Use of Scale Models as a Management Tool

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Maritime Administration

in cooperation with
Todd Shipyards Corporation

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FOREWORD

This manual is the end product of one of the many research projects being performed under the National Shipbuilding Research Program. The Program is a cooperative, cost-shared effort between the Maritime Administration's Office of Advanced Ship Development and the shipbuilding industry. The objective, as conceived by the Ship Production Committee of The Society of Naval Architects and Marine Engineers, emphasizes productivity.

The research effort contained herein is one of the nine General Category projects being managed and. cost shared by Todd Shipyards Corporation. It was performed in response to the task statement titled "Use of Scale Models as a Management Tool". The work was assigned, by subcontract, to Bath Iron Works Corporation after evaluation of several proposals.

Mr. William B. Volmer, Bath Iron Works Corporation, Marketing and Research Department, was the Study Manager; he was assisted by Mr. Steven G. Buttner and Mr. Stephen J. Lardie.

Mr. Louis D. Chirillo, Todd Shipyards Corporation, Seattle Division, was the Program Manager. Mr. Charles S. Jonson of the Los Angeles Division, was the Project Manager who provided technical direction.

Special acknowledgment is due also to the following for their constructive criticism of this report in its draft form: Mr. Francis Daly, Consultant to the General Manager, Commercial Ship Division, Newport News Shipbuilding and Dry Dock Company; Mr. Horst Gottel, Assistant to the Superintendent for Special Projects, Sun Shipbuilding and Dry Dock Company; and Mr. Roy Tucker, Facilities Engineer, General Dynamics Corporation, Quincy Shipbuilding Division.

EXECUTIVE SUMMARY

The objective of this effort was to investigate uses and develop cost data and techniques relative to the productive use of scale models in shipbuilding.

The uses reported herein are based upon detailed inquiries in eleven shipbuilding yards. Collectively, the modeling activities are significant and cover a wide range. As there was no one shipyard practicing all applications, there is believed to be sufficient new ideas contained herein to be of interest to even those shipyards who customarily use models.

The major topics covered by this illustrated manual are:

Model Types: The basic model types which can be employed to reduce shipbuilding costs are described. Examples are given.

Benefits: The types of benefits which can be derived through model use are described for each shipyard sector. The manner in which each model type should be used to best advantage is shown (who, why, where).

Costs: A thorough description of the models built as part of this research is provided. The cost of each is given. A labor and material cost equation provides model cost ranges for guidance only.

Model Building Methods: A "how to build models" Section is provided. It covers the subjects of material choice, tools required, fabrication and assembly methods, information flow, photography, shipping and others.

References: An extensive list of books, articles and papers which can be of use to shipyards employing scale models was compiled.

Other pertinent information is included such as a narrative of the current use of models in U.S. shipyards and other industries and the degree of success achieved.

In general, the investigation has shown that scale models indeed can be useful as management tools to reduce shipbuilding costs. It is hoped that this manual will help shipbuilders to make proper use of models to achieve this end.

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FIGURES

CHAPTER I
INTRODUCTION

Models may be defined as three-dimensional representations, built to scale, of an entire ship or some portion of a ship. The size, material, and completeness of detail are all a function of the objective desired. Models can range from the simplest piece of folded paper illustrating a structural interface problem to the most complicated, accurate and highly detailed facsimile displaying any three-dimensional arrangement.

Models are tools which aid managers, engineers, planners, and craftsmen to visualize new and/or complex three-dimensional objects. Interpretation of three-dimensions from a model is nearly instantaneous as compared to the same interpretation from drawings which requires both skill and a significant amount of time. Thus the need for models is greater for unprecedented special-purpose ship designs. This use is amplified if relatively inexperienced personnel are involved in the work. The ultimate cost savings are connected with preventing costly mistakes through insuring thorough and common understanding of the situation. Intermediate savings are connected with reducing the learning time of many people through the research and efforts of one person, the model builder.

As shipbuilding tools, the benefits derived from models fall into the following categories

- Design Control
- Improved decision making
- Improved communications
- Training
- Marketing

Another major use of models is that concerned with directly solving engineering problems such as stress/strain analysis, noise and vibration analysis, heat flow analysis, fluid flow analysis and mechanical interface analysis. This manual, however, emphasizes only those other applications directly connected with the use of models as shipbuilding and management tools.

With regard to design control, the most common model employed in shipbuilding is the machinery space model. It facilitates ideal arrangements of equipment and systems. Also, it will preclude major interferences and, if sufficiently accurate and applied in accordance with a reasonable discipline, will virtually eliminate design interferences which detract from productivity.

More novel applications involve the use of models for improved decision making, improved communications, and training. Models which can be more extensively used for these purposes are those especially made for display, shell expansion, structural design, planning erection units, mechanical design, and facilities layout.

The following are conclusions concerning the use of models:

- They must be available early in the sequence of events of a ship construction contract.
- They need not be overly elaborate, detailed or accurate for most uses.
- They should be constructed in the shipyard, preferably within or in close proximity to principal users, i.e., designers and planners, and accessible by others.
- They should be built only if potential users are convinced of their benefits or if it is probable that a discipline for use of models can be maintained.

An effort necessary to estimate dollar cost savings for each type of possible model usage is impractical. However, details of the methods by which models can be used (Chapters III and VI) and how much they cost (Chapter IV), are provided so that management will be aided in making decisions of when and when not to use models.

CHAPTER II
TYPES OF SCALE MODELS AND THEIR APPLICATION IN SHIPBUILDING

The most common types of models which can be employed in shipbuilding are described in this chapter. Several may be used for more than one function. That is, they may be utilized for secondary purposes after serving the primary use for which they were built.

The topics introduced for each model type are:

- usage
- construction
- materials
- scale, and
- cost

Two of the types, Detailed Structural Models and Distributive Systems Models, offer the greatest potential benefits. Therefore, they are discussed in more detail in Chapter VI.

A. *Display Models*

Usage: Display models, such as the one shown in Figure II-1, are primarily used as a marketing or publicity tool. To some extent they can be useful for designing or verifying rigging and other exterior arrangements. In the majority of cases, when a new class of ship is designed, a display model is built either prior to or following contract award. It enables potential customers to get an immediate appreciation of the general configuration of the ship and is especially useful if the vessel is unusual in any aspect. If some part of the ship's interior is of special concern, then a cut-away treatment of that area can be used. The potential owner may use a display model to make or verify decisions concerning functional requirements. He may use the outboard profile to ensure a satisfactory fleet image.

Model Construction & Materials: With a few exceptions, display models are subcontracted to professional model builders. Such professionals have the wide variety of tooling required for such intricate work and stock the many different materials needed. Display model hulls are generally fabricated of wood. Where cut-away views are included, plastics and brass are employed. Deckhouse structure may be wood or plastic. Outfitting work makes use of plastics, wood, castings (zinc alloy, brass plastic), wire, etc. Items such as lifeboats, railing, rigging are shown so as to create an overall impression. However, minute detailing is kept to a minimum. Accuracy to scale is not always of great importance, but painting and finish work should be kept at a highly professional level.

Scale Choice: The actual display model size is chosen to be consistent with the area in which the model is to be displayed; generally an overall length of two to four feet is desired. The scale, therefore, is usually 1/16" to 1/8" = 1'.

Cost: $2,000 to $10,000

B. *Scientific Test Models*

Usage: Scientific test models are models which are used to determine or verify the engineering properties of a given structure or system. A "structural engineering model" may be built to determine stresses, deflections, natural frequencies or other

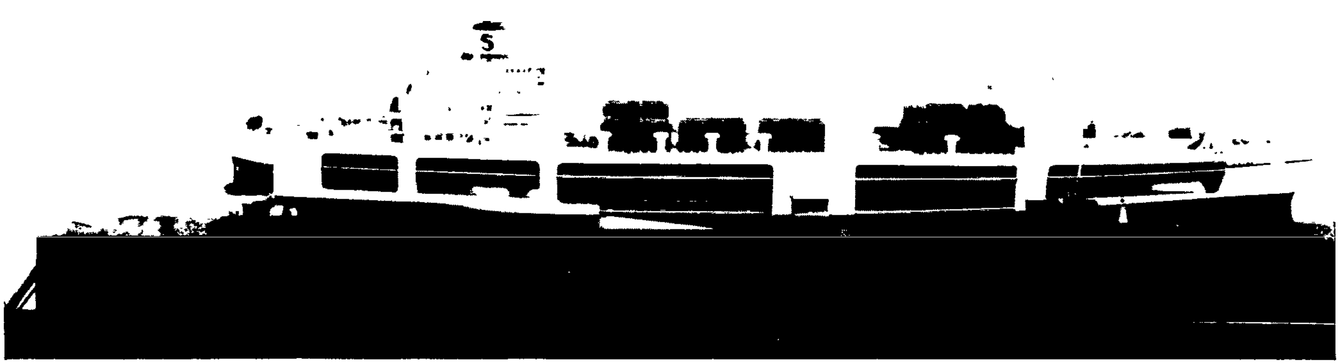


Figure II-1. Display Model of RO/RO Cargo Ship Showing One Side Cut-Away For Viewing Unusual Interior

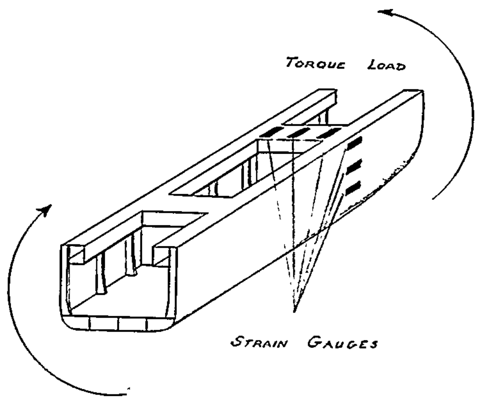


Figure II-2. Example of a Scientific Test Model Showing A Hull Girder Being Tested For Stresses Due To Torsion

mechanical properties. An example is shown in Figure II-2 of a hull girder being tested for stresses due to torsion. Instrumentation could be provided on this same model to determine its vibratory properties. One or more "shakers" and several accelerometers would be mounted on the model to determine its natural frequency and modes of vibration. Experience has shown that the results of such experiments are accurate within 5 percent. A thorough treatment of structural engineering models can be found in the article entitled "Prognosis with Plastic Models" referenced in Chapter VII, Section B.

A "systems engineering model" may be built to verify the functional properties of an engineering system. Such properties may include thermal conductivity, flow rates, system induced forces (lift, drag), system pressures, and other more specific system functions. Resistance testing of ship models would fall into this category. Recent examples of systems engineering models in shipbuilding are a cargo tank pumping system and a ship damage stability model.

At present, there are many areas where scientific test models could be employed in shipbuilding in lieu of costly and, many times, unreliable engineering calculations.

Model Construction and Materials: Models of this type are usually fabricated from either plastic or metal, although plastic seems to be the preferred material due to lower cost and ease of modification. An important aspect of such construction is carefully bonded joints. It is not always necessary to exactly duplicate the structure to be studied to obtain reliable results. In one case, an experiment was performed to determine the torsional rigidity of an innerbottom erection unit 96 feet in length. A plastic model was simply constructed by eliminating all longitudinal stiffeners (plating was increased appropriately) and local structure. Using appropriate scaling procedures, accurate estimates of the full-size deflections were determined (see Chapter VI, Section B). Construction methods and materials employed in such models vary with each case. Past experience in the literature (Chapter VII) should be consulted for specific problems to be solved.

Scale Choice: The scale choice for scientific test models is generally determined by testing and model construction facilities. Certain physical laws will also influence the choice of scale (for example, transition zones from laminar to turbulent flow in ship resistance testing).

Cost: Extremely variable.

C. *Shell Plating Models*

Usage: While some yards employ graphical or computer processes for determining shell-plate configurations, some still employ models. A shell plating model facilitates interpreting two-dimensional shell expansion drawings. It permits further analyses by engineers, loftsmen and planners to optimize

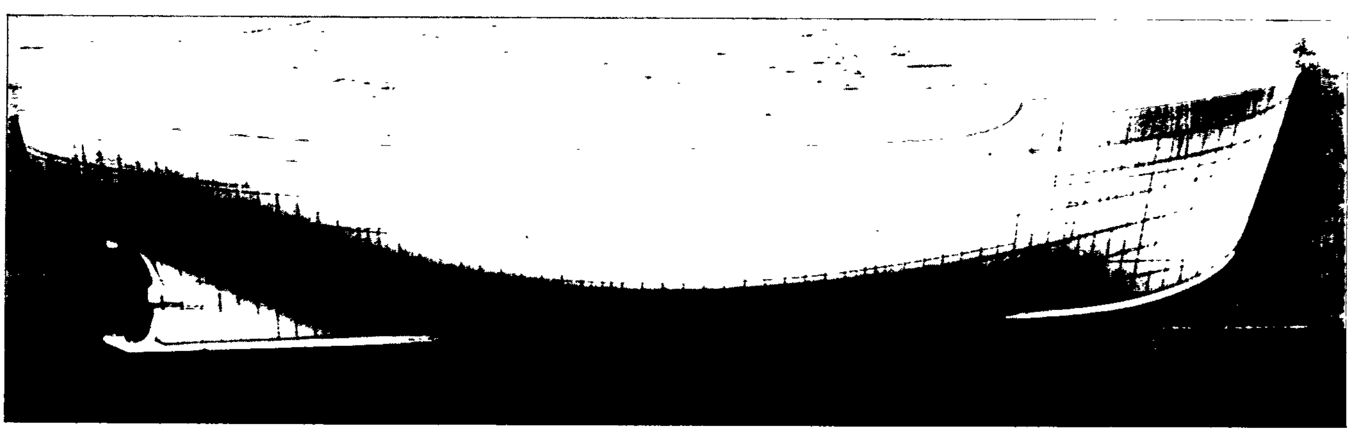


Figure II-3: Typical Shell Plating Model steel ordering and to minimize the number of plates with compound curvature (roll and backset). An example is shown in Figure II-3.

Construction and Materials: It is generally sufficient to construct a half model of the molded dimensions of the hull. The plating model is usually hand carved from laminated, solid soft pine or the best grade of some other suitable wood. Templates are used to accurately control the dimensions. The model is coated with varnish or white paint lightly sanded to allow ink marking. Plating sight edges and butts, longitudinal sight edges, frame lines, and deck traces are scribed or inked on the model.

A unique and perhaps more accurate method of constructing shell plating models is presented in Chapter V, Section B-1 1.

Scale Choice: 1/8" or 1/4" = 1'.

Cost: Average of $1,200.

D. *Detailed Structural Models*

Usage: With the growth in size of ships, material and labor costs for ship's structure have become a greater percentage of total ships' cost. Further, increases in sizes, which in itself necessitate changes in the design of ships' structure, has been accompanied by unprecedented special purpose ships. These trends and the decrease in the number of skilled shipbuilders has necessitated design development in greater detail and with more accuracy than has been customary.

The detailed structural model is a recognized tool which facilitates these needs. Accordingly, it is emphasized in this manual. Typical structural models, one in cardboard and one in plastic, are shown in Figures II-4 and II-5 respectively.

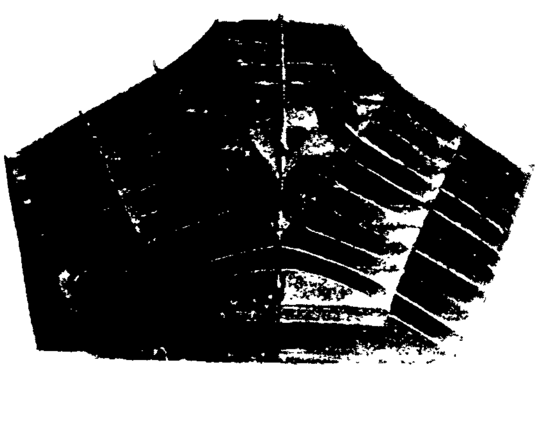


Figure: II-4: Simple Cardboard Model Showing Stern Structure of Tanker

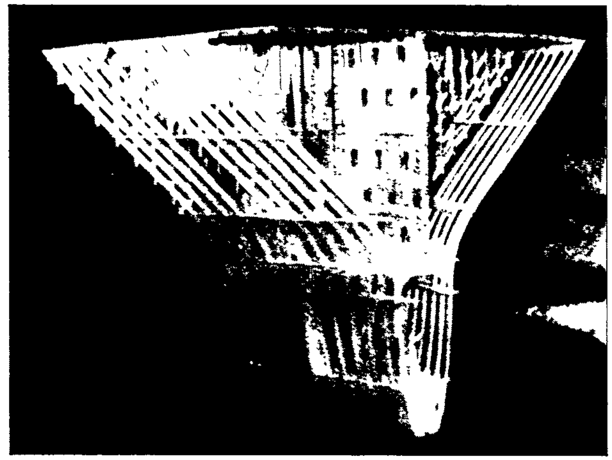


Figure II-5: Detailed Structural Model Built of Plastic, Showing Stern Section of Tanker

The structural model has potential applications in many areas of ship design and construction which is described in greater detail in Chapters III and VI. Some pertain to standardizing and simplifying the design. Others pertain to planning, i.e., for erection unit and subassembly divisions, in-process material handling, use of jigs and staging, and the work functions relating to welding, preoutfitting, painting, etc. They may serve to some degree, for interference studies and as training aids. The greatest benefit is derived where the structure in question is new to the shipyard or extremely complex. It facilitates management's understanding, discussions, and decisions concerning the effect of the project in-hand on the steel shop facilities, or conversely the effect on the structural design made necessary by existing facilities.

Construction and Materials: Structural models can be constructed from several materials and to varying degrees of detail depending on the resources budgeted. Ideally, the model should be built in the same sequence as planned for the full-size ship, i.e., by erection unit or panel. A detailed description of construction methods is covered in Chapter V. The basic materials used are cardboard, wood, and plastics. Each material has unique advantages. For instance, cardboard models can be constructed with a minimum of special tools or facilities. The obtainable accuracy is limited but, in most cases, it is sufficient for shipyard needs. Wood requires more shop equipment yet is somewhat more flexible in sizes and thicknesses available and is generally applied where a large scale is needed or a full-size mock-up of a special area is constructed. A combination of cardboard and balsa wood can be applied advantageously in some cases. The third group of materials used for this type of model is of the clear or semi-clear plastics family. The advantages of plastics are their see-through properties, stability, durability, easy bonding properties, and ability to produce the extreme accuracy and bending properties characteristic of steel. A disadvantage is that this type of construction requires an extensive model shop. Plastic structural models can double as scientific test models to determine deflections and vibratory properties.

Scale Choice: 1/4" = 1' to 3/4" = 1'.

Cost: Very crude cardboard: less than $100.

Detailed cardboard: $500 to $3,000.

Detailed Plastic $4,000 to $10,000.

These cost ranges are for typical midbody sections.

E. *Erection Unit Models*

Usage: Erection unit models are generally built by or for planners to represent components which will be assembled on the buildlng site. They are used to plan an optimum erection sequence and to solve handling, stowage and clearance problems. They are especially useful when building sites are scheduled to be loaded to maximum capacities. They are also useful when planning heavy lifts. A typical erection unit model is shown in Figure II-6.

Construction and Materials: Cardboard or wood is generally used for this type of modeling. Structural details are not required. Panels may be represented by flat pieces of cardboard and erection units by solid wooden blocks. The units and panels fit together using friction pins to allow repeated assembly and disassembly.

Scale *Choice: 1/16" = 1'* to 1/2"= 1'.
Cost: *$100* to $1,000.

F. *Distributive Systems Models*

Usage: Distributive systems models are generally built to develop and/or check the arrangements of components, piping, ducting and cable in selected areas. The major design issues involved are those of interference control, accessibility for installation and maintenance, and human engineering factors such as traffic patterns, headroom and lighting. The most common area chosen for this type of modeling is the machinery space, (Figure II-7). Significant benefit has resulted from modeling other areas of the ship, such as where there is a concentration of distributive systems in a deckhouse as shown by Figure II-8. The distributive systems model is by far the most common application of model usage in shipbuilding and other industries.

There are basically two major schools of thought on how this type of model should be used. One discipline believes that all design should be performed on the model by a master designer who receives various inputs. Thus, the model becomes a strict design control tool. Some advocate that drawings should be eliminated. They would substitute only working sketches made directly from the model. The second discipline believes that the model should be used primarily as a checking tool to verify design drawings.

