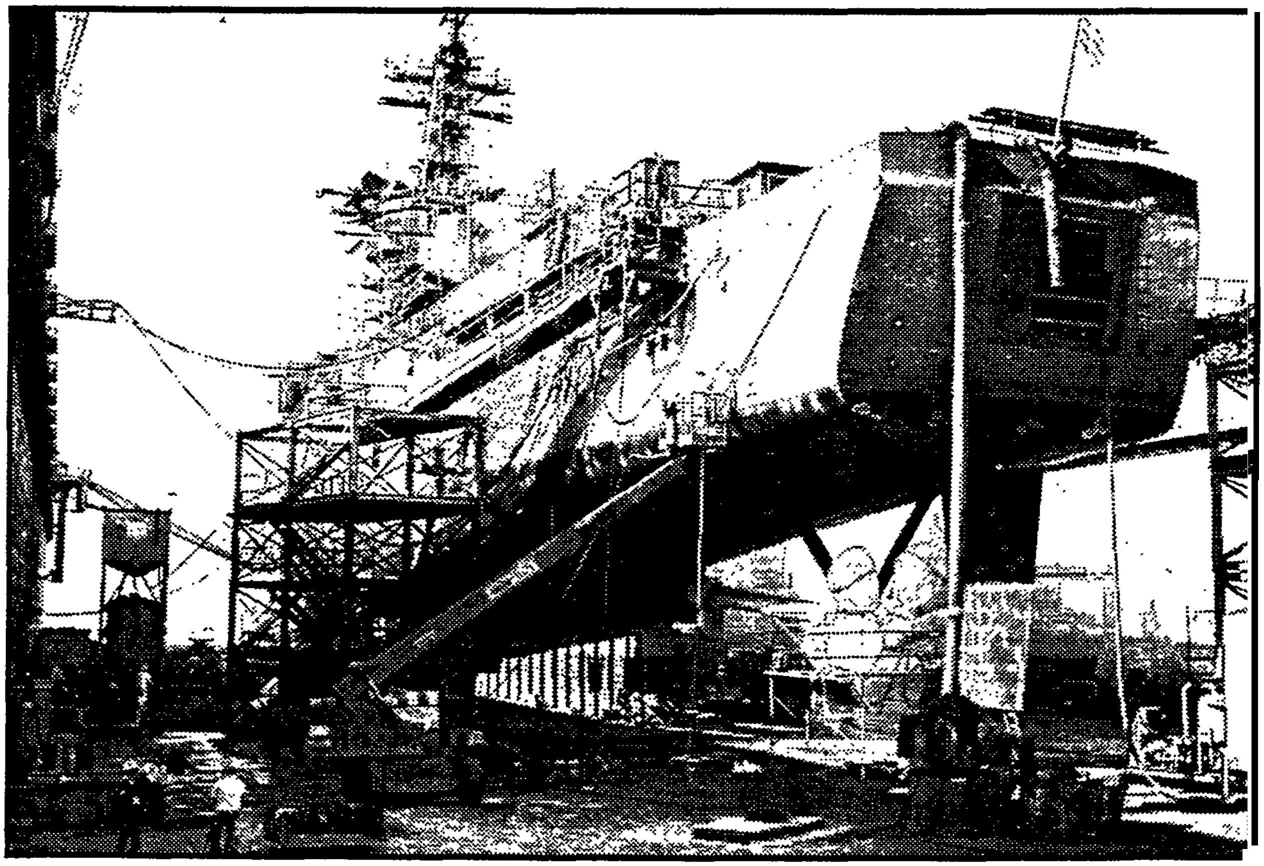


***Figure* 4.2: The figure displays a Navy vessel under repair. The surface was prepared with dry abrasive blasting. Notice grit on surface of the dock and blasting pots on the left side of dock. painting is in progress, notice the painter on the portable man-life spraying a coat on the ship.**

4.2.4.1 Procedure Generally Used for Dry Abrasive Blasting:

The following is a general description of the procedures used when dry abrasive blasting is performed in the shipyard:

1. Grit blast material is delivered to the shipyard by rail car, dump truck, barge, large vacuum truck, or some other transportation method.
2. The grit is then placed in a storage area.
3. Shipyard containers are used to transport grit to yard locations where blasting occurs.
4. Abrasive is transferred into the portable or permanent blasting machine pressure pots.
5. Shrouding (if required) is put in place to minimize the amount of fugitive abrasive during open air blasting.
6. Blasting will commence when the grit is loaded in the pressure pot and air pressure is at operating range.
7. Large amounts of dust are developed during blasting and spent abrasive, old paint particles, fouling organisms, and other debris fall to the underlying surface. Dust collectors and ventilation systems are used in enclosed areas.
8. The debris produced by the blasting operation is normally cleaned up with the aid scoop tractors, vacuum truck and machines, and/or hand brooms and shovels.
9. The used grit material and associated waste is then disposed of appropriately, or recycled.

4.2.4.2 Types of Abrasive:

The abrasive used may be either metallic or nonmetallic. Most abrasive blasting is performed with some by-product mineral abrasive low in free silica content. These mineral copper slags are the most common for large scale blasting repair blasting jobs. The specifications used by Naval shipyards for grit allow for a maximum of 5 percent free silica content and low limits on heavy metals. Rationale for purchasing different types of abrasive are low free silica content, less dusting, performance, availability and price.

4.2.4.3 Productivity of Abrasive:

Different types of abrasive and application techniques have various productivity per pound. As one would imagine, the productivity is also proportional to the cost of the abrasive. The amount of abrasive can be estimated by multiplying a consumption rate (lb/sq ft) by the surface area needing preparation. Also a production rate can be determined to allow for relative production time. Metallic abrasive generally are difficult to transport and collect because of their density, and are the most expensive. On the other hand, slags are the most productive, produce more waste because they are reused less, and are the least expensive.

4.2.5 Hand Tool Surface Preparation:

Hand tools such as grinders, wire brushes, sanders, chipping hammers, needle guns, rotary peening tools, and other impact tools are commonly used in the shipyard for surface preparation. The hand tools are ideal for small jobs, hard to reach areas, and areas where blasting grit would be too difficult to contain. Cleaning surfaces with hand tools seems comparatively slow although, when removing heavy paint formulations and heavy rust, they are effective and economical. Impact tools like chipping and needle guns are best for removing heavy deposits of brittle substances (i.e rust and old paint). On the other hand, hand tools are generally less effective when removing tight surface mill scale or surface rusting, because they can damage the metal surface. Hand tool surface preparation is generally not used for high performance coating applications. Satisfactory surface conditions can be obtained with reasonable labor costs and good paint adhesion. Surface preparation hand tools are generally pneumatic instead of electric because they are lighter, easy to handle, they don't over heat, and there is no risk of electric shock.

4.2.6 Wet Abrasive and Hydro Blasting:

Wet abrasive blasting and hydro blasting are mainly used for hull surface preparation for ship repair operations. Wet abrasive blasting uses a water or water/air mixture to project the abrasive onto the surface being prepared. On the other hand, hydroblasting only uses high velocity water projection to clean the surface. No fugitive dust is developed from wet abrasive blasting or hydro blasting operations. Where wet abrasive and hydro blasting are performed, a water containment and collection system should be put into place. Wet blasting is generally performed in a floating drydock, graving dock, or other building or repair position. Wet abrasive blasting does not occur throughout the shipyard like dry abrasive blasting because of the problem of water blast containment. Wet abrasive blasting is not extremely common in the shipbuilding and repair industry at this time. Hydro blasting is a widely used wet blasting technique which only uses high pressure water to remove chipping paint and marine growth from the ship's hull. Hydro blasting is frequently performed on repair ships when they are drydocked to wash salt water and mud from the hull. A small amount of rust inhibitor is frequently used in the water to prevent flash rusting. Hydro blasting is generally performed on the hull surface of repair ships and is followed by air nozzle blasting for final surface preparation.

