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# Concrete Ships

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# Concrete Ships

by

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# ABSTRACT

A chronological presentation of the development and diversity of application in concrete shipbuilding commencing with the history of a reinforced concrete rowboat built and patented in France in 1848, and concluding with an account of the arguments concerning the proposal by an American firm to build a prestressed concrete liquefied natural gas carrier.

Emphasis is placed on the two time periods which are most significant in the history of concrete shipbuilding: the final year of World War I when reinforced concrete marine construction reached its peak, and then virtually ceased to exist with the Armistice of November 1918; and a five year period beginning in 1968 which saw the revival of the 120 year old French construction technique, but using ferrocement.

Included are explanations of the various compositions, uses, and construction techniques relating to reinforced concrete, ferrocement, and prestressed concrete. The relative utility of concrete versus that of wood or steel is described in theory, and specifically in those instances where comparative data is available for a vessel type.

The incentive behind this study is based on a two-fold premise: 1) that a comprehensive outline of the historical development of concrete shipbuilding and its related technologies is either non-existent or defies discovery, and 2) that although this study is neither based on a hypothesis, nor intended to resolve a problem area or promote a position, its merit lies in its inductive nature.

The principal conclusion to be drawn from the study is that each of the three major phases in the history of the use of concrete for shipbuilding - reinforced concrete, ferrocement, and prestressed concrete - has resulted from a search for an alternative hull material precipitated either by economic need or opportunity.

A secondary conclusion, economic and technological considerations aside, is that the general maritime community has yet to accept the concept of a durable, self-propelled, and buoyant sand and gravel mixture.

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# TABLE OF CONTENTS

# INTRODUCTION

Nearly all technical shipbuilding developments have resulted from an economic need for either larger, less expensive, or faster vessels. This idea is analogous to a statement attributed to the late Jimmy Hoffa when once asked what his union really wanted from industry. His reply was simply, "More".

The success of any business is based on its return on investment, which in turn is affected by the extent to which capital and operating expenses can be minimized. The use of concrete offers shipbuilders the opportunity to minimize these expenses. Unfortunately, the chief drawback to ships made of concrete has been the idea itself.

This paper examines the physical properties of concrete and describes the three major historical phases in its development for marine applications. The phases could roughly be described as: 1) the use of reinforced concrete from 1848 through World War II, 2) the use of ferrocement from World War II into the 1970's, and 3) the use of prestressed concrete in the 1970's and beyond.

One thought to keep in mind during any discussion of concrete is that, no matter what, it always cracks. Of the four concrete shipbuilding techniques available, the latter three are used in marine construction: 1) <u>unreinforced concrete</u>: It always cracks. Concrete is a material which, in a marine environment, is chemically active for the lifetime of the structure. It heals minor cracks through internal chemical changes. 2) <u>reinforced concrete</u>: Does not prevent cracks. Reinforcing rods shorten in compression during the normal process of concrete shrinkage. Unstressed reinforcement is very ineffective in preventing cracking. After cracking, however, it does prevent the halves from falling apart. 3) ferrocement: Is a higher level of reinforced concrete, using layers of mesh in the concrete for additional cohesion. Cracks do occur internally in the concrete, but the mesh is so finely divided that it stops each small crack from joining adjacent small cracks, and prevents massive ruptures. 4) prestressed concrete: The primary reason for its use is that it is nearly twice as cost-effective as ordinary steel reinforcement. Threaded steel wire is either stretched prior to its insertion in the concrete mortar, or else is placed in ducts and then stretched and grouted. Either method results in very high compression concrete with a minimal cracking tendency.

Wherever possible, descriptive information concerning specific concrete ships has been included to illustrate the application of the particular concrete technology of that historical period.

# CONCRETE MORTAR COMPOSITION

The invention of Portland cement is generally credited to Joseph Aspdin, an English mason. In 1824 he obtained a patent and named his product 'portland cement' because it produced a concrete which resembled a natural limestone quarried in England on the Isle of Portland.[1] The first Portland cement made in the United States was produced at a plant in Coplay, Pennsylvania in 1872.

Concrete mortar has a very limited potential for tensile strength. The tensile stresses present in a concrete vessel must be carried to a great extent by the reinforcing steel, sometimes called "re-bar". The problems of stresses and bonding between the concrete and steel reinforcement must be resolved before the technique which has been relatively successful for various river barges can be used on larger ocean going vessels.[2]

One property of concrete which favors the bond with the steel reinforcing rods is its ability to absorb vibration. Steel vessels have higher tensile strengths, but tend to transmit vibrations.

Portland cements are hydraulic, since they set and harden by reacting with water. This reaction is called hydration. It is a chemical reaction which combines cement and water to form a stone-like mass.[3] The rise in concrete temperature caused by the heat of hydration is often beneficial in cold weather since it helps maintain favorable curing temperatures.[4] The thermal conductivity of concrete is one-sixth that of steel.[5]

Aggregates comprise 66 to 78 percent of the total concrete mortar volume. Particle shape, graduation, and maximum size are important factors in mixing a strong, dense concrete.[6] Fine aggregates of natural and manufactured sand vary in size from dust to a maximum of one quarter inch. Coarse aggregates of crushed stone and gravel are larger than one quarter inch and are particularly unsuitable for ferrocement mortar mixtures.

Any mixture thin enough to pour between forms and around the reinforcing requires at least twice as much water as will be used up by the cement itself during setting and curing. This surplus water bleeds to the surface, but in doing so leaves microscopic channels through which water can re-enter, especially if the concrete is immersed in water and is therefore under pressure.[7] The development of admixtures facilitated the production of a dense, impermeable cement paste.

Perhaps the most significant admixtures are the pozzolans. During Roman times it was found that a natural volcanic material from Pozzuoli, in the vicinity of Mount Vesuvius, when added to lime, produced a mixture capable of hardening under water. Portland cement produces large quantities of lime as it sets - a substance which makes no useful contribution to the strength of the cement. A siliceous material added to Portland cement at the time of mixing will react with the cement and form calcium silicates which will contribute to watertightness. Pozzolans also add to the workability of fresh mortar. Both fly ash - from boiler smokestacks - and diatomaceous earth are common pozzolans.[8]

Admixtures are designed to serve a three-fold purpose: 1) to reduce the amount of water used in the cement, giving it a greater strength, 2) to allow more time in hot weather for the placement of concrete, by retarding the set of the mortar, and 3) to impart minute air bubbles within the concrete, thus creating cold weather resistance and giving the concrete a longer life when exposed to alternate freezing and thawing cycles.[9]

In concrete mortar, admixtures include all materials other than Portland cement, water, and aggregates and can be classified as either air entraining, water reducing, retarding, accelerating, pozzolans, workability agents, dampening agents, permeability reducing agents, grouting agents, or gas forming agents.[10]

Mortar composition should vary between 50 and 65 pounds of cement per cubic foot. Admixtures are usually added in an amount equal to 10 percent by weight. Pozzolans are the most common admixture. The cement content of the mixture should not fall below 50 pounds per cubic foot of sand. The amount of water added should be the minimum necessary to achieve mortar workability.[11] In 1918 Professor Duff Abrams reported that the strength of concrete is governed by the ratio of water to cement.[12] The addition of a pozzolan to concrete mortar causes the mixture to increase in strength for approximately 50 years, especially in a moist environment.

The second most significant admixtures are the air entraining agents, which were discovered in the mid-1930's. Their addition to the mortar improves its behavior in the presence of high temperature differentials. They are added to the mixture as a liquid, and result in a 3 to 5 percent entrained, or trapped, air content by volume.[13]

Curing is the process of establishing favorable conditions which allow the mortar to properly set on the ship frame. It ensures complete hydration of the cement and minimizes surface cracking. The process may take the form of a continuous fine water spray on the hull, draping the hull with wet cloth sacks, or the use of a spray-on curing compound. Curing should last from 7 to 28 days, with 60 percent effectiveness after 7 days, and 100 percent after 28 days.[14]

An example of the effect that water content has on the quality of the internal bond and compressive strength of concrete is illustrated by the following empirical data:[15]

| gallons of water per 94 lb. bag of cement | 28 day curing compressive strength |
|---|---|
| 9 gallons per bag | 2000 psi |
| 8 " " " | 2500 psi |
| 7 " " " | 3200 psi |
| 6 " " " | 4000 psi |
| 5 " " " | 5000 psi |
| 4 " " " | 6000 psi |

The most recent innovation concerning concrete mortar has been the development of epoxy paste adhesives which can effectively bond new concrete to old, old concrete to old, and metal to any type of concrete.[16]

## EARLY CONCRETE SHIPBUILDING DEVELOPMENTS

The first seven decades of concrete shipbuilding involved an international group of inventors and investors, and a wide variety of vessels. This early history is presented in chronological sequence to illustrate the momentum that this new seagoing material developed with the approach of World War I.

1848: Jean-Louis Lambot, a French landowner, constructed several rowboats, plant pots, benches, and other servicable items from a material which he invented and called 'ferciment'. He obtained a French patent in 1852 which described his invention as "a new product that can replace timber that is exposed to damage by water or dampness. The base for the new substance is a metal net of wire, or rods interconnected to form a flexible woven mat. The net is fashioned into a form that is similar to the article I want to create, then I use hydraulic cement or bitumen tar to fill up whatever joints remain".[17]

One of Lambot's rowboats was exhibited at the Paris World's Fair in 1855, and was still in use during World War I. His invention was not immediately accepted, however, because 1) At that time there existed a very poor network for the exchange of international technological innovations; 2) Shipbuilding industries were firmly established, some centuries old, and all with craftsmen skilled in the use of timber. There was no economic need to investigate alternative construction materials because of the abundance of timber; and 3) The introduction of steel as a shipbuilding material and the development of the reciprocating engine quickly revolutionized both the traditional conception and physical structure of most European shipyards.[18]

Another Lambot rowboat sank on a lake in southern France in 1900. In 1955 the level of the lake dropped during a drought. The boat was discovered intact and structurally sound, and was placed in a museum in Brignoles where it is on exhibit today.[19]

During the period from 1850 to 1880 wooden ships cost more to build and maintain than their steel equivalents. Wooden ships were limited in length to about 300 feet because of the inherent strength of wood and difficulties in fastening.

1870: Unspecific reports indicate that concrete lighters were in service on some European rivers, but in a limited capacity.[20]

1887: The brothers Picha-Stevens of Sas van Gent, Holland built ZEEMEEUV, a large, reinforced concrete rowboat. It was left frozen in a Dutch lake for several consecutive winters without any noticable damage.

1897: Carlo Gabellini, of Rome, began experimenting with the construction of various scows, barges, and pontoons made of reinforced concrete. Eight years later he built a series of 150 ton river barges.

1909: The German government sponsored the construction of a 200 dead weight ton reinforced concrete river freighter at Frankfortam Main. The vessel had rectangular compartments which formed watertight bulkheads. An after cabin of reinforced concrete was added toward the end of construction.

1909: A. A. Boon, of Amsterdam, used an old wooden boat as an inner form for the construction of the JULIANA. He made a netting of one quarter inch iron bars, and spaced them to form a mesh with 2 inch squares. He then covered the netting with a fine wire mesh and 4 inches of concrete. This is the first reported return to the Lambot technique in 61 years. In 1910 Boon built a 50 dwt barge, the ANTOON.

1910: The PIONEER was built in England for use on the Welland Canal. It had a length of 80 feet, a beam of 24 feet, and a draft of 7 feet. Whole railroad carloads of stone were dropped into its hull from a 12 foot trestle without injuring the vessel.

1910: The Dutch used 47 by 10 foot barges with open tops to transport ashes and refuse through their canals. Each of the reinforced concrete barges had a 15 ton capacity.

1911: W. N. Downsey, of Iron River, Michigan, built a small reinforced concrete rowboat, and another in 1914. The second boat was presented to the United States Naval Reserve in Chicago in 1917.

In 1918 it made a recruiting trip from Pittsburgh to Chicago via the Ohio, Mississippi, and Illinois Rivers.

1912: A 500 dwt scow was built in Baltimore for transporting sand and gravel. Three others followed. During their first 4 years of service not one ever needed its bilges pumped; an event which was a daily occurrence on equivalent wooden scows.

1912: Johannes Lescher, of Dresden, launched a reinforced concrete sailboat. He later described it as being extremely seaworthy, but rough handling.

1912: A reinforced concrete barge with a length of 90 feet, a beam of 26 feet, and a draft of 9 feet was built in Mobile, Alabama. In 1916 it washed ashore in the Gulf during a severe storm, and in the process of grounding struck an obstacle which punctured its side. Two years later the barge was refloated, repaired, and restored to satisfactory service in the coastal trade.

1912: The English government built a 100 foot by 28 foot barge for carrying heavy equipment on the Manchester Canal. The barge was repaired several times without the necessity of drydocking.

1914: Four 100 ton pontoons were fabricated of reinforced concrete for use on the Panama Canal. More were built in 1916 as landing stages for small steamers.

1914: Reinforced concrete pontoons, 110 feet long, with a beam of 60 feet, and a draft of 8 feet were installed as landing stages in Sydney, Australia. Each had a displacement of 783 tons.

1916: Several members of the Sabin Hill Yacht Club in Dorchester, Massachusetts, built the WANDERER. It was a 41 foot by 8 foot motor launch powered by a 30 horsepower gasoline engine. Its 1000 gallon fuel capacity was sufficient for a 40 day cruise.[21]

1917: A small motor driven reinforced concrete vessel was launched in Montreal. Another vessel, the 200 dwt MALMO, was launched in Sweden.

1917: At the request of the United States, the Norwegian shipyard at Porgsrund sent the plans and a model of a reinforced concrete lighter to the U. S. Bureau of Standards so that its construction technique could be studied. Part of the evaluation was to compare the considerable bending stresses which had been observed in early steel ships with those projected for concrete ships. The 650 foot DEUTSCHLAND was observed to dip 11 inches from bow to midships along the keel, and the LUSITANIA 12 inches.[22] Another major concern was the probability of a considerable increase in the period of roll due to the greater mass of a concrete hull compared to a steel hull.[23]

## WORLD WAR I - THE YEARS OF MOMENTUM FOR CONCRETE SHIPBUILDING

It was also in 1917 that the United States began what turned out to be a short-lived, but intensive program for building reinforced concrete vessels. A majority of the design expertise was borrowed from the Europeans for the planning and design of the vessels, serving as a classical example of technology transfer.

In 1917 the chief engineer at the Norwegian shipyard at Moss was Nicolay K. Fougener, who had previously built reinforced concrete lighters in the Philippines. One innovation at the Moss yard was the use of steel bars from bridgework instead of the prefabricated steel beams favored by some American naval architects. Using the "Fougener System", the materials required are those which are readily available and can be had at relatively low cost. The high priced labor of steelworkers and riveters was not needed. Concrete hulls could be poured as one homogenous body, thus eliminating the need for advanced bonding technology. Fougener initiated the design and use of the hydraulic cement gun to force mortar between the reinforcing rods. This eliminated all operations except hull smoothing as handwork.[24]

The original Fougner test vessel was a small lighter with a hull having 3 watertight compartments and transverse bulkheads. Its tensile strength was tested using a "try it and see" formula by filling its center compartment with water and leaving both end compartments empty. Later the test was reversed by filling the end compartments while leaving the middle empty. Both tests had satisfactory results.[25]

Another Norwegian innovation was used to make the casting process easier. Some of their concrete ships were built upside down for pouring and were not righted until they were in the water. The hull was launched on a sledge, which was sunk. The hull was then floated upside down. Having been made perfectly airtight before launch, air was allowed to escape slowly until the hull turned on its side and then slowly righted itself. The first vessel using this launch method was the 200 dwt self-propelled lighter BETON I in 1917. For seagoing vessels reinforcement was made 50 percent heavier than for lighters used for inland waters. Rib and girder dimensions were also increased. The thickness of the seagoing vessels was also increased to 3 inches.[26]

In 1917 the Moss plant was building ships with displacements in excess of 3,000 tons.[27] Their design was so promising that, at the request of the Norwegian government, they built a reinforced concrete lightship intended for use in the stormy waters of the Skagerak.[28]

The first major vessel launched at Moss was the 200 dwt NAMSENFJORD. Its maiden voyage was from Christiania, Norway around the British Isles and back, a 2,000 mile voyage. The ship had a single screw, and was driven by heavy oil diesel engines of the Bolinder type. It had a 500 ton displacement and was designed for service between Norway and England.[29] Following a year of satisfactory service it was reported that the NAMSENFJORD had not shown any signs of structural deterioration.[30]

Moss soon thereafter launched 4 other major vessels: the 600 dwt STIER and PATENT, and the 1,000 dwt CONCRETE and ASKELAD.[31]

The ASKELAD had a length of 176 feet, a beam of 31 feet, and a draft of 19 feet. On its trial run in 1918 it was propelled at 8½ knots by twin Bolander crude oil diesel engines of 320 bhp each.[32] The vessel was driven ashore in the estuary of the River Somme in January of 1919. Its bottom bumped so violently that the deck personnel lost their footing as the vessel became stranded high and dry. The entire crew abandoned ship, as it appeared the ASLELAD would break up on the next tide. An onsight inspection a few days later showed the hull to be sound. Ten days later a thorough inspection in London confirmed this preliminary finding, and the ASKELAD was returned to service without repair.[33]

A Danish company was formed for $500,000 in 1917 to build ships of reinforced concrete. They anticipated a rapid return on their investment, because of "the rapidity with which such tonnage can be produced".[34] This yard had the capability to build vessels with a 1000 dwt capacity.

Because of the acute shortage of steel in the United States during World War I, R. J. Wig, a marine engineer with the Bureau of Standards, was chosen to evaluate the Norwegian success with reinforced concrete vessels. He determined that it would not be economically feasible to build a 7,500 ton ship of reinforced concrete unless concrete having a compressive strength of 5,000 pounds per square inch, and a weight of not more than 110 pounds per cubic foot could be developed.[35] Shortly thereafter, lightweight aggregates were being produced commercially in Birmingham, Alabama.

The opinion prevailed in 1917 that a concrete hull would be so thick and heavy that even if it would float there would be little room for cargo.[36] One vessel was under construction in San Francisco at the time at the cost of $750,000 compared to $2,000,000 for an equivalent steel vessel. Most debate centered on the economic and resource aspects of concrete construction, rather than their technological merit.

In 1917 Carl Webber, of Chicago, developed the "Torcrete System". It included a truss frame which was erected and riveted in the ordinary steel ship method. The steel frame was then entirely encased in concrete, thus recognizing the advantages of both steel and concrete. Ships completed in this fashion were to be seamless, monolithic structures.[37]

Concrete shipbuilding in 1918 was compared to automobile manufacturing in 1890. It was "just about on the verge of establishing itself, but not yet beyond serving as the butt of a good deal of controversy and a good deal of humor".[38]

By the fourth month of 1918, however, a great deal of the skepticism concerning concrete vessels was silenced by the FAITH.

The FAITH was a reinforced concrete cargo vessel with a length of 320 feet, beam of 45 feet, draft of 30 feet and a 6 foot loaded freeboard. It had a capacity of 5,000 dwt and was driven by a 1,700 bhp triple expansion steam engine. Internal frames were spaced 16 inches apart. The hull thickness was 4½ inches, and the deck 3 inches of concrete.[39] The San Francisco shipyard which constructed the FAITH was described as exceptionally unusual because of the noticeable lack of usual equipment. The workforce was also unusual in that the vessel was constructed by about 45 house carpenters.