Construction and Materials: Each distributive systems model has to include some structure. Only that structure which constrains nearby systems should be modeled. Minor details such as brackets, chocks, and stringers are not required unless they could possibly cause interferences. Extra structure is sometimes necessary for the purpose of strengthening the model itself. Plastics are usually the best

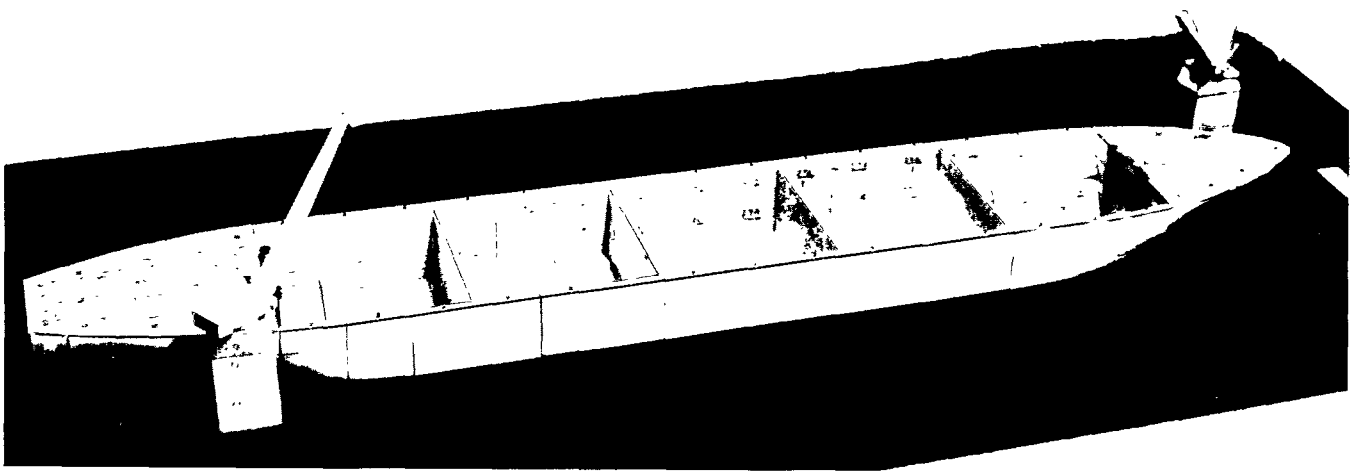


Figure II-6: Erection Unit Model Used for Determining Optimal Erection Sequence, Solving Clearance Problems, and Planning Unit Storage

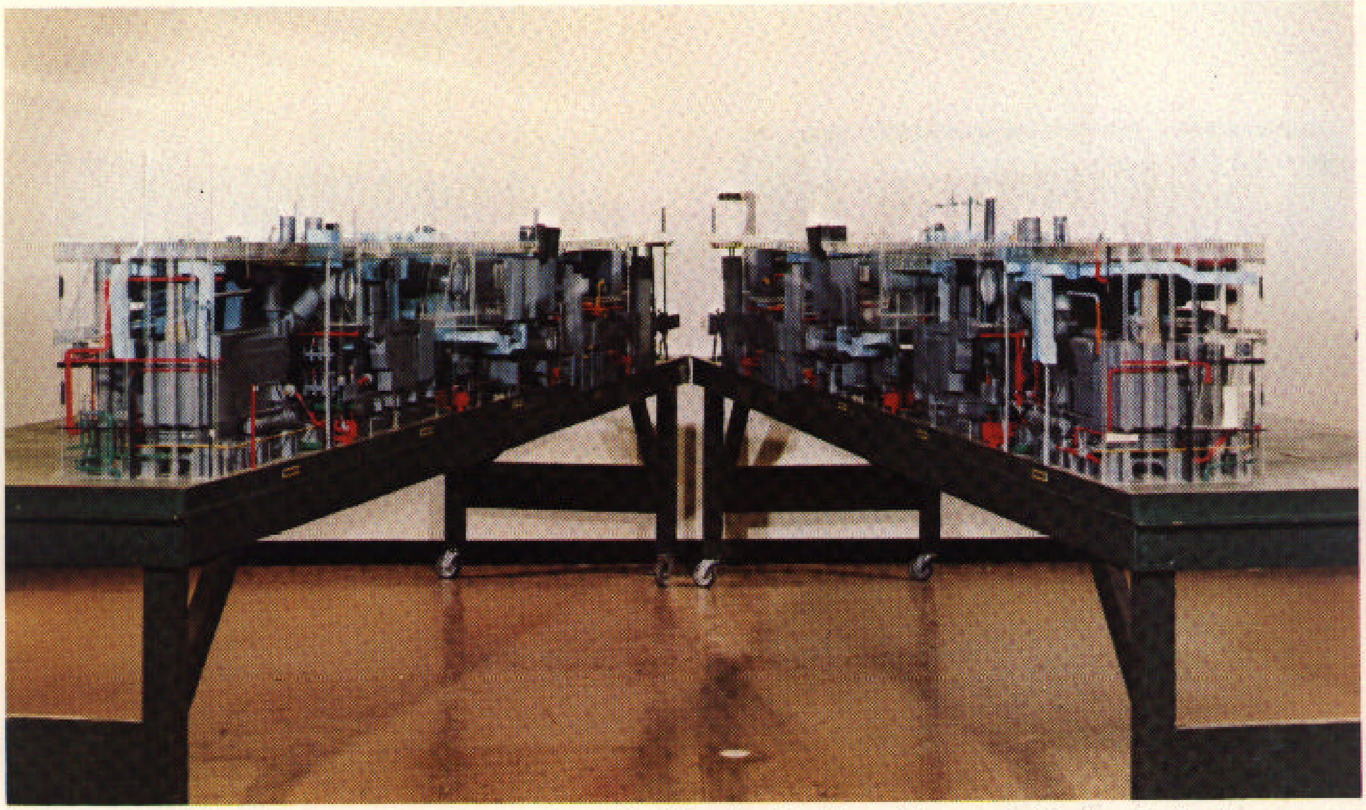


Figure II-7: Model Built as a Design Control Aid for the Machinery Spaces of a Modern Icebreaker

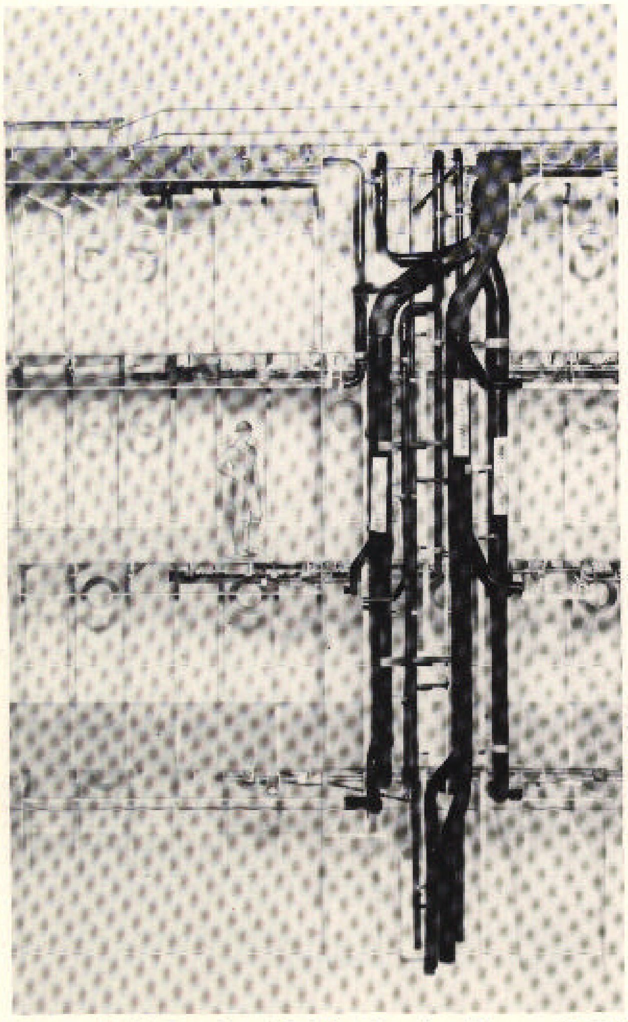
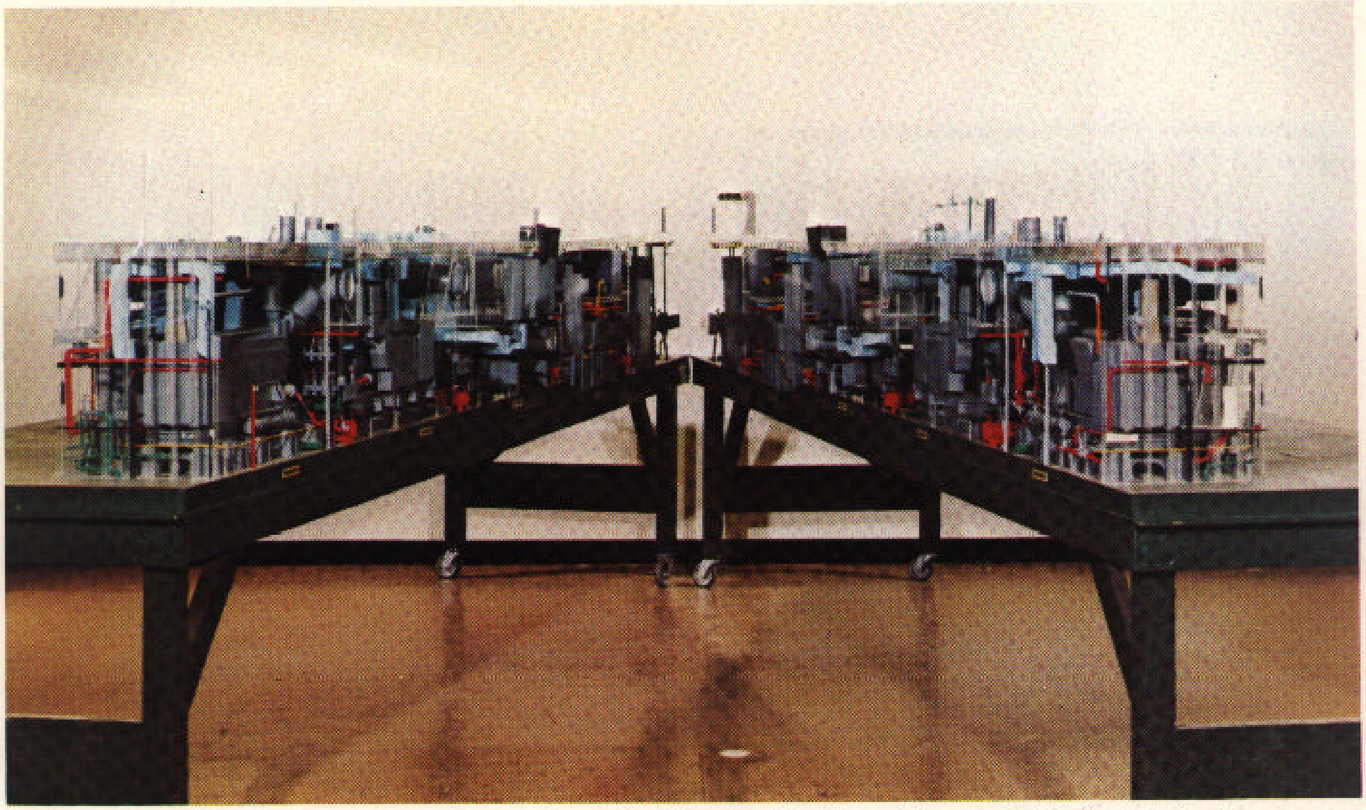


Figure II-8: Portion of a Tanker Deckhouse Model Showing a Concentration of Distributive Systems

materials for these applications as they are transparent and easy to form. In some cases, brass is employed for its higher strength.

The systems portion of the model consists of piping, ducting and wiring and their associated components. Component arrangement is the first area to be studied. Their accessibility for operation, repair, and replacement are of key interest. Once the components are laid out, the various ducting, piping and wiring may be routed to and from them. The final design should be the result of several interactions that eliminate interferences and increase productivity. Components are made of plastic, polyurathane foam or wood. Piping is either thin wire and disc (centerline method) or plastic tubing with plastic or wood fittings (full size O.D. method). Other materials readily available in the shipyard may be adapted. For example, aluminum wire inserted in rubber tubing to obtain the correct diameter for pipes. Factory-made plastic pipe fittings are readily available and some snap apart to make revisions easier. Ducting and wireways are made of foam, wood or plastic.

Scale Choice:	1-½" = 1'. Normally it is not beneficial to model pipe with less than 2" IPS. Full-size mock-ups are sometimes beneficial.
Cost:	Engine room model: $40,000 to $200,000.



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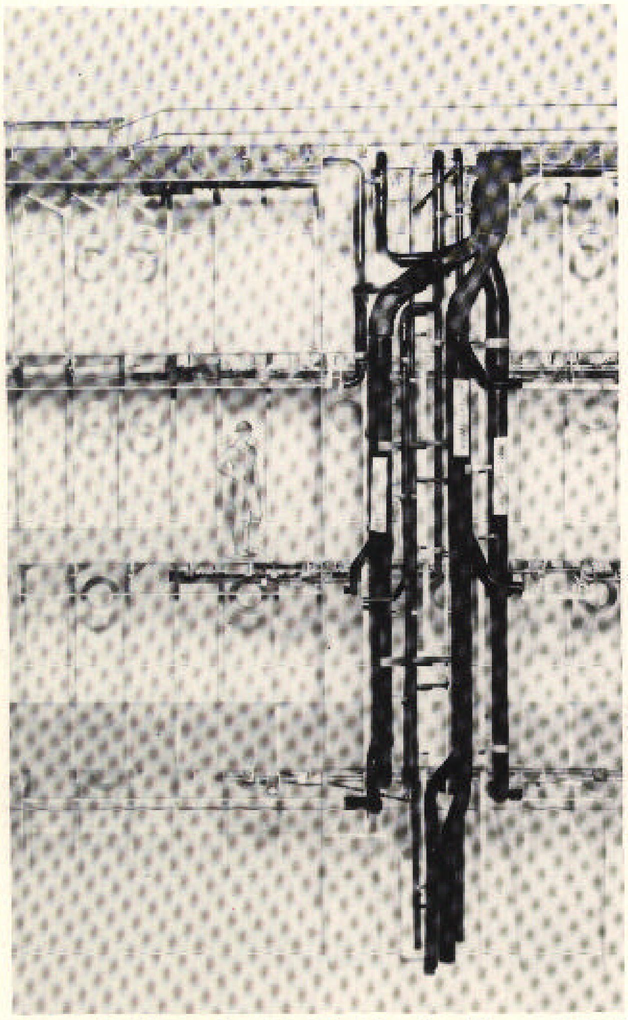

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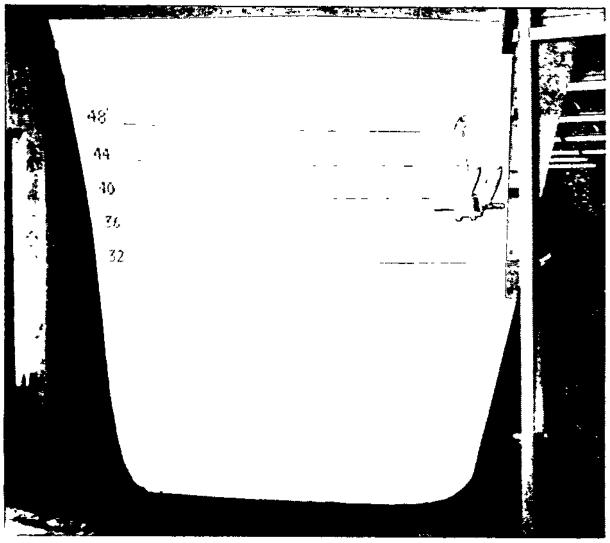


Figure II-9: Typical Anchor Handling Model

G. Mechanical Models

Usage: Mechanical models are constructed to develop or verify the operating aspects of anchor (Figure 11-9) or cargo handling gear. It is prudent to make an operating model of any new mechanical system, such as a barge elevator (Figure II-IO), in order to disclose design problems before components are released-for-manufacture.

Construction and Materials: Mechanical models are constructed from a wide variety of materials due to the special nature of each problem. Materials include metal castings, wood, fiberglass, plastics and sheet metal. Past experience in the literature with specific mechanical models should be consulted before proceeding with a project of this type. A professional model firm may be the most cost effective alternative.

Scale Choice: Generally, large scale 1½" = 1' to full-size mock-up.
Cost: Anchor handling: average of $3,500.
Other: $5,000 to $15,000.

H. *Facilities Models*

Usage: Facilities models are useful for planning a new facility or in optimizing the operation of an existing one. Figure 11-l 1 shows a working model of an existing shipyard. This model was used to plan crane service, staging, lighting, material handling and storage, ship movement, dock usage, ways scheduling and much more. Figure II-12 shows a model of a planned blast and paint facility. Modeling an anticipated facility generally allows clearance and material flow problems to be easily recognized, communicated and solved. It serves as an excellent planning tool for management decisions on capital improvement.

Materials and Construction: Facilities models are generally constructed on a rigid base of heavy plywood, making extensive use of solid wood or foam-plastic shapes to represent machinery, portable equipment, ships and small buildings. Balsa wood and heavy plywood are used for larger structures which cannot be made solid. Choice of materials is best made according to the modeled size of an item. The model is generally finished in bright colors for easy identification of key areas and good appearance. Normally the controlling shipyard department, industrial engineering or facilities maintains the model as an on-going planning tool.

Scale Choice: 1" = 30' or larger.
Cost: $600 to $10,000.

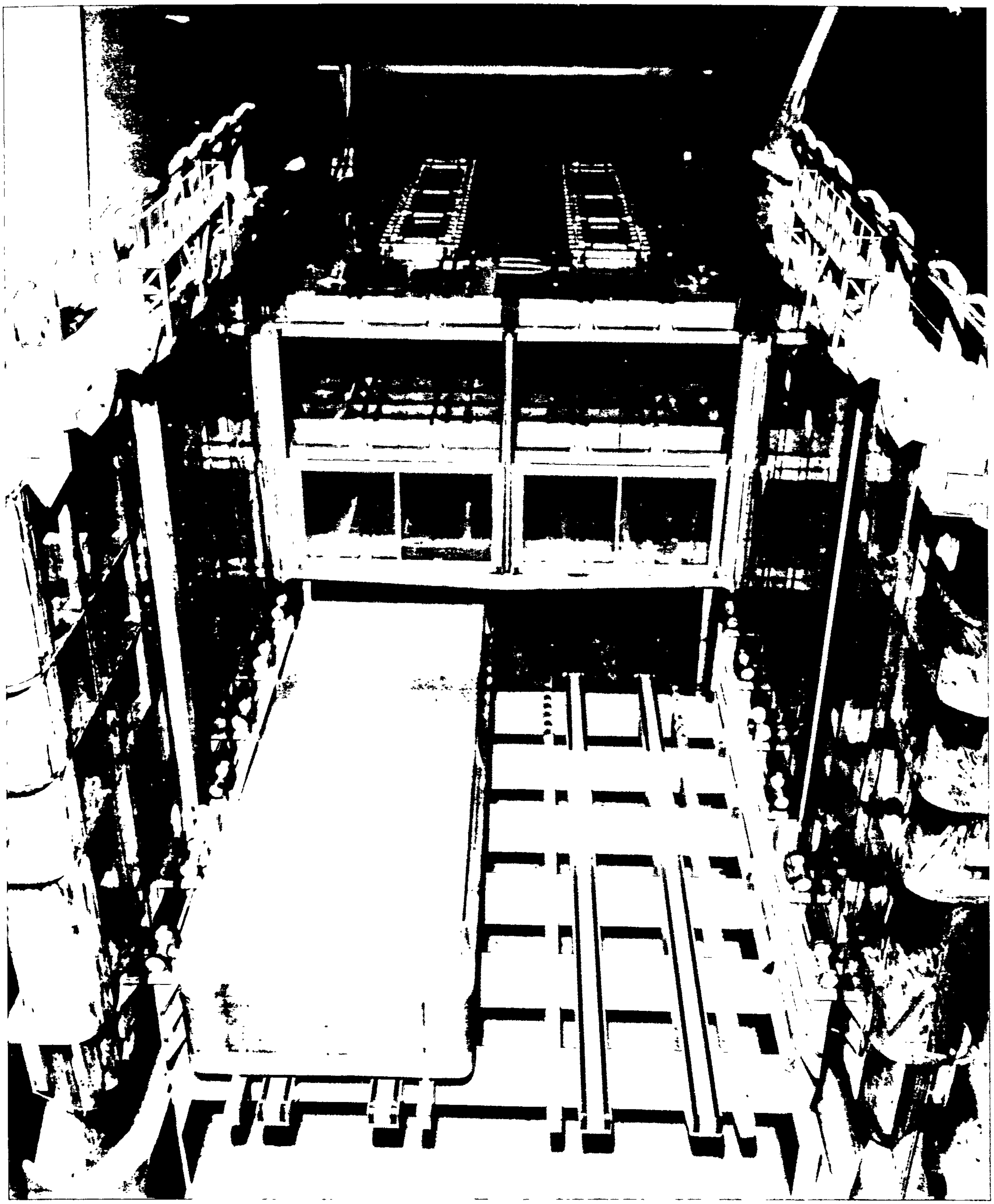


Figure II-IO: Specialized Mechanical Model of a Stern Elevator System. Such a Model is Used to Solve Problems of Clearance, Interference, Travel and Fit.