4.2.7 Chemical Surface Preparation:

Chemical surface preparation consists of alkaline paint removers and cleaning solutions, chlorinated solvents, and pickling. These alkaline cleaning solutions come in a variety of forms and are used in a variety of manners. Alkaline cleaners can be brushed on, sprayed on, and applied in a dip tank. Caustic soda dip tanks are frequently used for cleaning a variety of parts and preparing them for paint. After the surface is cleaned, it is important that the surface is rinsed well before a coating system is applied. Nonferrous metals like bronze, aluminum, and galvanized steel are frequently found on ships. Many solvents and alkaline cleaners cannot be used for the nonferrous materials.

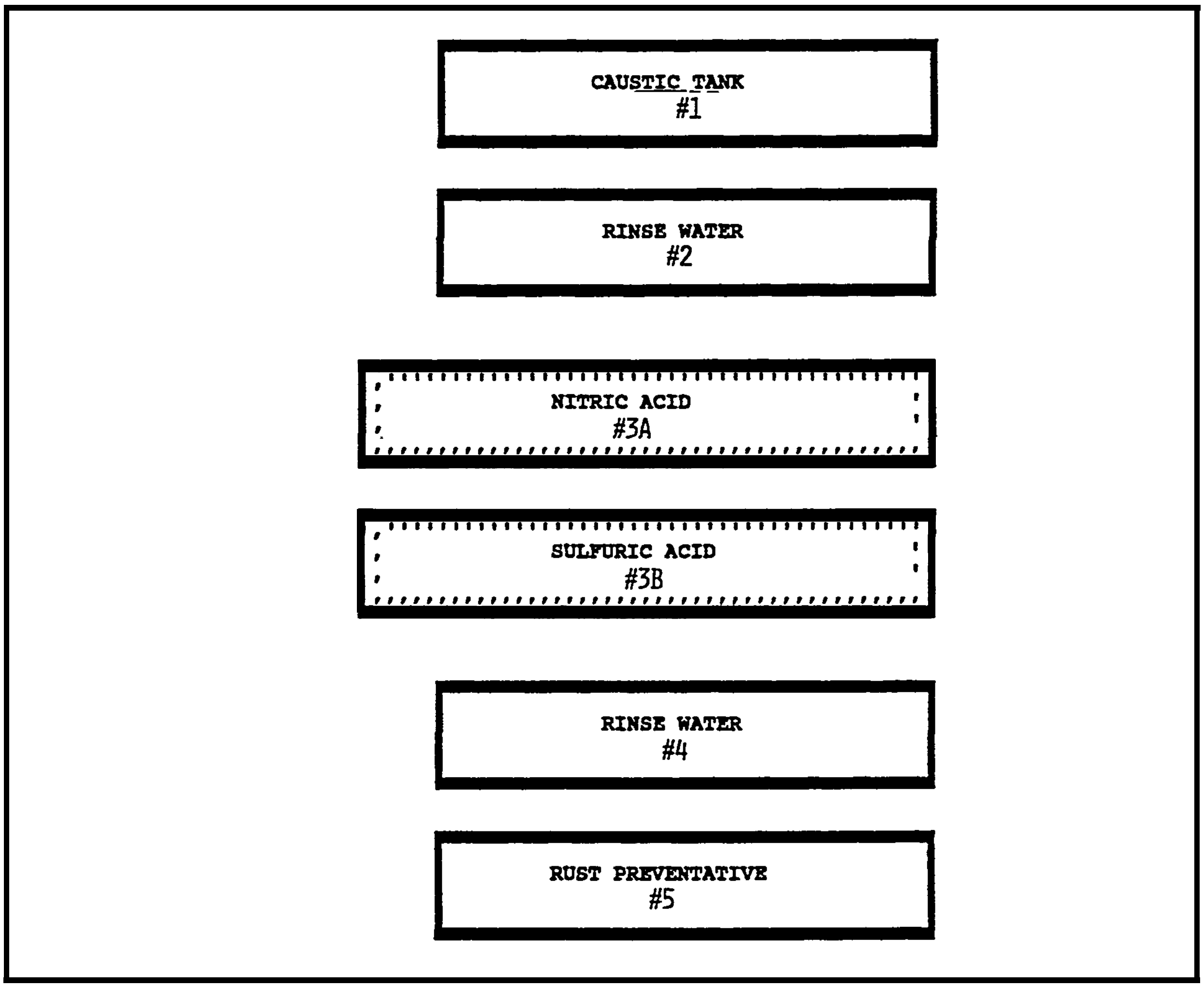


Figure 4.3: **Typical pickling tank arrangement for piping system surface preparation**

Pickling for Surface Preparation:

Pickling is a process of chemical abrasion/etching which prepares sutfaces for good paint adhesion. The pickling process is used in the shipyard mainly for preparing pipe systems and small parts for paint. Pickling process and qualities will vary from shipyard to shipyard depending on requests and technology. The process involves a system of dip tanks. Figure 4.3 displays how the tanks can be arranged.

(a) Pickling Steel:

Many piping systems and small parts in the ship industry are constructed of steel. In many cases, pipe sections and small awkward parts are pickled prior to painting. The following explains the pickling process: Tank #1 is used to remove any oil, grease, flux, and other contaminants on the surface being pickled. The contents in tank #1 are generally a 5-8% caustic soda and water mixture maintained at temperatures of between 180-200 DEG. F. The part is then immersed into tank #2, which is the caustic soda rinse tank (pH 8-13). Next, the steel is dipped into tank #3B, which is a 6-10 % sulfuric acid / water mixture maintained between 140-160 deg. F. Tank #4 is the acid rinse tank that is maintained at a pH of 5-7. Finally the steel pipe or part is immersed in a rust preventative 5% phosphoric mixture in tank #5. The part is allowed to fully dry and then paint is applied.

(b) Pickling Copper and Copper-nickel Alloy:

Some ships have large piping systems that are predominantly copper-nickel alloy or copper. Pickling of copper is generally only a two step process. The first step is to dip the pipe into tank #3A, a 3-6% nitric acid solution maintained at 140-160 deg. F. The nitric acid removes any flux and greases that are present on the surface and prepares the surface for paint. Next, the pipe is dipped into the acid rinse tank (#4) after which, it is considered to be treated. Once the part is dry, the final coating can be applied.

4.3 Introduction to Painting In The Shipyard:

Painting is performed at almost every location of the shipyard. This is due to the wide variety of work performed throughout the shipyard. The nature of shipbuilding and repair requires several types of paints to be used for a wide variety of applications. Paint types range from water-based coatings to high performance epoxy coatings. The type of paint needed for a certain application depends on the environment that the coating will be exposed. Paint applications equipment ranges from simple brush and rollers to airless sprayers and automatic machines. Various applications techniques are performed throughout the shipyard at several different areas. Paint coating systems are very important in shipbuilding applications. in general there are seven areas where

shipboard paint requirements exist:

- Underwater (Hull Bottom)
- Waterline
- Topside Superstructures
- internal Spaces and Tanks
- Weather Decks
- Loose Equipment

Many different painting systems exist for each of the previous locations, but Navy ships may require a specific type of paint for every application through a military specification (Mil-spec). There are many considerations when choosing a particular application. Among the considerations are environmental conditions, severity of environmental exposure, drying and curing times, applications equipment and procedures, etc. Many shipyards have specific facilities and yard locations where painting occurs. Enclosed facilities are expensive, but yield higher quality and efficiency. Open air painting generally has a lower transfer efficiency and is limited to good weather conditions.