Reports indicate that the FAITH had the appearance of a wooden vessel because of the impressions left on its hull by the wooden mold. The hull was eventually painted black. The shipyard estimated that a comparable steel ship would have a dead weight capacity of a little less than 1,000 tons more than the FAITH. The choice of steam engines was based on the decision to produce the maximum possible vibration to evaluate hull strength over a period of time. The vessel was built and launched right side up.[40]

On her maiden voyage the FAITH took a cargo of salt from San Francisco to Vancouver and Seattle, and carried coal on the return trip. During this voyage it ran into a stiff gale with 65 mph winds and heavy seas. The forward deck was covered with almost 2 feet of water for an extended period. Shipboard observers from industry and various government agencies, who had been apprehensive at the start of the trip, said upon their return that the FAITH "rode splendidly".[41] The skipper, Captain R. E. Connell said: "She acted just like any other vessel. She responded readily to her helm throughout the voyage".[42] He continued to say that the FAITH had not taken an inch of water into its hold. In 1921 the vessel was taken out of service, and stripped of its machinery. The hull was towed to Cuba and sunk for use as a breakwater.[43]

Having been the first American-built reinforced concrete cargo vessel, however, the FAITH had established an impressive record. Its log book included stops at Chile and Honolulu in the Pacific, and a voyage to New York via the Panama Canal in November 1918. In the Spring of 1919, after traveling 13,000 miles since her departure from San Francisco, the FAITH arrived in London as the first concrete ship to cross the Atlantic. It then left for New Orleans, Montevideo, and Buenos Aires.[44]

R. J. Wig inspected the FAITH in April 1918 and said: "This and other concrete ships will be durable for several years, and servicable throughout the probable duration of the war. The upper limit of life expectancy is 3 or 4 years because of deteriorating elements. The present emergency calls for ships, and their life is not of great importance at the present time."[45]

Wig then initiated the construction of the first United States government sponsored concrete ship. Mrs. Woodrow Wilson gave the name ATLANTUS at its launching in Brunswick, Georgia and christened it on November 21, 1918. The ATLANTUS had a length of 250 feet, a beam of 40 feet, and a draft of 16 feet. It was commissioned June 1, 1919.[46]

The ATLANTUS served for a year as a government owned but privately operated steamer in the New England coal trade.[47] It was one of three such ships built during the War. Their excessive weight made them inefficient to operate and difficult to handle, and the experiment was judged a failure. They were decommissioned in 1920 with one scrapped in Boston, and another sunk as a breakwater in Miami. The ATLANTUS was brought to Baltimore and stripped by a salvage yard.

In 1926 it was acquired by a prospective ferry corporation for use as a platform for landings at Cape May, New Jersey from Lewes, Delaware. The ferry would open a shoreline route from New York to Norfolk. That same year, after arriving in tow from Baltimore, the ATLANTUS was blown aground during a storm at Cape May Point before positioning as the ferry wharf. After grounding, the expensive efforts to refloat the vessel were a prime contributor to the failure of the ferry corporation. The ATLANTUS remains visible 200 yards off the beach today, in about 10 feet of water. It is now broken in half, and has been declared a historical sight by the State of New Jersey.[48]

In April of 1918 the Department of Concrete Construction of the Emergency Fleet Corporation issued a statement that "the development of concrete ships has given the shipbuilding industry the enthusiasm to make a revolutionary contribution to the cause of democracy - one that may be an important factor in turning the scales against autocracy".[49] The Department of Concrete Construction was divided into seven sections: concrete design, hull design, construction supervision, and four sections for quality control. Rudolph J. Wig, who had formerly been with the Bureau of Standards, was the Chief Engineer.

The parent organizations, the Shipping Board, and Emergency Fleet Corporation had offices in 24 different District of Columbia buildings and were having difficulties with internal communications. The Shipping Board was a temporary agency which anticipated becoming permanent and requested the construction of a 500,000 square foot building at an estimated cost of $5,000,000.[50] The request was never acted upon.

In 1918 the desparate need for oil tankers caused the Shipping Board to initiate the construction of tank steamers to replace the steel tankers taken from Mexican and coastal traffic for trans-Atlantic trade. It estimated that approximately 75 vessels would be required.[51]

The complete cost of a small cargo vessel of reinforced concrete was estimated as $210 to $300 per dead weight ton. The cost of a 7,500 ton tanker was estimated as $200 to $250 per ton.[52] The cost of a reinforced concrete hull alone was estimated as $100 to $125 per dead weight ton, with comparable steel ships averaging between $180 and $200 per ton. A 3,500 dwt reinforced concrete vessel was considered economical to operate. Hull construction took about 64 days with a double shift, and another 3 weeks to equip. Another cost consideration in favor of concrete was the fact that a small steel plant cost $500,000. A cement plant cost $15,000 and could be made portable. The same shipways could be used for steel and concrete vessels.[53]

In April of 1918 President Wilson approved a $50,000,000 bill for the construction of 5 new government shipyards as an experiment. The shipyards and the vessels they ultimately constructed were:[54]

San Francisco Shipbuilding Company
Oakland, California
    2 7,500 dwt oil tankers
    1 7,500 dwt cargo ship

Pacific Marine and Construction Company
San Diego, California
    2 7,500 dwt oil tankers

Fred T. Ley and Company
Mobile, Alabama
    2 7,500 dwt oil tankers
    1 7,500 dwt cargo ship

A. Bentley and Sons company
Jacksonville, Florida
    2 7,500 dwt oil tankers

Liberty Shipbuilding Company
Wilmington, North Carolina
2 3,500 dwt cargo ships

In theory, these five shipyards had the capability to produce 175 3,500 ton, and 250 7,500 ton reinforced concrete vessels within 18 months, or a combined tonnage of almost 2½ million.[55]

In June of 1918 Wig told a meeting of the American Concrete Institute in Atlantic City: "Concrete ships are expected to disintegrate, all we are asking for now is that they will last one and probably three years".[56] The following week the Shipping Board contracted for forty 7,500 dwt concrete vessels - 8 to each of the five government shipyards.[57]

The decision had been made that wood and steel would be reserved for vessels of 5,000 tons or more. The 3,500 dwt reinforced concrete vessel followed the basic design of the same size wooden vessel, including the number and location of bulkheads. They had a length of 268 feet, a beam of 46 feet, and a draft of 23 feet. Their full load displacement was 6,200 tons. The comparative hull weights for concrete, wood, and steel were 2,500 tons, 2,300 tons, and 1,160 tons respectively.[58]

The construction technique was generally accepted as consisting of four distinct steps: 1) The outside form, or mold, was built of wood. 2) Reinforcing steel rods were placed in position. 3) The interior form was built of wood. 4) The concrete was poured into the form continuously, day and night, to eliminate joints. Several days were required for pouring. Three or four weeks were then allowed for curing. The forms were then removed for reuse and the ship launched.[59]

A reinforced concrete hull cannot be built more rapidly than a steel hull in a well organized yard. The advantage of concrete is that a simple plant with mixers and hoists of the type available in any large city is all that is needed.[60] The need for highly skilled labor is all but eliminated. The concrete shipyard requires only a foreman, superintendent, and common laborers.

The sand and stone for the mortar aggregate was readily available at beaches near each of the five government shipyards. Reinforcing steel was available in abundance because of the decline in building and bridge construction, and did not interfere with the production of steel plates. The lumber used in molds was small and came mostly from what was leftover at wooden construction shipyards.[61]

In June of 1918 E. J. Tully, a draftsman for the Emergency Fleet Corporation, was arrested and held on $25,000 bail for stealing an almost complete set of blueprints and plans for concrete ships. His accomplice, a German agent, was arrested while waiting for the plans in New Orleans.[62] The psychological effect of this event was to strengthen the credibility of the concrete shipbuilding effort.

In 1919 H. C. Turner, an engineer with the Shipping Board, told the American Concrete Institute in Chicago: "The experience of the (concrete) vessels in service thus far indicates that, so far as cargo vessels are concerned, there is ample structural strength. The hope that reinforced concrete would provide a material from which hulls could be built with much greater speed than is possible in the case of steel has not been realized. The average time of constructing the concrete hull has been 7 months. Outfitting and equipping the hull takes another 3 to 4 months".[63]

During this same period the British Ministry of Shipping built 50 seagoing concrete lighters and 12 concrete steam tugs. The tugs CRETEBOOM and CRESTEM, built in 1919, were reported in good condition in 1934 after 15 years of continuous service.[64]

The cargo steamer CAPE FEAR, a 3,500 dwt vessel built by the Liberty Shipbuilding Company in Wilmington, was documented in December 1919 and placed in the coastal coal trade from Hampton Roads to the Panama Canal Zone. While in unfamiliar waters, it was rammed and sunk by the steel steamer CITY OF ATLANTA in Narragansett Bay on October 29, 1920.[65]

Another concrete ship, the SELMA, was constructed in 1919 and carried the following statistics:[66]

displacement: 7,500 dwt
length: 434 feet
beam: 54 feet
loaded draft: 26 feet
full displacement: 13,000 tons
triple expansion steam plant: 2800 bhp
speed: 10.5 kt
total concrete content: 2660 cubic yards
total reinforcing rods: 1500 tons
total aggregate content: 7500 tons
side hull thickness: 4 inches
bottom hull thickness: 5 inches

The SELMA, after being cured for 28 days, had a compressive strength of 4417 psi using a diatomaceous earth pozzolan with lightweight aggregates in a quantity about 1.5 percent by weight.[67]

Constructed at a cost of $2,000,000, the tanker SELMA ran into the rock jetties at Tampico in early 1921 and ripped a large hole in the bottom of its hull. The vessel was subsequently raised with compressed air and towed to Galveston. There, shipbuilders decided it would not be practical to repair the damage. The SELMA was allowed to sink in the mud at a wharf and lay there at a cost of nearly $1500 per month. It was then offered for sale by the Shipping Board, but no bids were received. The proposal was then made to tow the vessel out and beach it near the Galveston jetties for use as a recreational fishing pier.

An objection to the fishing pier proposal was that it might set in motion currents that would undermine the jetties. An alternative action would have been to take the SELMA to sea and allow it to sink. This idea was also abandoned because it was feared that the vessel would sink before it could be towed far enough to sea, and thereby become a hazard to navigation. At its sunken position at the wharf the SELMA could only be raised high enough so that it drew 24 feet of water. The only spots it could reach in the immediate area were heavily traveled and could not be obstructed. The Gulf of Mexico is so shallow in that area that the Selma could not be towed within a mile of the beach.[68]

The SELMA's disposal problem was solved by dredging a 30 foot deep by 400 foot long channel into the sand flats near its mooring. In 1922 it was finally towed there and allowed to sink. Its main deck and superstructure remain above water, and local currents have since filled in the channel.[69]

Tests were conducted on the SELMA 34 years later, in 1956, using hull specimens from above and below the waterline. The condition of the reinforcing rods was excellent, showing no signs of rust except for a light coat from when the concrete was poured. The general condition of the concrete was also described as excellent.[70]

By 1920 only 3 concrete ships were in active service in the United States, along with 20 canal barges. The original program in 1918 had called for the construction of 42 self-propelled vessels. That number was reduced to 14 at the time of the Armistice, and in 1919 two of those orders were cancelled. The size and type of the vessels actually completed are listed in the table on pages 17 and 18.[71]

One of the concrete vessels was reported to have run aground near Penobscot Bay, Maine in 1920, and was abandoned.

Two 7,500 dwt tankers, the CUYAMACA and the SAN PASQUAL, were documented in mid-1920 and carried oil between Tampico and Baton Rouge. Both were retired from service in 1924. The CUYAMACA was converted for use as a floating oil storage tank in New Orleans. The SAN PASQUAL was converted into a floating storage vessel for use in Cuba.[72]

The 2,000 dwt oil tanker DURHAM was launched at Aranas, Texas in 1920 to operate between Tampico and Aranas. A sistership was completed at about the same time, with the construction of another 14 similar vessels pending the success of the first two.

The hull of the DURHAM consisted of two interlocking cylinders which were connected at the top and bottom by flat slabs which formed the deck and keel sections. The interlocking cylinders provided a fore and aft passageway through the hull, and served as a buoyancy chamber from bow to stern. Both vessels were twin screw and diesel driven. Their main body of 210 feet was composed of seven 30 foot sections which had been built and poured in the vertical position. The sections were positioned, and then joined with overlapping reinforcing rods by a hydraulic cement gun. The bow and stern sections were molded and joined separately. Each vessel had a 14,000 barrel cargo capacity. Their overall length was 298 feet, with a 34 foot beam, and an 18 foot draft. The hull thickness was 10 inches. Each tank interior was given 2 coats of spar varnish.[73]

The SAPONA has rested on the flats in Barnett Harbor off South Bimini since 1926. It was a concrete hulled cargo ship which had been purchased after World War I by Carl Fisher, a wealthy Miami developer, for use as a private clubhouse in the Florida Keys. Government restrictions, however, prevented the realization of his plan. He sold the vessel to Bruce Bethel, a "one-armed Bimini saloon keeper", for use as a warehouse and rendezvous with Florida rumrunners. Later in 1926 a hurricane blew the SAPONA about 5 miles from Bethel's dock and grounded it in open view of the telescopes of the local government agents. Bethel then made plans to convert the SAPONA into a lavish nightclub, but never did. During World War II U. S. training aircraft used the vessel for bombing practice. Today it is virtually intact, but retains the cracks and holes from that experience.[74]

## CONCRETE SHIPBUILDING DURING WORLD WAR II

Marine engineers had long been aware of the possible superior strength of welding over riveting. The problems of incomplete welds and cracking prevented its widespread adoption until the beginning of the 1940's. Even with this significant technological development, however, continued interest in concrete shipbuilding resulted in twice the production of World War I.

In 1942 McCloskey and Company, of Philadelphia, built a new concrete shipyard in Tampa and received a contract for twenty-four 5200 dwt cargo vessels. The contract was based on the concept that concrete ships were feasible because of the shortage of steel and the need for United States coastwise transportation. Each vessel had a length of 360 feet, reciprocating steam engines, and a single screw. The American Bureau of Shipping allowed, for the first time, the pneumatic placement of concrete.[75] The details of variations in vessel specifications are listed in Figure 5.

During World War II a total of 24 reinforced concrete steamships and 60 barges was ultimately constructed. The concrete fleet was retired at the end of the war, and eventually sold as surplus.[76]

Extensive research indicates that only 2 of the reinforced concrete steamships made any significant contribution to the war effort. Both were intentionally sunk as landing platforms in preparation for the invasion at Normandy Beach.

The most important development in concrete ship design during this period concerned the method of propulsion rather than the concrete. In 1929 the British firm of Doxford and Sons had build an 800 bhp, 3 cylinder, opposed piston engine for the British North-East Coast Exhibition. This was the first time such an engine had been built under 1500 bhp. After the Exhibition it was removed and kept in running order until placement in the 2000 dwt reinforced concrete LADY WOLMER in 1941. Each cylinder had an internal diameter of 15.75 inches. Fuel consumption was 0.355 pounds per bhp (3 tons per day) at a classified cruising speed which must have been between 10 and 12 knots. The boiler oil consumption was 2 tons per day to run the bilge, ballast, fuel transfer, boiler feed, and condenser circulation pumps. The complement consisted of a master and 2 deck officers, 3 engineers, and 18 crewmen.

A sistership to the LADY WOLMER was completed in a British shipyard in 1942 with an identical propulsion plant.[77]

The year 1943 marked the beginning of a new era in concrete shipbuilding, when Professor Pier Luigi Nervi was commissioned by the Italian government to begin ferrocement hull construction experimentation. His initial tests were conducted with smaller vessels constructed in a non-electric shipyard.[78]

## FERROCEMENT THEORY AND CONSTRUCTION TECHNIQUES

Following his initial experiments with ferrocement for boat and ship construction, and after the War, Nervi began using this new material in building construction. He described ferrocement as "thin slabs of mortar reinforced with superimposed layers of wire mesh and small diameter rods, giving a product with a high degree of elasticity and resistance to cracking, and requiring a minimum of formwork".[79]

Almost all ferrocement development since then has been of a nontechnical nature, and there has been considerable debate among builders as to which construction material is actually the best. The information available to amateur boatbuilders is generally incomplete because of the independent and competitive nature of the small boatbuilding industry. Most commercial interests seem to protect themselves with patents, and are generally reluctant to offer detailed information to the public. The process, however, has been described as being so simple that at best, any advantage of secrecy will be temporary.[80]

The following attributes have been given to ferrocement small boats of various sizes and designs: good sound and vibration dampening, little inside condensation, poor thermal conductivity, good thermal resistance, durability, rust resistance; it will not rot, swell, shrink, corrode, or burn, and it grows stronger with time. The hull may be repaired below the waterline while underway with a simple cement patch. It has a poor resistance to organic acids, and a fair resistance to other acids. Except for the sake of appearance, no painting is required. Ferrocement has no odor, and because of the lack of internal frames there is more interior room.[81]

In terms of price, performance, maintenance costs, and life span ferrocement boats seem an ideal investment for developing nations. They require a minimum of qualified personnel to construct, and few imported raw materials or equipment.[82] Additional savings are available where ferrocement boat builders are able to use the fittings from older boats as the fabrication process lends itself to this reuse.[83]

There are four major ferrocement construction considerations: 1) the mold must have a very accurate shape, 2) the reinforcing mesh must be uniformly spaced and tied, 3) the mortar must thoroughly and completely penetrate the mesh, and 4) the mortar must be properly cured after application to ensure the strength of the hull.[84]

Martin E. Iorns, of the Fibersteel Company, has proposed a fifth item of basic concern to the ferrocement boatbuilder:[85]

> "Builders will look ahead far enough to brace their frame to support the weight of the wet mortar itself but do not forsee the dynamic loading which will be placed on the frame in trying to force the mortar to penetrate the mesh. These deflections become worse of course, near the close of the working day, when the dead weight of the wet mortar is almost all present and the workmen are still trying to push more mortar into place. The whole framework may be pushed out of fair. If this is noticed soon enough, temporary shoring can be provided to give some support to the sagging areas. Unfortunately, it usually happens near the close of a hard work day when the light is poor and it is not discovered until the next morning, too late to do anything. One such builder is reported to have brought in a bulldozer at this point, dug a trench alongside the boat, shoved the boat into the trench and buried it."

Welded steel mesh with one half inch squares of about 19 guage is generally accepted as the best shaping and reinforcement material. When the mesh is placed on the surface of the mold it should be able to be bent into the contours of the hull without buckling or breaking. Because of its relative stiffness, however, the welded steel mesh must often be cut and pieced into place and results in high waste because of the odd shapes which are left after cutting the pieces.[86]

Chicken wire has been used in ferrocement construction, but it is generally not heavy enough to establish the proper balance between strength and flexibility. Bright wire is usually preferred over galvanized because the latter is subject to attack by caustic solutions such as calcium hydroxide, and begins to deteriorate upon placement in the mortar.[87]

Ferrocement tools and equipment include a power plaster/mortar mixer to thoroughly integrate the water, cement, aggregates, and pozzolans into a dry and homogenous mass; a cement mortar vibrator to prevent premature setting; a pair of wire cutters and a notched blade screwdriver to cut and twist the wire used to tie the mesh; a trowel to place the mortar on the mesh; and a wooden board bolted to the face of an orbital sander to smooth the hull after the mortar has been placed.[88]

In the 1960's Windboats Limited, of Wroxham, England originated the "Seacrete" process for ferrocement construction, but will not disclose whether the name "Seacrete" applies to the process, the materials used, or to both in combination.[89] It is known that they have made a policy decision to plaster only a certain number of square feet on a hull in a day. The reason for this policy is due to physical exhaustion and loss in quality of workmanship after a hard day's work. Quality control problems involving porous areas sometimes result from improper pneumatic placement due to the fluctuating incentiveness of the nozzleman.[90]

Standard ferrocement construction is suitable for boats of 18 feet and larger. There is no limitation on smaller sizes except weight considerations.[91] Sixty feet has been suggested as the upper limit for ferrocement construction.[92]

In the 1960's the high and rising costs of boat construction with conventional materials forced some designers and builders to look for an alternative material. With ferrocement, relative construction costs go down as length increases. Low labor costs favor small commercial builders and protect against competition from mass producers because of the much greater cost of finished product transportation.[93]

Commercial ferrocement boatbuilders are claiming a saving of about 10 percent on a 20 foot sloop hull. Since hull cost is about 25 percent of the total cost, overall savings on this type of vessel can be expected to be about 2.5 percent.[94]

In 1972 the material content of ferrocement cost approximately $1.20 per square foot for a 1 inch thickness. The total surface area of a standard 45 foot hull is 1200 square feet. That would make the total cost of the hull, exclusive of mesh and steel reinforcement, $1440.[95]

There are two basic ferrocement construction techniques: 1) the frame method, where either the pipe frame, the welded frame (which is left in the mortar), or the wooden frame provide the support for the mesh; and 2) the molding method, which uses either a male, female, or injection mold to provide the support for the mesh.[96]

The iron pipe method is probably the most popular method, and involves a three step process: 1) iron pipe is carefully bent to the desired lines of the vessel, and then small rods are wired to them fore and aft; 2) 3 or 4 layers of steel mesh are laid on both the inside and outside of the small rods and are painstakingly wired down; and 3) cement, applied from the inside, is forced through the mesh and is then smoothed off with standard plastering tools. The wires to the pipe frame are cut after the mortar has set, and the frame is removed.[97]

The keel section is usually plastered or poured before the hull. The joint between the keel and the hull shell is treated with a "wet-to-dry" epoxy resin glue before plastering the hull. It is important to adequately and evenly support the keel before pouring, so that its weight does not distort the rest of the hull.