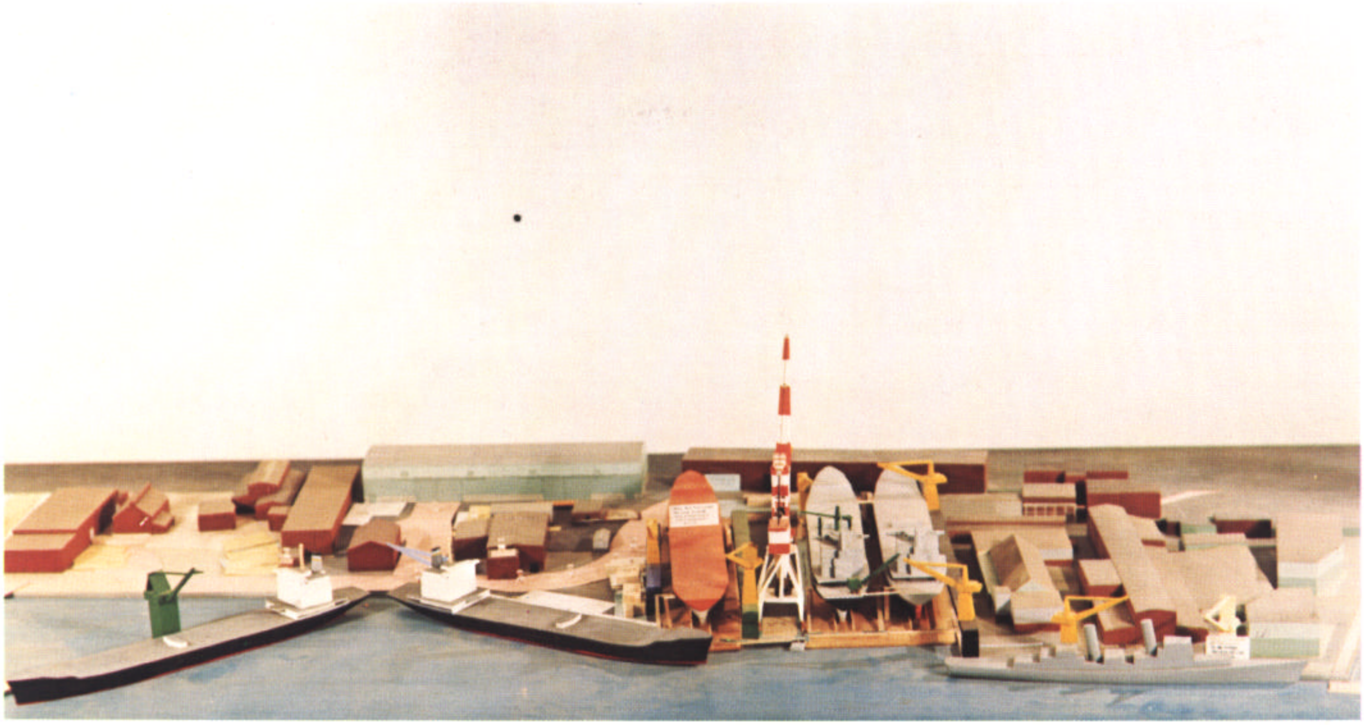


Figure II-11: Overall Facilities Model Used Continuously to Plan Staging, Material Handling, Storage, Crane Use, Ship Movement, Dock Usage, Ways Scheduling, etc.

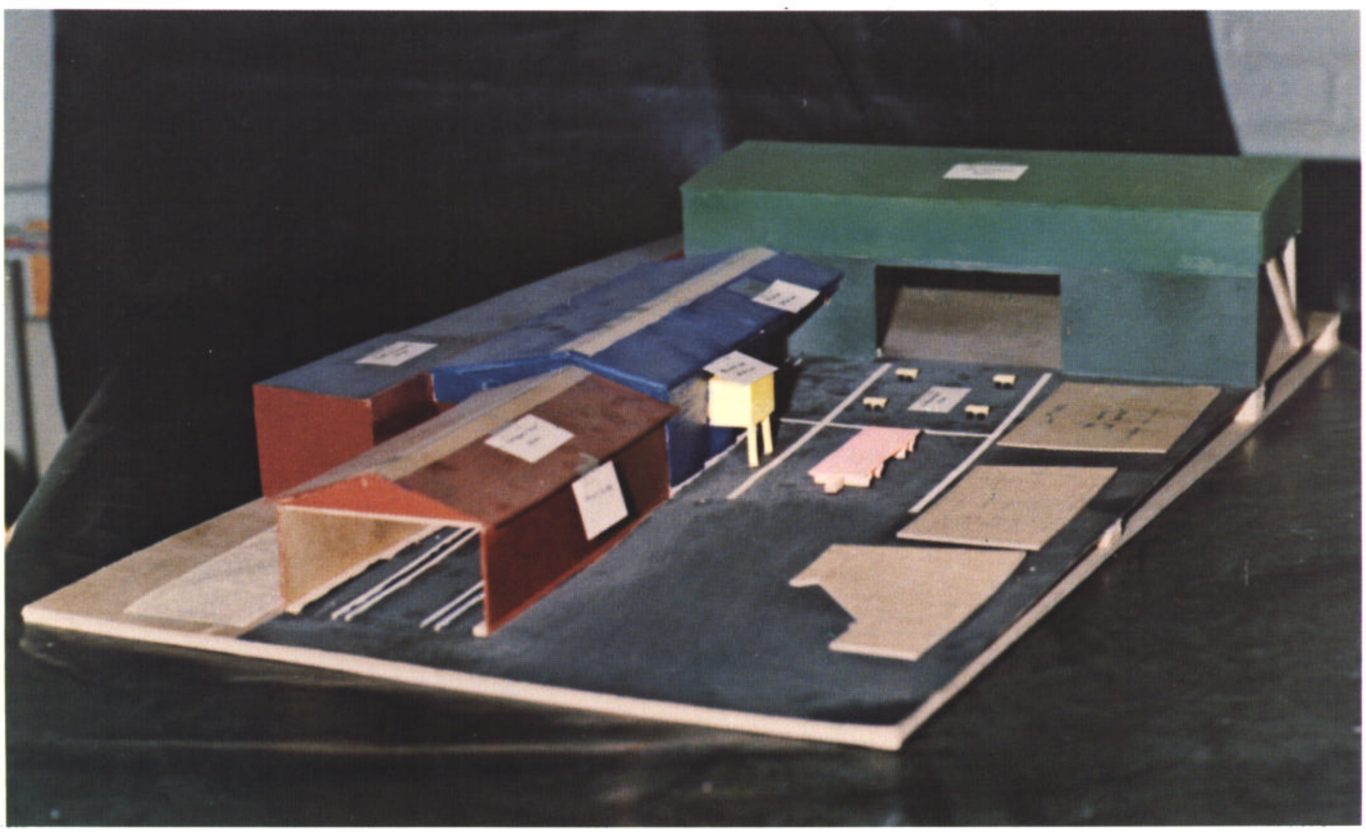
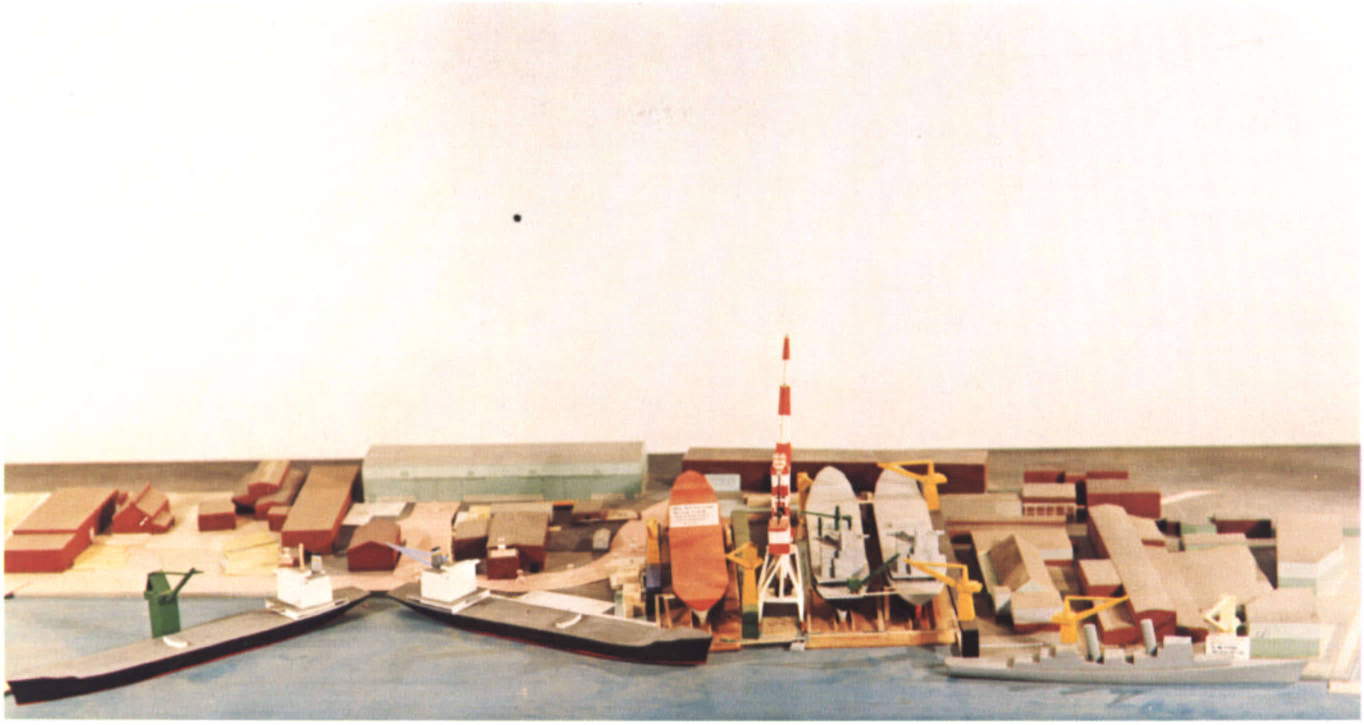


Figure II-12: New Blast and Paint Facility Modeled Before Actual Construction, to Plan Locations, Clearances, Flow-Through, etc.



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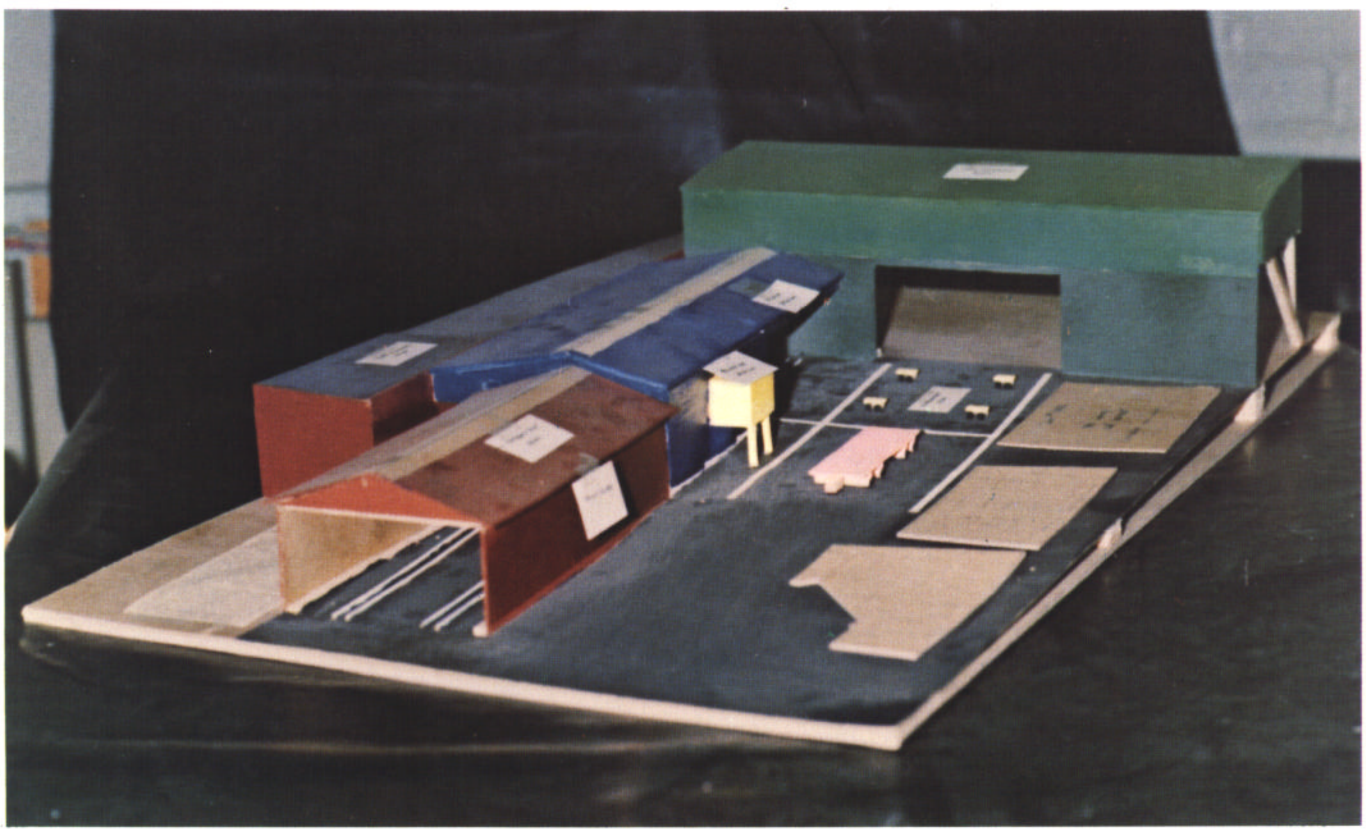


Figure II-12: New Blast and Paint Facility Modeled Before Actual Construction, to Plan Locations, Clearances, Flow-Through, etc.

CHAPTER III
THE BENEFITS OF USING SCALE MODELS AS A SHIPBUILDING TOOL

All levels of management representing various decision centers may derive some or all benefits from each of the model types listed in Chapter II. However, the decision to construct and make extensive use of a particular model type generally comes from one shipyard center. Figure III- 1 illustrates the nature of this relationship. This could be used as guidance for apportioning costs of a particular model type against the budgets of six potential users. The remainder of this chapter notes the potential benefits that can be derived from models by each user category.

In most cases, models are merely tools to aid managers, engineers, planners, and production craftsmen. Models help them visualize three-dimensional objects, acquire a common understanding, and to reach agreement concerning a project-in-hand. The extent of the dollar benefits attributable to a model is therefore a function of how well it succeeds in improving a person's perception or expression of three dimensions. In this context, a model may be thought of as being used to prevent mistakes and to prevent serious problems from being overlooked through a more thorough understanding of a situation. It is, therefore, impractical to estimate the value of a particular model for the general case since it is highly dependent on the skill and experience of those using it. Generally, the lower the available skill and experience, the higher the value of a model. Sound judgement in this regard is therefore the key factor in predicting or assessing the benefits of a model program.

A. *Benefits For Top Management*

Models are effectively used to get top management's attention efficiently focused on specific problem areas identified by engineers and planners. Often they are the means of increasing communications among managers which leads to the solution of problems from a common viewpoint.

1. *Production Processes*

Management must be informed, in a timely manner, about bottlenecks in production, new production methods, unusual erection sequences and other exceptional matters in order to make optimum decisions. A facilities model and/or an erection unit model, enables managers to quickly "grasp" the situation.

MODEL TYPES – USER CATEGORIES

USER CATEGORY	MODEL TYPES							
	Display Models	Scientific Test Models	Shell Plating Models	Detailed Structural Models	Erection Unit Models	Machy Space Fluid & Electrical Syst Models	Mechanical Models	Facilities Models
A. Managers	⊕				X			X
B. Design Engineers	X	⊕	X	X		⊕	⊕	
C. Loftsmen			⊕	X				
D. Planners			X	⊕	⊕	X		X
E. Production Craftsmen				X	X	X		X
F. Industrial Engineers								⊕

⊕ Denotes Primary Use
X Denotes Secondary Use

Figure III-I: Table demonstrating the degree of benefit of various model types to various user categories.

2. *Facility Improvement Decisions*

Improvements in shipyard facilities involve large capital expenditures. Considering the contemplated expenditures, a facilities model is a "good buy" for assuring that all problem areas are identified and that the proposed improvements are clearly understood. It eliminates the need for the time-consuming study of drawings and facilitates presentations to directors and financiers. More detail concerning the use of facilities models appears in Chapter III, Section F and Chapter VI, Section H.

3. *Marketing*

The display model can be used as a means of conveying certain basic information to potential customers concerning proposed vessels or those already under construction. Overall vessel appearance, cargo handling equipment, and general arrangements can be discussed on a superficial basis or on a level suitable for development of a specification or contract drawing.

Potential and actual customers may also be interested in the planned or actual construction sequence. The erection unit model can be used to clearly convey this information.

The existing production capabilities, present and future, are of interest to the customer especially if his contract requires shipyard expansion. A facilities model is one of the best ways to convey such concepts.

4. *Public Relations*

Any type of model, if artistically acceptable, may be used to great advantage in public relations. The model types most appropriate to this application are display models and facilities models. One shipyard used the models effectively to support the combined functions of production processes, facilities improvement, marketing and public relations. A structural model was used to redesign a portion of the ship described in the contract plans prior to negotiating the contract. This ship structural model was integrated with the shipyard facilities model. This yielded assurances that the ship, as redesigned, was ideally suited to the shipyard's production facilities. The ship structural model was then used to convince the prospective owner that the redesign was better than the design shown in the contract plans. It was, therefore a true marketing tool that facilitated successful negotiations. After award of the contract, both models were used as public relations tools for demonstrating the shipyard's capabilities.

B. *Benefits For Designers*

Designers have the opportunity to make use of many different model types as shown in Figure III-1. Development of a detail design, although often subcontracted, for the purposes of this section is considered as a basic shipyard function. Models which can be used effectively by the designers are display models, scientific test models, shell plating models, detailed structural models, distributive systems models, and operating mechanical models.

1. *General Arrangements and Miscellaneous Mechanical Problems*

Most general arrangements can be properly developed using graphic techniques. However, where tight or unusual arrangements are required, three-dimensional modeling may be effectively employed. A complex structure can be simply and quickly modeled in cardboard which will "prove" the design and which will facilitate testing a number of alternative construction plans.

Main deck arrangements often warrant careful consideration. The arrangement of anchor handling gear, cargo handling gear, mooring winches, fair-leads, bits and chocks can be laid out on a simple model if it is felt that graphic techniques are inadequate to insure proper design. If a display model is constructed for other primary purposes, it may be used for this secondary purpose. If certain aspects of these arrangements are unusual or if critical mechanical problems are envisioned, a working mechanical model of particular cargo handling or mooring systems may be constructed. In most ship designs an anchor handling model is the only way to "prove" a complete ground-tackle design prior to actual construction. It is often prudent to make operating mechanical models for unprecedented designs for davits, large watertight doors, cargo stowage equipment, below deck conveyors, power operated hatch and ramp covers, etc. Generally the engineering department will initiate construction of mechanical models.

2. *Detailed Structural Configuration*

While general arrangements are being developed, compatible structural configurations must also be developed. Where structure is very complex, the designer may find it of great benefit to construct a detailed structural model. In addition to structural adequacy, such issues as standardization, allowable clearances, and foundation locations can be readily resolved. The same model can be used by planners, at an early stage, to comment on features which effect productivity.

3. *Ship Resistance and Propulsion*

With few exceptions; engineering conventionally requires model tests to be performed for propeller and hull design. Such test models are generally built by professionals and tested at model basins. The techniques for construction and testing are highly developed and automated. They are not within the scope of this manual since such models are not normally constructed in shipyards.

4. *Strength and Vibration Analysis*

Scientific test models are often effectively employed to solve complex problems in stress, deflection, or vibration analyses. Evidence suggests that in some cases they can be more accurate and even less costly in the long run than analytical methods presently available. This is especially true for ship structure which is often asymmetrical and always complex. With careful planning of materials and construction, the detailed structural models mentioned can also be used as scientific test models.

5. *Fluid and Electrical Systems Development*

One of the most critical design functions in the shipbuilding process is the location of components, piping, ducting, and wireways in the ship. The major problem is that many different systems are being developed by many different groups. To insure that the locations of these systems are compatible with each other as well as the surrounding structure, a design control method must be employed. As implied in Chapter II, the distributive systems model can be a highly useful tool to accomplish this task. Component arrangements can be more carefully thought out for functional and cost purposes. Piping, vent duct, and cable runs can be more readily located so as to minimize interferences. When one considers the high cost of. removing, refabricating, and reinstalling a pipe run to make way for a length of ducting, it is easy to see the value of eliminating every interference at the onset. It is not surprising that estimates of 2 percent to 4 percent savings in total vessel cost have been made for interference elimination. On a ship costing $30 million, this becomes very significant. It must be noted, however, that simply having a model constructed does not guarantee that interferences will be eliminated. There is a companion need for a system of discipline which identifies responsibilities and provides for systematic information flow. This system must allow the model to control the design, not the design controlling the model. This is the major differences between a design-control model and a design-check model.

6. *Training*

All types of models discussed in this report can perform the very important function of training engineering personnel new to the project or new to the job. Such visual aids should not be neglected for use in this regard and careful thought should be given to retaining models which would normally be discarded after their primary job was completed.