4.3.1 Shipyard Paint Coating Systems:

Paints are used for a variety of purposes on a variety of locations on the ships. No one paint can perform all of the desired functions (i.e., rust prevention, anti-fouling, alkaline resistant, etc.). Paints are made up of three main ingredients: pigment, a vehicle, and a solvent. Pigments are small particles that generally determine the color as well as the many properties associated with the coating. Examples of pigments are as follows: zinc oxide, talc, carbon, coal tar, lead, mica, aluminum, and zinc dust. The vehicle can be thought of as the glue that holds the paint pigments together. Many paints are referred to by their binder type (i.e., epoxy, alkyd, urethane, vinyl, phenolic, etc.). The binder is also very important for determining the coating's performance characteristics (i.e., flexibility, chemical resistance, durability, finish, etc.) The solvent is added to thin the paints and allow for flowing application to surfaces. The solvent portion of the paint evaporates when the paint drys. Some typical solvents include acetone, mineral spirits, xylene, methyl ethyl ketone, and water. Anticorrosive and antifouling paints are typically used on ship's hulls and are the main two types of paint used in the shipbuilding industry. The anticorrosive paints are either vinyl or vinyllead-based and epoxy-based paint, inorganic zinc, chromate, or lead oxide. Antifouling paints are used to prevent the growth of marine organisms on the hull of vessels. Copper-based paints are widely used as antifouling paints. These paints release small quantities of toxic gas which discourage marine life from growing on the hull. Antifouling paints are designed to prevent growth and attachment of marine organisms on the underside of ships. Antifouling paints release minute quantities of toxic substances in the immediate vicinity of the vessel's hull. To achieve different colors, lampblack, red iron oxide, or titanium dioxide may be added to the paint. Anticorrosive paints are either vinyl, lacquer, urethane, or newer epoxy-based coating systems. The epoxy systems are now very popular and exhibit all of the qualities which the marine environment requires.

4.3.2 Shipyard Primer Coatings:

The first coating system applied to raw steel sheets and parts is generally pre-construction primer. This pre-construction primer is sometimes referred to as shop primer. This coat of primer is important for maintaining the condition of the part throughout the construction process. Preconstruction priming is performed on steel plates, shapes, sections of piping, and ventilation ducting. This shop primer has two important functions; (1) preserving the steel material for the final product and (2) aiding in the productivity of construction. Most preconstruction primers are zinc-rich with organic or inorganic binders. Zinc silicates are predominant among the inorganic zinc primers. Zinc coating systems protect coatings in much the same manner as galvanizing. If zinc is coated on steel, oxygen will react with the zinc to form zinc oxide which, forms a tight layer that does not allow water and air to come into contact with the steel.

4.3.3 Paint Applications Equipment:

There are many types of paint application equipment used in the shipbuilding industry. Two main methods used are compressed air and airless sprayers. Compressed air sprayers are nearly phased out in the industry because of the low transfer ability of the system. Air assisted paint systems spray both air and paint which causes some paint to atomize (dry) quickly prior to reaching the intended surface. The transfer efficiency of air assisted spray systems can vary from 65% to 80%. This low transfer efficiency is due mainly to overspray, drift, and the air sprayer is inefficiencies. The most widely used term of paint application in the shipbuilding industry is the airless sprayer. The airless sprayer is a system which simply compresses paint in a hydraulic line and has a spray nozzle at the end. To reduce the amount of overspray and spillage, shipyards are maximizing the use of airless paint sprayers. Airless sprayers use hydrostatic pressure instead of air to convey the paint. Airless sprayers are much cleaner to operate and have fewer leaking problems because the system requires less pressure. Airless sprayers have close to 90% transfer efficiency depending on the conditions. A new technology which can be added to the airless sprayer is called High Volume Low Pressure (HVLP). HVLP offers an even higher transfer efficiency, in certain conditions. The previous percentages are estimates and include allowances for drips and spills which can occur when painting.

4.3.4 Thermal Spray Coating Systems:

Thermal spray is the application of aluminum or zinc coatings to steel for long term corrosion protection. This coating process is used on a wide variety of commercial and military applications. Thermal spray can also be referred to as metal spray or flame spray. Thermal spray is significantly different then conventional coating practices due to its specialized equipment and relatively slow production rates. The initial cost of thermal spray is usually high compared to painting, although when the life-cycle is taken into account, thermal spray becomes more economically attractive. Many shipyard have their own thermal spray machines and other shipyard will subcontract their thermal coating work. Thermal spray can occur in a shop or onboard the ship. There are two basic types of thermal coating machines: combustion wire and arc spray. The combustion wire type consists of combustible gasses and flame system with a wire feed controller. The combustible gasses melt the material to be sprayed onto the parts. The electric arc spray machine instead uses a power supply arc to melt the flame sprayed material. The arc flame spray system includes an air compression and filtration system, a power arc supply and controller, and an arc flame spray gun. The surface must be properly prepared for proper adhesion of flame sprayed materials. The most common surface preparation technique is air blasting with fine grit (i.e. aluminum oxide). Figure 4.4 displays a typical cross section of a thermal spray coating system which includes a base metal with a blasted surface, flame sprayed metal, a sealer, and a painted top coating.

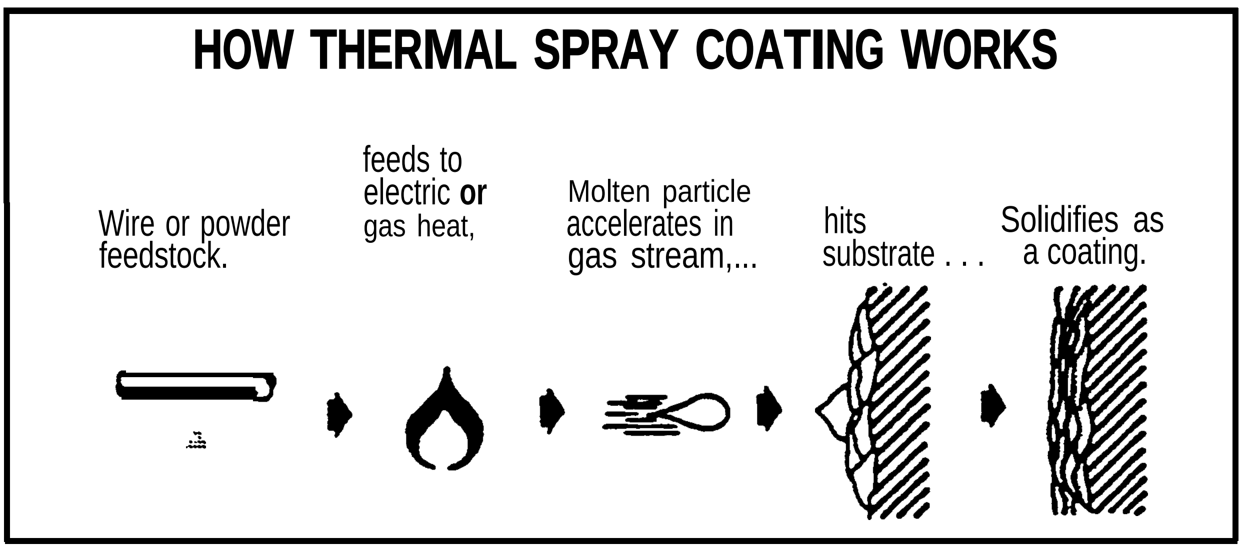


***Figure* 4.4: Illustration of how thermal coating systems work**

4.3.5 Painting Practices and Methods:

Painting is performed in nearly every area in the shipyard from the initial priming of the steel to the final paint detailing of the ship. Methods for painting vary greatly from process to process. Mixing of paint is performed both manually and mechanically and is usually done in an area contained by berms, tarp, secondary containment pallets, some of which are in covered areas. Outdoor as well as indoor painting occurs in the shipyard. Shrouding fences, made of steel, plastic, or fabric, are frequently used to help contain paint overspray or by blocking the wind and catching paint particles. New technology will aid in reducing the amount of airborne particles. Reducing the amount of overspray also reduces the amount of paint used and thus saves the shipyard money.