The average hull thickness for a boat 18 feet or less is 1/4 inch; for a boat 18 to 25 feet it increases to 1/2 inch; for a boat 25 to 35 feet it increases to 3/4 inch; and usually for any boat over 35 feet the thickness is increased to 1 inch.[98]

The labor involved in placing the mortar on a hull averages between 1½ and 2 man hours per square foot. With the development of new cement adhesives it is no longer to complete the plastering in one operation. In order to plaster a 45 foot hull in one operation a crew of 15 experienced workers would be required.[99] The plastering of a 52 foot ketch hull reportedly took 28 semi-experienced people 22 hours.[100]

Ferrocement and wooden boats have approximately the same weight at a length of 30 feet. Thereafter, ferrocement remains about 5 per cent heavier than wood. Ferrocement construction gives an average 12 percent increase in interior space compared to wood because of the elimination of thick beams and frames. This comparison was based on a concrete thickness of 1 inch.[101]

The normal composition of ferrocement mortar includes 1 part of sulfate resistant cement, 1½ parts of chemically inert plaster sand, enough of an air entraining agent to develop a 3 to 5 percent air content by volume, and as little water as possible. Fifteen to twenty percent of the cement may be replaced by a pozzolan to react with the lime secreted by the cement, forming an insoluble silica gel. The pozzolan reduces temperature sensitivity and permeability. It also strengthens the concrete by lessening the water requirement.[102]

Five basic types of cement are suitable for ferrocement construction: ASTM Type I - an all purpose cement for use where the surface is not subject to sulfate action; ASTM Type II - has moderate resistance to sulfate attack, and a moderate cost; ASTM Type III - is a high early strength cement, is faster curing than either Type I or II, and allows for the early removal of the forms; ASTM Type V - is a sulfate resistant cement for use when the surface is subject to extremely high sulfate action, and is considerably more expensive than Types I, II, or III; White Portland Cement - is very expensive because of its minimal iron and manganese oxide content, and is used primarily by individuals who find gray cement unattractive.[103]

Experience has shown that the minimal practical cement cover that can be applied to the steel mesh and still give protection against corrosion is approximately 1/12 inch. Because of the requirement for greater strength and thicker plaster, the mesh becomes virtually immune to corrosion. Each layer of mesh adds to the difficulty of complete penetration, however, and can leave some of the mesh exposed to open pockets in the mortar.

The curing process for ferrocement involves covering the hull with polyethelene sheeting, wet burlap sacks, or tar paper to make a vapor proof enclosure, and then ensuring a high relative humidity and moderate temperature until the mortar sets.[104] Curing retains sufficient moisture within the concrete to permit the complete hydration of the cement. Ideal curing is completed after 28 days at a constant temperature of 70 F, in a moist greenhouse environment.[105]

Epoxy resin protective finishes are sometimes applied to hulls exposed to salt water. In some climates, anti-fouling paint is necessary and must be applied twice each year. No exterior treatment is necessary in fresh water.[106]

Ferrocement hulls have very good resistance to impact. This includes the sudden surface area stress overload resulting from wave action and other large area type stresses. It has a very poor resistance to punching, which would include sudden small area stresses from anchor flukes, head on collisions, protruding pier bolts, and other sharp objects.[107]

Ferrocement boats are very insurable. Lloyd's has not only certified some ferrocement vessels, but has given them insurance discounts because of their fire-resistant nature.[108]

## FERROCEMENT VESSELS

In 1945 the first ferrocement vessel, the 165 ton IRENE, was built by Nervi and Bartoli in Anzio It had a hull thickness of 1 3/8 inches and was perfectly watertight. It required no outside hull maintenance during the first 6 years of service. Its grounding in 1947, and a collision with a wreck in 1950 caused localized cracking of the skin at the points of impact and slight deformation of the internal steel mesh without any serious rupture or opening through the hull wall. Repairs were made by hammering the internal reinforcement back to the original contour with a sledge and plastering the surface breaks with cement and epoxy. The IRENE was constructed and afloat within three months.[109]

Between 1960 and 1967 Windboats Limited produced 107 "Seacrete" ferrocement hulls. Firms in 28 countries outside England have been licensed to build with their material. Lloyd's has granted a 100.1.A classification for yachts and launches built of "Seacrete", one of which is a 28 foot twin screw diesel cruiser with a 7/8 inch hull. They have also constructed trawlers for the fishing fleets of at least 3 African nations.[110]

The Lloyds certification process involved flexing a strip of "Seacrete" 2 million times without fracture, and heating it to 1700 degrees Centigrade without damage. The tensile and compressive strength was found to equal or exceed that of all other common shipbuilding materials.[111]

Jack Rouse had been commissioned by Martin Iorns, of the Fibersteel Corporation in West Sacramento to create designs for 32 and 55 foot hulls. The 32 foot series has 2 sail and 4 powerboat designs from the basic hull. The 55 foot series has 3 ketch designs and a motoryacht. The tanks, bulkheads, compartments, cabins, hull, and deck are made of newly developed waterproof Portland cement formulas at a cost approaching 50 percent of other boatbuilding methods and materials. The patented "Fibersteel" technique is less than ½ inch thick, but has tremendous strength and rigidity. The 55 foot hull has twin centerboards to facilitate self-steering and a shallow draft of 4 feet.[112] All the hulls are covered with a gel coat. The first 32 foot hull was used as a towboat around the shipyard.[113]

Most developing countries urgently need modern fishing fleets to help solve their acute food shortage problem, and vessels to facilitate transportation where rivers are the primary means of communication. Wooden hulls are not always advisable. They require skilled labor to produce and maintain, particular types of wood, and frequent stops for repair and maintenance. Steel hulls also require skilled labor to produce and maintain, and expensive facilities.[114]

The United Nations Industrial Development Organization is interested in ferrocement construction because of the increased importance of shipbuilding and repair facilities to developing nations. The Indian Ocean cyclone of 1970 destroyed 65 percent (12,000) of the fishing boats in East Pakistan. The United Nations Food and Agricultural Organization is considering the replacement of these vessels with ferrocement hulls in a report entitled "Ferrocement and Reconstruction of the Fishing Fleet in East Pakistan".[115]

Six hundred people are now employed in the mass production of small fishing boats in a factory near Shanghai, China.[116]

The remainder of the ferrocement vessels described in this section have been listed in order of increasing length rather than by age to place emphasis on the variety and not necessarily the chrolology of ferrocement innovations.

Concrete canoe racing began in the early 1970's when the University of Illinois and Purdue University took their canoes to a state park near the Illinois state line and raced them. Subsequently, the American Concrete Institute has developed rules governing the design and safety of concrete canoes, and has sponsored races in various parts of the country.

The typical ferrocement canoe is 13 1/2 feet long, with a 34 inch beam, and 6 1/2 inches of freeboard. Plastering is usually accomplished in 90 minutes. The surface is then covered with lightweight plastic and smoothed by hand to eliminate rough areas.[108]

In 1964 the "Seacrete" hull MARS exploded, hurling the cabin top 50 feet in the air. The mast landed 200 yards away. Flames completely gutted the interior. The only damage to the hull was minor cracking at the transom corners.[119]

In November 1970 the Naval Ship Research and Development Center conceived and initiated plans to build an advanced, state of the art ferrocement boat. It was launched 2 months after design began in February 1971. Called CRAB (cement river assault boat), it had a length of 24 feet, beam of 9 feet, draft of 2 feet, and a displacement of 6435 pounds including a 5 man crew and military payload. It was designed for a speed of 31 knots.

Seven performance requirements were placed on the CRAB: 1) operate in the 30 knot speed range with high acceleration, 2) operate very quietly at slow speeds, 3) be outboard propelled, 4) have a range of at least 100 nautical miles at an average speed of 20 knots, 5) have a low profile, 6) be transportable by vehicle or helicopter sling, and 7) carry a 1615 pound payload. CRAB was rough water tested with satisfactory results in all categories.

At a displacement of 6435 pounds, CRAB consumed 12.4 gallons per hour at maximum speed of 31.3 knots. In a comparative test at 5698 pounds the consumption was 13.0 gallons per hour at 31.6 knots. The difference in weight on the two tests corresponds to the difference between fiberglas or aluminum and ferrocement. The penalty of ferrocement construction in this instance was 0.3 knots in speed, and 0.4 gallons per hour in consumption.[120] The outboard power is unknown.

The ROLLING STONE has a ferrocement hull and deckhouse, and was built in Kalamazoo, Michigan in 1934. It has a length of 30 feet, and a beam of 9 feet, and is still in use on Spring Lake, Michigan. The ROLLING STONE is not removed from the water in the Fall, and has been exposed to many severe winters without any apparent harm or deterioration.[121]

In 1964 a two ton auxiliary yacht rammed the side of the 34 foot "Seacrete" motor cruiser TRADEWIND FOUR at a speed of 5 knots. A 2½ by 2 foot area of the hull was pushed in to a maximum depth of 13 inches. A hydraulic jack placed against the engine mount easily pushed the hull back into shape. Two small 1/8 inch surface cracks were filled and smoothed. The entire repair operation took 30 minutes.[122]

Joe Miller, of Tiburon, California, has built a 40 foot ketch with an 11 foot beam and a 6½ foot draft from his own plans in his backyard.[123] No report is available on the success of this vessel, but it should be noted that many one time, original design ferrocement vessels are slow, tend to over steer, and consume an inordinate amount of fuel while delivering a steady ride.[124]

In 1948 Nervi built the 41 foot ferrocement ketch NENNELE with a ½ inch thick hull.[125]

In 1967 the first large ferrocement fishing vessel was built in North America by Gordon Ellis of Victoria, British Columbia. It was a 41 foot salmon troller that has since proven very satisfactory.[126]

William Preston of New Orleans designed and built a 50 foot ferrocement ketch with a 13 foot beam and 7 foot draft. It displaced 49,000 pounds, and carried 1,066 square feet of sail. Its construction used 3/8 inch transverse rods, 1/4 inch longitudinal rods, each covered on both sides with 4 layers of 1/2 inch grid chicken wire.

The final hull thickness was 7/8 inch.[127]

In 1967 Jack Rouse, a naval architect from Los Angeles, designed a 55 foot ferrocement motor sailer which can be produced exclusive of auxiliary power and sailing rig for under $10,000. The same vessel in fiberglas would cost nearly $50,000.[128]

The MARCO POLO is a 55 foot, double ended, 3 masted schooner designed and built by L. Francis Herreshoff and his wife. Their list of materials includes:

| | |
|---|---|
| cement | 48 bags (ASTM Type III) |
| aggregates | 96 bags (94 pounds per bag) |
| steel rods | 10,670 feet, ¼ inch diameter |
| metal lath | 300 sheets, 30 by 96 inches |
| plywood | 30 sheets, 4 by 8 feet, 3/4 inch thick |
| equipment | 1 mortar/plaster pump (rented) |

The hull was plastered by 5 professionals, and with the exception of the labor of Herreshoff and his wife, the construction and curing took 7 weeks and cost $1,500 (1970).[129]

The HARAMBEE, a 60 foot ferrocement ketch, was designed and built by Jay R. Benford, of Washington, in just over a year. It is now used as a house and for summer charter cruises in the San Juan Islands.[130]

## PRESTRESSED CONCRETE

Prestressed concrete is actually reinforced concrete in which the reinforcing rods have been put into tension before the concrete has hardened.

In 1886, F. H. Jackson applied for a patent with a technique which described a method of prestressing the reinforcing rods. The reduction of this idea to practice was not fully realized until Eugene Freyssinet exploited the potential of very high tensile strength wire. His technique produced a tension free, and nearly crack free concrete. By building-in sufficient internal compression, the tensile stresses produced by internal loads merely relax the built-in compression.[131]

Increased interest in prestressed concrete may be due in part to Pier Nervi's buildings for the Rome Olympics, and its diverse use at Expo '67 in the Habitat '67 dwelling units. Many of the newer refinements and improvements in structural concrete are directly transferable to vessel construction.[132]

Prestressed concrete is of interest to designers of Arctic structures and refrigerated gas container vessels because "the high tensile wire, under single direction stress, working in concert with the precompressed concrete behaves very well at cryogenic temperatures".[133] The strength of concrete rises with decreasing temperature.

Large structures have stresses going in 3 different directions. It is very difficult to provide prestress in every direction and at every corner to resist all possible tensile stresses. Prestressed concrete normally has some auxiliary reinforcing in the form of unstressed steel to take care of these concentrations of stress at certain corners and details.[134]

The severing of a reinforcing rod, called a tendon, in prestressed concrete does not affect tensioning fore or aft of the break. The normal threaded tendons, if broken, can be cut away and new sections installed and coupled to the original. Replacing the concrete is a simple operation.[135]

## PRESTRESSED CONCRETE VESSELS

The U. S. Navy constructed 2 prestressed concrete vessels during

World War II. Both were built by Roger Corbetta in New York. One was a landing craft; the other was a barge.

They were constructed as open ended precast cells with interior walls of 3/4 inch, and exterior walls of 1 1/2 inch concrete laid out in checkerboard (or honeycomb) fashion. The tendons were tensioned along the space between the precast concrete boxes, and then covered with a layer of gunite, a form of sprayed concrete. This was the essence of the raft-like vessels.[136]

The Atlantic Richfield Company has constructed a liquefied petroleum barge terminal to recover the gas being wasted at offshore wells in the Ardjuna Field north of Kjakarta, Indonesia. They estimate that $100,000 per day is being burned as waste. The LPG barge will recover the propane and butane content of the gas, liquefy it, and store it in large steel tanks. Refrigerated tankers will periodically come alongside, take on the gas, and transport it to market. The lighter constituents of the gas, methane and ethane, will be piped ashore and used for the developing steel industry.[137]

The LPG barge is actually a large prestressed concrete box which is fastened to a single point mooring. It has a length of 460 feet, a beam of 136 feet, and a draft of 56 feet. The barge's displacement is 65,000 tons, or somewhat more than that of a conventional aircraft carrier. It carries 12 steel tanks, 6 of which are above deck. The maximum capacity is 375,000 barrels, which is 60,000 cubic meters, or 36,000 tons. The LPG barge has a 10 inch thick hull, and accommodations for a crew of 40.[138]

The Dytam Corporation of New York has recently received concept approval for a 900 foot prestressed concrete liquefied natural gas carrier from the U. S. Coast Guard. The plan calls for concrete tanks as well as a concrete hull. The next stages in the approval process would be for design, and then for construction. The concept approval merely indicates that an application for design approval has been received by the Coast Guard and that the receipt has been acknowledged.

The Dytam Corporation is a joint venture by Dykerhoff and Widman of Munich, and Tampimex Tankers Limited of London. They have also reported approval by Lloyd's Register of Shipping for the entire hull structure, but again only in concept.[139]

If there is skepticism on the part of approval agencies concerning structures for the handling or transportation of liquefied natural gas, it dates to 1941 when an LNG storage tank was built in Cleveland. Its operation was uneventful until 1944 when one of the storage tanks failed. No dike had been built around the tank to contain a spill, and the gas flowed away unimpeded. It boiled at atmospheric pressure and the vapors reached a source of ignition, touching off an explosion which killed 128 people.[140]

Following that accident liquefied natural gas was virtually ignored as a fuel source in the United States for 2 decades until the National Aeronautics and Space Administration developed the technology and safety procedures for storing cryogenic liquids.

Dytam lists the operational advantages of its prestressed concrete LNG carrier as a longer than steel and essentially maintenance free hull life of over 25 years. The need for painting or coating, aside from the steel superstructure and rudder is eliminated, unless the owner opts to do so for aesthetic reasons.[141]

The economic risk associated with this innovative ship design has complicated its financing. The materials and technology are available. Only the capital and a suitable graving dock are needed.

A Dytam spokesman has said that the choice of prestressed and reinforced concrete for the tanker design material was based on economic grounds because of the soaring cost of steel construction, technical grounds because of the favorable behavior of concrete under cryogenic conditions, and ecological grounds because of the smaller risk to the environment in case of fire, collision, or grounding.

The actual dimensions of the proposed tanker include a length of 951 feet, a beam of 144 feet, a draft of 38 feet, a hull depth of 77 feet, and a displacement of 56,250 dwt. It will be driven by 40,000 shp at a speed of 19.5 knots, and will have an LNG capacity of 126,875 cubic meters. The secondary barriers between the inner and outer tanks will be filled with an inert gas.[142]

Due to the wire mesh nature of the reinforcing, any explosion aboard the vessel would tend to be contained to a greater degree than in a steel ship, and with a lesser danger of structural failure.

Dytam estimates that a conventional LNG carrier has an average utilization of 340 days per year, with the same downtime for deck equipment, cargo systems, and navigational gear. They feel, however, that they can conservatively add 13 days per year to the operation of a concrete ship because of the lack of periodic hull maintenance.[143]

At present there does not seem to be enough information available to evaluate the operational feasibility of a prestressed concrete LNG carrier. This concept would definitely not apply to the construction of oil tankers because of hogging and sagging due to the weight of the cargo, and any concrete vessel will have a deeper draft, and more fuel consumption than a comparable steel hull vessel, but also less sail area.[144]

# CONCLUSION

During the second half of the 19th century the use of reinforced concrete as a shipbuilding material was almost entirely experimental, and limited to use by individual inventors. Economic opportunity provided the incentive for their efforts.

During the closing years of World War I, and during World War II the use of reinforced concrete was predicated by economic necessity due to the critical shortage of steel and skilled labor.

Ferrocement became the alternative material of choice for a significant number of individual boatbuilders in the 1960's for economic reasons, and for some as a hobby project; and for a few small commercial builders who saw the opportunity to capture what seemed to be a new market.

The use of prestressed concrete in recent years has been limited to only one major operational vessel and one proposed vessel. In both cases concrete was chosen as the building material for economic reasons. The environmental and safety considerations mentioned in the final section of the paper seem more of a public relations effort than a reality.

Each of the four situations described above has been dependent on either economic necessity or opportunity. The first three can be summarized as having ended less successfully than expected. The future of prestressed concrete as a shipbuilding material remains to be evaluated.

Although little primary evidence is available, it would also seem that the success of any concrete ship endeavor depends on the dissolution of a psychological barrier in the minds of both shipbuilding investors and consumers.