C. *Benefits For Loftsmen*

Perhaps the shipyard personnel most skilled in their ability to visualize the third dimension are those in the mold loft. Even so, there is still an opportunity for them to derive significant benefit through the use of shell plating models and detailed structural models.

A more novel use of models in the loft is the use of structural models as training tools. Especially when the shipyard is building a new class of vessels, it has been shown during this study project to be quite beneficial to build one highly detailed plastic model to a scale of 3/4" = 1' of a typical section. By familiarizing loftsmen with typical structure and standard details for each new contract, much learning time is saved. In effect, one model maker does the research for many loftsmen. Start-up time saving can be significant and rework may be reduced.

D. *Benefits for Planners and Production Craftsmen*

Because the planning function is closely related to actual production, this section treats the potential model uses of these two areas together. In fact, the very existence of such models promotes better communications between designers, planners and production craftsmen. The model types which can be used effectively by planning and production are detailed structural models, erection unit models, distributive systems models, and facilities models.

1. *Erection and Sub-Assembly Planning*

Establishing the master butts and seams which define erection units is one of the earliest planning functions. Subsequently the manner in which each erection unit is divided into subassemblies must be planned. For the first ship of a new design, detailed structural models of typical units may be made in order to verify structural interfaces and to determine erection feasibility. Only structure which is pertinent for the erection process or key sub-assembly butts and seams should be shown. Repetitive structure should be avoided. In addition to typical units, it may be especially helpful to model any complex or unusual unit to identify problems at an early stage. By constructing such models, the planners can solicit comments from production personnel before drawings are completed, and with minimal time away from their existing work.

2. *Erection Scheduling*

Very often, especially when the building site is loaded to capacity, crane clearances and limited buffer storage areas can become severe problems. In such cases, a simple erection unit model may be constructed to simulate and “prove” proposed erection sequences. Later, the model can be used to monitor the actual sequence and study alternatives that may become necessary as work progresses.

3. *Assembly Planning*

The methods of unit and sub-unit assembly can often be more easily determined through the use of detailed structural models. Special jigs must often be designed. The geometry of such jigs can be tested by modeling them and simulating the manufacture of modeled sub-assemblies. Modern construction methods require turning of large flat panels and sub-assemblies to facilitate downhand welding. Detailed structural models can be used to determine centers of gravity, to locate lifting pads and to design special rotating jigs. The models can often be used to reduce the cost of lifting pads by making the maximum use of existing structure.

Many shipyards in the U.S. were designed and built at a time when practically all assembly was carried out on the ways. As a result, many yards lack all but barely adequate clearances on roadways and craneways for today’s larger units. Under such conditions, it can be extremely useful to planners to have an overall and continuously updated shipyard facilities model to plan or verify the routing of units and panels through the yard. In addition, the most efficient use of buffer storage areas can be planned by the systematic arrangement of sub-assembly models directly on the facility model.

4. *Pre-Outfit Planning*

Planning the extent of pre-outfitting and its sequence in relation to the assembly process can be facilitated through the use of models. Drawings are usually sufficient for pre-outfitting of flat panels and innerbottom units. However, if structural models already exist, the process can be made easier. In larger, three-dimensional spaces such as the engine room, there is much difficulty in visualizing pre-outfit candidate items from plans. An engine room model can be invaluable in this regard. Further, a model serves as excellent orientation if the drawings used for pre-outfit do not anticipate working in a unit that is upside-down.

5. *Welding*

Insuring welding access to complex structural joints and seams is of utmost importance in controlling and minimizing assembly cost. Detailed structural models allow easy input from the welding engineer and foremen toward correcting design inadequacies of this nature.

Distortion and shrinkage is another serious welding related problem in shipbuilding. Proper welding sequence can serve to minimize distortion. Again, the detailed structural model can aid the welding engineer to specify the optimum welding sequence in order to minimize distortion without seriously increasing welding manhours.

6. *Staging*

The necessity of staging, both fixed and portable, is a significant cost factor in the shipbuilding process. Detailed structural models can be invaluable in developing the most efficient staging plan or in designing improved staging methods.

7. *Training*

A significant benefit from building structural models for planning and production purposes is their use in training personnel from management to mechanic. Detailed structural models, erection unit models, distributive systems models and facilities models can all be used to educate and/or orient personnel new to the job.

E. *Benefits for Facilities and Production Planners*

The benefits to be gained from a shipyard facilities model are the ability to make management fully and accurately cognizant of present conditions in the shipyard and to foresee future situations and needs. There is really no analytical method of assessing the dollar value of benefits as the largest derived are from the *prevention of mistakes* and optimization of facilities brought about by the use of models.

1. *Movement Flow and Space Allocation*

With an overall shipyard facilities model, including representations of ships currently under construction, the planners can readily see and foresee problems related to movement and space within a yard. This is a particular need for those yards where space is critically limited. The model is used to determine how items can best be moved from point to point. The model will instantly identify physical restrictions that impede specific movements. For flow, the model can be used to determine the best routing for raw materials, fabricated and assembled structural units and outfitting components.

2. *Key-Event Planning*

The facilities model can serve to quickly provide the information necessary to make the best decisions concerning such matters as crane availability, ship lay-down on building sites, berthing locations, and ship movements between docks. For these purposes the facilities model shall include scale representations of all ships as partially erected, or afloat during final outfitting. Thus, time phased situations can be created in order to visually represent the loading on the entire shipyard in terms of key events and schedules.

3. *Facilities Planning*

A facilities model can be used as a prime tool in developing and evaluating plans for contemplated new or modernized shipyard facilities and equipment. The three-dimensional aspects will quickly verify clearances, interferences and other spatial factors of new structures or equipments. If one specific area of the yard is to be upgraded, it can be modeled separately and perhaps in a larger scale. Presentations of this nature will aid management in ensuring that improvements or expansions are consistent with their long-range plans. More detail regarding the use of facilities models in this regard is presented in Chapter VI, Section H.

CHAPTER IV
THE COST OF SCALE MODELS EMPLOYED IN SHIPBUILDING

In order to assess the value of an “in-house” model program, it is necessary to evaluate the cost of models previously built for shipyard use. As part of the research for this manual, several model sections were constructed. Throughout the project, log books were kept of daily events to note progress, and accurate records were kept of all time and money spent in connection with the model building. Since this project included many indirect sources of time and expense, such as research on modeling methods and materials, only that time which was directly spent in model building was included in the cost analysis. It should be noted, however, that most companies would want to include a set-up cost on model shop equipment and place some value on model shop space to determine the real company expense for the model building.

The model work for BIW was done by subcontract to a professional model builder with established facilities. The labor cost data reflects a true learning situation, since the model builder had never built plastic structural models and his helper, hired to help meet the project schedule, was inexperienced in reading drawings and in building models. The labor cost also included the time and material expenditures for rework. The cost of rework was reported to be a small percentage of the total (although no specific totals were available) except in the case of the complex RO/RO midbody and the 25,000 DWT tanker engine room, where continually changing designs necessitated much repetition of efforts.

In the following sections, a description of each “model package” is presented to give clear meaning to the cost of materials and the manhour expenditures associated with each. Then, using the cost data available, a method for estimating the cost of a hull structural model is developed and presented along with examples.

A. *Model Package Descriptions and Cost Data*

Four structural models were built by BIW. Three were hull structural models of a 25,000 DWT tanker, and one was a hull structural section of a roll-on/roll-off cargo ship. The following describes the sections modeled:

1. *Model Package I*

This model package consisted of a hull structural section of a 25,000 DWT tanker midbody. The model represented a structural section 78' long, 66' wide and 45.5' high. The scale was 3/4" = 1', and the material used was clear plexiglas and “Lexan” sheet in thicknesses of 1/16" and 1/32". The section included structure from frame 62 to frame 71 and from the baseline to the main deck of the tanker representing four erection units. In order to avoid unnecessary duplicity, the model included only one wing tank, a centerline tank and detailed structure for one web frame, one swash bulkhead, one oil-tight bulkhead and all unit interfaces. The material costs were approximately $202, and the model took 890 manhours to build. With a hypothetical three-man model shop including two men working 40 hours per week

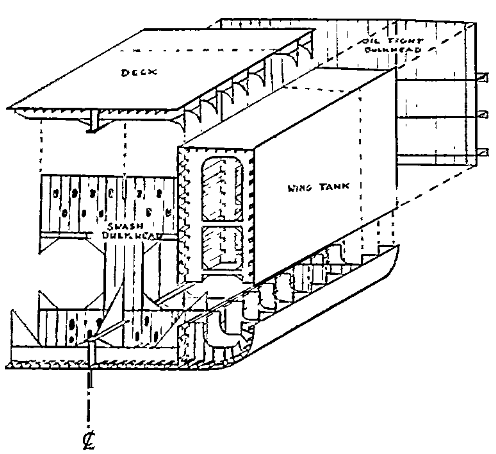


Figure IV-1: Sketch of Model Package 1, 25,000 DWT Tanker Midbody, Looking Aft

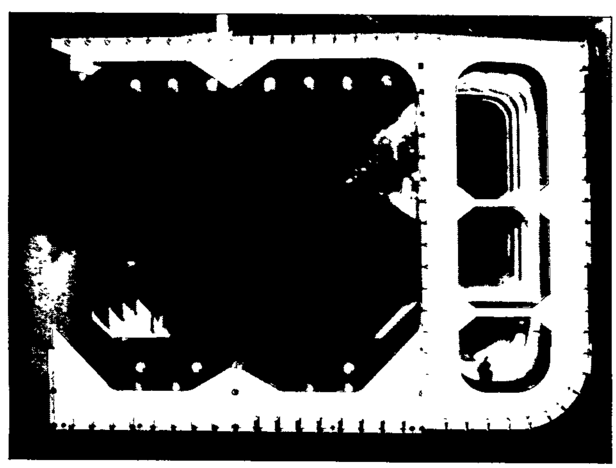


Figure IV-2: Photo of Model Package 1,25,000 DWT Tanker Midbody Model Scale 3/4" =1', Material: Plastic

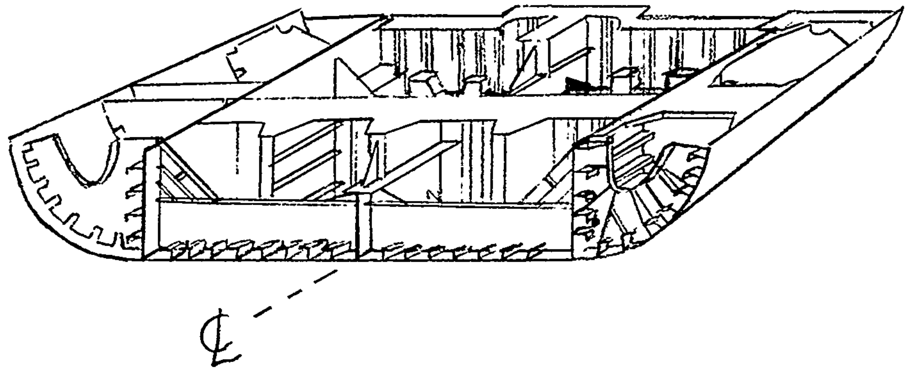


Figure IV-3: Sketch of Model Package 2, 25,000 DWT Tanker Pumproom Base, Looking Aft

and the third man working 20 hours per week, the manhour expenditure represents about two months of work. However, with an experienced shop, it is believed that these hours could be reduced by as much as 30 percent. Model package 1 is shown in the sketch in Figure IV-1 and the photo in Figure IV-2.

2. *Model Package 2*

This model package consisted of a hull structural section of a 25,000 DWT tanker from frame 71 to frame 80 and from the baseline to the 12' level. The model represented a section of one unit in a size 30' long, 60' wide (average) and 12' high. The scale was 3/8" = 1', and the material used was cardboard in 1/16" thickness. The model included detailed structure for the lower webs. The material cost was approximately one dollar and required 112 manhours to build. Using the hypothetical model shop with 100 manhours a week, this model package would have required about one week to complete. Model package 2 is shown in the sketch in Figure IV-3 and the photo in Figure IV-4.

3. *Model Package 3*

This model package consisted of a complex hull structural section of a RO/RO cargo ship. The model represented a section that was 42.5' long, 41.5' wide (average) and 69.5' high. The scale was 3/4" = 1' and it was constructed of clear plexiglas and "Lexan" sheet of 1/16" and 1/32" thicknesses. The section included

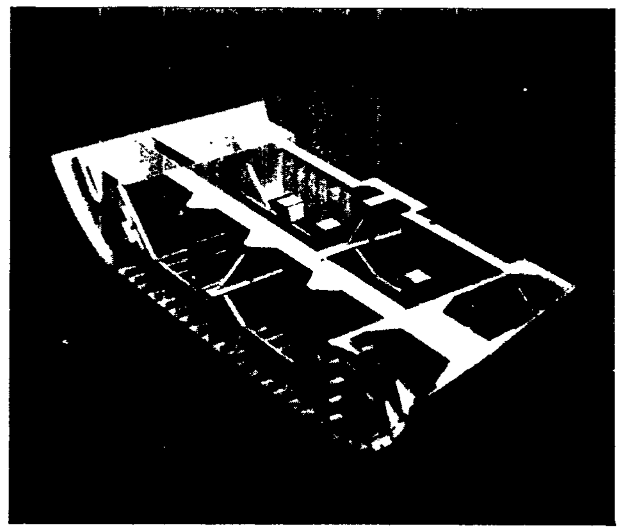


Figure IV-4: Photo of Model Package No. 2,25,000 DWT Tanker Pumproom Base. Model Scale 3/8" = 1', Material: Cardboard

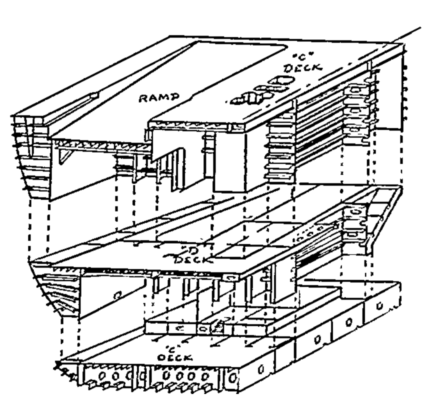


Figure IV-5: Sketch of Model Package 3, RO/RO Midbody, Looking Aft

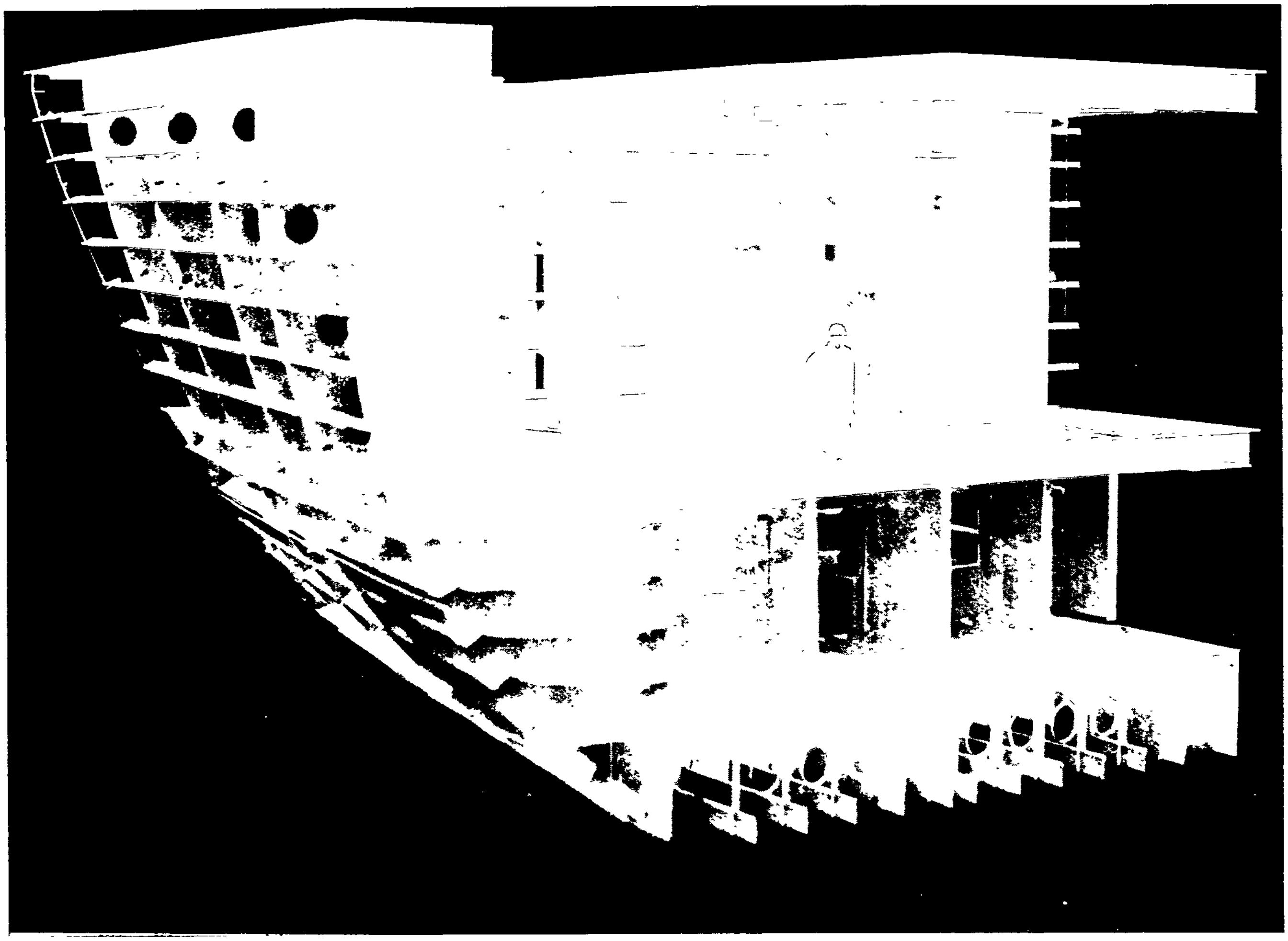


Figure IV-6: Photo of Model Package 3, RO/RO Midbody. Model Scale 3/4" = 1'. material: Plastic

structure from frame 158 to frame 172 and from the baseline to the main deck. The structure was detailed for the starboard side and overlapped the centerline to include pillars at the centerline and the first seam on the port side. Typical webs, longitudinals, stiffeners, cutouts and brackets were detailed. The material costs were $230 and required 600 manhours to complete. Using the hypothetical model shop with 100 manhours a week, this model package would require about six weeks to complete. Model package 3 is shown in the sketch in Figure IV-5 and in the photo in Figure IV-6.

4. *Model Package 4*

This model package consisted of a hull structural section of a 25,000 DWT tanker stern. The model represented a section that

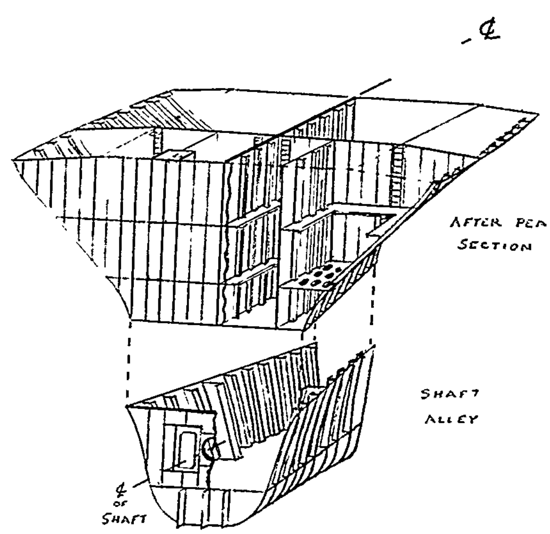


Figure IV-7: Sketch of Model Package 4, 25,000 DWT *Tanker Stern Section, Looking Aft* was 27.5' long, 50' wide (average) and 45.5' high. The scale was 3/4"= 1', and it was constructed of clear plexiglas and "Lexan" sheet of 1/16" and 1/32" thicknesses. The section included detailed structure from frame 104 to frame 116 and from the baseline to the main deck. This model encompassed two erection units. The material costs were $125 and required 400 hours to complete, which corresponds to four weeks' work for the hypothetical 100 manhour per week model shop. This

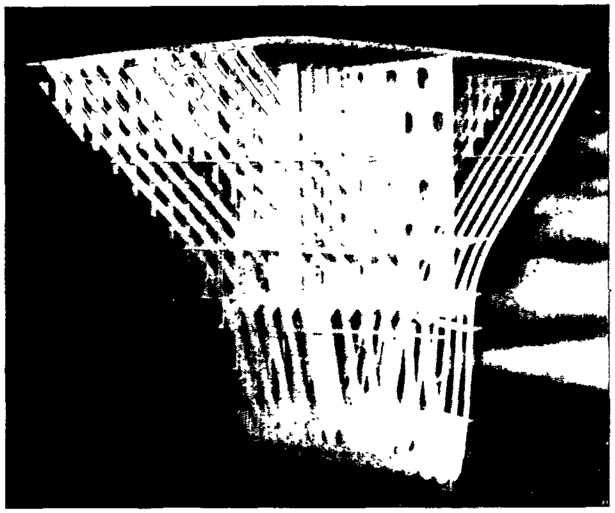


Figure IV-8: Photo of Model Package 4, 25,000 DWT Tanker Stern Section. Model Scale 3/4" = 1'. Material: Plastic

model package is shown in the sketch in Figure IV-7 and in the photo in Figure IV-8.