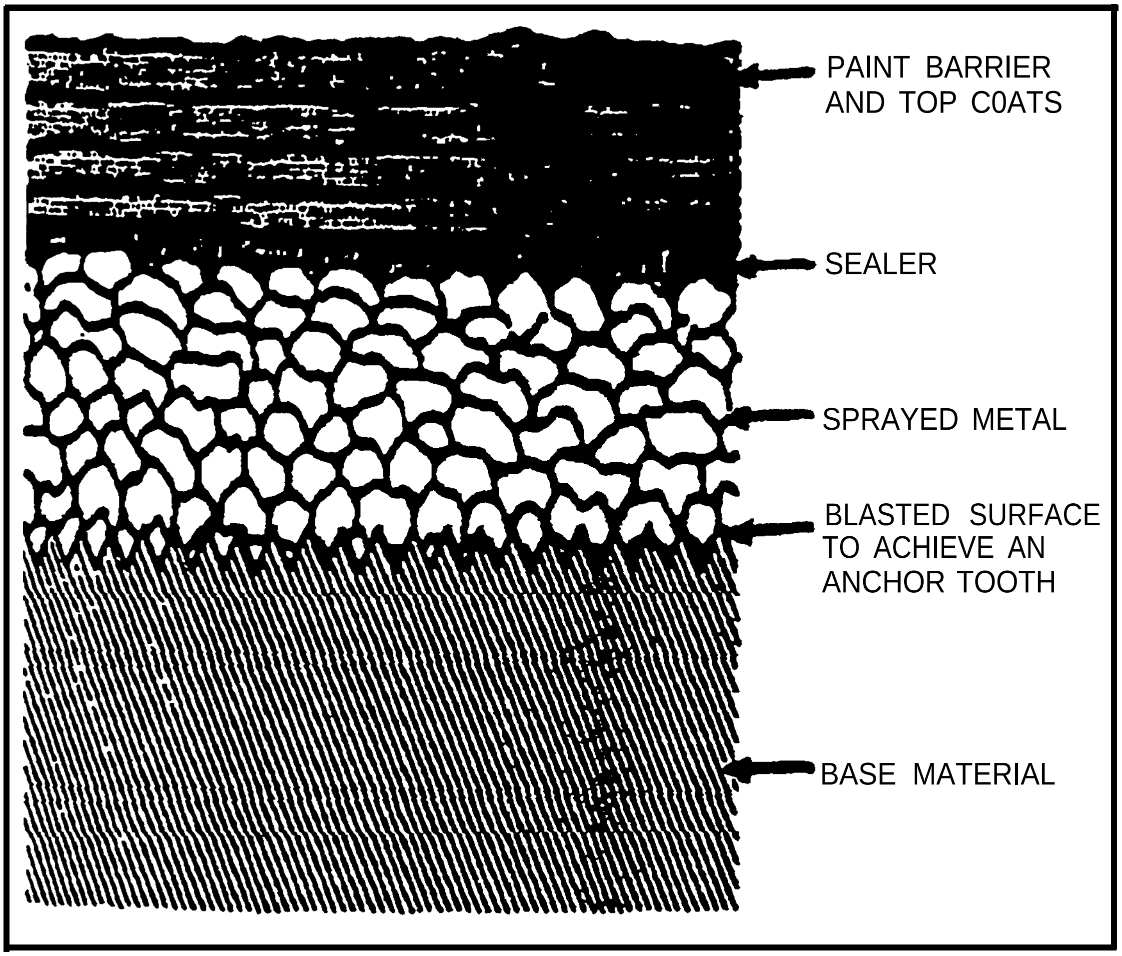


Figure 4.5: Cross section of how thermal coating systems are applied to a base material.

4.4 Surface Preparation and Painting Areas in the Shipyard:

To illustrate painting and surface preparation practices in the shipbuilding and repair industry, practices can be generically described in five main areas. The following five areas help to illustrate how painting occurs in the shipyard:

4.4.1 Hull Painting:

Hull painting occurs on both repair ships and new construction ships. Hull surface preparation and painting on repair ships is normally performed when the ship is fully drydocked (i.e., graving-dock or floating drydock). For new construction, the hull is prepared and painted at a building position using one of the techniques discussed in the previous sections. Air and/or water blasting with mineral grit are the most common types of surface preparation for hulls. Surface preparation involves blasting the sutface from platforms or manlifts. Similarly, paint systems are sprayed onto the hull using airless sprayers and high reach equipment such as man-lifts, scissor lifts, or portable scaffolding. Hull paint systems range in the number of coats required.

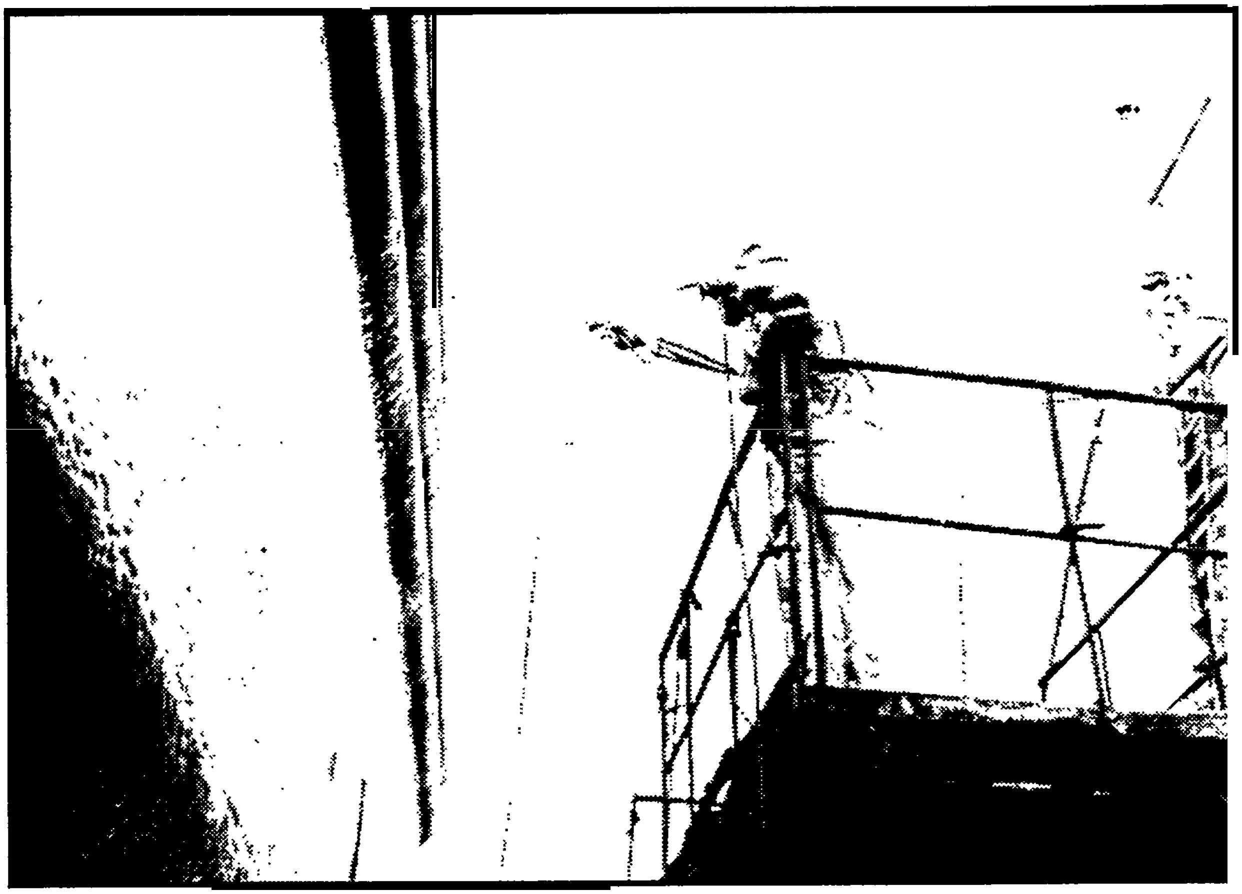


Figure 4.6: Hull painting at South West Marine. Notice the man-lift required to provide access to the hull's surface.

4.4.2 Superstructure Painting:

The superstructure of the ship consists of the exposed decks, deck houses, and structures above the main deck. In many cases, scaffolding will be used onboard the ship to reach antennas, houses, and other superstructures. If it is likely that paint or blast material will fall into adjacent waters, shrouding is put into place. On repair ships, the ships superstructure is painted mostly while berthed. The surface is either prepared using hand tools or air nozzle blasting. Once the surface is prepared, the associated surface materials and grit are cleaned up and disposed of, then painting can commence. Paint systems usually are applied with airless paint sprayers. The painters access the superstructures with existing scaffolding, ladders, and various lifting equipment that was used during surface preparation. The shrouding system (if applicable) that was used for blast containment will stay in place to help contain any paint over; spray.