# FOOTNOTES

(1) Design and Control of Concrete Mixtures, p. 12

(2) Scientific American (a), p. 63

(3) Design and Control of Concrete Mixtures, p. 12

(4) Design and Control of Concrete Mixtures, p. 18

(5) Gardner (b), p. 37

(6) Whitener, p. 8

(7) Iorns, p. 7-B

(8) FerroCement Boats, p. 9-C

(9) Whitener, p. 11

(10) Design and Control of Concrete Mixtures, p. 38

(11) FerroCement Boats, p. 9-C

(12) New York Times (t), p. V-9

(13) Whitener, p. 12

(14) Boats From FerroCement, p. 23

(15) Whitener, p. 7

(16) Whitener, p. 19

(17) Boats From FerroCement, p. 1

(18) Boats From FerroCement, p. 1

(19) Canby, p. 6

(20) Scientific American (c), p. 81

(21) Scientific American (g), p. 165

(22) Scientific American (d), p. 354

(23) Literary Digest (d), p. 134

(24) Scientific American (b), p. 361

(25) Scientific American (c), p. 81

(26) Literary Digest (c), p. 21

(27) Scientific American (a), p. 63

(28) Scientific American (b), p. 361

(29) Scientific American (b), p. 361

(30) New York Times (h), p. VII-5

(31) New York Times (t), p. V-9

(32) Anderson, p. 125

(33) New York Times (t), p. V-9

(34) New York Times (a), p. 13

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(36) Scientific American (b), p. 361

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(40) New York Times (h), p. VII-5

(41) New York Times (p), p. 4

(42) New York Times (l), p. 13

(43) Anderson, p. 127

(44) New York Times (t), p. 9

(45) New York Times (g), p. 6

(46) New York Times (r), p. 9

(47) About New Jersey

(48) Atlantus

(49) New York Times (h), p. VII-5

(50) New York Times (g), p. 6

(51) New York Times (e), p. 17

(52) Literary Digest (d), p. 134

(53) New York Times (g), p. 6

(54) Anderson, p. 128

(55) New York Times (h), p. VII-5

(56) New York Times (p), p. 4

(57) New York Times (n), p. 5

(58) New York Times (h), p. VII-5

(59) New York Times (h), p. V11-5

(60) New York Times (g), p. 6

(61) New York Times (h), p. VII-5

(62) New York Times (o), p. 7

(63) Literary Digest (d), p. 134

(64) New York Times (t), p. V-9

(65) Anderson, p. 129

(66) Whitener, p. 121

(67) Whitener, p. 121

(68) Literary Digest (c), p. 26

(69) Literary Digest (c), p. 26

(70) Whitener, p. 66

(71) Literary Digest (d), p. 134

(72) Anderson, p. 129

(73) Scientific American (j), p. 68

(74) Concrete Fish Haven, p. 308

(75) Ships of Concrete, p. 56

(76) Anderson, p. 123

(77) A British Built Concrete Motor Ship, p. 108

(78) Gardner (a), p. 6-B

(79) Whitener, p. 115

(80) Gardner (b), p. 21

(81) Gardner (b), p. 37

(82) Boats From FerroCement, p. v

(83) Brauer, p. 94

(84) Boats From FerroCement, p. 25

(85) Canby, p. 62

(86) Boats From FerroCement, p. 116

(87) FerroCement Boats, p. 4-C

(88) Whitener, p. 2

(89) Boats From FerroCement, p. 22

(90) Canby, p. 63

(91) FerroCement Boats, p. 4-C

(92) Gardner (a), p. 6-B

(93) Iorns, p. 23-B

(94) Keith, p. 45

(95) Boats From FerroCement, p. 5

(96) Boats From FerroCement, p. 27

(97) Gardner (b), p. 20

(98) FerroCement Boats, p. 4-C

(99) Boats From FerroCement, p. 22

(100) Gardner (c), p. 8-A

(101) Whitener, p. 99

(102) Iorns, p. 23-B

(103) Whitener, p. 7

(104) Iorns, p. 24-B

(105) Whitener, p. 66

(106) Whitener, p. 74

(107) Boats From FerroCement, p. 7

(108) Brauer, p. 94

(109) Gardner (b), p. 34

(110) Gardner (b), p. 36

(111) Gardner (b), p. 37

(112) Valeo, p. 46

(113) Rouse, p. 23-B

(114) Boats From FerroCement, p. v

(115) Gardner (c), p. 9-A

(116) Gardner (a), p. 6-B

(117) ASCE Student Chapter, p. 44

(118) ASCE Student Chapter, p. 44

(119) Gardner (b), p. 37

(120) Brauer, p. 103

(121) Canby, p. 6

(122) Gardner (b), p. 37

(123) Iorns, p. 23-B

(124) Whitener, p. xii

(125) Gardner (b), p. 34

(126) Gardner (a), p. 6-B

(127) 50' Ferro-Cement Ketch, p. 1-B

(128) Gardner (a), p. 6-B

(129) Whitener, p. 64

(130) Benford's FerroCement Book, p. 21-B

(131) Anderson, p. 134

(132) Gardner, p. 6-B

(133) Anderson, p. 135

(134) Mast, p. 248

(135) Concrete Ships, p. 72

(136) Mast, p. 245

(137) Mast, p. 245

(138) Mast, p. 245

(139) Concrete Ships, p. 68

(140) Scientific American (k), p. 22

(141) Concrete Ships, p. 68

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d) HOW CONCRETE SHIPS HAVE WORKED
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e) SHIP BOARD TO TRY CONCRETE TANKERS
April 6, 1918

f) HAS $50,000,000 PLAN FOR CONCRETE SHIPS
April 9, 1918

g) PRESIDENT RATIFIES CONCRETE SHIP PLAN
April 14, 1918

h) PROMISE OF SUCCESS FOR THE CONCRETE SHIP
April 21, 1918

i) CONCRETE SHIP A SUCCESS
May 6, 1918

j) CONCRETE SHIP HAS TRIAL
May 6, 1918

k) FIFTY-EIGHT MORE CONCRETE SHIPS
May 17, 1918

l) CONCRETE SHIP TESTED
May 27, 1918

m) PLANT FOR CONCRETE SHIPS
June 6, 1918

n) ORDERS 40 CONCRETE SHIPS
June 11, 1918

o) AFTER OUR SHIPPING PLANS
June 16, 1918

p) LIFE OF CONCRETE SHIPS
June 30, 1918

q) PUSHING CONCRETE SHIPS
October 5, 1918

r) FIRST CONCRETE SHIP IS ATLANTUS
November 16, 1918

s) LAST CONCRETE WAR TIME SHIP TO BE SUNK AS LANDING PLACE FOR FERRY AT CAPE MAY
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t) CONCRETE SHIPS
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e) CONCRETE SHIP 'FAITH'
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f) THE FRENCH DESIGN AN UNSINKABLE SHIP
July 13, 1918

g) SHIPS OF STONE - 1848 TO 1918
August 31, 1918

h) ELECTROLYSIS IN REINFORCED CONCRETE
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i) SHIPS OF PUFFED BRICK
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j) A DARING SHIP DESIGN
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k) THE IMPORTATION OF LIQUEFIED NATURAL GAS
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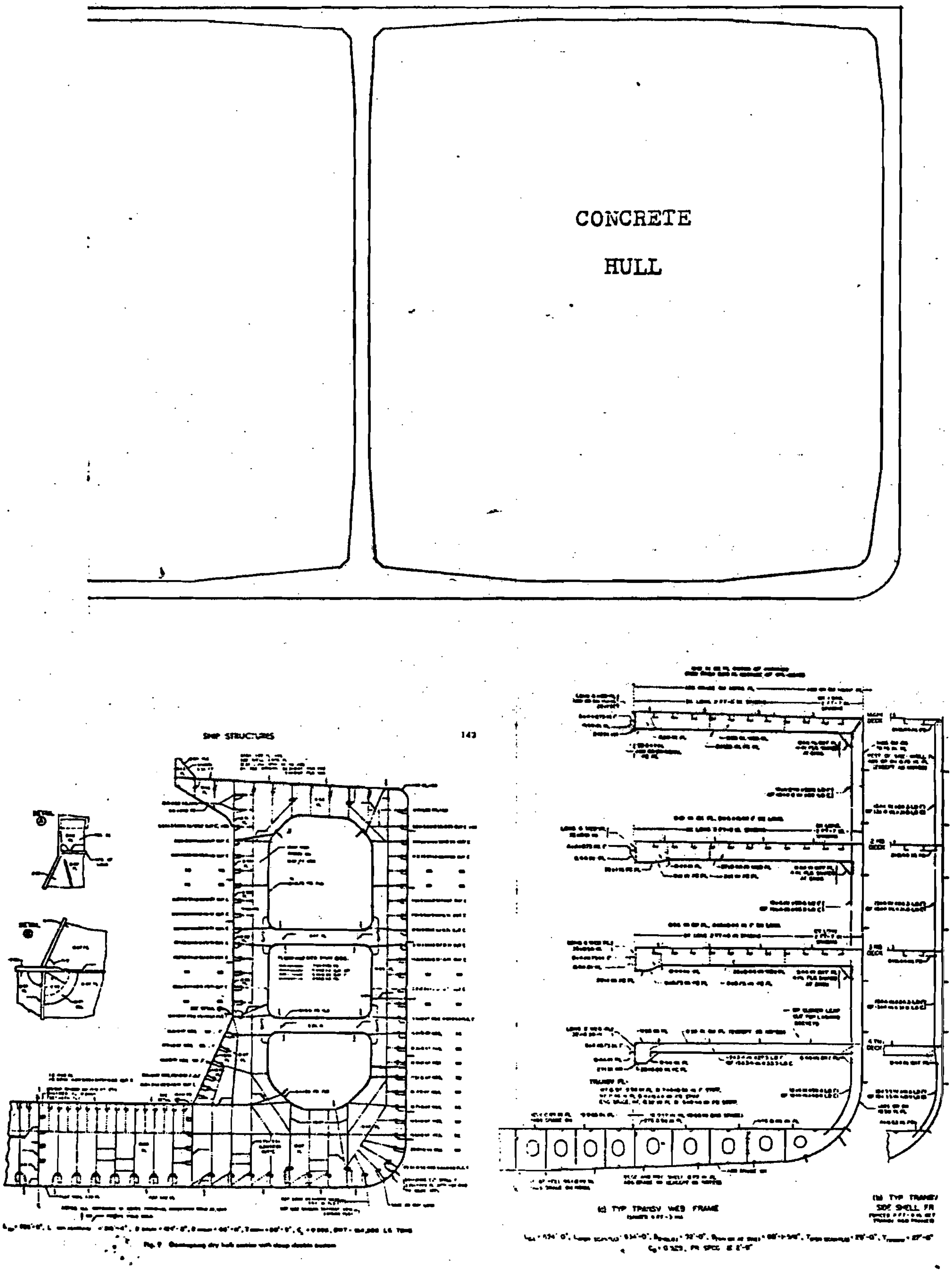
# LIST OF FIGURES



<u>Figure 1</u>: Comparative Cross-Sections of Concrete and Steel Hulls Showing Internal Strength Members. (Mast, p. 143)

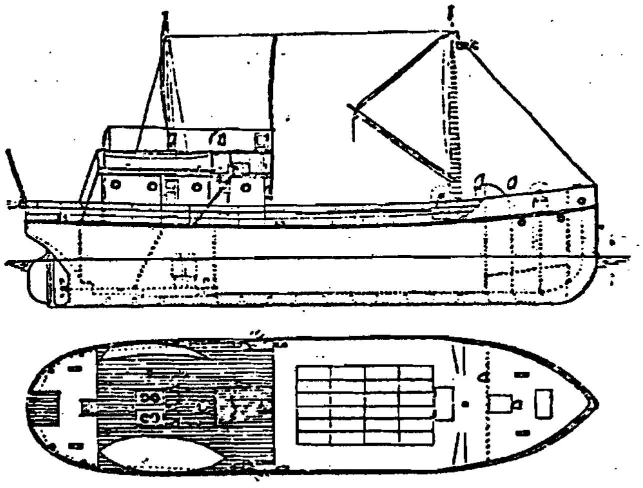
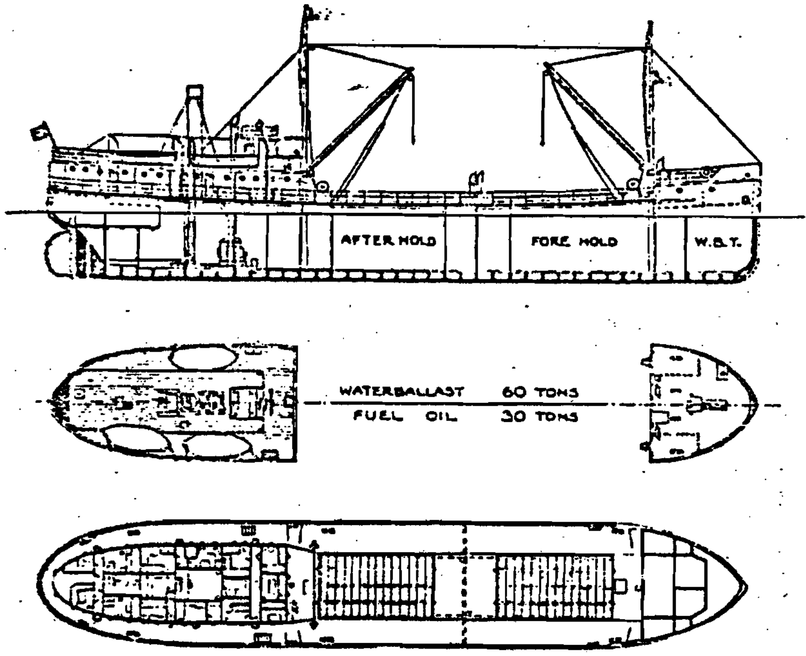


Figure 2: M. S. Namsenfjord (Anderson, p. 125)



**Particulars of the Askelad**

| | Tons |
|---|---|
| Weight of reinforced concrete hull | 733 |
| " " equipment | 120 |
| " " machinery | 31 |
| Displacement, light | 884 |
| Deadweight, freeboard 2' 6-1/2" | 1,036 |
| Displacement, loaded | 1,920 |
| Deadweight/Displacement | 0.54 |

Figure 3: M. S. Askelad (Anderson, p. 126)

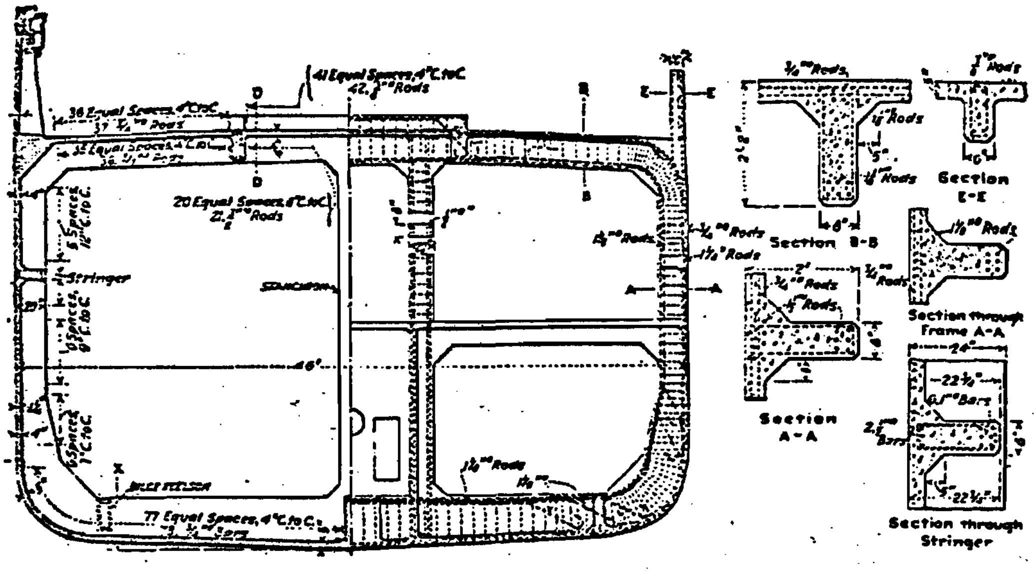
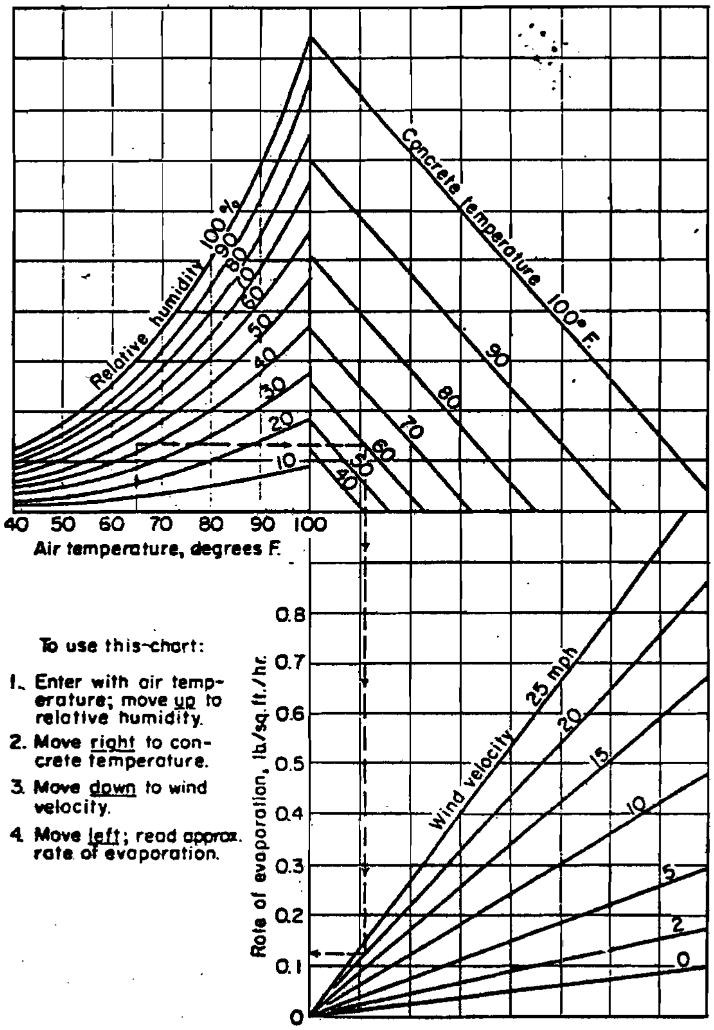


Figure 4: Cross-Section of Shipping Board's World War I 3,500 dwt Concrete Ship. (Anderson, p. 131)

| Design type | B7A1 | B7A2 | C1SD1 | B7D1 | B5BJ |
|---|---|---|---|---|---|
| Cargo | Oil | Oil | Dry | Dry | Dry |
| Length O.A., ft. | 366 | 375 | 366 | 366 | 265 |
| Molded depth, ft. | 35 | 38 | 35 | 35 | 17.5 |
| Molded beam, ft. | 54 | 56 | 54 | 54 | 48 |
| Maximum draft, ft. | 26.25 | 28.50 | 27.25 | 26.25 | 12.75 |
| Displacement, tons | 10,940 | 12,890 | 11,370 | 10,970 | 4,000 |
| Longitudinal bulkheads | 2 | 1 | None | None | 2 |
| Trans. bulkheads | 10 | 10 | 10 | 10 | 5 |
| Bale capacity, c.f. | 325,000 | 354,000 | 282,000 | 292,000 | 183,000 |
| Deck thickness, in. | 4 | 4.75 | 5.50 | 5/6.25 | 7 |
| Side thickness, in. | 4.25 | 4.5/5 | 6.5 | 6 | 8 |
| Bottom thickness, in. | 5 | 5 | 6.5 | 7 | 8 |
| Framing system | Long'l | Trans. | Long'l | Trans. | None |
| Block coefficient | 0.77 | 0.79 | 0.77 | 0.77 | 0.86 |
| DWT/Displacement | 0.53 | 0.50 | 0.47 | 0.53 | 0.42 |
| Reinforcing steel, long tons | 1,360 | 1,520 | 1,120 | 1,004 | 430 |
| Concrete, cu.yds. | 2,940 | 3,200 | 2,890 | 2,440 | 1,500 |
| Number built | 11 | 22 | 24 | 20 | 27 |

Figure 5: Principal Features of the U. S. Concrete Shipbuilding Program of World War II. (Anderson, p. 132)



To use this chart:

1. Enter with air temperature; move up to relative humidity.
2. Move right to concrete temperature.
3. Move down to wind velocity.
4. Move left; read approx. rate of evaporation.