5. *Model Package 5*

This model package consisted of a detailed superstructure model of the after deckhouse of a 25,000 DWT tanker. The model, built in 3/4" = 1' scale, represented a section 60' long, 62' wide and 55' high. It was constructed with 1/16" clear plexiglas for decks and bulkheads and gray plastic injection molded structural shapes for stiffeners. The modeled section included the main deck, 01, 02, 03, 04 and 05 levels and partial outfitting including ladders, windows, doors and storm rails. The internal structure, joinery bulkheads, one-inch diameter and larger piping (including insulation), vent system, electrical wireways, and all electrical systems' components were modeled. This model encompassed four erection units. The material costs were $1,100 and required 2,500 hours to construct. The high material cost was due to the use of expensive injection moldings for stiffeners that cost four times that of similar stiffeners fabricated from plexiglas and accounted for over 1/3 the total material cost. The model is shown in the photo in Figure IV-9.

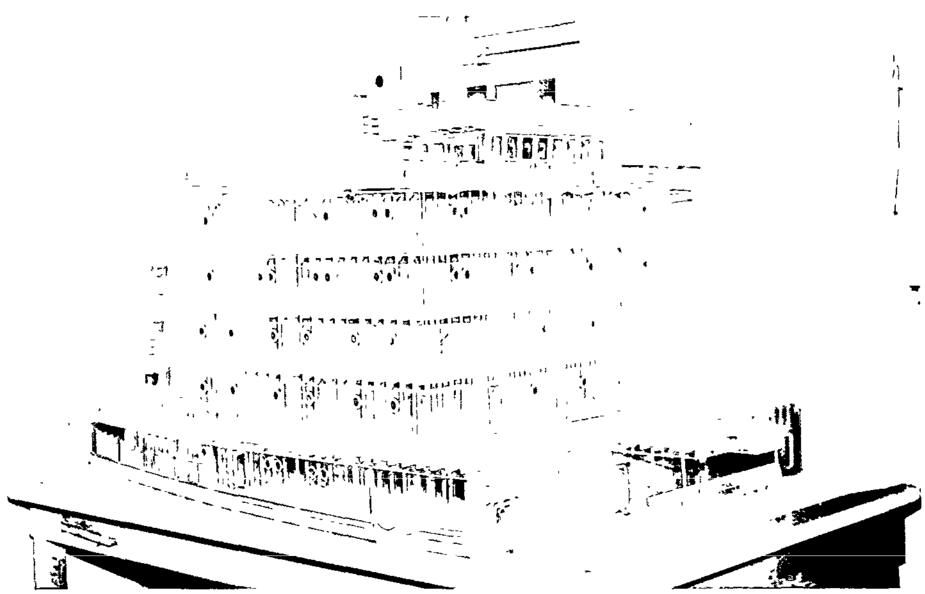


Figure IV-9: Photo of Model Package 5, 25,000 DWT Tanker Deckhouse. Scale ¾" = 1'. Material: Plastic.

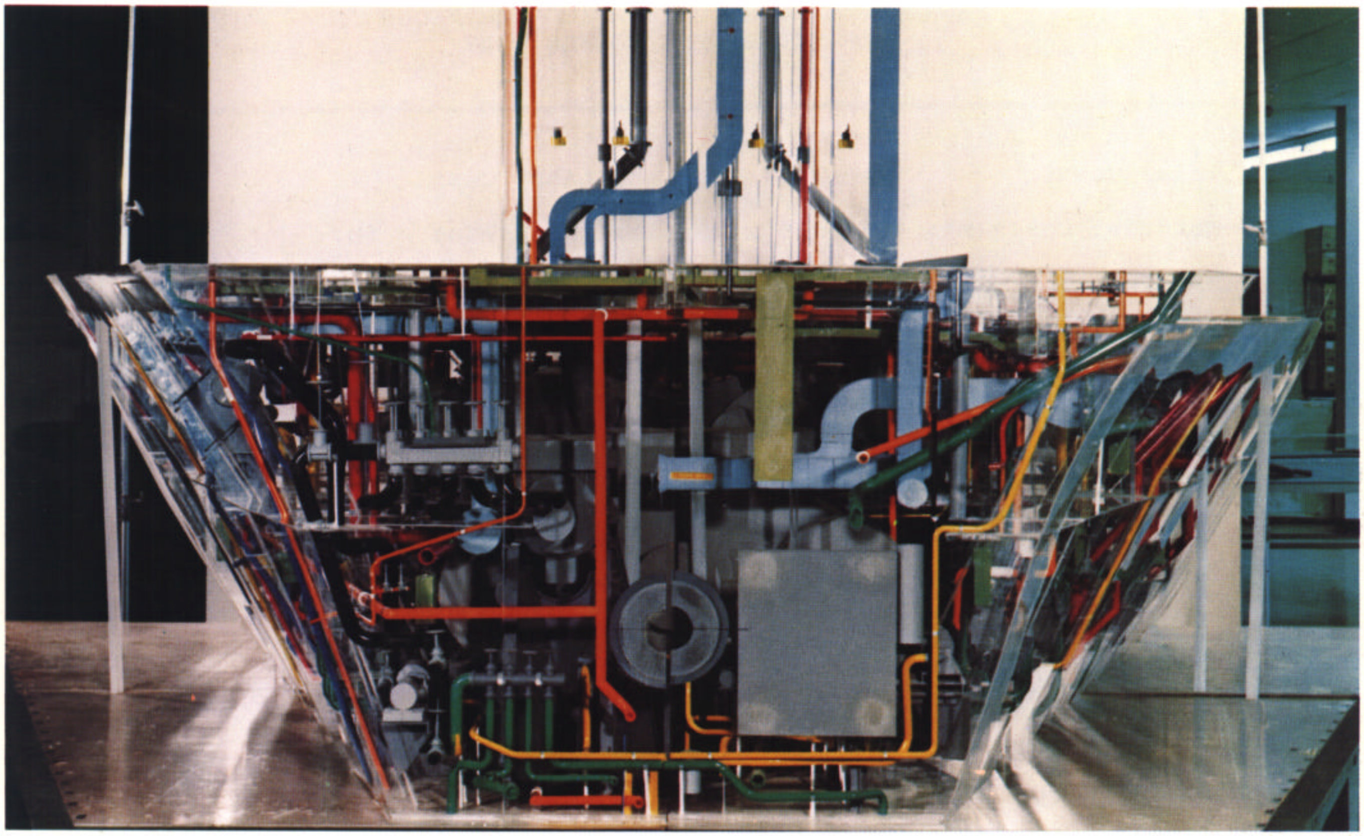


Figure IV-10: Photo of Model Package b, Machinery Spaces for 25,000 DWT Tanker. Scale: 1-½″ = 1′. Materials: Plastic Sheet, Foam, Plastic Pipe and Fittings.

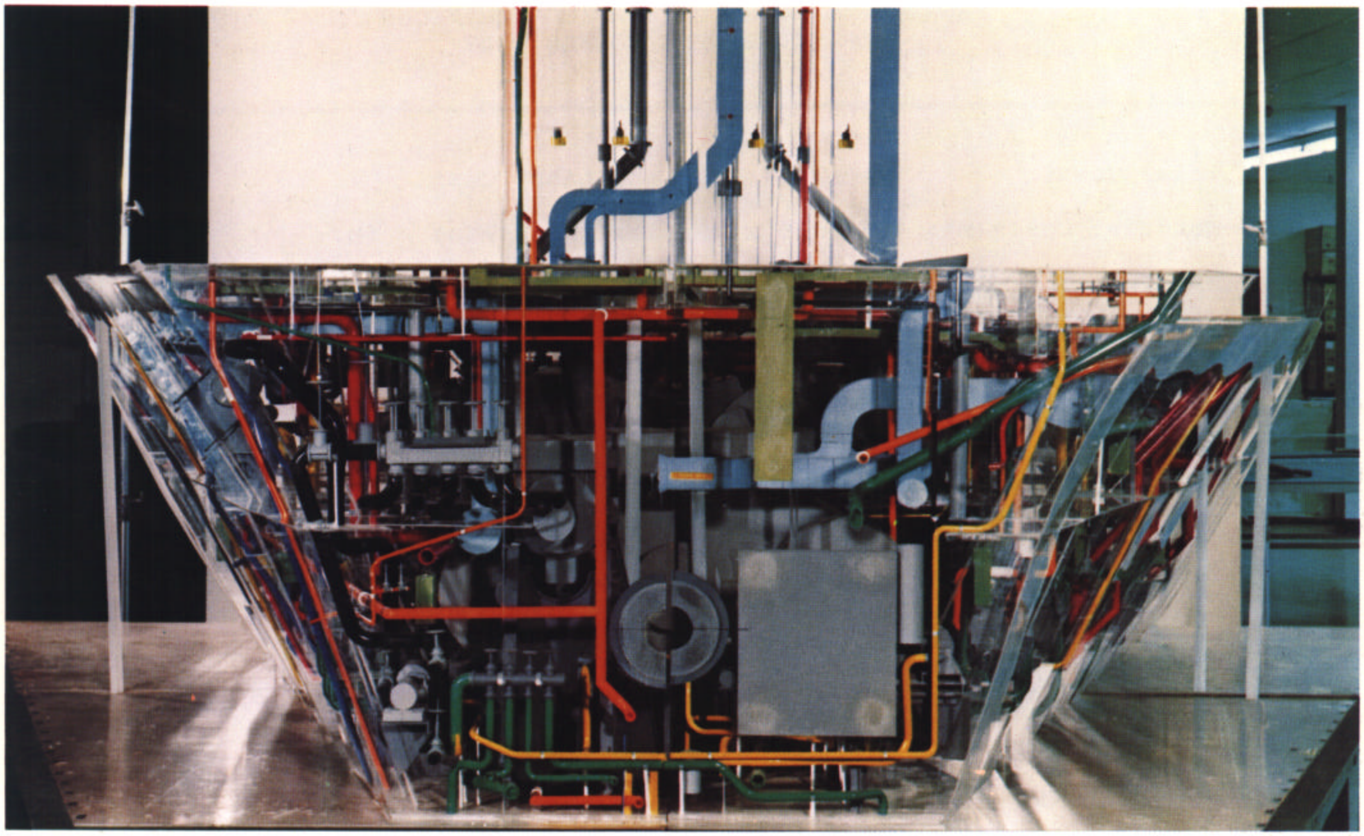
6. *Model Package 6*

This model package consisted of an engine room layout of a 25,000 DWT tanker. The model was constructed in 1½″ = 1′ scale and represented a section 61.5′ long, 61.5′ wide (average) and 27′ high. It was constructed of clear plexiglas for the engine room structure in ⅛″ and $^{3}/_{16}$″ thicknesses. Detail outfitting was accomplished by the use of No. 4 density foam for odd shaped items, premolded plastic piping obtained from a model parts suppliers, and plexiglas sheet and tubing. The section included all detailed outfit of the engine room and pump room including machinery, foundations, piping, ladders, ventilation ducting and electrical outfit. The material costs were $3,865, and the model required 4,190 manhours to construct. This model is shown in the photo in Figure IV-10.

B. *Approximating Model Costs*

When a decision is made to investigate the potential benefit of utilizing a model, one must have some means of estimating the costs that will be incurred. If cost data is available for a similar modeling job, a quick comparison may yield enough information for an adequate estimate. However, each modeling project can vary significantly from other "similar" projects. The scale and overall size of the ship section modeled, its complexity, the scale chosen, the materials used, the degree of outfitting, the extent of rework, degree of accuracy, the experience of the model builder and the model builder's hourly rate are among the various factors that have impact on the final cost.

With this in mind, a method of estimating the rough order of magnitude cost range for structural models is developed. Because of the limited data base available in developing and verifying the model cost equation and the vastly differing types of models and modeling situations, careful judgment must be applied when using this cost estimate equation. *It is best used for guidance only*. The basic assumption is that model costs are proportional to the size of the ship-section to be modeled when corrected by several significant factors. The ship-section size is always described by its "block number" (length × breadth × depth).



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SUMMARY OF COST ESTIMATING EQUATIONS FOR STRUCTURAL MODELS ONLY

Total Cost: Material Cost and Labor Cost.

1

Material Cost*(M): 489 x B x $(Scale)^3$ x (fs+fo) x fm.

1

Manhours (L): 526 x B x (fs+fo) x fb.

B = Block Number = L x W x D of Section Modeled. (In **actual** ship Dimensions = ft^3)

Scale = Scale of model in inches per foot.

fs = Structural complexity factor.

Ship Type	Location	fs Range	fs Average
Tanker-Bulk Carrier	Midbody	.5-1.5	1.0
Tanker-Bulk Carrier	House	1.0-2.0	1.5
Tanker-Bulk Carrier	Stern	1.5-2.5	2.0
Container	Midbody	1.0-2.0	1.5
Container	House	1.0-2.0	1.5
Container	Stern	1.5-2.5	2.0
Barge Carrier	Midbody	1.5-2.5	2.0
Barge Carrier	House	1.0-2.0	1.5
Barge Carrier	Stern	1.5-2.5	2.0
RO/RO	All Hull Sections	2.0-3.0	2.5
RO/RO	House	1.0-2.0	1.5

fo = Outfitting factor
- 4.0 Detailed Outfitting
- 2.0 Partial Outfitting
- 0 No Outfitting

fm = Material factor
- 0.2 Cardboard
- 1.0 Plastic
- 70.0 Balsa Wood

fb = Model builder factor
- .5 Highly Experienced
- 1.0 Experienced
- 1.5 Average
- 2.0 Inexperienced

*1973 Dollars

FIGURE IV-11

1. *Cost Estimate Equations*

Figure IV-1 1 is a summary of the equations and constants developed to separately estimate material costs and labor costs incurred in building a structural model with or without outfitting. The equations are based on constructing a precise model of high detail similar to those shown by the photographs of Figure IV-1 through IV- 10. *Therefore, an upper limit is represented.* If less detail is developed, if less attention is paid to precision (which may be desirable) the costs will be reduced. This is where judgement must be applied.

The equations do not apply to machinery space models. They are usually built by professional model builders and they vary considerably in complexity and method of use (affects rework). Therefore, an estimate of the cost of a particular model is best obtained from several of the professionals listed in Appendix A. For guidance, the cost of a 25,000 DWT tanker machinery space model is given in Section A-6 of this chapter.

The following is a brief explanation of how the structural cost estimate equations were developed for material and labor.

a. *Material Cost*

The material cost equation is:

M(dollars) = 1/489 X B X $(\text{Scale})^3$ X (fs + fo) X fm. (See also Figure IV-1 1.)

The assumption here is that material cost is porportional to the physical model size (B X scales) corrected by a structural complexity factor (fs) plus an outfitting complexity factor (fo) multiplied by a material factor (fm).). The constant 1/(489) was solved for using data from a 25,000 DWT tanker midbody section. The values of fs, fo, fm shown in Figure IV-11 were determined using the judgement of model builders and engineers. The equation was tested using other data available from the project as shown above:

Model	*fs*	*fo*	*fm*	*Calc Cost*	*Actual cost*
Tanker Midbody*	1.0	0.0	1.0	$202	$ 202
Tanker Stem	2.0	0.0	1.0	108	125
RO/RO Midbody	2.5	0.0	1.0	264	230
Tanker Deck-house	1.5	2.0	1.5**	926	1,100***
TankerPump-room Base	2.5	0.0	0.2		1

*Base
**Expensive Injection Molded Stiffeners Used
***Approximated From Material Report

b. *Labor Cost*

The labor cost equation is: L (Man-hours) = 1/526 X B X (fs + fo) X fb (See also Figure IV- 1 1.)

The assumption here is that labor is proportional to the ship size of the area modeled corrected by a structural complexity factor (fo) plus an outfitting complexity factor (fs) multiplied by a builder experience factor (fb). The constant, 1/526, was solved for using data from the MSC midbody section. It is assumed that the labor cost is relatively independent of the scale factor used. This is not entirely true. The same number of parts will be lofted, fabricated, and assembled regardless of scale but the linear feet of cutting and joining is increased by the ratio of the scales. The above equation is for a scale of 3/4 " = 1'. A slight reduction in labor cost for cutting and joining may be be realized if the scale is reduced. The labor cost equation was tested in a similar manner to the material cost equation as shown below.

Model	*fs*	*fo*	*fb*	*Calc Hours*	*Actual Hours*
Tanker Midbody*	1.0	0.0	2.0**	890	890
Tanker Stem	2.0	0.0	105**	357	400
RO/RO Midbody	2.5	0.0	100**	583	600
Tanker Deckhouse	1.5	2.0	2.0	2,723	2,500
TankerPump-room Base	2.5	0.0	1.0	103	112

*Base
**Note Learning Situation For Same Model Builder

C. *Example*

The following is a simple example of a cost estimate for a RO/RO mid-body section. Assume:

fs = 2.5 (complex midbody)
fo = 0.0 (no outfit)
fm = 1.0 (plastic material)
fb = 1.0 (experienced model builder)

Block Number:

B = L X W X B = 42.5' X 41.5' X 69.5' = 122,581'^{3}

Material Cost:

M = 1/489 X B X $(\text{scale})^3$ X (fs + fo) X fm

M = 1/489 X 122,581 X $(3/4)^3$ X (2.5+ 0.0) X 1.0

M = $264

Actual Material Cost: $230.

Labor Cost:

L = 1/526 X B X (fs+fo) Xfb

L = 1/526 X 122,581 X (2.5 + 0.0) x 1.0

L = 583 manhours

Actual manhour expenditures = 600 hours.

CHAPTER V
CONSTRUCTION METHODS AND TECHNIQUES

For the shipyard contemplating a model program, there are three approaches that should be considered:

- Fabricate the models of cardboard or balsa in the department that is concerned with solving a problem. This approach is desirable because the actual people who must find a solution are the ones involved with constructing the model as an aid in finding that solution.
- Establish a general use shipyard model shop. This approach will enlarge the scope of possible model work. More exacting work in various materials, primarily plastics, can be accomplished. The prime advantage to such a shop is that any department needing a model will have a skilled staff to call on.
- A combination of the above two approaches. This is the approach that was found to work most successfully. Areas of concern that can be clarified by a cardboard model are built within the using department. Scientific test models or any structure needing the accuracy of plastic fabrication methods, parts for facilities models, etc. can be handled by the model shop.

Because models vary to such a great extent, no set of rigid "how-to" instructions can be established. If structural models are assembled in the general sequence of the actual ship structure (see Section B-10 of this Chapter), and systems models follow generally the step-by-step procedures in Section C of this Chapter, no great difficulty should be experienced. It was found during the project that the learning curve of adequate modeling techniques rises rapidly with shipyard personnel who have certain qualifications as described in Section B-6 of this Chapter. As skills develop, accuracy increases and manhours required to accomplish set goals decrease almost without individual awareness.

Certain criteria apply to all modeling irrespective of the subject modeled. The size, material and completeness of detail are all a function of the objective desired. While the cardboard study model is only a three-dimensional sketch which usually needs neither dimensional accuracy nor good visual impact, a plastic structural model should be strictly to scale to aid in the quality of data available from it. At the same time, the extent of detail modeling should be strictly controlled as the tendency of the builder is to overmodel. Only those details required for clearance, access, function, etc. should be included. The accuracy of the information the modeler works from will greatly affect the achievable detail. For example, on a cardboard study model the hull curvature at frames can be derived from blue print tracings but it is futile to pursue the accuracy needed in a plastic model using this method. A lines drawing of the needed area, to the same scale as the model should be reproduced from the master lines on mylar. Also, immediate notification of design change-s to the model builder will greatly reduce needless modeling and its associated expense.

A. *Structural Models Built In Design And Planning Departments*

Models that are to be built as a function of the engineering and/or planning departments are generally limited to cardboard or balsa wood as building materials. The materials used must be capable of being cut and formed quickly, with no dust or noise and with a minimum of tooling. In some phases of construction, cardboard modeling will save little, if any, construction time as compared to plastic modeling. The multiple cutting possible with plastic (set-up jigged operations on a table saw) must all be done individually by hand for cardboard. Generally, however, a cardboard model will be constructed in a shorter time than a plastic model as it is a relatively gross product in terms of material thickness, and no attempt should be made to pursue the accuracy or detail found in a plastic model.

1. *Materials, Scale and Techniques*

a. *Cardboard*

The major advantage of a cardboard model is its ability to be constructed in an engineering or planning department atmosphere where it can be subject to constant scrutiny and change. Under this concept, it is a three-dimensional aid in discovering problem areas, but should not be used for taking off accurate dimensions as can be done with plastic models.

The choice of scale for a cardboard model is generally controlled by the scale used on the drawings. While 3/8" = 1' is most common and produces the optimum size model, it need not be adhered to in all cases. Model pieces with other than straight edges, such as frames and bulkheads that show hull curvature, can best be taken directly from the drawings by carbon paper transfer or prickpunching through the drawings with a fine point on to the cardboard. The scale of the drawings showing those parts will, therefore, control the choice of model scale.