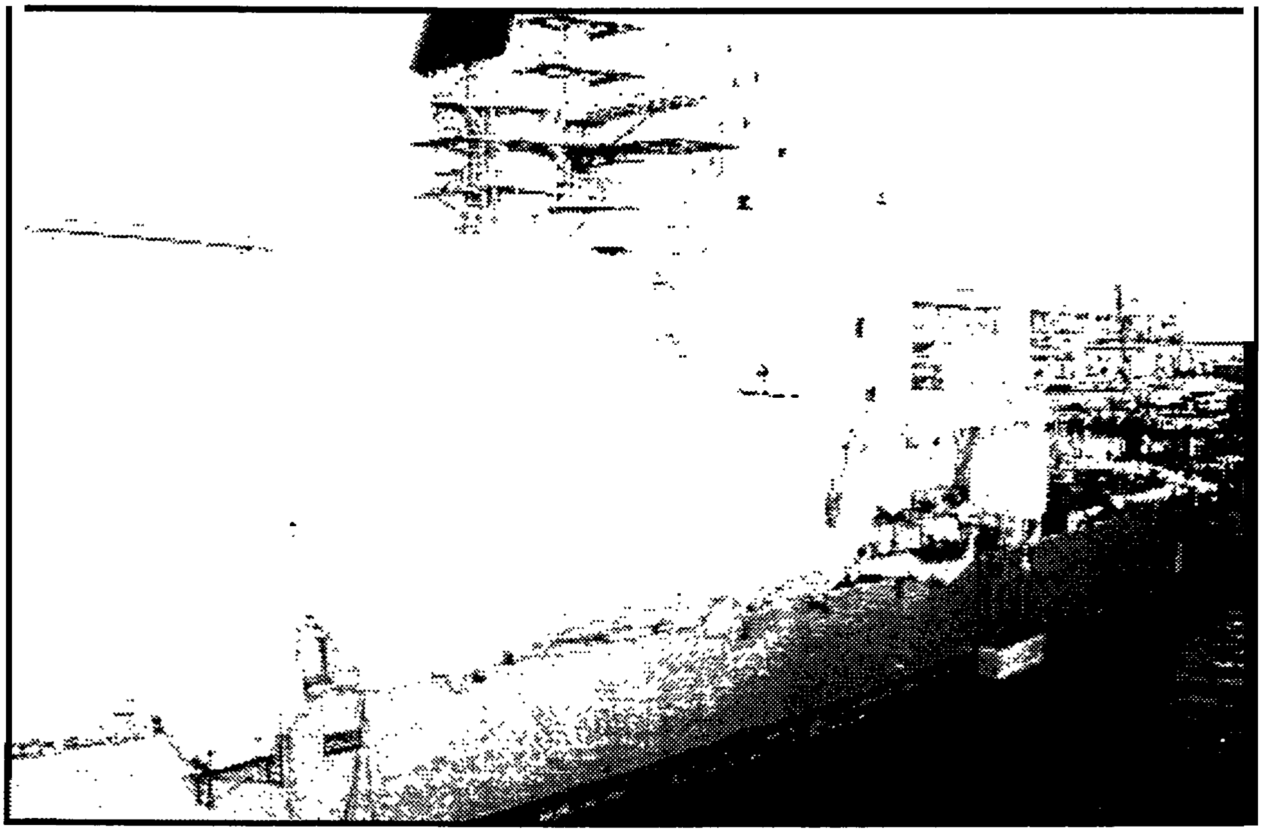


***Figure* 4.7: Superstructure shrouding is frequently required at South West Marine to control blasting materials and paint overspray.**

4.4.3 **Interior Tank and Compartment Painting**

Tanks and compartments onboard ships must be coated and re-coated to maintain the longevity of the ship. Re-coating of repair ship tanks requires a large amount of surface preparation prior to painting. The majority of the tanks are at the bottom of the ship (i.e., ballast tanks, bilges, fuel, etc.). The tanks are prepared for paint by using solvents and detergents to remove grease and oil build-up. The associated waste-water developed during tank cleaning must be properly treated and disposed of. After the tanks are dried, they are blasted with a mineral slag. During the blasting operation, the tank must have recirculating air and the grit must be vacuumed out. The vacuum systems used are either of a liquid ring or rotary screw type. These vacuums must be very powerful to remove the grit from the tank. The vacuum systems and ventilation systems are generally located on the dock's surface and access the tanks through holes in the hull. Once the surface is blasted and the grit is removed, painting can begin. Adequate ventilation and respirators are a strict requirement for all tank and compartment surface preparation and painting.

4.4.4 Paint and Surface Preparation As Stages of Construction:

Once the blocks leave the assembly area, they are frequently transported to a blast area where the entire block is prepared for paint. At this point, the block is usually blasted back down to bare metal (i.e., the construction primer is removed). The most frequent method for block surface preparation is air nozzle blasting. The next stage is obviously the paint application stage. The paint system is applied by painters generally using airless spray equipment on access platforms. Once the blocks coating system has been applied, the blocks is transported to the on-block stage where outfitting materials are installed.

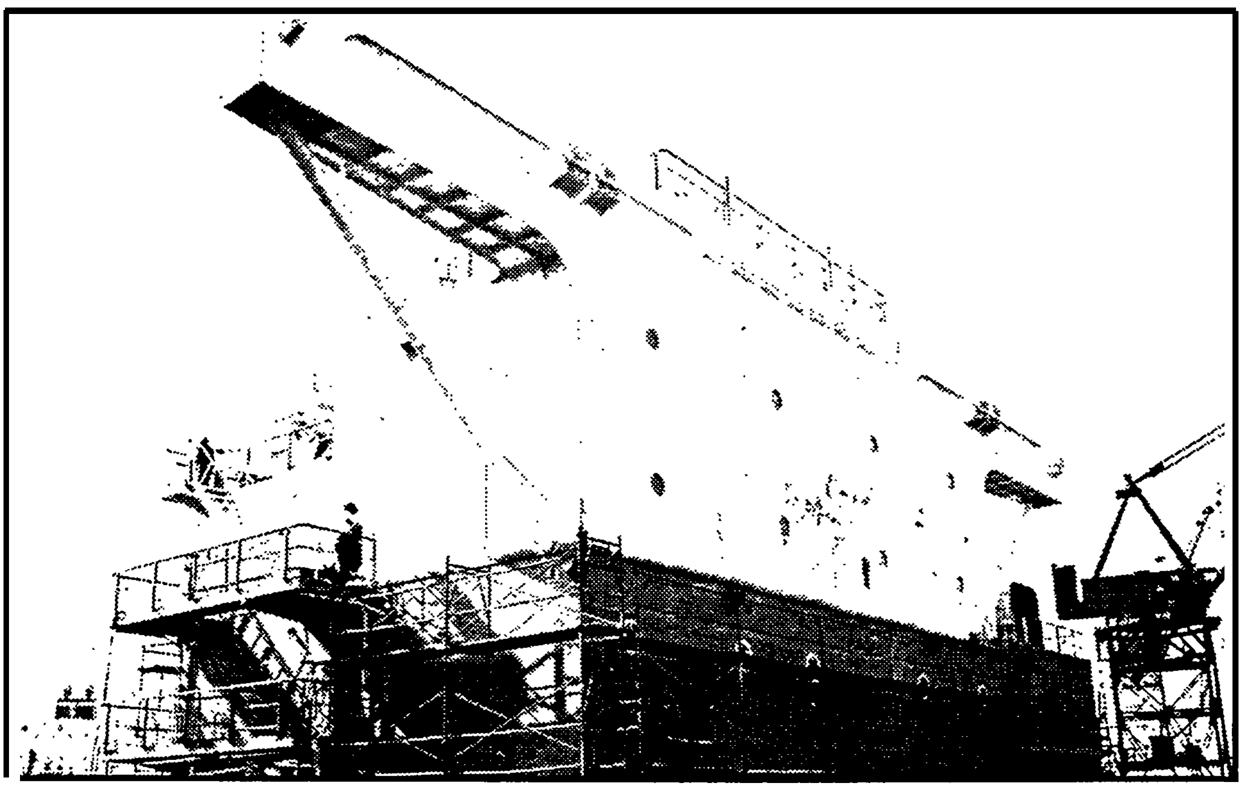


Figure 4.8: Painting at Stages of Construction. The Deckhouse is blasted, primed, and painted prior to erection on the ship.