Figure 6: The effects of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. (Whitener, p. 70)

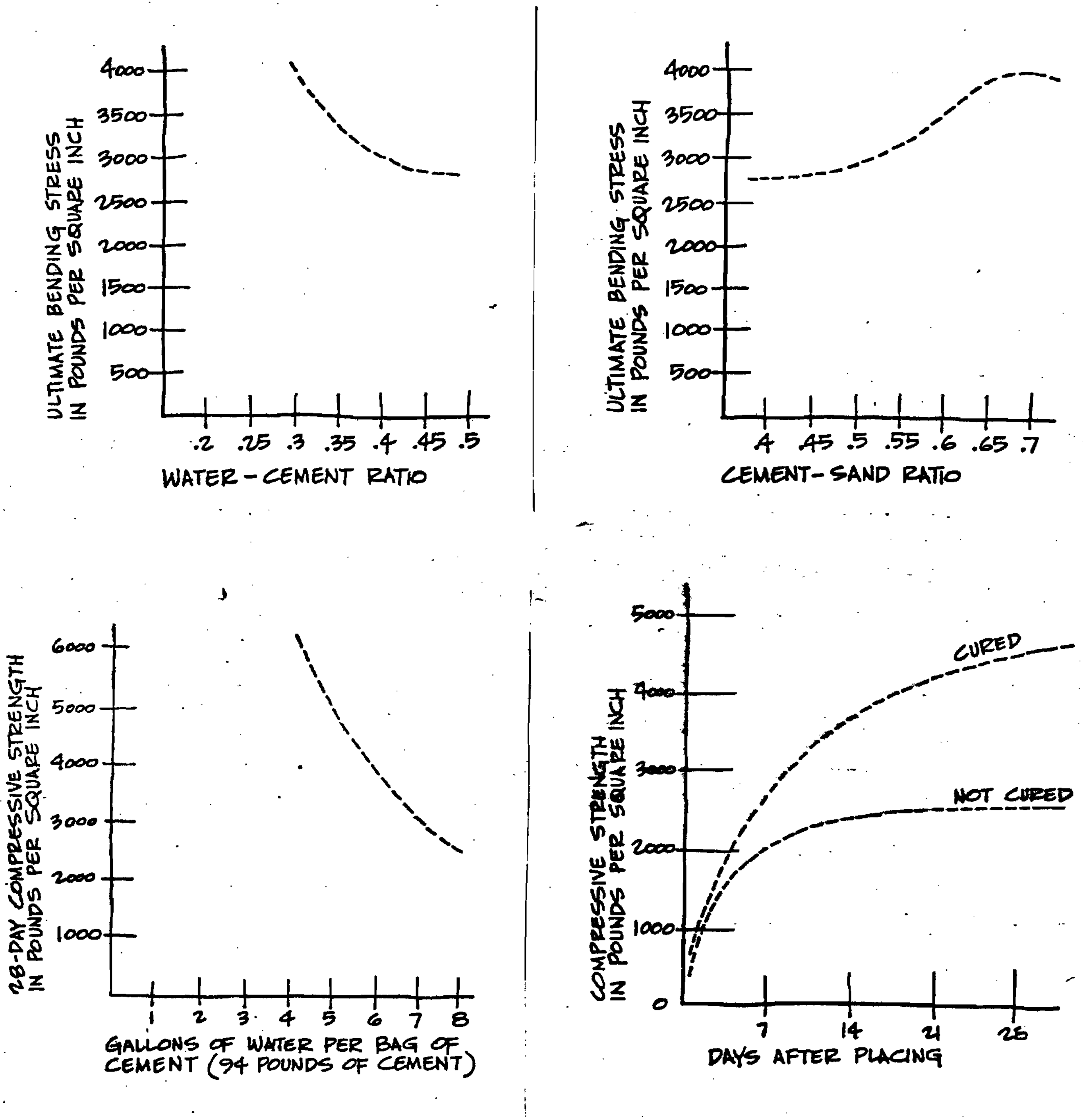
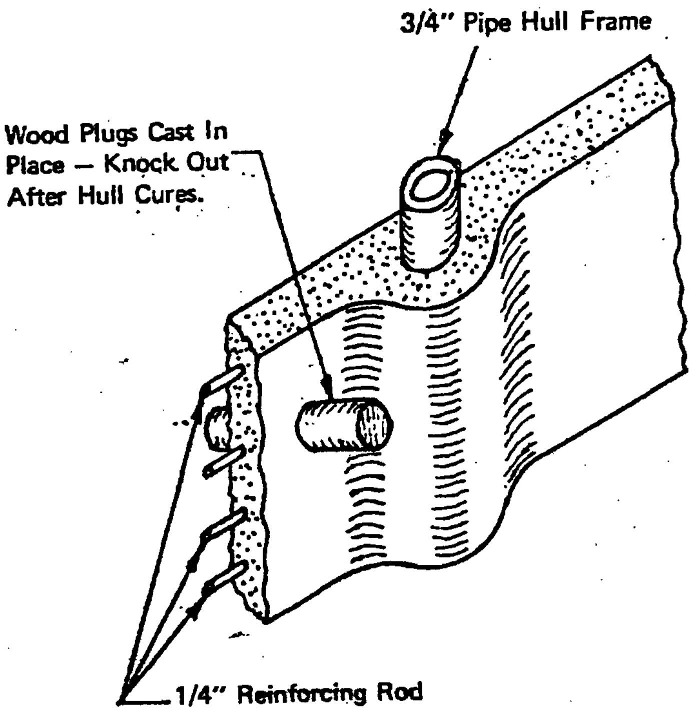
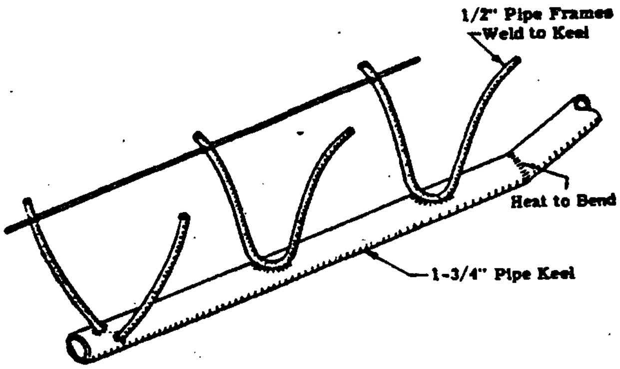


Figure 7: Effect of Various Mix Proportions on Cement Strength. (Abercrombie, pp. 162-163)



<u>Figure</u> <u>8</u>: Reinforced Concrete Hull Section Showing Wooden Plug For Fitting Hole. (Whitener, p. 42)



<u>Figure</u> <u>9</u>: Single Pipe Keel, Welded Method. (Whitener, p. 34)

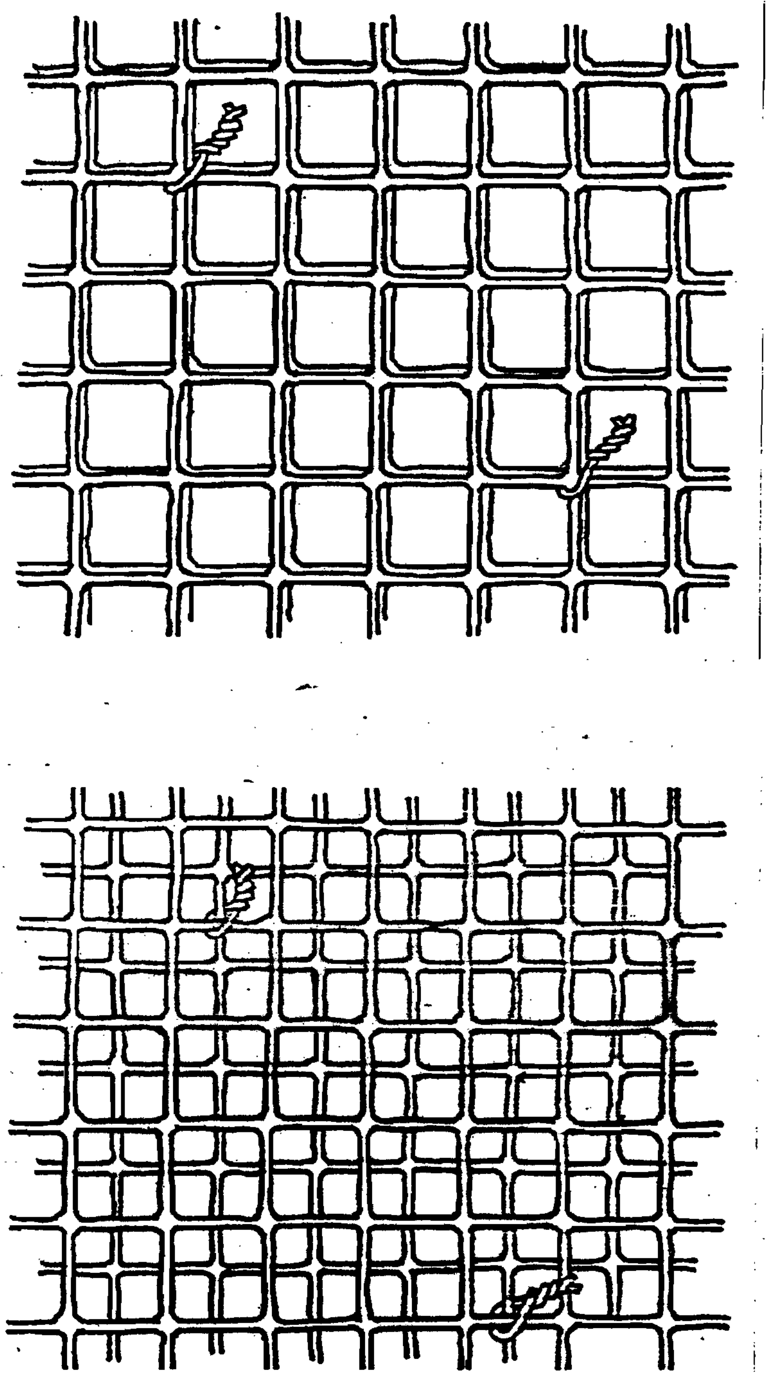
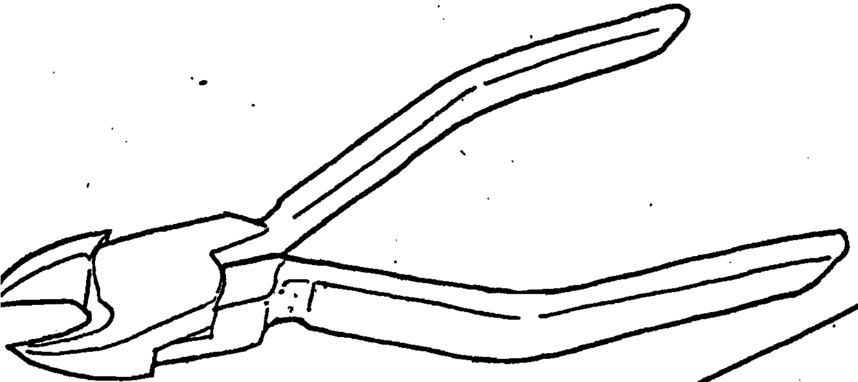
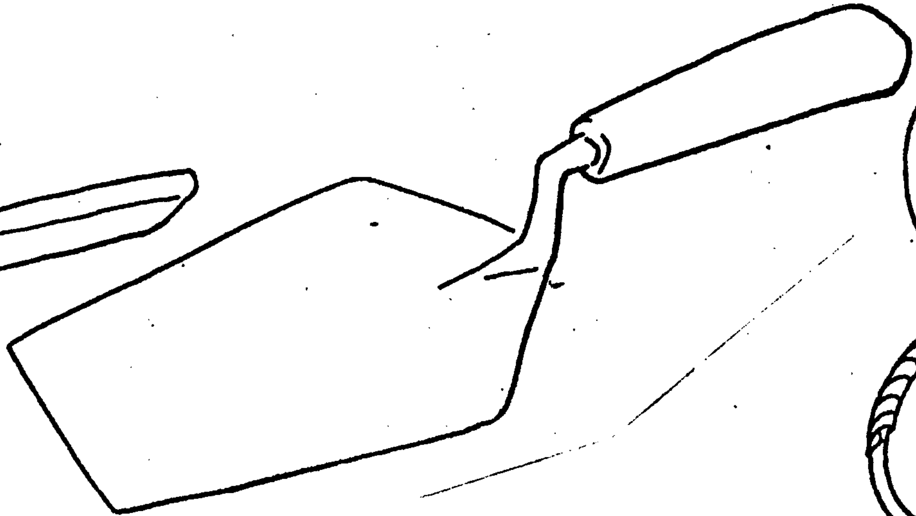


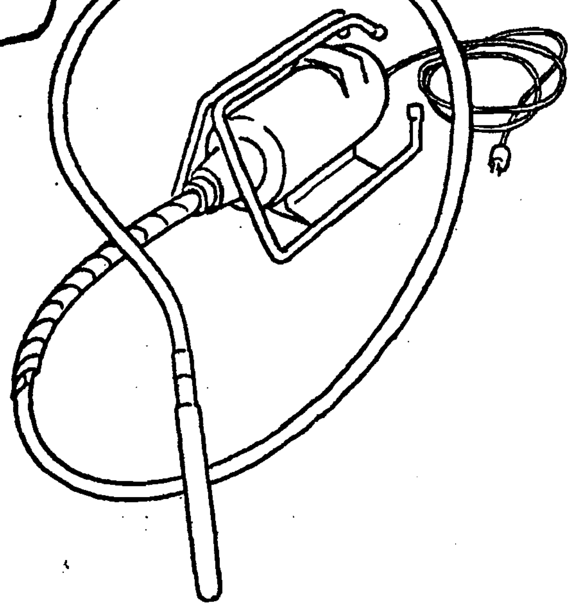
Figure 10: (top) Mesh Layers Improperly Tied Together With Undesirable Alignment of Strands. (bottom) Mesh Properly Tied For Minimum Alignment. (Abercrombie, pp. 44-45)



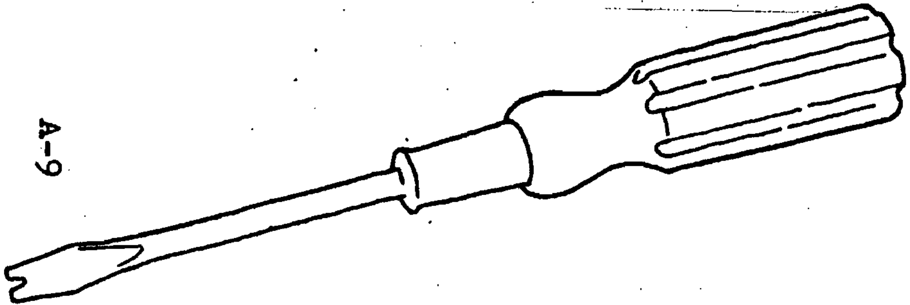
re cutters, a basic tool for work with wire mesh



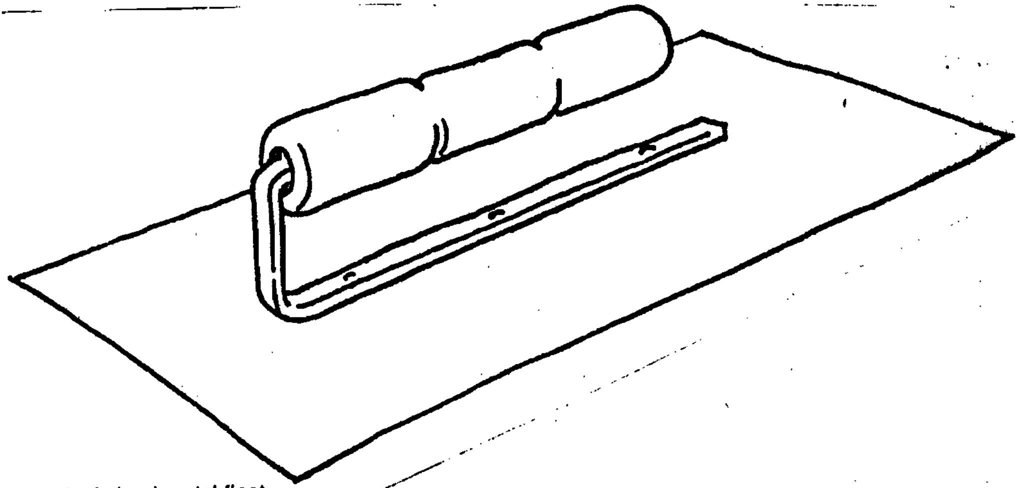
Blunt-bladed trowel



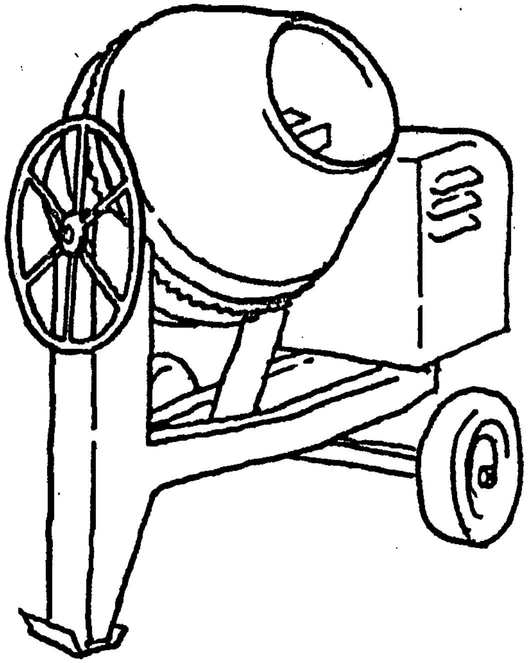
Concrete vibrator with a remote power source



Notched-blade screwdriver for turning back stubs of cut wire

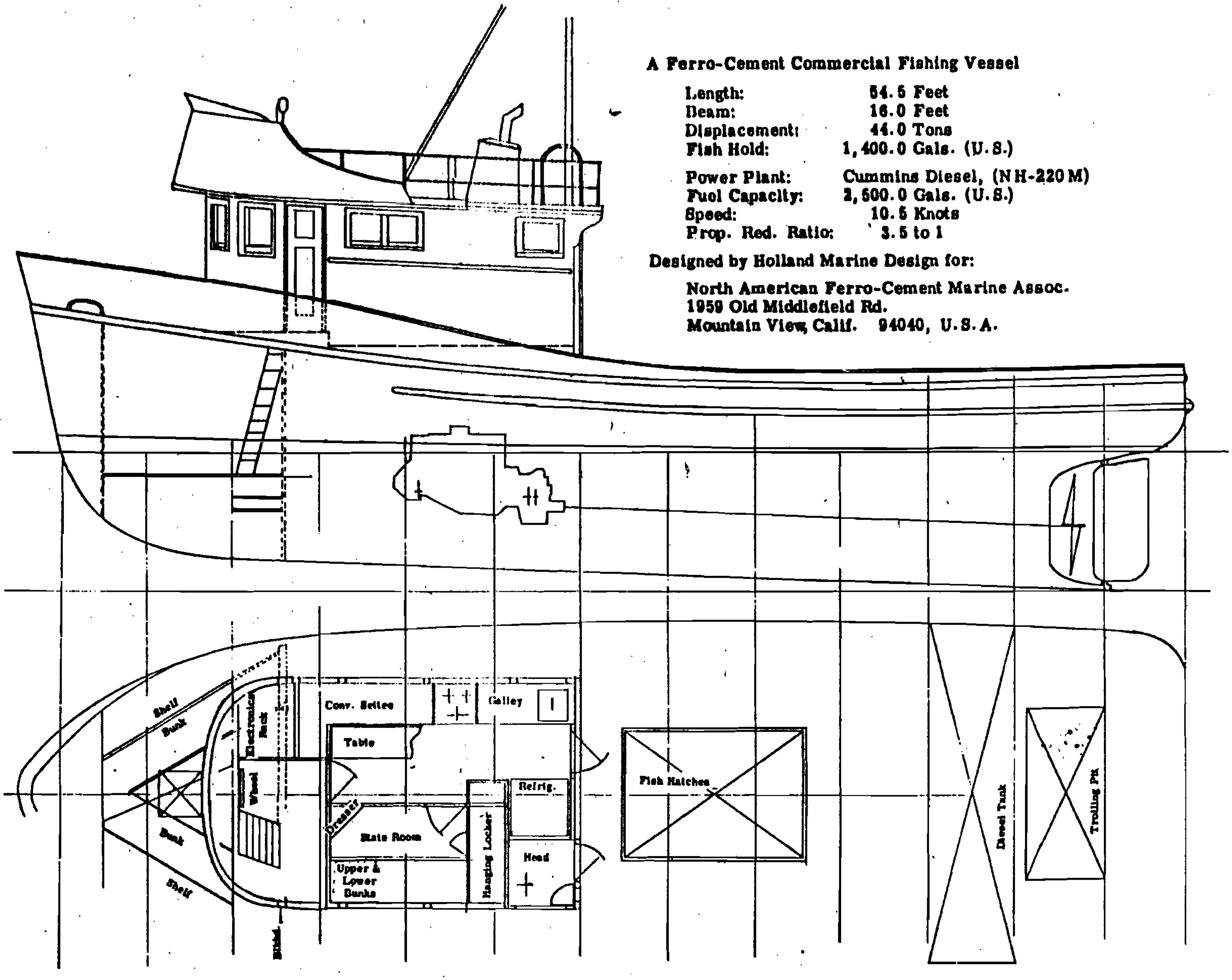


Typical sheet metal float



Standard mixer with a rotating drum

Figure 11: Ferrocement Tools. (Abercrombie, pp. 61-70)