An advantage of prime importance gained from the relatively small size and light weight of the usual 3/8" = 1' cardboard scale model is portability. They can easily be picked up, revolved, viewed from all angles, carried to conferences, and taken out to the shops to demonstrate points of construction. Sealing and painting the model with inexpensive paints from spray cans will greatly increase their strength and add to their readability.

The soft grades of cardboard used by most yards as pattern stock are adequate for most model work. The thickness range for this type is from 1/32" to 3/32". Poster board or coated stock with a smooth surface on one or both sides can also be used. Thin, stiff file folder stock can be used for forming small brackets and shapes. It is advisable to use the thinner grades of template cardboard (1/32" thickness) for most of the model as difficulty in working cardboard increases with the thickness. If a full cross section of the ship is to be modeled, the thicker grades (1/16" thickness) should be used in constructing longitudinal or athwartship bulkheads for added strength.

It should be noted that because most cardboard has a grain, it will bend freely in one direction but not in the other. Advantage should be taken of this characteristic for ease of forming shell plating and other curved surfaces. Shell plating can be partly pre-formed by wetting the inner surface and leaving it to dry overnight. A natural shrinkage curve will develop. Plating curvature can also be formed by holding the cardboard by its edges and pulling it it over the rounded edge of a table several times until the proper curvature is achieved. The grain of the material should run parallel to the table edge. Curved surfaces of template cardboard should not be forced into place with the expectation that glue will hold it. The material has so soft a density that such a stress will separate the layers. Pre-formed shell plating can be held by contact cement. Compound curvature can be formed to some degree by rubbing the inside of the cardboard with the bowl of a warmed spoon.

Sharp bends should be scored on the outside of the bend line on all cardboard materials. This can be done with a dull knife or by cutting part way through the material. The forming of narrow flanges by bending is not advised with the heavier grades as the material separates. More satisfactory methods are to glue on the flange or to use lighter cardboard such as file folders. When constructing flanged members or shapes, the grain of the cardboard should run parallel to the flange. This will insure a clean, sharp bend and add rigidity to the finished member.

b. *Balsa Wood*

Balsa is a material that finds little favor with professional model makers due to its softness. It does serve well, however, in the engineering department model program because of its ease of cutting with a razor blade. It can be purchased from model supply stores in strips and sheets of many sizes and thicknesses. The hardness of the material varies, so the hardest should be specified when purchasing balsa.

2. *Adhesives*

Plastic resin glue (white glue), marketed in many brands such as Elmer's Glue All, is adequate. A better glue for the purpose is Tite-Bond sold by art, craft or model aircraft supply stores. For faster drying, Duco, Ambroad, Testors or comparable household or model cement is recommended. For contact cement, a brand such as Weldwood was found to be very effective.

3. *Tooling*

Among the most useful cutting tools available are matt knives or utility knives for heavy cardboard cutting, and fine, thin-bladed knives such as scalpels, X-Acto or Grifhold knives, and single edge razor blades for thinner material. Manholes, access holes and similar round cutouts can be done best with punches. X-Acto knives have some punch blades available and additional sizes, normally used for leather, can be obtained. Steel straight edges and steel scale rules such as those sold by Engineering Model Associates are used for layout and assembly. They are available in %”, 1/2” or 3_A” = 1', in 6", 12" lengths and in 8' steel tapes.

It should be noted that cardboard and other paper products dull cutting edges rapidly. For this reason blades should be frequently honed. A piece of No. 360 grade wet and dry sanding paper or comparable fine emery, kept at the work table, will serve the purpose.

When cutting cardboard of any appreciable thickness, care should be taken that knife is held vertically to achieve a square edge cut that will insure right angle joints.

4. *Paints*

Several paint types which are excellent for their application on cardboard or balsa models are:

Ž Spray cans in various colors of fast-drying finishes such as Krylon Sealer available from most art or drafting supply houses.

Ž Touch-up paints from automotive supply stores.

Ž Home decorator spray cans from discount stores.

The important point in choosing paint for models is fast drying ability, not durability, so the least expensive finish will do. Where conditions make it more advisable to brush the paint on, the rubber base decorator colors found in builder’s supply or paint stores will apply well and are quick drying.

Cardboard should be sprayed with a sealer such as Krylon before color is added. Shellac is not recommended as a sealer because it will warp the structure. Sealer and any lacquer type paints should be sprayed first. Other type paints will apply well over lacquer but the reverse is not true. Models constructed for planning purposes usually have their units painted in different colors, for quick identification of breakdown lines when assembled. The sealing and painting of cardboard models stiffens and strengthens them to a great degree, thus adding to their durability and handling qualities.

Similarly, balsa models should be sealed before painting. Translucent sanding sealer is excellent for this purpose.

5. *The Model Builder*

The chief requirements for any model builder are manual dexterity and the ability to interpret drawings. These requirements are met by many draftsmen, loftsmen and mechanics in the yard. The one additional ingredient is that he have the ability to learn quickly and be responsive to the purpose for which the model is being built.

B. *Models Built By A General Use Model Shop*

1. *Setting up a Model Shop Facility*

This section, although covering the tooling and materials requirements for most categories of models, will concentrate on those needed for structural models, as they have been the prime concern of this study. However, a model shop set up for structural models and manned by experienced personnel will have little difficulty handling any type of modeling that a shipyard requires.

The creation of a complete model shop, while being the ideal answer to a shipyard’s ability to produce what it needs with full control, must be tempered with the knowledge that it may not have fill-time use. While it is true that having a complete model making facility will breed work for itself, the work load will rise and fall. For this reason, a more cost effective situation will result if the model shop is a combined function of an allied department. It should, in any case, meet the following requirements:

Ž It should be near and easily accessible to the engineering and planning department.

Ž Its personnel should be production and engineering oriented as well as being good, careful craftsmen.

The floor space required and the completeness of the model shop will, of course, be greatly affected by the demands put on it. Adequate work can be done in small areas but certainly not as efficiently. The ideal arrangement is to have one room for power cutting and shaping equipment, a paint room, and an assembly room. The latter should have adequate floor space for the following:

Ž Work benches and table areas for drawing perusal, hand work and sub-assemblies.

Ž A drawing board with drafting machine, plus a desk for the chief model maker.

Ž Adequate flat surfaced tables for assembly of models with sufficient walk-around working space.

Ž Walls in this area should be suitable to be used as photographic backgrounds.

Ž Storage areas for raw materials should be provided at easily accessible places.

Figure V-1 illustrates a practical model shop layout with suggested area dimensions. The arrangement is designed around material flow. A large outside door from a loading platform leads into the raw material stowage area. Racks for 12' wood lengths, 4' X 8' sheets of plywood and plastics, and plastic rod and tubing should be provided. As needed, raw material is moved to the power tool shop to be cut into workable pieces or for direct layout and finish cutting of parts. From here, workable raw material is sent to individual model maker's benches for layout. Finished parts flow to the paint room or directly to the assembly tables. Storage bins in the main shop supply purchased parts for pre-fabricating pipe runs at the modeler's work bench. All outfitting is installed at the assembly tables. All shop areas should have double or oversized doors for the movement of raw materials, large model components, or final assemblies.

Floor areas, of course, will be a variant of the amount of tooling, number of personnel and size and number of models built at one time. As with most space requirements, it is desirable, if possible, to have a larger floor space available than current needs call for, thus insuring that future demands can be met. Dust-free conditions should exist as' far as the exhaust system will permit. Good housekeeping should be mandatory, and, of course, good lighting is a must.

2. *Materials*

a. *Acrylic Sheets*

Acrylic sheet is available in clear. and transparent or translucent colors and in a wide range of thicknesses starting at .030". (Plastic rods, tubes and blocks are also available.) It is used for structural models, cases, scientific test and mechanical models, for internal visability. It is easily machined and easily joined. It is stocked in all plastic supply houses under various trade names such as Plexiglas and Lucite. Plexiglas should be purchased as quality "G" or commercial grade.

b. *Lexan*

Lexan is available in clear, tough surface coated sheets which, in the .030" thickness, may be brake bent cold for forming angles.

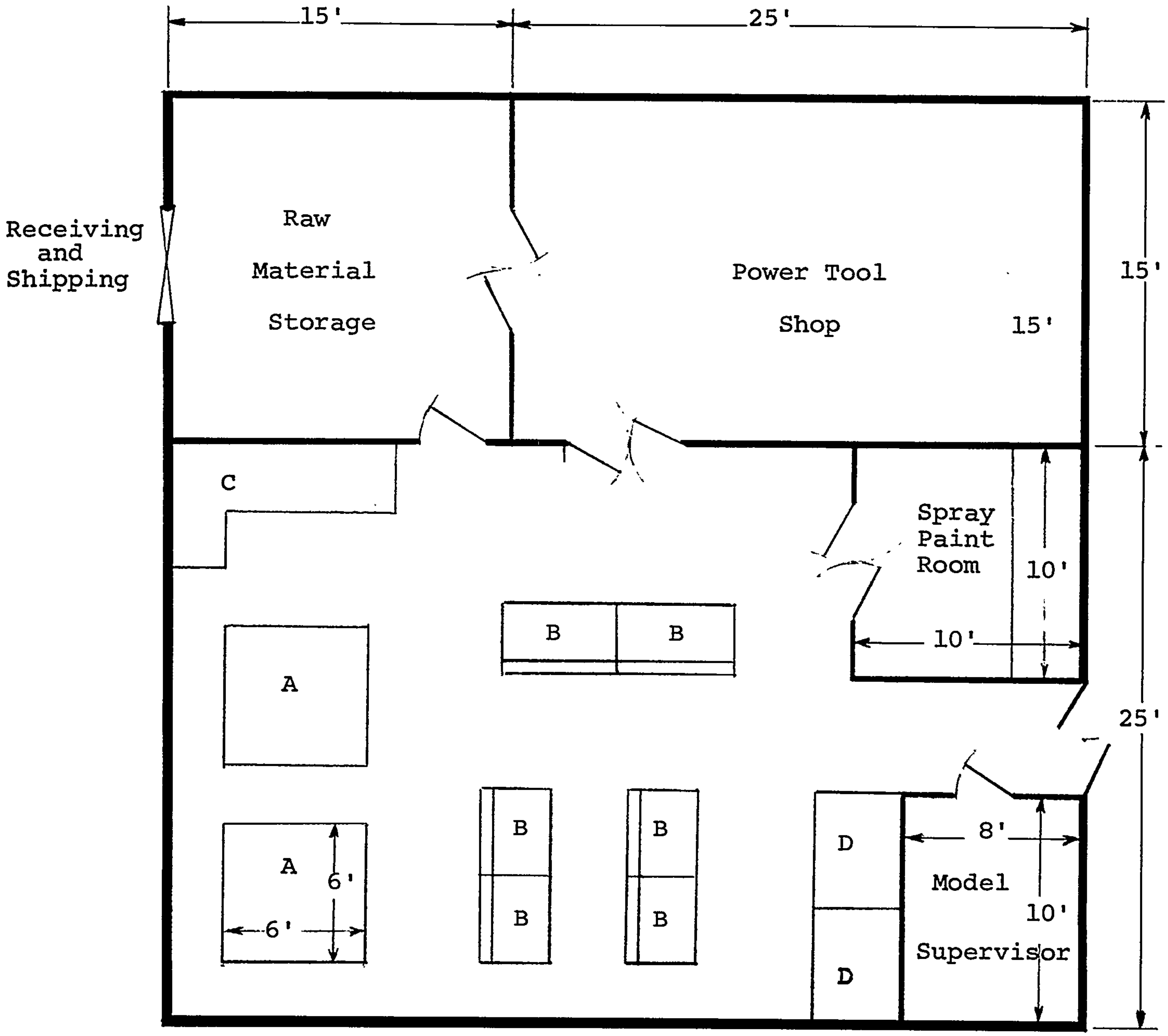
c. *Butyrate*

Butyrate, available in clear sheet form, is used for cold wrapping on curved (developable) surfaces. This is the same material used for factory made purchasable items such as pipe, fittings, shapes, ladders.

d. *Foamed Plastic*

Foamed plastics are used for build-

PRACTICAL MODEL SHOP LAYOUT



A - Assem. Tables

B - Model Makers' Work Benches

C - Prefab Parts Storage

D - Drafting Tables

Figure V-1

ing up large units, equipment and duct work. It is easily cut and light in weight.

e. *Polystyrene*

Polystyrene is better known by its trade name, Styrofoam. It is a white expanded foam available in one density. It may be cut with a hot wire cutter. It can be cemented but is attacked and will be dissolved by lacquers and by the cements used for plastic sheet.

f. *Polyurethane*

Polyurethane is a white expanded foam available in varying densities and colors (white, blue, yellow). Two-pound density is a good weight for most model shop requirements. It may be sawn, carved, sanded and cemented, but must not be cut with a hot wire cutter, as the resulting fumes are highly toxic. Dust from sanding and cutting this material can be an annoyance.

g. *Wood*

Wood is best employed for plating models, display models, facilities models, and test models. Below are the types most appropriate for constructing these models:

Ž*Select White Pine*

Suitable for framing and supports. In addition, white pine is a good carving wood for hull shapes.

Ž*Poplar, Whitewood, Basswood*

These woods are good for small details where more durability and workability are required than foam plastic offers. It is best purchased kiln dried. It has no prominent grain or sap.

h. *Metals*

Metals are seldom used today in models, because plastics fill most requirements satisfactorily at a more reasonable cost. To work metal, a whole new family of tools must be introduced into the model shop. Plastics have taken over even in mechanical working models because of their easier machinability and see-through properties. However, in display model work, rails and stanchions, deck fittings, spars or booms are frequently made of metal either for strength purposes, or duplication ability through casting techniques. When metal is used, brass is generally preferred because of its ease of workability and joining. Soft solder adapts itself to modeling methods more than riveting or other mechanical fastening methods. The easy machining properties of brass make it useful for lathe turning and milling, although aluminum is frequently substituted for large turning because of its lightness. The soldering of aluminum is difficult in model work, so mechanical fastenings or epoxy are generally used for joining this metal. Lead alloy castings (white metal) are to be avoided, particularly on display models, as they decompose in time, developing a fungus type growth on the surface. If the model shop is to do any casting of small metal parts, “brittania” metal, which contains no lead, should be used.

3. *Glues, Cements and Solvents*

a. *Plastic Resin Glue (White Glue, Elmers Glue-All)*

This glue should be used for all wood-to-wood joints, wood-to-cardboard, or on other porous materials. It is available in small quantities at hobby shops or can be purchased in larger amounts from local cabinet making shops or wholesale distributors.

b. *Epoxy*

Epoxy glue is best used for occasional non-porous material cementing, where high strength is required, metal-to-metal, metal-to-acrylic, etc. It is available in most hardware stores. A quick setting type is available from model aircraft hobby shops, or in larger quantities from industrial suppliers.

c. *Duco Cement*

Household cement, available in most stores, is quick drying and will hold fairly well on roughened surfaces of plastic as well as on wood and cardboard.

d. *Double Surface Tapes*

Double surface pressure sensitive tapes can be regarded as an adhesive in model work. These thin paper tapes will hold well where only light loads are applied if used on close mating smooth surfaces. In any other applications, the double-surface types with a sponge-type center hold best.

e. *Cements and Solvents for Plastics*

Plastic Parts and Sheets

Most cements for acrylic, buty - rate and Lexan are solvent types, flowing by capillary action, with a base of methylene chloride. Commercial plastic supply houses usually package their own brands, but the product Rez-N-Bond will answer most needs and is a good all-around solvent to stock.

Foams

Polystyrene foam will be attacked by the solvents in some glues. Epoxy resin adhesives or rubber cements work reasonably well for polystyrene. Polyurethane foam is less susceptible to solvent attack. However, white glue, epoxy, duco and rubber cement will work well for polyurethane. All adhesives used on foam should first be tried on a sample.

4. *Tooling*

Conveniently, both wood and plastics are worked by the same family of power tools. Speeds, feeds and blades can take care of most differences in cutting properties. Power tools are listed generally in their order of importance.

a. *Table Circular Saw and Blades*

The best all-around circular saw size for model building is 10", with provisions for varying arbor speeds. It should be equipped with oversize table extensions for handling 4' X 8' panels of plywood or plastic. A full complement of wood-working blades should be available. Plastic will rapidly dull blades, and most shops handling a large work load choose carbide tip blades for long life. These should be of the thin rim (.070 kerf) 66-tooth, 8" diameter size. It was found that they would, however, shatter 1/32" plastic. One alternate, smoother cutting blade, is a high-speed steel, 8" diameter, 150-tooth, 1/16" thick blade for cutting plastic. Their greatly reduced initial cost (as compared to carbide tipped) pays for many regrindings. Two of these blades kept in rotation between working and re-grinding serve well. Another alternative is to purchase inexpensive veneer plywood cutting blades, 6-1/2" diameter, 150-tooth and dispose of them when dull. When cutting plastic, blade speed should be in the range of 8-12,000 RPM.

b. *Drill Press*

A small, bench-type drill press should be adequate. Lock on chucks and the addition of a milling table will greatly expand its work range.

c. *Jointer*

A 6" medium-duty unit is sufficient.

d. *Disc and Belt Sander*

A 12" disc, 6" belt sander is a good size for most model shops. This tool is most important for making accurate joints.

e. *Band Saw*

A standard 14" wood cutting band saw is sufficient for most model shops.

f. *Scroll Saw*

A 24" scroll saw with step pulleys or variable speed device is sufficient for most model shops.

g. *Router*

A medium-duty, 1/2 to 7/8 H.P. router is desirable in most model shops.

h. *Lathe*

A metal turning 6" swing type lathe is sufficient for most model shops.

i. *Paint Spray Equipment*

A source of compressed air can be supplied by a portable medium-duty compressor in the event that the model shop is not connected to the shipyard's air supply. The most usable spray gun was found to be the DE VILBISS touch-up or equivalent.

An exhaust system with filters will be needed for the spray room or booth. All motors, switches, and lights must be fume and explosion proof.

j. *Brake*

A 3' bench model is sufficient for most model shops.

k. *Oven*

An electric oven with controllable heat range is usually required. A home electric oven, bakery pizza oven or larger type may be used, depending upon particular needs.

l. *Strip Heater*

A 3' electric strip heater is sufficient for most model shops.

5. *Hand Tools And Accessories*

For the wood working side of the model shop, the standard hand tools found in any cabinet or pattern shop are necessary. The following are of importance

- Hammer
- Screw drivers
- Model maker's plane
- Adjustable sole plane
- Draw knife
- Spoke shave
- Set of gouges; inside and outside
- Set of chisels
- Carving tools
- Clamps
- Carpenter's square
- Adjustable square
- Sliding "T" bevel
- Wood rasps and files
- The following additional tools are needed for plastics:
- Twist drills sharpened for plastic cutting
- Electric rotary tool (Dremel or equivalent)
- Electric heat gun (500 °F. to 750° F.)
- Miniature soldering iron
- Small back saw
- Scale rules
- Micrometer
- Squares
- Straight edges

6. *Skills Required*

Staffing a model shop must, of course, start with an experienced model maker/supervisor. As well as having the necessary manual skills and model making experience he ideally should be very familiar with lofting and marine terminology. Outside the shipbuilding field, model makers with aircraft experience will most closely come within the needed requirements. The modeler with only hobby experience should be avoided. While his skills may be very high, his understanding of commercial work is likely to be limited.

Model makers will probably have to be trained, as it will be a rare shipyard that can produce an experienced person from their labor pool. Trainees should be chosen from personnel who have:

- Drawing experience and good spatial understanding
- Knowledge of lofting
- Ability to perform manual operations with precision
- Ability to adapt materials, no matter what they were originally intended for, to express three-dimensional concepts.

Within the shipyard, personnel with these requirements usually come from the loft, cabinet shop, shipfitting or joiner departments. The model supervisor may set up a training program so that all personnel work within the" framework of his techniques (see references in Chapter VII, Section F).

Through practice, exposure to other examples of model making, and a well rounded collection of reference materials, a novice can develop into a craftsman capable of constructing models of varying complexity. Secondary talents that can be nurtured are the ability to plan each construction step thoroughly before undertaking it and a more expert knowledge of tools, materials and shortcuts.

The model maker must understand precisely what the designer is trying to achieve. Ideally, he should be able to draft and read technical drawings, to speak the technical language of the engineer or designer and be knowledgeable about model photography.

7. *Cutting And Forming Of Plastics*

Since plastic is by far the most commonly used model making material, methods of cutting and forming them will be treated in detail in this section. Much information on cutting and forming may be gained from the handbooks, *Design and Fabrication Data* by Rohm & Haas, and *Plastics for the Craftsman* by Newman and Newman. The information in the former is generally aimed at the large manufacturer of finished acrylic products, and in the latter, at artistic and exotic uses of all plastics. However, detailed instructional material that will be of constant use to the shipyard model maker is included in both books.