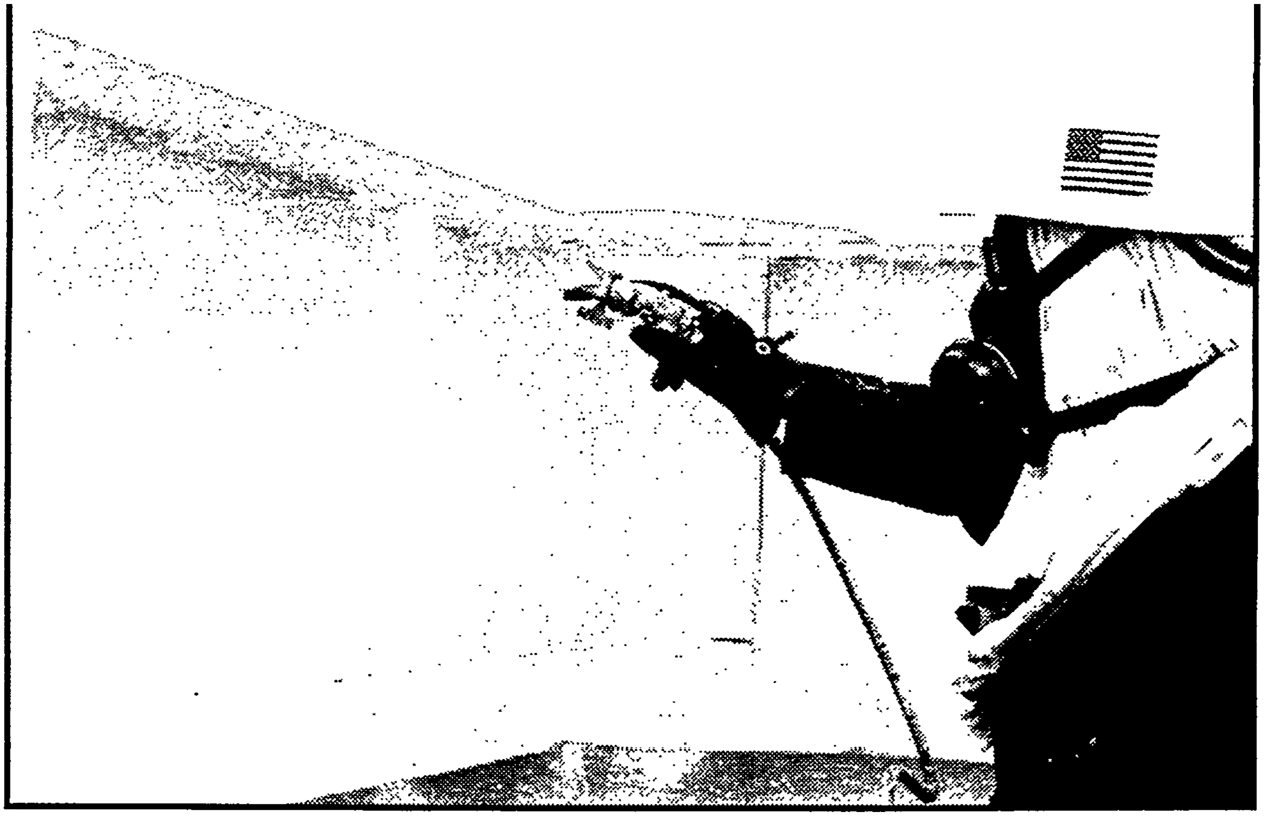


Figure 4.9 **Compartment painting at General Ship Repair, Baltimore, Maryland.**

4.4.5 **Small Parts Painting Areas:**

Many parts that a ship is composed of need to have a coating system applied to them prior to installation. For example, piping spools, vent ducting, foundations, and doors are painted before they are installed on-block. Small parts are generally prepared for paint in a designated area of the shipyard. Some of the parts are prepared for paint in a wheelabrator machine, air blasted, or one of the other techniques discussed in previous sections. Small parts painting can occur in a designated location in the shipyard that best matches production needs. Some small parts painting occurs in the various shops while others are painted in a standard location operated by the paint department.

4.4.6 **Surface Preparation and Painting On-Block and Onboard:**

Final painting of the ship occurs onboard and touch-up painting will frequently occur on-block. On-block touch-up painting occurs for several reasons. In some cases, paint systems are damaged on-block and need to be resurfaced, or perhaps the wrong paint system was applied and needs to be replaced. On-block painting involves using portable blasting and painting equipment throughout the On-block outfitting areas. Onboard painting involves preparing and painting the interface sections in between the construction blocks and repainting areas damaged by welding, rework, onboard outfitting, and others. The surfaces can be prepared by hand tools, sanding, brushing, solvent cleaning, or any of the other surface preparation techniques. Paint is applied with portable airless sprayers, rollers, and brushes.

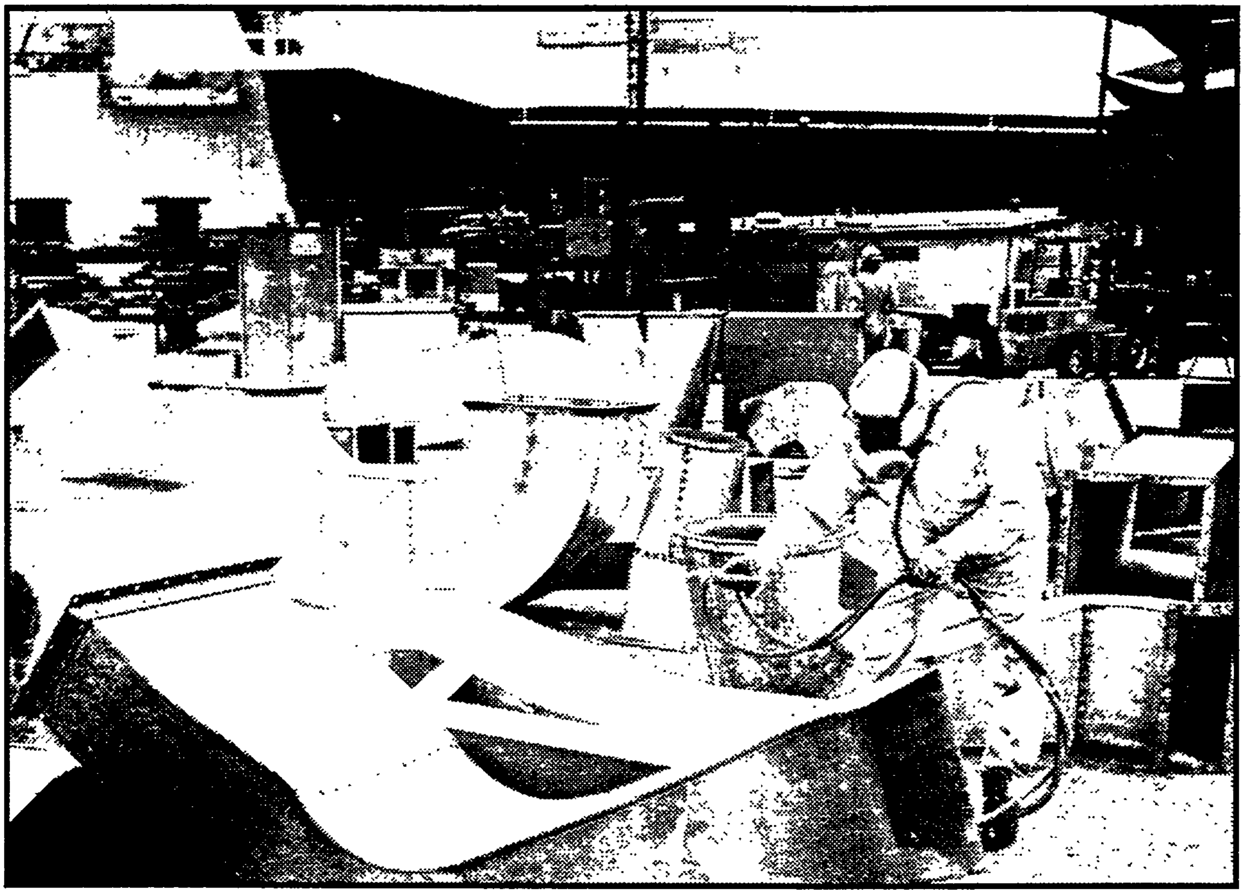


Figure **4.10: Small parts (i.e. pipes, vents, foundations) are painted prior to installation on the blocks. Displayed is a ventilation painter applying a coat on the vent system sections.**