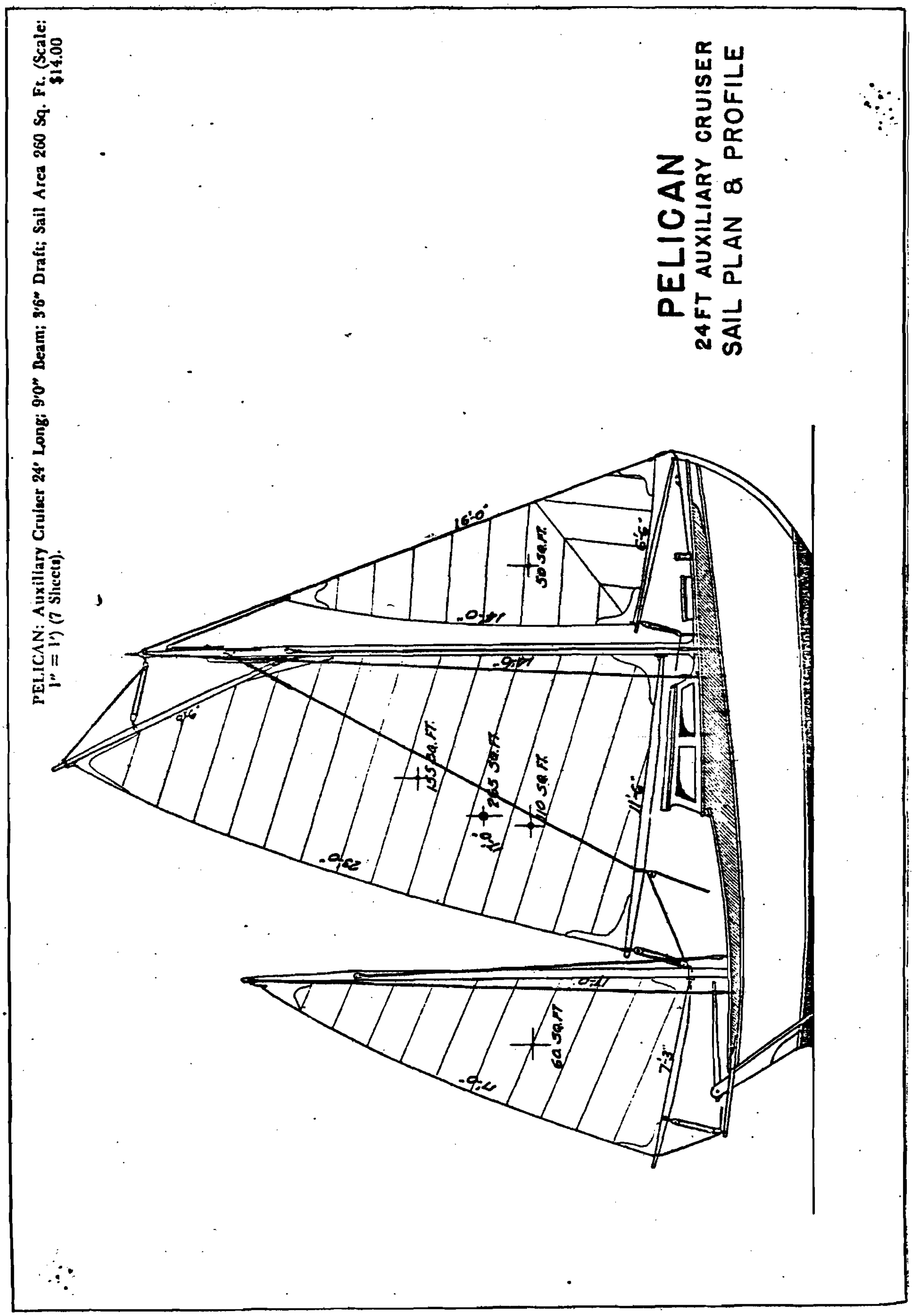
**A Ferro-Cement Commercial Fishing Vessel**

| | |
|---|---|
| **Length:** | **54.5 Feet** |
| **Beam:** | **16.0 Feet** |
| **Displacement:** | **44.0 Tons** |
| **Fish Hold:** | **1,400.0 Gals. (U.S.)** |
| **Power Plant:** | **Cummins Diesel, (NH-220M)** |
| **Fuel Capacity:** | **2,500.0 Gals. (U.S.)** |
| **Speed:** | **10.5 Knots** |
| **Prop. Red. Ratio:** | **3.5 to 1** |

**Designed by Holland Marine Design for:**

**North American Ferro-Cement Marine Assoc.**
**1959 Old Middlefield Rd.**
**Mountain View, Calif. 94040, U.S.A.**

Figure 12: Commercial Ferrocement Fishing Vessel Design. (Whitener, p. 101)



PELICAN: Auxiliary Cruiser 24' Long; 9'0" Beam; 3'6" Draft; Sail Area 260 Sq. Ft. (Scale: 1" = 1') (7 Sheets). $14.00

Figure 13: Ferrocement Auxiliary Cruiser Design. (Whitener, p. 102)

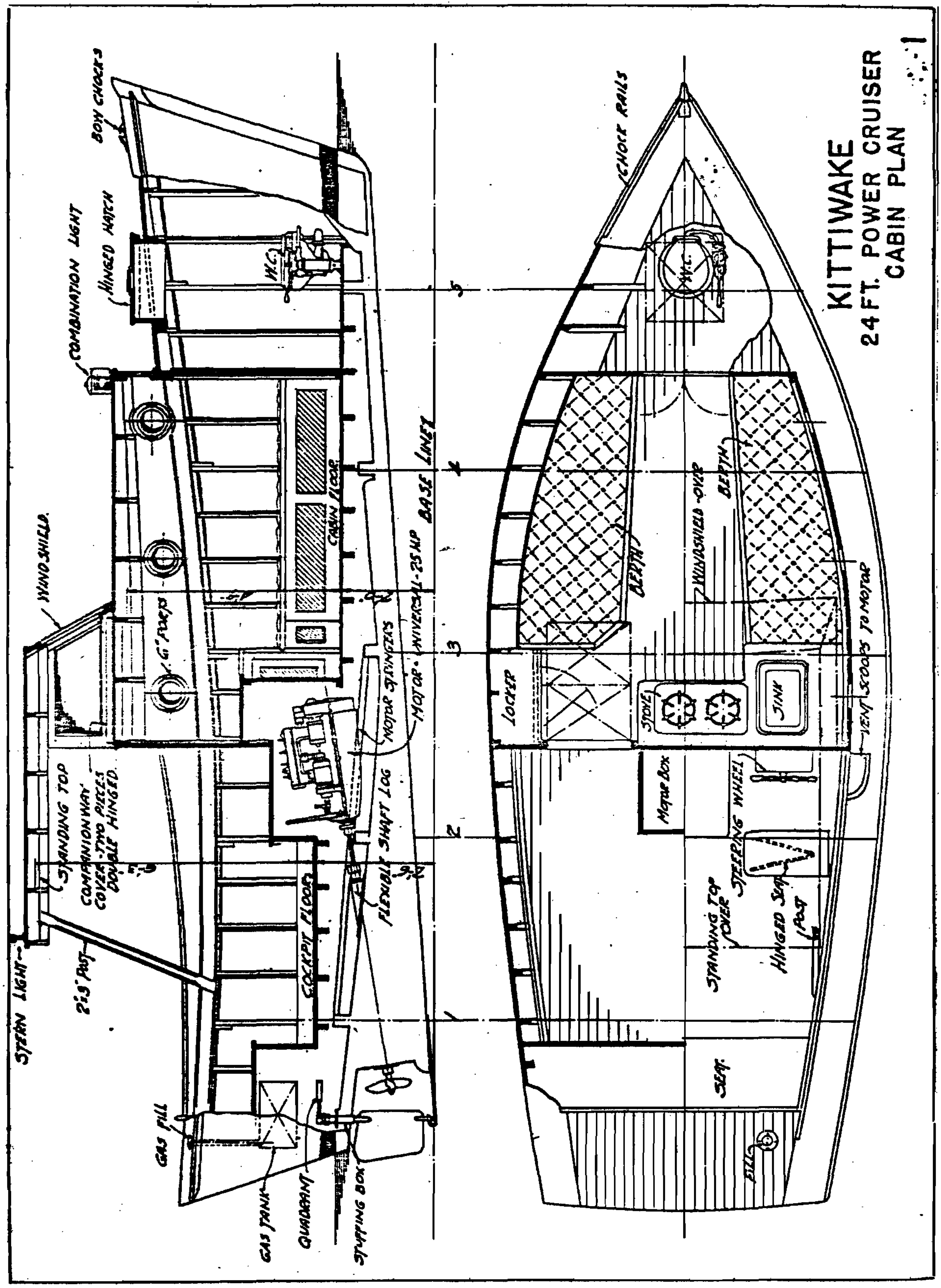
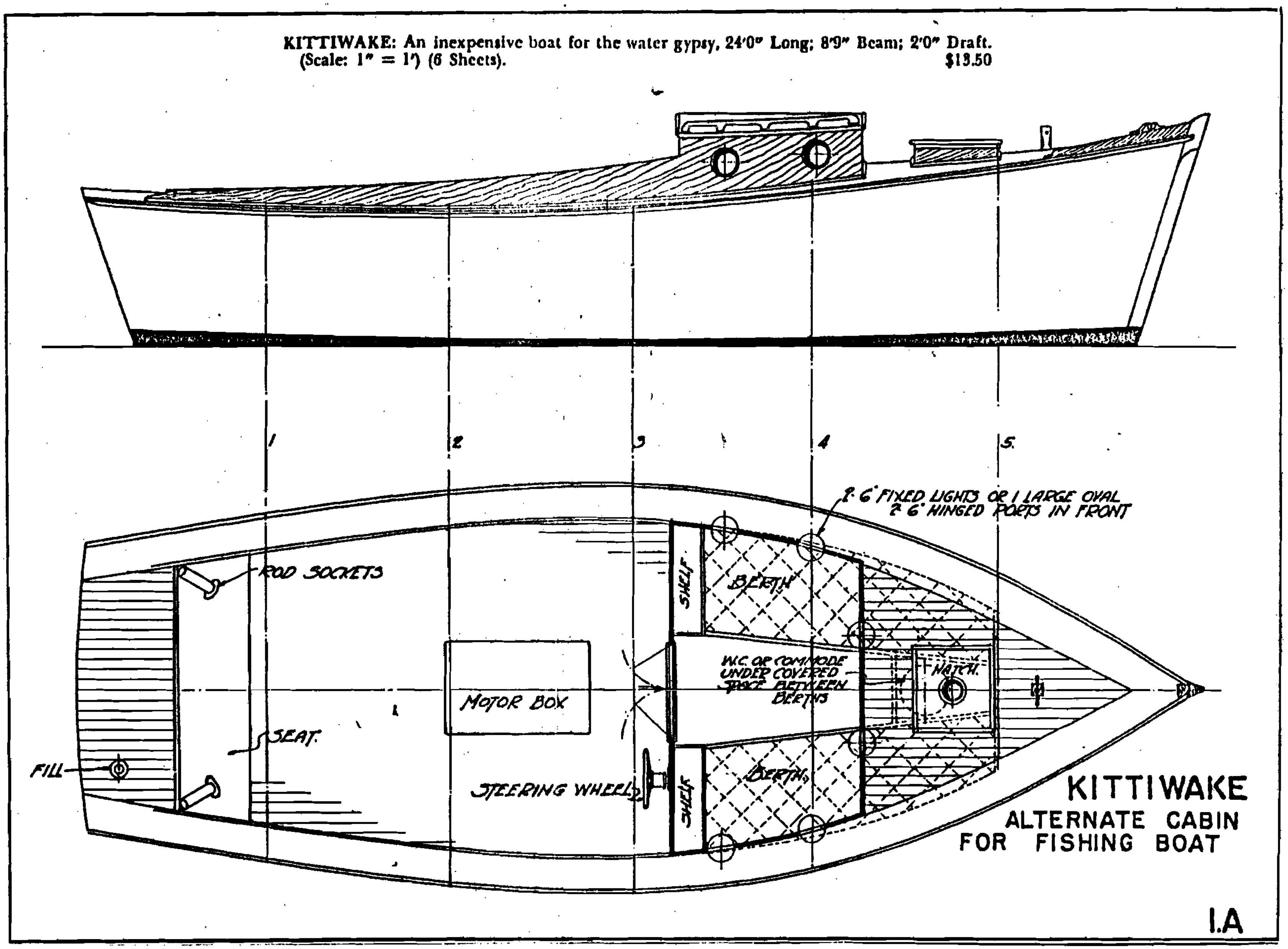


Figure 14: Ferrocement Power Cruiser Design.
(Whitener, p. 103)



**KITTIWAKE:** An inexpensive boat for the water gypsy, 24'0" Long; 8'9" Beam; 2'0" Draft.
(Scale: 1" = 1') (6 Sheets). $13.50

Figure 15: Alternate Ferrocement Power Cruiser Design. (Whitener, p. 104)

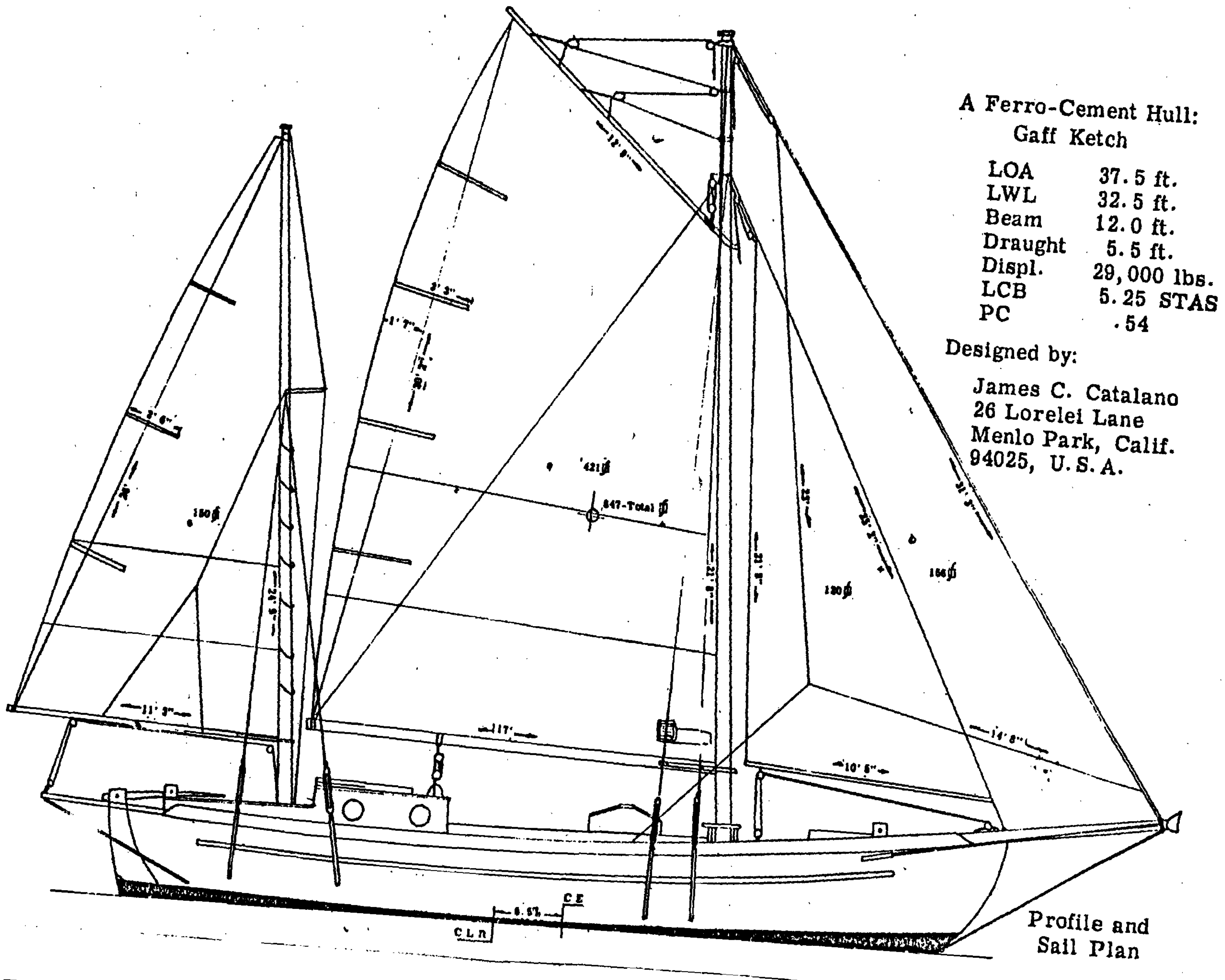


Figure 16: Ferrocement Ketch Design. (Whitener, p. 106)

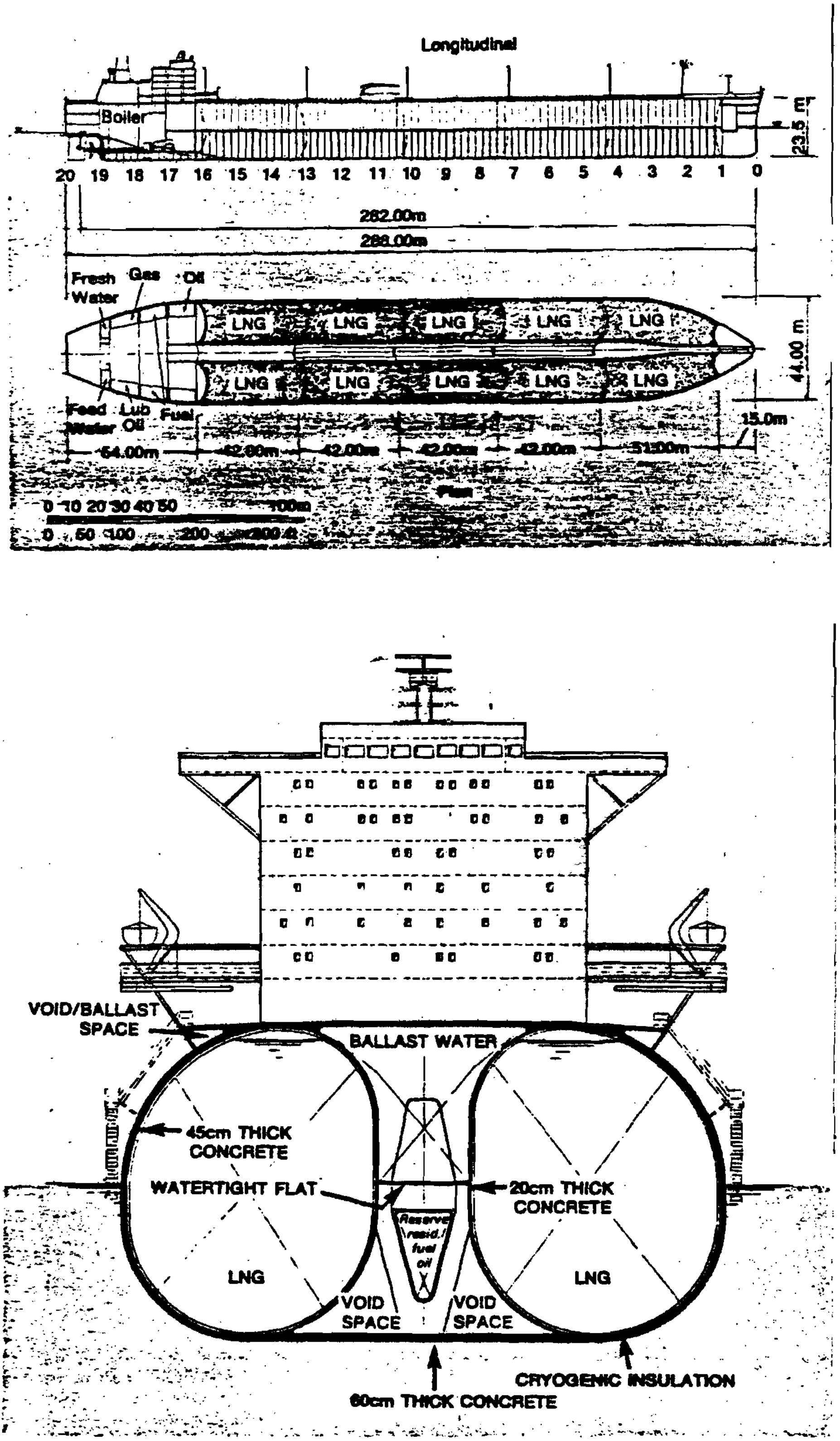


Figure 17: Proposed Prestressed Concrete LNG Carrier. (Ocean Industry, pp. 67-68)