It should be remembered that model making is a combination of the techniques of various trades, adapted by the ingenuity of the model builder to satisfy his requirements, and as such, it is rather futile to look for published "how to do it" information under a heading of "model making." There is much information available for the hobby modeler under his subject heading, be it trains, planes or ships, but the professional uses techniques from all these fields with refinements of his own.

a. *Cutting*

Ž *Circular Saw*

Carbide tipped blades are recommended but to use them successfully, exceptionally good arbor and face plate trueness is needed. Plastic cutting blades of hardened steel will save on initial cost but must be sharpened more frequently. Blades should run at 8,000 to 12,000 RPM. The feed-in should not be excessively rapid and the blades should be positioned slightly higher than the plastic thickness. The work must be held firmly and fed in true to the blade. No attempt should should be made to hand file blades for use on plastic.

Blades used for cutting plastic should be reserved for this purpose.

When purchased sheets are in the untrimmed condition, they may be cut on one long edge and run over the jointer to achieve a true line.

Generally, acrylics are worked with the masking paper left on (except during heat forming), to prevent abrading the surface. Some makes of acrylics have poor bonding paper but most have good surfaces for layout.

Ž *Scroll Saw*

Fine tooth blades are required with a slow feed to prevent melting the chips and welding shut the kerf. Use of the holddown to prevent chipping and fracturing is important.

Ž *Band Saw*

Metal cutting and skip-tooth blades should be used. Wheel tires should be kept clean to prevent build-up from paper and plastic dust.

Ž *Routers*

Both portable and table routers are suitable for trimming edges square. Two-bladed bits running at a minimum speed of 10,000 RPM are best.

Ž *Drilling and Hole Cutting*

Use standard twist drills with the point ground to a 60° angle and the cutting edges dubbed off to zero rake. Large holes can be cut with a fly cutter or course tooth hole saw.

Ž *Thin Sheet Cutting*

Where a square edge is not important on thin plastic, up to .060", a hook knife can be used. It should be run along a straight edge for several passes to make a proper kerf. The cut line is then placed on the edge of the table and snap broken along the line, much like cutting glass. This is a good method of reducing large sheets to workable sizes. The broken edge should be run over the jointer before using it as a guide edge for sawing.

b. *Forming*

Ž *Brake Forming*

It was found that Lexan sheets can be cold bent on a brake in .030" thickness to form bracket flanges and angle stiffeners. This resulted in a considerable savings of time over heat forming when the number of running feet of angles used in shipbuilding is considered.

Ž *Local Heat Forming*

Normally, bent or curved parts in acrylic are formed after removal of masking by applying heat until the plastic takes on a "rubbery" condition. Heating can be done by a heat gun, strip heater, or even depending on the type of forming required. Needed heat varies with the thickness of material, thinner material needing more heat. Forming time is very short, approximately 1/2 minute for .060" thickness, so forms and bending procedures must be prepared before the sheet is heated.

Ž *Oven Heating*

As a general guide to heating temperatures, oven heating can can be used as a base. Regulation of sheet temperature is better done by varying the exposure time to heat rather than varying oven temperatures. Oven temperatures should run 10 percent higher than the difference between sheet temperature required and room temperature. For example, to drape or make a two-dimensional bend in 1/16" thick strip requires a sheet temperature of approximately 300°F. so for working in a 70°F. room, oven temperature should be set for 323° F. Time in the oven should roughly follow the rule of one minute for every one hundredth of an inch sheet thickness. On removal from the oven, if the surface is allowed to cool slightly before putting in the forming jig, surface marking will be reduced. This is difficult in the thinner grades and unnecessary for structural models where surface appearance is not critical. Heated pieces should be handled with soft cotton workman's gloves. Forming in stages cannot be done with oven heating as acrylic is a "memory" plastic and will revert to a flat sheet state on reheating.

Stretch forming of compound curves requires greater sheet temperatures and more complicated forming jigs. Shell plates with compound curves are seldom used on a structural model because of the expense and time involved in building forming blocks.

Ž *Strip Heaters*

For straight bends along a line, a strip heater is the ideal tool as it allows the rest of the sheet to remain cool and flat. Locate the bend area over the strip heater groove with the surface that will be the outside curve towards the heat. If the bend line has been marked by a grease pencil, remove marks after locating but before heating. Never scratch or scribe a bend line or permit the plastic to touch the heating element. A change in the surface character of the plastic will show that it is reaching the point of flexibility. Bend by hand or in a jig.

8. 8. Joining Methods

For large structures that must be disassembled, cover or access plates and other similar sections, acrylics may be through bolted or tapped for machine screws. Normal tapping procedures are used, but it is best to use course threads wherever possible. Clean threads may be cut by filling the tap drill hole with lubricating wax and backing out the tap frequently to clear chips. Round head screws through an oversize hole with a thin fibre washer will allow thermal expansion and contraction of the sheet and prevent cracking.

Most joining of sheet plastics will be done by cementing with a solvent material. There are many variations to satisfy different requirements but the shipyard model shop usually requires speed of joining, reasonable strength, and ease of use. Methylene chloride fulfills these requirements. It should not be used at temperatures below 65 °F. or in high humidity as excessive moisture causes clouding.

Most cementing is done by capillary action flow which necessitates a good close fitting joint. The two parts are mated and held with slight pressure while cement is applied by either a fine pointed brush or a hypodermic needle. The latter is preferable. The plunger on a glass syringe is too heavy for accurate control and too much cement is dispensed. The plastic “throw-away” types are preferred even though the cement attacks and swells the rubber gasket on the plunger. The gaskets are initially sanded slightly by holding them against a disc sander. Continual use swells the gasket until it is no longer useable. Left to dry, the gasket will return to normal size. For this reason, it is advantageous to have several syringes handy and work them in rotation.

The cemented joint needs to be held for only a few seconds, but will not generate full strength immediately. Edge cementing of 1/32" thickness material is barely adequate at best, as the sheet thickness is not great enough to effect a satisfactory bond. Where there is not a good fit between joining surfaces or a weld type bead needs to be generated, epoxy cements can be used. The surfaces should be roughened slightly to produce an adequate bite. The “five-minute” epoxies will do the job quickly but will, of course, not equal the time savings of capillary cementing.

For edge-to-edge cementing of sheet, the soak or dip method will prevent underrunning of the solvent and surface spotting. A long, narrow tank containing solvent is used to dip the edges of the sheets and soften them. Excess solvent is shaken off and the edges pressed together. For more information on cementing the Rhom & Haas fabrication data sheets should be referred to.

9. *Finishes*

It was found that by using clear acrylic throughout there was no need to stock colored plastic. However, a totally clear structural model is too confusing to be of use so all stiffeners and certain other areas were painted yellow to simulate primed steel. The plastic was sprayed with automotive lacquer and no attempt was made to produce a perfect finish coat. A simple dusting is sufficient. The gun should be kept well back in order to produce a dry dusting. Wherever possible, surfaces that will later be cemented should not be sprayed. Lexan plastic sheet should never be sprayed with a wet coat as it will dissolve the surface.

10. Example Of Typical Construction Procedures

No one description can cover a step-by-step procedure for building all structural models due to their variation. However, a description of building the port and starboard bottom erection units of the 25,000 DWT tanker (Figure V-2) in acrylic is given as a typical example of procedures. The scale employed was 3/4" = 1'.

A true and flat building surface is a necessity. Birch faced 3/4" plywood was used, framed on the underside with 1-1/2" X 3" dry pine stiffeners. The entire unit was then mounted on horses at a good working height, shimmed and made truly flat with no twists.

a. *Flat Bottom Sections*

A master layout of the flat bottom section structure was made on mylar. The layout indicated the centerline, moldlines of longitudinal stiffeners, longitudinal bulkheads, transverse frames and docking brackets. The mylar was then turned bottomside (shiny side) up and taped to the building surface. Since the lines were symmetrical about the centerline, this reversal had no effect on proper layout. All lines were properly labeled with a marking pen to avoid confusion. Care was taken in the accuracy of the master layout as it was used for each subsequent unit construction to assure conformity and mating of units.

The bottom model unit was constructed in port and starboard units similar to the actual ship construction. The starboard unit included a heavy keel plate so this strip was cut from 1/16" clear acrylic, laid down on the master and cemented to 1/32" clear starboard bottom shell that extended outboard to the longitudinal

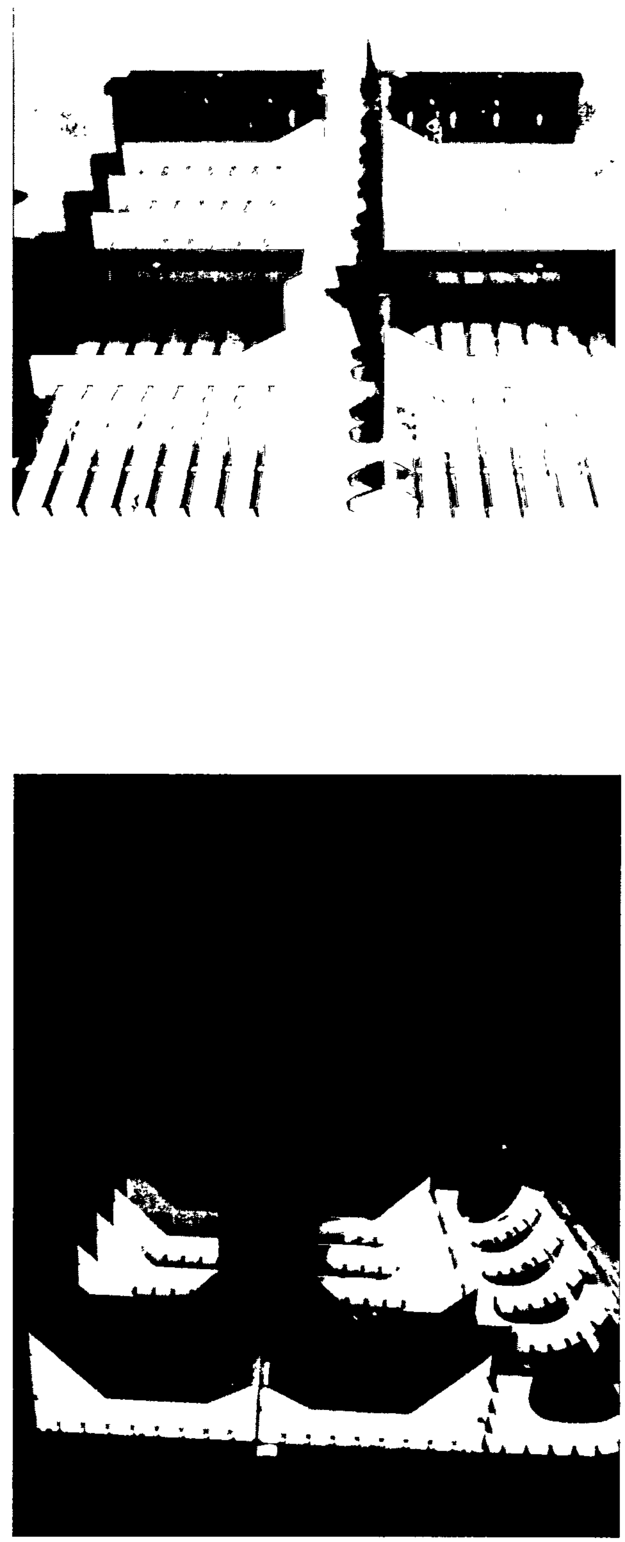


Figure V-2: Progress Photos of Tank Sections of 25,000 DWT Tanker Being Modeled bulkhead line. After cementing, the plate was reversed so the upper surface was flush at the joint. The 1/32" shell plate was shimmed up flat and level by another 1/32" sheet underneath, and the unit taped down in proper position on the master layout. The port bottom shell was then shimmed and taped down but not cemented to the keel. All pertinent lines were traced on to the bottom shell from the mylar below with an accurate straight edge and scriber. The bottom shell then became the building board for erecting structure.

Pieces for the center vertical keel were next cut and frame and docking bracket positions scribed on. These positions were located from the scribed lines on the bottom shell. Longitudinal stiffener positions were scribed in and then the unit constructed as a sub-assembly. When cementing frames, girders, stiffeners, face plates, etc., it is always important to erect them at a true 90° angle. Small blocks of ground steel with the sharp edges beveled off were used for this purpose as they were found to be more accurate and efficient than a square. Beveling prevented underrunning of cement. The center vertical keel assembly was next erected on the keel. Great care was used in aligning it by using a straight edge to keep it true along the centerline. A true position is necessary for it is the controlling factor in the athwartship location of all floors.

The next step was to cut material for all bulkheads and floors. One floor was detailed with all stiffeners, brackets, etc. using to scale, 1/32" material. Repetitive floors were cut from 1/16" white material with no detailing. It was important that all longitudinal stiffener cutouts be laid out accurately from the master so that true running parallel stiffeners would result. The floors were then installed on the shell. In cementing floors to the port side, care was taken not to cement the port sub unit to the starboard. Small pieces of thin mylar were slid into joints to prevent overrunning solvent from such adhering. The lower portions of one oiltight bulkhead and one swash bulkhead were made on the bench, assembled, given a dusting spray coat of color and erected on the shell.

When all floors and bulkheads were in place, stock for shell stiffeners was ripped out of Lexan sheet on a circular saw. These were cut slightly oversize in width. The flange was brake bent and the resulting angle shape resawn for correct height and trueness, painted and installed.

Docking brackets and other similar flanged parts were cut from Lexan sheet, the flanges brake bent, painted and installed.

b. *Bilge Sections*

Another master layout was made of the longitudinal bulkhead with the correct vertical heights of stiffeners shown. This was used to lay out on acrylic that bulkhead portion below the unit break. Port and starboard plate bulkhead panels were then cut from this layout. A 3/4" = 1' computer-drawn body plan was used to lay out the wing tank web frames and bulkheads with curvature. Clear plastic was taped over these lines and scribed using splines and batten weights. All sight edges and longitudinal framing positions were ticked off at the same time. The web frames and bulkheads were then cut out with a scroll saw and the edges smoothed up on the disc sander. Detailing of one web frame and the two bulkheads was completed. They were then installed on the longitudinal bulkhead which had been laid flat. Longitudinal stiffeners were next slid in place and cemented on the longitudinal bulkhead. The outboard ends of the bulkheads and frames were kept the proper distance apart with temporary wooden spacers taped in place. The shell longitudinals were then installed on the webs and bulkheads. No attempt was made to install shell plating on these curved sections. Instead, the sight edges were shown by installing 1" wide strips of 1/32" acrylic. This entire bilge assembly was set in place and cemented to the center sections. All remaining brackets and stiffeners were installed to complete the unit. Using felt nib marking pens or stick-on labels, break lines, station numbers and any other needed identifying marks were applied.

c. *Summary*

Most of this work was straight forward layout, cutting and assembly, but the following points will aid the first-time builder.

- Ž All layout and cutting should be done with precision.
- Ž When the table saw is set up for a certain cut, such as floor heights, then enough material should be cut to make all necessary pieces of that height. This speeds fabrication and more importantly, insures dimensional consistency.
- Ž The standard snipes and ratholes for the tanker were of various radii. On detailed frames, these were duplicated exactly with the idea in mind that the model may be used as a teaching aid. As many of the snipes were on the edge of the material, a twist drill could not be used satisfactorily. Thin wall tubing with a cutting edge ground on the inside diameter and used in the drill press worked well. These tools act as a combination punch and friction drilling device. It did not seem to matter what material they were made from. Brass tubing worked as well as steel. A little experimenting will have to be done on drill speeds as the optimum varies with the drill diameter and material thickness.
- Ž When making a subassembly all stringer and reinforcement member ends that will join others on assembly should be left loose. This is similar to the welding practice used on full size work.
- Ž All units that have a deck are built upside down with the bulkheads erected on the deck.
- Ž Wing tank units are built on their sides with transverse bulkheads erected on the longitudinal bulkhead.
- Ž The importance of using master layouts on mylar cannot be overemphasized. It enables all the participating model makers to derive dimensions from the same source, eliminates repetitive measuring and insures a proper fit of all parts. If several deck levels are to be built with the same frame spacing, use of the same master layout will insure proper alignment.

11. *Shell Plating Models - A novel Approach to Construction*

The use of wood for half hull or plating models has long been a tradition in shipbuilding. Carving one accurately takes a highly skilled woodworker and many hours of careful work to reduce the hull to its finished size.

A more efficient approach, long used by the aircraft industry for mock-ups, is to build the plating model with metal templates and plaster. It is a faster method and assures more positive control of accuracy. The method is briefly outlined below.

On a metal base plate cut to the lines of the inboard profile, templates of the sections are erected. If desired, deck and bottom flat zm-plates can be added. Section templates should have reference lines, site edges, or any needed locations scratched in on their outboard edges, deep enough to be felt. All templates should be erected true and square (Figure V-3).

Rough wooden blocking or threaded metal tie rods, depending on model size, is next

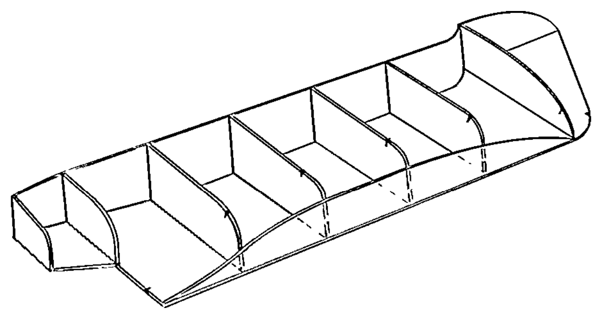


Figure V-3: Step I in Constructing Shell Plating Model Using Plaster

added for reinforcement. Wood blocks can be epoxied in place (Figures V-4 and V-5).

Wire mesh screening is now added, tacked to the blocks or wired to the rods. Over this the first coat of plaster is applied. A putty knife can be run along each side of the section frames to allow for plaster expansion. The first coat

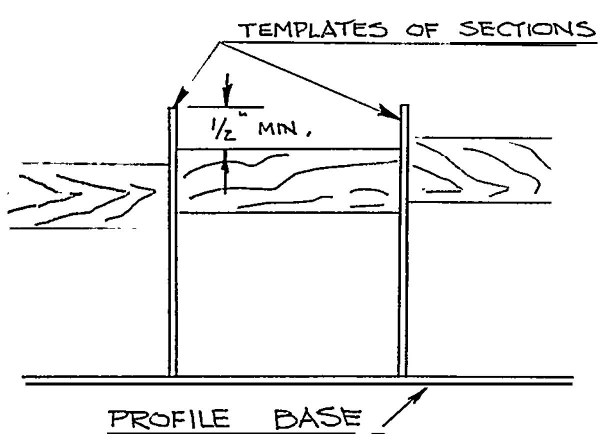


Figure V-4: Step 2 in Constructing Shell Plating Model Using Plaster

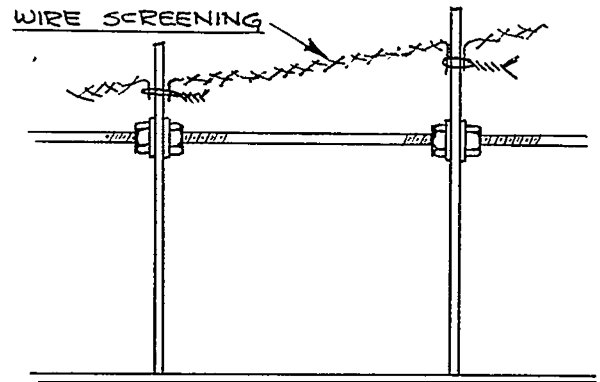


Figure V-5: Step 3 in Constructing Shell Plating Model Using Plaster

should be kept approximately ¼" below the template edges to allow for the finish coat (Figure V-6). The second coat is then applied and any excess is swept off with a flexible batten. When dry, the surface can be sanded down until fair and all control point template edges show. The plaster may then be painted to provide a drawing surface.

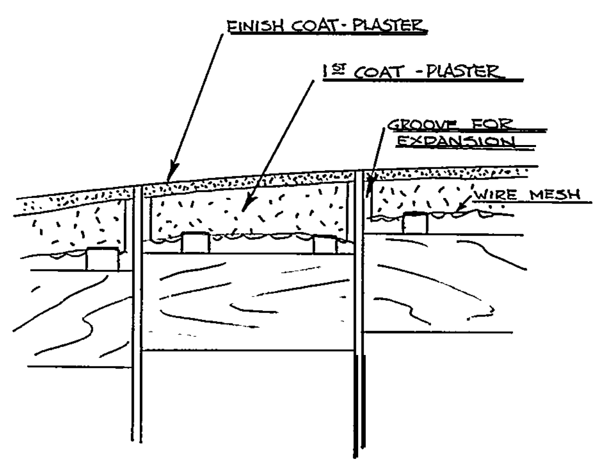


Figure V-6: Step 4 in Constructing Shell Plating Model Using Plaster

C. *Distributive Systems Models*

With the addition of certain purchased parts and varying procedures, the tools, materials, techniques and methods discussed in the preceeding sections are all applicable to machinery space and systems models, as well as to structural models.

It is possible to combine structural and systems models in some cases, such as a deck house, where a reasonable portrayal of structure is first accomplished for unit break studies. Later the same model may have added to it those systems needed to demonstrate clearances, accesses, interferences and systems locations.