4.4.7 **Paint Storage, Transportation, and Disposal:**

Paint is stored many places on the shipyard, depending on how long it will remain there and how much paint is stored. Paint material in the main storage area can be stored for days or months. Secondary containment in this area is critical to prevent a major spill. When paint is needed throughout the shipyard, it is transferred to satellite storage and work areas. Finally, paint is transported by individual cans or pallets from the satellite storage areas to individual work sites where paint is mixed and sprayed.

Once the painters are done with their individual paint job, they must discard any unused paint and clean their equipment. The majority of paints used in the shipyard must be sprayed, or disposed of, once they are mixed. Generally, a shipyard will have 55 gallon drums for painters to discard their paint and paint associated waste (i.e., rags, rollers, gloves, thinner, etc.). These satellite collection areas should have receptacles for the three main waste streams: paint waste, thinner, and solids (i.e., rags, gloves, paint brushes). When the receptacles are full, they are transported to a reclamation or main disposal area. The containers are generally transported on pallets by forklift. The main reclamation area then has 90 days to send the waste out for proper disposal. Many shipyards have assembled waste minimization programs. Paint and paint associated waste are being minimized in shipyards throughout the country. Reducing paint waste reduces the amount of paint purchased, saves money in disposal costs, and reduces environmental liabilities. Pollution caused by painting processes center around overspray and spillage problems. Such spillage cannot come into contact with state waters. Where large and small parts are painted, there is overspray which ends up on the ground. If grounds are not cleaned frequently, paint particles can be blown or moved by rain water, causing them to come into contact with state waters. The objective is to provide a means of control for airborne paint particles. Paint which enters the atmosphere should be controlled so it does not contaminate other processes or enter state waters either directly or through the storm drain system. This can be accomplished by either reducing the amount of airborne particles, controlling the direction of overspray, or both.

***Figure** 4.11:* **Satellite Storage Areas**

Glossary of Terms

Accommodation. All spaces on a ship that are associated with the crew's normal living, including navigation, radio, and similar spaces when incorporated in the same deckhouse.

Aft. Toward, at, or near the stern.

Amidships. A point which is exactly halfway between the fore and after perpendiculars.

Anchor. A device, usually of steel, used to hold a ship against the movement of current, tide, and wind.

Assemble. To fit and join parts together.

Assembly. See Subassembly.

Auxiliary Machinery. Various pumps, motors, generators, and other equipment required on a ship, as distinguished from main propulsive machinery units.

Ballast Tank. Watertight compartment to hold water ballast.

Berth. Where a ship is docked or tied up; a place to sleep aboard ship; a bunk or bed.

Bilge. Curved section between the bottom and the side of the vessel; also the lowest part of a vessel's internal spaces into which water drains.

Bilge and Ballast System. A piping system generally located in holds or lower compartments of a ship and connected to pumps or educators. This system is for pumping overboard accumulations of water in holds and compartments and also for filling and emptying ballast tanks.

Bilge Blocks. Blocks set under the bilge for support during construction or during docking.

Bilge Plates. The curved shell plates that form the bilge.

Block. A section of a ship structure which is a three dimensional entity. Blocks are combined to form a ship during erection, and are normally the largest sections to be assembled away from the erection site.

Blue Sky. In the open; not under a roof or other protection from the weather.

Blue Sky Outfitting. Outfitting done in the open during hull erection, e.g., landing outfit units or components before a space is enclosed.

Boody Hatch. An access hatch from a weather deck protected by a hood from sea and weather; also called companionway.

Boom. A round spar hinged at its lower end, usually to a mast or a crane, and supported by a wire rope or tackle from aloft to the upper end of the boom. Cargo, stores, etc., are lifted by tackle leading from the upper end of the boom.

Bow. Forward end of a ship.

Bracket. A structural member used to rigidly reinforce two or more structural parts, which are joined at approximately right angles to each other, such as deck beam to frame, or bulkhead stiffener to the deck or tank top; usually a plate.

Bridge, Flying. The platform forming the top of the pilothouse.

Bridge House. A part of the upper superstructure of a ship. The officers' quarters, staterooms, and accommodations are usually located in the bridge house and the pilothouse located above it.

Building Basin. A structure essentially similar to a graving dock, in which one or more ships or parts of ships may be built at one time; no launching operation is required, the ship is floated by flooding the basin.

Bulbous Bow. A bow with a rounded, protruding shape at the bottom to improve flow and resistance characteristics.

Bulk Carrier. Ships designed to carry bulk cargo, usually not in liquid form, such as coal, ore, grain, etc.

Bulkhead. A vertical partition, which subdivides the interior of a ship into compartments or rooms. Bulkheads which contribute to the strength of a vessel are called strength bulkheads; those which are essential to the watertight subdivision are watertight or oiltight bulkheads. Gastight bulkheads serve to prevent the passage of gas or fumes.

Butt. The joint formed when two parts are placed edge to edge; the end joint between two plates; also transverse joints for connecting two parts, subassemblies, or blocks.

CNC. Computer Numeric Control.

CAD. Computer Aided Design.

CAM. Computer Aided Manufacturing.

Come Along. A hand-operated lever hoist used during shipfitting for pulling together or supporting ship's parts or subassemblies.

Compartment. A subdivision of space or room in a ship.

Compartmentation. The subdividing of the hull by watertight bulkheads so that the ship may remain afloat under certain conditions of flooding.

Crane. A device for lifting and moving heavy weights by means of a movable projecting arm and/or a horizontal beam.

Deck. A horizontal surface in a ship corresponding to a floor in a building. It is the plating, planking, or covering of any tier of beams in either the hull or the superstructure of a ship. Decks are usually designated by their location, as boat deck, bridge deck, upper deck, main deck, etc. Decks at different levels serve various functions; they may be either watertight decks, strength decks, or simply cargo and passenger accommodation decks.

Deckhouse. A comparatively light structure, built on the hull, which does not normally extend from side to side of the ship. It commonly is composed of spaces that are used for crew accommodations and control of the ship (bridge, radioroom, etc.)

Deck Machinery. Miscellaneous machinery located on the decks of a ship such as windlasses, winches, etc.

Double Bottom. Compartment at the bottom of a ship between inner bottom and the shell plating, mostly used for ballast water, fresh water, or fuel oil.

Draft. The depth of the ship below the waterline measured vertically to the lowest part of the hull, propellers, or other reference point. When measured to the lowest projecting portion of the vessel, it is called the **extreme draft,** when measured at the bow, it is called **forward draft, and** when measured at the stern, the **after draft.** The average of the forward draft and the after draft is the **mean draft, and the mean draft** when in full load condition is the **load draft.** Also, in cargo handling, the unit of cargo being hoisted on or off the ship by the cargo gear at one particular hoist.

Engine Room. The location of main propulsion and some auxiliary machinery onboard a ship.

Erection. The placing and connection on the ways or other building position of sub-assemblies, blocks, and/or outfit units of a ship.