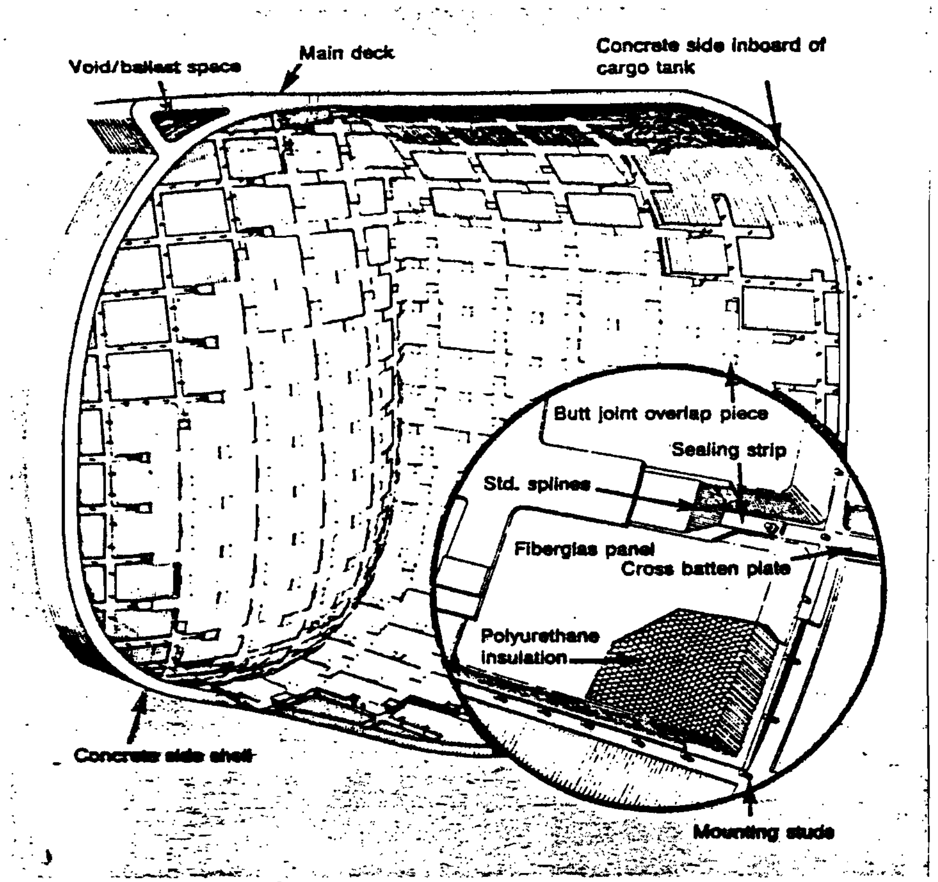


Figure 18: Cryogenic Insulation Installed in LNG Cargo Tanks. Insulation is Fiberglas. (Ocean Industry, p. 72)

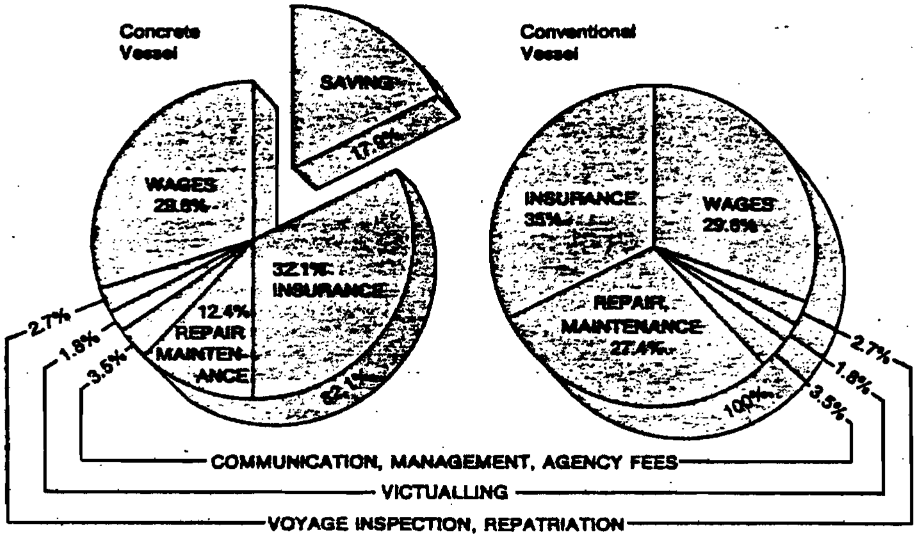


Figure 19: Comparative Operating Costs for Concrete and Steel LNG Carriers. (Ocean Industry, p. 74)

Thesis —
Leopold

# The Federal Waste Water Treatment System
# Construction Grant Program
## What It Requires of States and
## How It Works

L.C. Leopold

MMA 65-652 (72-73)

May 1, 1973

MASTER OF MARINE AFFAIRS
UNIV. OF RHODE ISLAND

# TO THE READER

To create a more readable result, this paper has been written in four parts. The main text, in Part 1, is the interview series. Part 1 contains the answers to questions posed in the Introduction. All quoted portions in Part 1 are reference the person being interviewed. Part 2 contains recommendations for possible further study. Part 3 is, in effect, an annotated Reference List for this study. It is the guide to Part 4. Part 4, an integral part of the whole, is a packet containing copies of primary documents indexed in Part 3. In this manner, the whole document is here at the reader's convenience, but it is not quoted in parts, as filler, in Part 1. It is felt that this collection may be the most valuable contribution of this study to other people. The assembled documents should save untold hours to anyone else pursuing this topic.

# ACKNOWLEDGEMENTS

Thanks go to Dr. Louis Alexander who provided the guidance for this study. Thanks also go to my wife, Cindy, who completed her Ph T.

For the purpose of this study, EPA was represented by personnel at the Boston Office of the New England Regional Offices (Region I). Rhode Island provided the structure, people, and documents which represent state-level and local-level government activities.

More specific areas investigated within the framework of the study include:

Pertinent laws and Guidelines of the granting programs; lc
Mandatory planning and documentation requirements;
Review actions of controlling agencies;
Requisite procedures to achieve a grant;
Actual content of grants (cash, technical aid, other?)
Extent, if any, of regulatory and/or police powers available to each agency;
Court recourse, if any;
Freedom from, or presence of, political pressures at each level;
Degree of interaction between successive levels of governments;
Evidence of personal contact between agencies;
Formal and/or informal problem-resolving mechanisms between agencies;
Evidence of how efficiently the total system effects the quality of the nation's waters and waterways.

The federal law from which most of the direction and grants flow is the Federal Water Pollution Control Act, As Amended (33 U.S.C. 466 et seq.) through April 3, 1970. This is the extension

# PART 1

## Interview Sequence

The first interview was with Mr. Stuart Peterson, Chief, Construction Granting Division, EPA Region I (New England Region). The conversation was relatively short. He provided an Application Kit for Construction Grants (Part 4, entry 11). Essentially his office is the pipes and pumps technology end of the operation. His office determines that the actual physical plant is engineeringly sound and will do that which is specified in the design concept.

Further, he said that his office does no processing of a grant application until the following prerequisites are completed. First, the EPA Regional Planning Division must tell him that the proposed project is in compliance with an approved Basin Plan and/or an approved Metropolitan/Regional Plan, all of which must be within an EPA-approved State Plan. Second, the fully approved project must have been priority ranked by the state from within which the application originated. The state's priority ranking requires that all other more highly ranked projects must receive earlier EPA consideration.

Third, the Construction Grants Division Office must be notified by the Administrative Office that all federal requirements relating to the Applicant's financial soundness, accounting prodedures, employment practices, and over all operational capabilities have been met. In retrospect, it was somewhat odd to note that Mr. Peterson never mentioned the 72 Amendments.

It became obvious that although his office has the title, other offices have greater impact upon the fate of an application for waste water treatment plant construction grants, Mr. Peterson then supplied the following names: Mr. Donald Smith, Chief of Section, Basin Planning Section, EPA Region I, and Mr. Carleton A. Maine, Chief, Division of Water Polution Control, Rhode Island Department of Health.

The next interview was with Mr. Donald Smith, Chief of Section, Basin Planning Section, Water Quality Branch, EPA Region I. His formal training was as a Sanitary Engineer. He has been with Federal Water Quality Control Programs for over 10 years.

Mr. Smith's first statement was indicative of his pragmatic, not academic, approach to the Planning Section's role in waste water treatment facilities and programs. "The EPA is like the Corps of Engineers. We're in the construction granting business. The more grants we make, the greater our impact upon the problem." In order to approve a grant, the new facility must be part of a much larger approved planning effort. The basic plan required is that from the state of the applicant. Without the EPA approval of that document, everything is halted. EPA has accepted minimal interim state plans to facilitate grant approval. Because the regulations and requirements have become more complex over the last four years, the quality of plans actually submitted has tended to lag.

People in the Basin Planning Branch recognize that grants being issued now tend to be based on the problems and realities of today; not on the kinds of long term goals that should be sought. "If there appear to be no great problems with the particular facility, assuming a reasonable function in the Basin Plan Area, this office, in all probability, will go ahead with, approve, the project." Again, he emphasized the underlying philosophy of cleaning up the water, and if "thereis no grant, there is no cleaning up."

The Federal Interim Regulations, if followied in their entirety (see Parts 3 & 4), require extensive area research even by the smallest unit of local government, let alone the Plan for a complete state. If no grants were approved until a complete plan was approved, nothing would have been granted in the last 4 years. On the other hand, the "so-called" plans fall far short of what they should be, and they do little justice to the intent of area-wide and state-wide planning. In passing, it was noted that what is really being sought is effective land use planning in the fullest meaning of the concept. Plans should really be addressing future growth patterns and/or the limits thereto.

State and local applicants are still trying to write minimum-content statements that will be allowed to "slide By." While the lc Planning Branch is gradually upgrading its own standards of what is minimal, they are constantly fighting the inertial lag of one community questioning why its material 'which is at least as good as what the neighboring town did last year' is not now acceptable.

In effect, earlier the Planning Section used "logical and reasonable tests" of a proposal when getting started. This early laxity is now breeding no new efforts; or essentially useless (poor) plans. It is the Planning Section's goal to induce a greater amount of pre-thinking, instead of costly (time and money) re-thinking, of submitted documents.

EPA's lack of staff and resources to adequately handle legally mandated levels of performance significantly contributes to the acceptance of far less than ideal planning documents. One might characterize this emerging process as the dynamics of lowered goals.

Mr. Smith was asked whether his section tends to feel much, if any, political pressures. He stated that the system is now set up such that EPA is essentially insulated from state or local government pressures. EPA works through the state office of waste water treatment control and utilizes that office as an effective pre-filter.

If, on the other hand, a member of Congress may want to "know why such and such a program is going in a particular direction." Usually the Planning Section can provide sufficient data to show how a "political solution" will lead to "cost ineffectiveness and therefore loose EPA funding." The response information, returned to the legislator through the Regional Administrator, is "usually sufficiently authoritative to satisfy the legislator and therefore his constituents."

While not mentioning the untried penalty powers within the 72 Amendments, Mr. Smith indicated EPA really had very weak and limited enforcement powers. Beyond moral suasion, EPA may first, not fund a project; second,threaten to or actually hold up funds to a project; third, rigidly enforce particular contractual matters that are within an already granted contract. EPA's ability to withhold the carrot is much greater that their stick. Therefore. a community must genuinely want the federal funding before it (the town) can be made to respond to strong EPA influence.

While obviously not speaking for all of EPA, Mr. Smith established that EPA is generally a source of planning directives and requirements, and also grant moneys, to state level governments. Except for minimal technical aid and advice to waste water treatment plant operators, EPA provides little or no direct technical, engineering, or general assistance to states or smaller governmental units. This procedure further helps to isolate the Regional Offices of EPA from any bodies of government within a state's jurisdiction. This author feels that the lack of outward flowing real assistance may, in part, be due to limited personnel & resources; not simply intent.

Mr. Smith reflected that EPA's fairly strong leadership role tends to be diminished by its continuous inability to meet legislatively mandated, and operationally required deadlines. When a state agency submits a document, it reasonably expects a reply within the 30, 60, or 90 day response period established by federal standards. When the Regional Office can not respond in the required time, the submitting authority begins to wonder; 1, why the rush in the first place; 2, those people don't really care anyway. "For each overshot deadline, the states and local units loose a bit more confidence in us and bit more respect for us." Functionally each missed deadline does not change from where the money flows, but it does alienate and discourage the very people with whom EPA must interface if progress is to be rapidly achieved.

The somewhat sour note, while at the end of the 2 hour session, does not truly reflect the dynamic and optimistic outlook of the Basin Planning Section Chief.

The final interview was with Mr. Carleton A. Maine, Chief, Division of Water Pollution Control (DWPC), Rhode Island Department of Health. He provided sufficient information to establish that his office appears to be the most vital link along the local, regional, state, and federal chain. Our conversation lasted almost 3 hours. Mr. Maine is a very knowledgeable, energetic person who shares a similar sense of pragmatism with Mr. Smith.

The first topic of discussion was money; where it comes from, how it's gotten, and where it goes. Within this framework, the costs to the local communities were explained. He first explained why and how HUD has gotten out of supporting local waste water treatment construction planning. Under HUD's 701 program, HUD actually advanced the loans for a local community to do its preliminary site planning, its engineering, its drafting, and its construction proposals. This was usually 40 to 60 thousand dollars worth of paperwork preparation. The process usually produced good engineering documents. However, the local community had obtained the work with no expenditure from the local budget. Then when the question of funding the community's share of the construction costs was put before the citizens, they would usually turn the issue down. With no local funding mechanism, the construction project would die.

This phase of the HUD 701 program had a loan forgiveness clause ⑨
in it which cancelled the debt if the local community did not receive

a construction grant. What was supposed to be an advance loan program became a money loosing give-away which has now been cut off by HUD.

While it means higher initial costs to a local community, Mr. Maine firmly believes that the community's true interests lie where their money is. Internalizing the funding forces real community involvement. When asked why a town would even begin to incur a planning cost, let alone a construction cost, Mr. Maine said that it was usually in response to a state Department of Public Health requirement or direction.

Under the EPA funding program prior to October, 72, the federal share was 55% of the total costs of a construction project. Rhode Island's share was 25%, and the local government's share was 20%. EPA's funding, when granted, actually comes as reimbursed money provided to the building agency after requisite portions of the construction are completed; not as an advanced front-money loan like the eliminated HUD program.

Under the 72 Amendments, the federal share has been raised to 75 % and the required state portion has been "cut out." This leaves the local government with an unexpected additional 5% load. Mr. Maine feels that Rhode Island can and should pick up the 5% difference to avoid additional burdens to local bodies beyond that level of bonding already authorized. He pointed out that it is both costly and difficlut for a community to return to the voters for additional funds for the same project.

He went on to show that Rhode Island now has EPA committments be required to maintain closed holding tanks, the contents to be pumped out and trucked away at regular intervals. While this seemed like an acceptable sollution, the court held the store, pump and truck method was an "unreasonable sollution" due to costs incurred by the homeowner. Discouraged, no further DWPC action was taken in the matter.

Mr. Maine further related that the state can go after a municipality if it maintains any kind of facility that is doing an inadequate job. He choose Jamestown as a classic case where the Division won the court fight, but the town got its own way. Jamestown has a collector system that provides only partial primary treatment at best before pumping the effluent into Narragansett Bay. In 1967 the DWPC got a court order banning any new hook-ups to the system until it was upgraded. Instead of spurring community action for improving the treatment system, Jamestown has used the court order to severely restrict new construction on the island. The islanders wanted, and still want, to inhibit growth, so they have used the court order to their own ends. The order has had the same effect as highly restrictive zoning and Jamestown is happy with it. Obviously this was not the intent of Public Health Department. This writer got the distinct impression that Mr. Maine has very little patience with long delaying procedures that generate little or no positive results; the court system in this case.

Returning to the granting procedure, it was noted that Mr. Peterson, Mr. Smith,and Mr. Maine had all mentioned the phrase 'priority ranking' and that it had seemed to be a state function.

Mr. Maine confirmed that each state assigns specific rank order for all applications for waste water treatment system construction grants from within that state. This led to a request to know more about how such ranking was assigned. It would appear to put the DWPC, and the Department of Public Health, in line for potentially untold amounts of political pressure. Mr. Maine was quick to respond that much controversy is avoided since the ranking is achieved by use of a "detailed" priority rating system. A copy of the system's breakdown and point values is appended to this paper(Part 4, entry 12).

There are three major subdivisions in the total system. Section A attempts to evaluate how much change for the better(reduced amount of pollution impact)will be gained by the project. Part B is a per capita cost factor: the Reasonable Cost of Facilities divided by both the Present Population and also the Future Design Population. The higher the per capita cost - the more points earned. Part C is titled "Applicants Readiness to Proceed." That scale ranges from a low of "Preliminary Report Prepared" to a high of "Ready to Award Contracts (Local Money Available)." The priority ranking is earned by summing the points awarded in each section: Priority= A + B + C. The project is then placed on the state list wherever its point total places it. The ranking system is not a first come, first served system; but one that assigns priority according to established value. It also means that a more recent proposal may "bump" one already ranked if its point total warrants it.

When asked how well the ranking worked, Mr. Maine said that it was "not a bad system" except that he would like to alter or eliminate Part B. He noted that a community of relatively fewer people with more land per person (an affluent bed-room community) would almost always have higher per capita costs than a densely peopled urban area. While Part B represents only 5 points out of a maximum possible of 60 points (A(35) + B(5) +C(20)), projects are often separated in rank order by 1 or 2 points. This writer wondered why the system was used when the Division Chief had such strong negative feelings about Part B.

Officially the priority ranking system was established by the Rhode Island Department of Public Health with gubernatorial approval. However, the DWPC's program is "very closely modelled after recommendations from EPA." Pressed further, Mr. Maine related that the recommendations, in this case, came through discussions and negotiations with Region I EPA personnel, not laws as published in federal guidelines. EPA, therefore, has had real influence on how project priorities as assigned, but makes sure that all actual ranking is an in-state function.

Having finally introduced the more direct EPA-Rhode Island functional relationship, Mr. Maine was encouraged to descirbe it. (His following comment was very much in keeping with the impression of this writer.) Almost all of the EPA people with whom the DWPC office must deal are "technitions in the sense that they are engineers - not trained planners." They tend to be both flexible and reasonable in their approach to, and demands upon, the state. "They have to be or they'd make no grants. No grants means nothing

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is built, and no building means no corrective action." He feels he gets fairly good cooperation and respect from the EPA personnel as opposed to being forced into the role of a lesser entity.

Mr. Maine was asked why he chose the words "reasonable" and "flexible" to describe the federal people. He said that it stems from the problems and realities of the least well done, yet truly most important phase of the DWPC's work as tasked by federal regualtions. This progressed into a discussion of plans and planning activity. Most fundamental of all is supposed to be an approved statewide plan for water resources and waste water treatment requirements. These general area requirements are supposed to be based on more detailed Basin Plan evaluations of each of Rhode Islands hydrologically delimited & separate regions. Within each of the watershed basins are supposed to be Regional/Metropolitan Planning Districts. The R/M Planning Districts (politically defined areas) are supposed to generate and maintain criteria that limit effluent loading of streams and waterways to within water quality standards as set by the Department of Public Health for the state's waters. All of the plans, criteria,assigned levels of water quality, and effluent loading limitations are supposed to be reviewed and approved by EPA before they become effective.

This rather cyclical and complex sequence seems to have been created by urban planners looking to employ more planners. But, as Mr. Maine emphasized, <u>no</u> project is supposed to receive a federal grant unless there exists an EPA APPROVED State Plan, a Basin Plan, and an M/R Plan.

For each local project proposal, the requesting government must submit an Environmental Assesment Statement (EAS) alng with all of the engineering documents. Local governments have the resources to write little more than the sketchiest of Assesments. This EAS is passed on to EPA with no state-level review. If EPA is going to fund the project, then it, not the local government, must write an Environmental Impact Statement (EIS) based on the EAS. EPA's EIS usually falls far short of their own goals because of the minimal information in the original EAS. (This was one of the areas Mr. Smith had indicated was such a weakness also.)

By Mr. Maine's own admission, "Rhode Island has very crude Basin Plans. The plans for each defined basin are piecemeal in nature and not of good quality. EPA has designated them as Interim Plans in order to keep the granting process going." The degree of "crudeness" referred to above is in relation to the product as anticipated in federal laws and guidelines (Parts 3 & 4), not in relation to the planning products of other New England states.

One of the major requirements of the Statewide and of the Basin Plans is that all waters in Rhode Island must be designated as to their use-type quality, labeled A through D. Type A water is for body contact recreation; whereas type D can be used for commercial shipping - but not for shellfishing, body contact or drinking. Once a designator has been assigned, new effluent loadings must be limited so as to maintain and/or raise the use-quality of the water, never to lower it. The Plans are supposed to be of such descriptive detail that effluent absorption capabilities per unit length for a given water body are known. According to Mr. Maine such qualitative and quantitative knowledge simply does not yet exist. Further, the Plans are supposed to contain dynamic flow models for each water system described. So far neither Rhode Island nor EPA has developed an effluent and particulate-matter behavior model that works when tested in the field. Apparently the chemical and physical interactions of the bottom sediments is not well known. In response to an aside, Mr. Maine said he had not drawn on the State University for either field data or stream modeling assistance. Further, unless one is talking about a very expensive tertiary waste treatment system, all treated effluent introduces some additonal loadings to its receiving waters.

This inability to establish predictive models should, in the letter of the law, result in non-approval by EPA of all Rhode Island planning efforts to date. It was pointed out, however, that this was one more situation in which an unmet requirement was seen from a "reasonable point-of-view." Recognizing the inability to meet federal requirements, EPA has labeled current plans as "interim" documents. The continued extension of these permitted "temprary" plans is an unsettled question. Meanwhile they suffice until something better is mandated.

The topic of planning and attendant state-federal responses was pursued. Once, under the pressure of an EPA initiated emerging deadline, Mr. Maine's office submitted a simple two page report containing only the most recent hard (quantitative) data. A few days later Mr. Maine received a call from EPA asking why all of his reports "weren't so short and sweet?" He guesses that the technical people want facts but the legislative writers want volume. This demand for extensive planning has apparently caused some real negative response on the part of the state level personnel.

Mr. Maine quoted an un-named friend of his in New York who claims to pad present data with material from 1950's planning documents. "By the time they (EPA) realize the stuff is old and repetitious, it's two years later and the project is already going." When asked if poor planning didn't dilute and/or reduce the effort to regulate and clean up the environment, Mr. Maine reiterated his pragmatic point of view. Hard regulations and stric interpretation would effectively stop all new construction, thus no clean up.

Since both the EPA and state personnel seem to be able to negotiate their way around problems, Mr. Maine was asked if there existed problems which were not so amicably solved. To this writer's surprise there is and it is not simply a paper detail. The conflict is the question of by-pass gates. (A diverting valve and pipe sub-system whereby untreated effluent may be routed directly to receiving waters whenever emergencies completely shut down the normal pumps and/or other parts of the plant system.)

EPA flatly says, "No by-pass gates." Rhode Island directs that all installations must have them. Rhode Island requires that the gates be manually operated, sealed, and opened only on orders from the DWPC of the Public Health Department. Even redundancy of normal pumps and an on-site auxiliary generator will not satisfy the state. Mr. Maine related an incident from Groton, Connecticut to illustrate his point. An automobile hit a power pole causing a pump to shut down with subsequent failure of the on-site generator. There was no by-pass gate in the system; and, although the power line was repaired in 6 hours, the effluent flow backed up into private homes and primary treatement tanks of local industry. The back up was so extensive that effluent overflowed in the river anyway. It took several months to put the treatment system back on line because the pumps themselves had become shorted out due to in-plant flooding. About six hours of bypassed raw sewage was prevented at the expense of several months of improper treatment and excessive repair costs.

This naturally led to a question and response as to the mechanism for accommodating the conflict. First, there can be no EPA funds spent on the by-pass portion of the construction project. That phase must be all local funds even though state mandated. Second, EPA building inspectors "don't see the by-pass going in." This mention of on-site inspection introduced official, direct contact between the local agency and EPA.

Once the grant has been approved and issued, EPA Administrative, Accounting, and Engineering people deal directly with the sponsoring municipality. EPA oversees all phases of the bonding, hiring, site preparation, construction, auditing, completion, and performance as required by any and all applicable federal regualtions.

When the project is initiated, the state is no longer invloved unless the construction plans or system capacities need to be altered. While rare, all alterations must have state approval before installation.

When asked what significant changes, if any, his Division realized as the result of the October, 72 Amemdments, Mr. Maine listed several, both large and small. In addition to 1) a number of very confusing deadlines and 2) the altered grant ratio; there was particular concern about the more limited water quality standards. Only use-types A and/or B are to be allowed. Less clean, but commercially usable water use-types C & D are to be discontinued. In theory this means that ALL waters within and without a state are supposed to be fit for fish/shellfishing and/or body contact recreation. While special case by case exceptions may be permitted by EPA, this is felt to be unreasonable and probably unattainable for any time in the near or far future

Another major change of which Rhode Island would rather have no part has to do with permits for industrial effluent discharge levels into navigable water of the nation. Under the 72 Amendments, EPA ahs been assigned the U.S. Army Corps of Engineers Permit Licensing Program. EPA now wants to officially give the function to the states. Apparently most states have opted to control the industrial licensing; Rhode Island, Maine, and New York have not. Rhode Island has estimated that it would cost $700,000 the first year and $500,000/yr on a continuing basis for it to license, monitor, and administer the program itself. EPA has offered Rhode Island $200,000 in assistance for the first year only if were to assume the program.

In addition to costing the state an extra $500,000/yr, EPA would still retain an item by item review power over the state licenses. Since the state already must concur with any EPA decision before a license may be issued, Rhode Island can not see benefits in paying more for a function which, in fact, it already has.

The large blocks of grant money appropriated in the law, and subsequently impounded by the Executive branch, have not really altered the DWPC's operation. If the additional money becomes available, Rhode Island has projects ready to absorb at least 33 million more federal dollars. In fact it may be questionable whether local and state building capability could absorb that much new work without, at least initially, high inflationary costs.

Another seemingly small change in the 72 Amendments now allows EPA grants to cover construction of lateral lines (pipes in the streets for home hook-ups) for the first time. Rhode Island's DWPC feels that these should still be a local cost. Lateral lines have an expected design life of 50 years whereas the treatment plant facility has an expected life of 20-25 years. Lateral lines are not considered by the state to be an excessive burden upon the local government given the life expectancy.

Mr. Maine stated that if lateral lines appear as part of a project proposal, the state will tend to assign a lower priority ranking to it than to those which cover more major facilities only. This would be under Part A, amount of pollution reduced for dollars spent. Knowing that their grant applications would get lower ranking, why should a municipality include the lateral lines in a proposal. The answer was that it was "political suicide not to." The local government leaders, by excluding the lateral lines, leave themselves wide open to charges at the next election that 'they did not take advantage of all possible federal aid; they caused our local taxes to rise unnecessarily.'

Exposing the area of political pressure, Mr. Maine was asked if the granting process was usually affected by politics. "No, but," was his answer. Normally the ranking system takes care of local people trying to gain early grants. However, there was one circumstance, a circuitous case. HUD wanted to put housing for the elderly into Warwick as demonstration project. But, there were no sewer hook-ups (lateral lines) in the streets; nor was there any state or local money budgeted for the additional piping. This was before the 72 Amendments. Because money for the necessary lines was not available; the state had assigned the sewer construction grant application a rather low priority based on sub-Part C of the ranking system. Therefore, EPA could not fund the needed sewage treatment plant, and HUD can not put in dwellings without proper waste treatment. HUD got EPA to ask Rhode Island to 'reconsider' the priority of the project. Chosing not to explain how, Mr. Maine related that funds were found to cover the street pipes, the application was reranked, the lines went in; and HUD housing was built. This was claimed to be atypical especially since HUD is now completely out of the waste water treatment planning effort.

Mr. Maine believes that federal and state efforts will become more sophisticated and complete as they both gain experience. Of course the necessary resources and personnel must also be forth coming. Yet experience dictates, and present circumstances force, that some time must pass before high quality planning is achieved. Neither legislative works nor quick money will create instant results. The goals, which have been expanded in the 72 Amendments, are there, but it will take a while to reach them.

In order to cover the problem of grant acquisition from the point of view of the municipality, an article titled "Steps Municipality Must Take for Federal Aid, 75-25% 'Matching' Grants for Water Cleanup" has been included as entry 14 in Parts 3 & 4. It is a brief scenario of a small town organizing toward, applying for, and receiving a construction aid grant from EPA under the new 72 Amendments. While it adds little of any substance to that which has already been presented, it definitely helps to more fully complete the picture of the federal-to state-to local-to state-to federal sequence of observations.

# PART 2

## Recommendations for Further Studies

The study, having fully completed its initially stated goals, leads inevitably to more unanswered questions. Available time and resources limited the scope of this study in a number of ways.

It is a strong assumption, not a proven fact, that EPA Region I is characteristic of both the activity and attitudes of Regional Offices nationwide. A full review of the Legal and Enforcement Division of EPA Region I may provide intricacies of operation and influence not provided in this paper. No extremely detailed account of EPA cash flows was attempted, so no knowledge of possible political pressures on the net distribution of grants was attempted.

No estimate was made to determine how potential, future Land Use Planning under the Coastal Zone Management capabilities of NOAA or the Department of Interior may effect EPA's activities. It seems obvious that some integration and coordination, at least at the federal level, will have to take place. No guess was attempted to predict how future Congressional funding of the 72 Amendments will proceed.

The same assumption concerning the resentative nature of the activities of Rhode Island's DWPC is, in fact, untested by comparisons with that of other states. The true problems of states licensing, monitoring, and administering industrial effluent discharge into coastal waters is unexplored. No attempt was made to factually compare and establish the efficacy of Rhode Island's DWPC. An appraisal, either economic or social, of the non-existant long range use-goals of Narragansett Bay was not tried. It is clear that a definitive statement about the ultimate usage(s) of

Narragansett Bay is needed before any valid, long range water planning models for Rhode Island can be made. No in-depth review of the relative activities of the state's legislature was undertaken.

No economic study identifying the relative and absolute costs to local governments needed to satisfy the goals of the 72 Amendments was done. It might be of even greater value to determine if local governments even care (in a functional way) about the new regulations. This list is limited only by the imagination of the reader. It is clear that the amount of information gained by this writer during the study is only the groundwork for many potentially expansive studies.

# PART 3

## Index to Reference Documents

This section contains a series of short content inventories of the documents in Part 4. These are not intended to be critical reviews, but rather a rapid ready reference set. Only portions which are of direct bearing to this paper are described. The documents are arranged by chronological sequence of publication.

The first entry is the Federal Water Pollution Control Act, As Amended (33 U.S.C. 466 et seq.) through April 3, 1970. This text serves as a legal history of the evolving basic Act (PL 84-600) approved July 9, 1956. Its Sections include:

1) Policy Declarations to enhance quality and value of water resources and for abatement of water pollution.

3) Federal - state cooperation is desired.

7) There shall be grants for water pollution control programs.

8) There shall be grants for construction of treatment works-establishes the federal grant sharing ratio.

10) Enforcemnet measures against pollution of interstate or navigable waters - much review procedures and no teeth.

13) Control of Sewage from Vessels - establishes that standards need to be promugated.

15-20) Sections that deal with training and research grants.

21) Other Federal Agencies are supposed to Cooperate in the Control of Pollution.

22) Administrative organization.

23) Definitions.

This document also includes the texts of Reorganization Plan No. 2 of 1966 and Executive Order 11507 of February 4, 1970. Both expand and attempt to define more clearly the federal effort for pollution abatement and control.

The second entry is EPA's Guidelines for Water Quality Management Planning published January, 1971. They are officially still in effect as of this writing. These Preliminary Planning Guidelines are to provide the basic areas of concern to be addressed when attempting to meet the requirements for EPA Waste Water Treatment Works Construction Grant Program and for HUD Water and Sewer Facilities Grant Program. The document has 5 chapters:

1) Approach to Water Quality Management Planning
2) Basin Plans
3) Metropolitan/Regional Plans
4) EPA Plan Evaluation Procedures
5) Evaluation of Construction Grant Applications for Conformance to Plans.

This document also contains a copy of the Rules and Regualtions for Grants for Water Pollution Control, Part 601, Federal Register, Vol 35, no. 128, July 2, 1970. It notes the need for an "effective Basin Plan" (para. 601.32 (a)). On pages 1-9, the text of the Guidelines sanctions Interim Plans in order to reconcile lead time for planning with flow of construction projects. Much other conceptual data is included and this document serves well as a non-legalistic introduction to the whole problem addressed by this project.

The third entry, titled Water Quality Management Planning, Institutional Arrangements for Water Quality Management Planning, is a critique prepared for EPA by an outside contractor published September, 1971. The report identifies the status and problems of the State level water quality management planning programs. Paricularly it notes that the lines of communication which are not based on dollar flow are either weak on non-existent. There are constant references in this document to the previously cited Guidelines. This too is a good, readable reference for understanding the relevant Federal, state and local intergovernmental relationships.

The fourth entry, published November 27, 1971, Federal Register, Vol 36, no. 229, titled Grant Programs Interim Regulation, begins to supply the kinds of functional details not found in either the actual Laws or Agency Guidelines. It codifies and establishes procedures for grants awarded by EPA.

The fifth entry is Water Quality Standards Summary, a Joint Publication by EPA and the Rhode Island Department of Health, Division of Water Supply & Pollution Control, published December, 1971. The text provides both verbal and quantitative description of what water use-types A through D are. It also defines the hydrological basins for the State of Rhode Island and assigns classifications to the major water bodies in each basin. It is a deceptively simple,but important document since it supplies numbers and names to otherwise abstract requirements.

The sixth entry is titled <u>Environmental Impact Statements, Procedures for Preparation</u>, Federal Register, Vol. 37, no. 13, January 20, 1972, It is a further EPA elaboration clearly requiring local grant seeking governments to include Environmental Assesment Statements (EAS) with the grant application. Para 6.23 states that the EAS should follow the form and format prescribed in Para 6.45. A reading of Para 6.45 indicates why local governments have real difficulties submitting an EAS of anything more than minimal value. The required open ended narrative is expansive and complex, and this is the officially required product.

The seventh entry is titled <u>General Grant Regulations and Procedures</u>; <u>State and Local Assistance Interim Regulations</u>, Federal Register, vol. 37, no. 112, June 9, 1972. These regulations were published in an effort to provide grant applicant with more explicit statements of grant-award and administrative requirements. These regulations are a more detailed statement of prior regulations and of previously uncodified policies, procedures, and terms of respective grant programs. The quantity of specific information is indicative of the level of confusion that state and local governments were having while trying to conform to a rapidly evolving and changing program.

The eighth entry is a copy of PL 92-500, "Federal Water Pollution Control Act Amendments of 1972," as passed on October 18, 1972. There are five Titles to this Act. The most dramatic portion is Section 101.(a)(1-5), the statements of national policy which set as a goal the elimination of the discharge of all pollutants into navigable waters by 1985. Each of the Titles sets more greatly defined standards than did the Water Pollution Control Act of 1970. Each of the Titles has extensive funding authorizations; portions of which are presently under Executive Impondment. It is therefore difficult to guess at the true impact of each Title. There is much internal cross referencing in the document which makes it as whole, and as separate new deadlines and requirements, difficult to understand.

Under Title III, Sec. 309. (c)(1&2), the EPA is now fully authorized to bring civil suit against persons, corporations, or municipatities for non-compliance and/or violation of licenses or orders issued by the EPA. Both imprisonment and cash fines are detailed for conviction of such offenses. This is a far cry from Sec. 10.(d) & (e) of the 1970 Act which was a drawn out sequence of reviews, with no penalties, for situations of non-compliance.

It is an Act that should eventually have great impact upon the ultimate improvement of the nations's waters.

The nineth entry is a very readable set of Guidelines for Developing or Revising Water Quality Standards under the 1972 Amendments (entry eight above) published by EPA in January, 1973.

The text attempts to unravel the complicated sequence of reports and deadlines required by the Act itself. It instructs Regional EPA personnel that upgraded and revised state planning activity schedules should be as complete as possible relative to the shortness of the deadlines. Operating Procedures defining State-Federal interfacing is described on pages 32-36. On page 39 is a sequential listing of the newly mandated deadlines. It is this writer's opinion that they will most likely be overshot.

The tenth entry titled Preparation of Environmental Impact Statements, Interim Regulation, Federal Register, Vol. 38, no. 11, January 17, 1973, is an expanded elaboration of the January 20, 1972 Interim Regulations (entry six above). One of the purposes of this document is to help define when Impact Statements need not be made for purely administrative actions. By expanding the scope of the available details, the text severly limits when a Declaration of Negative (translate "none") Impact may be used. This eliminates a dodge many local governments have been using to avoid and evade writing an EAS of any substance. Also new is the requirement (Para 6.56.(b)(5)) that the local government must conduct a public hearing on its EAS, and that a record of the hearing must accompany the EAS when a grant application is submitted to EPA. While most of this document is directed to in-house EPA personnel, local municipalities will need to digest it as planning requirements become more sophisticated and rigidly enforced.

The eleventh entry is an Application Kit for Construction Grants provided by Mr. Stuart Peterson. This Kit is what would be provided to a local government should it desire to initiate an application for waste water treatment construction aid assistance. There are 5 documents in the Kit. Two of the documents relate to Compliance Requirements of Title VI, Civil Rights Act of 1964. The multiple page form even goes so far as to ask for a percentage racial distribution of those members of the community that will not benefit from the project.

A one page Environmental Assesment Outline is included. It is a deceptively simple form. It is an open ended essay. According to Mr. Donald Smith, Chief Basin Planning Section, Region I, EPA, too often Sections II through VII are answered, "none." The fourth form is simply a population census sheet for federal indexing of the grant area. The final form is a detailed budget proposal in Parts I through III. Part IV is a narrative and covers much the same kinds of information as the EAS. In addition, however, it requires evidence of Comprehensive Planning and also the requestor's committment for adequate staffing and funding for the facility once it has been completed.

The twelth entry is the Rhode Island Department of Health, Division of Water Pollution Control, "Priority for Construction Grants under P.L. 660" schedule. It is a self explanatory, guileless document, except that the actual evaluation of each portion remains a human decision. While given as a state regualtion, the format andcontents were suggested and approved by EPA as a proper ranking device.

The thirteenth entry is a carbon copy of a letter from Mr. Carleton A. Maine, Chief, Division of Water Supply and Pollution Control, Rhode Island, to the Governor's Office. It relates possible state responses to the funding change created by the October, 72 Amendments. It is a precise and detailed statement concerning percentage sharing support for waste water treatment facilities. The letter quite accurately reflects the facts and the direct, fair, informed, and concerned nature of Mr. Maine himself. It would be interesting for someone interested in Rhode Island State Govervent to follow the evolving patterns suggested in the letter.

The fourteenth entry is a copy of an article titled "Steps Municipality Must Take for Federal Aid, 75-25% 'Matching' Grants for Water Cleanup" taken from the magazine Catalyst for Environmental Quality, Vol III, no. 1, V. Fletcher, ed.. The article is co-authored by 3 men who are all in the Engineering and/or Consulting business; Dib, Larkin, and Fleming. It is a brief scenario of a small town organizing toward, applying for, and receiving a construction aid grant from EPA under the new 72 Amendments. It has been included in order to provide another view of the local - state - federal interaction process; only this time oriented to the local point of view. Although written in a somewhat informal style, this writer feels that the article presents an accurate statement of the problems and processes except for one major detail. On the last column of the last page (no. 22), the text indicates that the project will get state priority ranking of Number 1 without the local bond issue having first been passed, and the money made available. This is contrary to what has been presented earlier in this paper. The critical assumption is that the Rhode Island ranking system is a representative example, not the exception, of state-level operations. It may be that the authors of this article have taken an improper liberty in order to create a smooth story line. Otherwise it appears that the "Governor's Office" in the article is acting in ways that violate the rights and interests of other municipalities in the state. The other point completely missing is any mention af anything that resembles an Environmental Assesment Statement for submission to EPA. Either the authors forgot (ignored?) the requirement or it is assumed to be part of the services produced by the hired consulting service.