Fabricate. To process materials in the shops, to create parts needed for both hull and outfit assemblies. In hull work, fabrication consists of cutting (shearing), shaping, punching, drilling, countersinking, scarfing, rabbeting, beveling, and welding.

Flange. The part of a plate or shape bent at right angles to the main part; to bend over to form an angle.

Fore. A term used in indicating portions or that part of a ship at or adjacent to the bow.

Fore and Aft. In line with the length of the ship; longitudinal.

Forward. In the direction of the bow.

Foundation. A structural support for equipment and machinery installed on a ship. The structural supports for the boilers, main engines or turbines, and reduction gears are called the main foundations. Supports for auxiliary machinery are called auxiliary foundations.

Frame. A term used to designate one of the transverse members that make up the rib-like part of the skeleton of a ship. The frames act as stiffeners, holding the outside plating in shape and maintaining the transverse form of the ship.

Freeing Port. An opening in the lower portion of the bulwark which allows water on deck to drain overboard.

Galley. A cookroom or kitchen on a ship.

Gangway. A passageway, side shell opening, and ladderway used for boarding a ship.

Gantry Crane. A hoisting device, usually travelling on rails, having the lifting hook suspended from a car which is movable horizontally in a direction transverse to the rails.

Graving Dock. A structure for taking a ship out of water, consisting of an excavation in the shoreline to a depth at least equal to the draft of ships to be handed, closed at the water side end by a movable gate, and provided with large capacity pumps for removing water; blocks support the ship when the dock is pumped out.

Hatchway. An opening in a deck through which cargo and stores are loaded or unloaded.

Hold. The large space below deck for the stowage of cargo; the lowermost cargo compartment.

Hull. The structural body of a ship, including shell plating, framing, decks, bulkheads, etc.; also the outfit specialty design group dealing with all areas of the ship except machinery and superstructure.

Hull Block Construction Method. A shipbuilding system wherein hull parts, sub-assemblies, and blocks are manufactured in accordance with the principles of group technology.

Jig. A device, often with metal surfaces, used as a tool or template.

Keel. The principal fore-and-aft component of a ship's framing, located along the centerline at the bottom and connected to the stem and stern frames. Floors or bottom transverses are attached to the keel.

Keel Blocks. Heavy wood or concrete blocks on which a ship rests during construction or drydocking.

Labor Turnover. The number of separations divided by average employment during a specified time interval multiplied by 100 (the number of separations during the period per 100 employees). Annual turnover rate is the monthly turnover multiplied by 12.

Launching. To set a ship afloat for the first time.

Layout. The process of making a plate assembly showing the location of longitudinals, frames, edges, and attached parts.

Loftwork. The laying off of full form details at full size in preparation for cutting plate and structural members. The process is now almost entirely computerized.

Longitudinal. A fore-and-aft structural shape or plate member attached to the underside of decks or flats, or to the inner bottom, or on the inboard side of the shell plating.

Machinery. All spaces on a ship that primarily contain operating equipment such as main propulsion machinery, auxiliary machinery, pumping systems, heating, ventilation, and air conditioning machinery, etc.; also the outfit speciality design group dealing with machinery spaces.

Manning. The number of workers or equivalent workers assigned to a particular ship (ship manning), program (program manning), or shipyard (yard manning).

Material Control. The functions of purchasing, expediting, warehousing, palletizing, and delivering material to the work site.

Mooring. Securing a ship at a dock or elsewhere by several lines or cables so as to limit its movement.

Oil Tanker. A vessel specifically designed to carry of oil cargo in bulk.

Outfit. All the parts of a ship that are not structural in nature, it including items such as pipes, derricks, masts, rigging, engines, machinery, electrical cable, hotel services, etc.

Pallet. A portable platform upon which materials are stacked for storage or transportation; also in zone outfitting a definite increment of work with allocated resources (information, labor, and materials) needed to produce a defined interim product.

Panel. A section of a ship consisting of one or more plates with associated strengthening members; also called a subassembly or block.

Panel Line. A production line where individual plates, framing members, webs, etc. are successively welded together to form an assembly unit which may include some outfit items.

Parts. Refers to all the steel components that are welded to a plate assembly, including stiffeners, Iongitudinals, frames, girders, web frames, headers, etc.

Pin Jig. A jig consisting of a grid of adjustable pins (screw jacks) used as a building position for curved blocks or a template for curved plates.

Planning. The listing of all jobs that must be performed in order to complete a project.

Platen. A flat, level structure upon which subassemblies, blocks, and/or outfit units are built.

Porthole. A hinged glass window, generally circular, in the ship's side or deckhouse, for light and ventilation; also called portlight, air port, or side scuttle.

Process Lane. A work center specifically designed to efficiently perform a certain type of work or a certain series of work steps.

Production Control. The monitoring of the difference between actual and scheduled performance of a project.

Propeller. A revolving screwlike **device that drives the** ship through the water, consisting of two or more blades; sometimes called a screw or wheel.

Quenching. In steelmaking, an operation consisting of heating the material to a certain temperature and holding at that temperature to obtain desired crystalline structure, and then rapidly cooling it in a suitable medium, such as water or oil. Quenching is often followed by tempering.

Rigging. Wire ropes, fiber line, tackle, etc., used to support masts, spars, booms, etc., and for handling and placing cargo onboard ship.

Rudder. A device used to steer a ship. The most common type consists of a vertical metal area, hinged at the forward edge to the stern post or rudder post.

Scaffolding. See Staging.

Scheduling. The laying out of the actual time order in which jobs are to be performed in order to complete a project.

Sea Chest. An opening for supplying seawater to condensers, pumps, etc., and for discharging water from the ship's water systems to the sea. It is a cast or built-up structure located in the hull below the waterline, having means for the attachment of the associated piping. A suction sea chest is fitted with strainers or gratings, and sometimes has a lip that forces water into the sea chest when the ship is underway.

Seam. A fore-and-aft joint of shell plating, deck and tank top plating, or a lengthwise edge joint of any plating.

Seam Line. Symbol for a welded butt joint; also called erection butt.

Seam Strap. A strap of plate serving as a connecting strap between the butted edges of plating. Strap connections at the ends of plates are called butt straps.

Shape. A rolled bar of constant cross section such as an angle, bulb angle, channel, etc.; also to impart curvature to a plate or other member.

Shell. The outer skin plates of a ship, including bottom shell and side shell.

Shell Plating. The plates forming the outer aside and bottom skin of the hull.

Stage. A classification of work based on when it will be performed (in what sequence) during the construction process relative to other work.

Staging. Temporary or movable wooden or metal structures for supporting workmen tools, and materials; also called scaffolding.

Stern. After end of a ship.

Stiffener. A structural section (usually angles, tees, or l-beam) attached to a plate to strengthen it.

Subassembly. An assembly of parts (primarily structural parts). Subassemblies, when joined together, form blocks.

Superstructure. A decked-over structure above the upper deck, the outboard sides of which are formed by the shell plating, as distinguished from a deckhouse that does not extend outboard to the ship's sides.

Surface Preparation. The work required to permit coating materials (primarily paint) to be satisfactorily applied to metals.

Tank, Wing. Tanks located well outboard adjacent to the side shell plating, often consisting of a continuation of the double bottom up the sides to a deck or flat.

Waterway. A narrow gutter along the edge of the deck for drainage.

Web. The main part of a bent or flanged plate or structural section.

Work Package. A resource subdivision which specifics the material and/or labor required to complete some portion of a shipbuilding or repair contract. A work package should correspond to the work breakdown structure in use and may be either system or product oriented.

ACKNOWLEDGEMENTS AND SOURCES OF INFORMATION

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NASSCO and I would like to thank the members of the SP-1 Panel who participated in the shipyard facilities surveys and supplies information for the development of this manual. For the photographs in this report we would like to thank the following individuals: Fletcher Hunt, Port of Portland, Dana Austin, Southwest Marine, Wikkiam McGarrah, Metro Machine Corp, Kim Lee and Marc Nguyen, National Steel and Shipbuilding, and General Ship Repair, Baltimore, Maryland.

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