Models constructed for the purpose of allocating space for systems usually are built with a different approach than that used for strictly structural models. For structural models, all structure duplicates that of the actual ship as closely as possible. In the machinery space or systems model, only that structure necessary for foundations, holding of pipes or equipment, or demonstration of spatial limitations, is shown. In addition, structure for strength reasons is sometimes added to the model outside the geometry of the actual ship. Only minimum ship structure is built first with additions at later dates when areas of possible interferences become known. Before starting to construct the systems and install them into the model, a decision on how much detail is to be included and in what sequence it is to be installed is necessary. It is felt that as these types of models are very specialized, it would be advantageous to describe step-by-step procedures used in the construction of the basic structure and equipment for a typical systems model — in this case the engine room model built by a designer for the shipyard and used during this research study (Figure V-7). Refer also to Chapter VI, Section F.

1. *Basic Structure and Major Equipment*

An engine room model was built of plexiglas on wooden bases which were split on the centerline and on a convenient frame for ease of construction.

The bases were built of ½″ plywood with select 2″ × 6″ fir siderails and reinforcing members. The siderails were jointed down to a straight side and resawed to a finished thickness of 4″ to eliminate warping stresses and to provide a flat table top. The legs were cut from standard 2″ × 4″ stock and permanently attached to insure a stable wooden base suitable for shipment without disassembly upon model completion.

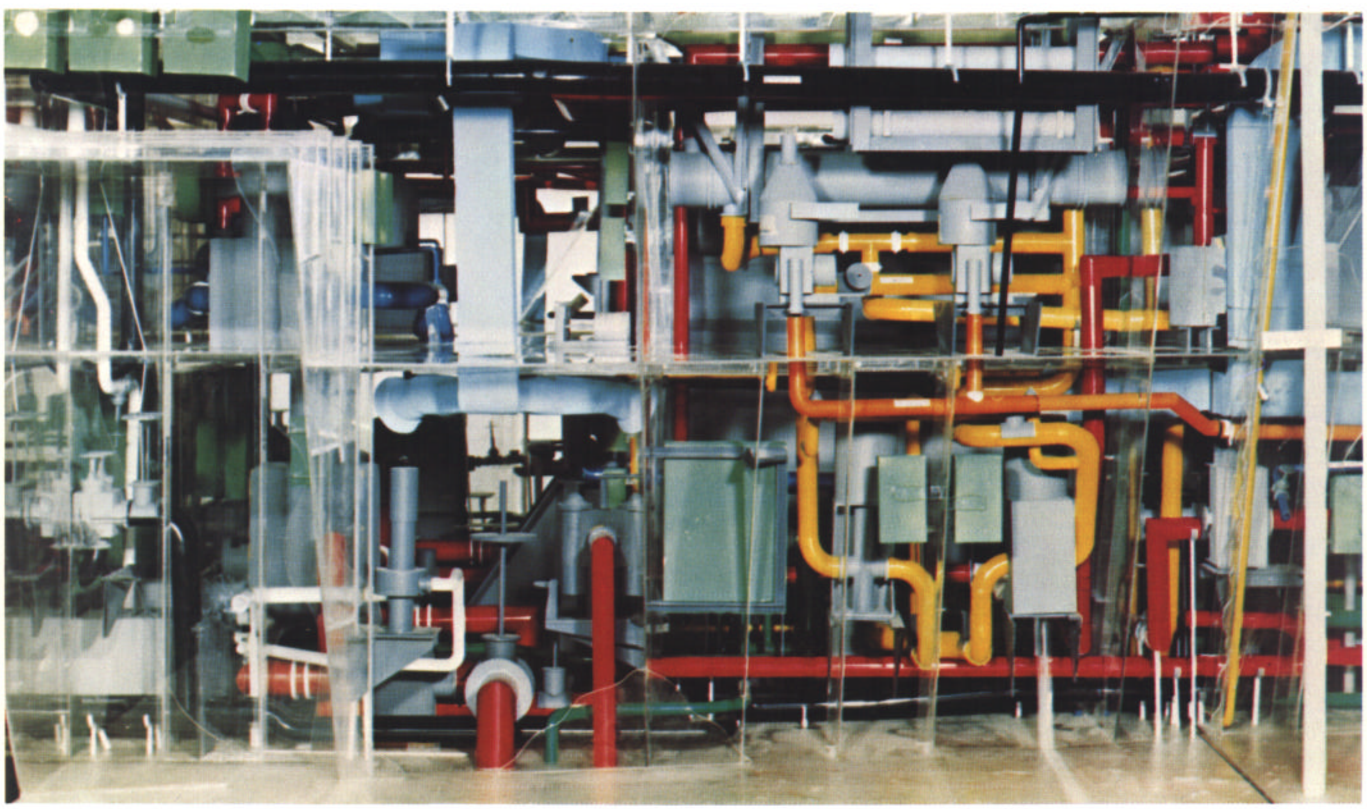


Figure V-7: Engine Room Model for 25,000 DWT Tanker.

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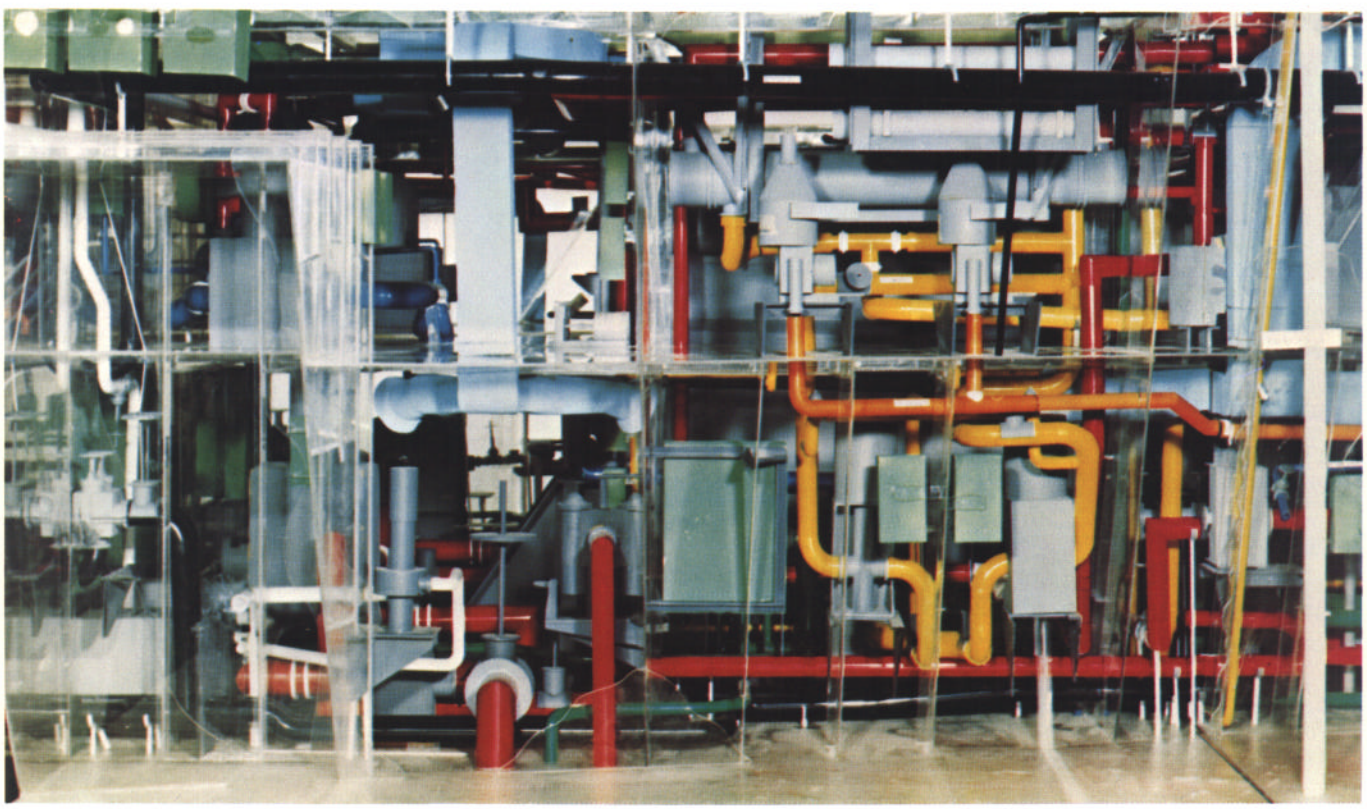

Figure V-7: Engine Room Model for 25,000 DWT Tanker.

The table tops were covered with1/8" plexiglas to within 2" of the edges. The plexiglas tops were sanded with a vibrator sander to make a smooth and easily cleaned surface. The surface was indexed and scribed along frame lines and lines fore and aft at one foot on centers for measurement reference lines. These lines were then identified at their extremities with DYMO labeling tape for further reference.

The structural framework of the shell was next started on the tables in an inverted position. The platforms were laid out from the table of offsets and lines drawings. The bottoms of the platforms were scribed with lines indicating where the deck beams and girders were to be located.

All deck beams and girders were then cut to stock (flange and web) sizes and random lengths and were then taken to the inverted platforms, marked for proper lengths, cut and centered in place. Care was taken to set the beam back far enough from the molded lines to allow for the frames and web frames.

Next cut were the web frames whose dimensions were taken from the engineering plans, table of offsets and lines drawings. These were cemented into place along with the pillars where indicated on the plans.

The next step was to invert the completed deck and frame assemblies and assemble them in place on the bases. At this point simulated shell plating was cut to add to the strength of the assembly and was cemented to the edge of the model in order to provide structural strength while leaving access from the sides for equipment and systems installations.

Equipment such as engines and pumps was built to extreme perimeters and the material used was mostly plexiglas shapes and four-pound density foam where eccentric and curved surfaces were required.

2. *Piping, Ducting And Wireways*

As a result of the petro-chemical industry's move to designing process plants by the use of models, there is now on the market a comprehensive selection of colored plastic scale pipe and fittings. These are available in the centerline system where all pipe, regardless of size, is represented by plastic coated 1/16" diameter wire indicating the centerline of the pipe run. Sizing sleeves are available to show actual size and allow the use of full-scale pipe and fittings. Also available are full-scale pipe and components, and as the fittings are inter-changeable, a very versatile system is available to the modeler. Available stink is supplemented by acrylic tubing for larger size pipe where needed. Scale pipe and fittings are manufactured to provide a good friction fit so that trial assemblies may be made up and readily disassembled. Cementing need not be done until the final design of the system is frozen.

Wireways and ducting are most easily portrayed by the use of four-pound density foam which can be cut to intricate shapes by hand and are light enough to be hung with a minimum of support.

Small equipment can be made of acrylic rod, tube, or block. Large items of equipment are fabricated in a built-up hollow box style from acrylic sheet. Large, odd-shaped pieces are carved from foam blocks.

3. *Marking and Tagging*

As most pieces of equipment will be shown as representational shapes they should be labeled by name and part number or other identifying means. This can be done by pressure sensitive labels with the proper wording hand lettered or by the popular embossed tape system. Pertinent information such as "high-low", "in-out" and other needed facts should be indicated on the equipment.

Tagging of lines and piping to show flow direction or needed information can be accomplished by arrow tags with a write-on surface and pressure sensitive backs. These are purchasable items.

4. *Color Coding*

It is of prime importance to establish a color coding system for model work and maintain it for all models. Once the coding is known it aids in systems recognition throughout the yard. Models should carry a legend card showing the coding. A suggested list of systems color follows:

System	*Color*
Equipment	Gray
Salt Water	Red

Bilge & Ballast	Green
Diesel Fuel Oil	Black
Chilled Water	Blue
Hydraulic & Lube Oil	Yellow
Plumbing	White
Steam	Orange
Cargo Oil	Light Gray

5. *Information Flow*

a. The typical management plan employed by a *designer constructing a machinery space model for a client shipyard* coordinates detail system design with model construction. Since contract plans and specifications form the starting basis for detail design, initial planning is accomplished by the design resulting in milestone schedules and plan schedules. Correlation of plan production with the shipyard is a key factor in this activity. This phase of initial planning is accomplished by the designer's chief of production with the assistance of the project manager. Based upon the initial planning and the anticipated receipt of data from the shipyard, such as certified approved vendor plans, a schedule for model construction is prepared by the model making manager and established after approval of the project manager and chief of production.

Initial model making costs are established by the model making manager and negotiated by the contracts manager. Internal engineering and design costs, plus direct costs, are established by the contracts manager who thereafter monitors overall program costs.

Throughout the term of the project, the project manager maintains liaison with the shipyard and overall responsibility for program status and progress. The chief of production supervises the flow of general arrangement plans, diagrams and vendor plans and information to the model making manager through an assigned individual. Related information such as engineering revision notices, reservations and revisions are immediately transmitted.

Following completion of the structural envelope and installation of major components in the model, detail modeling of systems proceeds. Problems are quickly identified as they develop, both in modeling and detail design, and resolved, bringing plans and model into conformity.

b. *Proper information* flow to *and from an in-house shipyard model shop* is of vital importance if full value from a model is to be realized. The following suggestions are made in this regard.

Ž When planning the drawing schedule, the model should be part of that schedule and considered as a drawing as well. It may replace diagrammatic layout and arrangement drawings to a large extent.

Ž An engineer (possibly a project engineer for the ship) should be assigned as a liaison man between the model shop and the engineering department. He then is responsible to supply the model shop with the necessary information and is also responsible to see that the various engineering disciplines will determine pipe, duct and wireway runs at the model. He then can solve interferences, and most importantly, will make sure that any changes or resolutions solved on the model become incorporated into all affected drawings.

Ž As soon as even preliminary information is available to the. hull engineering group, modeling of the ship's structure should be started. It should be possible, if the scantling plan has been developed as the basic reference and approval drawing, to use this scantling plan for starting the construction of the structure. On the other hand, working from the scantling plans and not from detail working plans will require rigorous control of the model work to achieve it effectiveness and still control its cost.

- Sketches and other aids from the engineering department would be all the model maker needs to assemble pipes, duct and wireway runs. Interferences can be solved on the spot and and correct drawings can be developed with a minimum of revision. Complete information for routing such runs is seldom available, except in a later stage of the design. At this point the model is essential and can be used to analyze any extensive alterations which may be indicated, keeping in mind that under normal shipyard conditions the actual manufacturing keeps pace with the drawing office and the current model configuration.
- Procedures to be followed when using the model as a piping, ductwork or wireway design tool must be prepared in complete detail for each activity involved in producing the finished model. The "how," "when" and "by whom" must be spelled out, and individual responsibilities as well as the coordination required between groups must be specified. These procedures must be rigidly enforced by the liaison engineer.
- Develop a plan for use of the model by departments other than engineering, such as planning, scheduling, estimating, shops, etc.

Summarizing the above, it can be said that the model can only pay for itself and serve a useful purpose if enough initial planning is done and if as many open minded people as possible are involved. Good communication between the model shop and the specific disciplines involved is vital.

D. *Model Photography Techniques*

Photography can be an important part of any model program. Photographs are the best possible means for conveying information to personnel not having ready access to the model and can be used for:

- Recording before and after design changes
- Information at owner/shipyard design conferences away from the yard
- Visual communications tool between remote designer and shipyard
- Information to the trades at the stage where the model is still being worked on
- Sales aids, public relations etc.

If black and white photography is used, orthochromatic film is best for differentiating between colors. It is recommended, however, that only color film be used as color coding forms a large part of the understandability of systems on the model. Dulling sprays are an advantage on clear plastic construction to reduce glare and hot spots.

The model shop walls should be painted a neutral tone so they can be used as a backdrop. Large "window shade" types of background paper can also be erected and taken down as needed.

Good model photographs have the following characteristics:

- Pictures should be taken from viewpoints that portray the model as an actual installation.
- The resulting vanishing points should be similar to what could be expected in an actual installation.
- The picture should be reasonably in focus throughout its depth.
- Scale figures should be used to establish relative sizes.

Polaroid color photographs can be of great aid in situations calling for immediate results.

Color stereo photography was tried on the tanker model sections. There is no doubt that this system effectively portrays three-dimensional objects such as models for greater understandability. The separation of parts from front to rear of the picture is outstanding and a real sense of depth is pictured.

The great drawback to the stereo process is that transparencies may only be viewed by one person at a time. There are stereo projectors available, but it was found that they are difficult to use and the results not satisfactory.

E. *Model Shipping Techniques*

Shipyards doing their own model work will seldom be faced with the problem of shipping. When shipping is necessary it is well to keep in mind that the most dangerous time is at transfer points where the crate is off-loaded and re-loaded. “Fragile” and “Handle With Care” signs have little effect by themselves.

For short hauls and small units the use of a station wagon with a model maker along is advisable. For long hauls, a transfer company with experience in moving valuable consignments such as art work for museums should be contacted. They supervise all loading and unloading and their extra fee is justified. Insurance for each shipment should be carried, as no transfer company will cover the loss for such valuable items.

Structural models in plastic should be inspected for loose joints and recemented where necessary. The theory behind successful model shipping is to see that all parts of the model are held rigidly to the model structure. Fragile parts of structure, heavy equipment installed, and parts with little support should be temporarily braced and taped on the model with filament tape. A dust cover of lightweight clear plastic can be used. Structural models with no base of their own should be taped to a base of plywood or some type of flat rigid platform. The platform itself should be floated on pads of 2" foam to absorb shock and road vibration. Loose tape can be used to prevent extreme movement. Figure V-8 shows the minimum procedure for shipping structural models in a station wagon.

When a crate is to be used, similar procedures are followed. All units of the model are held rigid to the model. The model can float in the crate. Crates should be rugged to prevent racking. Windows of clear plastic should be provided on crates going out of the country for customs inspections. Figure V-9 shows a typical crate packing method.

Instructions should be given on the outside of crates for correct opening and model removal procedures to prevent model damage at that stage. The ideal procedure is to have the model maker at the delivery point to supervise uncrating.

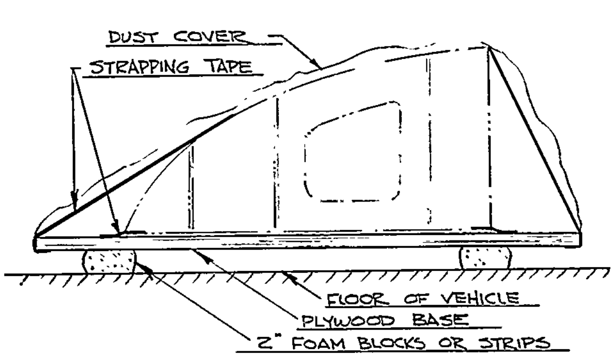

Figure V-8: Sketch Showing The Shipment of a Structural Model in a Station Wagon

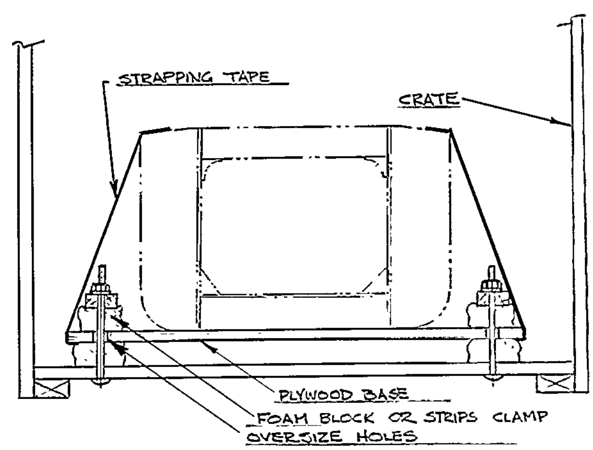

Figure V-9: Sketch Showing the Crate Packing of a Model For Shipment

CHAPTER VI
CURRENT USE OF MODELS IN U.S. SHIPYARDS AND OTHER INDUSTRIES

Ideas, techniques and benefits of scale modeling employed in U.S. shipbuilding have been incorporated in other sections of this manual. This chapter describes the kinds of models being used and the degree of success being experienced.

The spectrum of use of scale modeling as a shipbuilding tool among major U.S. shipyards ranges from those yards who feel that modeling is of no use at all to those who maintain full-time, comprehensive model shops and derive great cost-saving benefits from modeling. Between these two extremes are the shipyards who use models in varying degrees. Some may employ informal and crude — but useful — paper models. Some may employ machinery space models as design control aids only. Some may employ traditional shell plating and anchor handling models. Some may use permanent facilities models to great advantage. Others may use mechanical or structural models on an as-needed "crash" basis to solve very specific problems.

It was found that whether a shipyard makes valuable use of modeling as a shipbuilding tool depends to a large extent on the philosophies of various management levels whose departments might be involved. Some feel strongly that their personnel — engineers, planners, production people — are skilled and experienced enough so that the use of models would constitute a superfluous effort. Other managers recognize models as tools that help people to think, and therefore help them to perform their jobs more efficiently. Of the yards which find models most useful as an aid in the shipbuilding process, all are in accord on one key finding of the study, that being the value of a model as a *communications* tool. A physical, three-dimensional representation has the unique ability to keep a discussion of a problem germane to that problem and to promote genuine and uniform understanding among all parties as to the nature of the problem. It naturally follows that the best solution to the problem will be forthcoming far more quickly and, therefore, more economically.

Another key element of successful model use found throughout the project was that timing of the model's availability is critical. This is particularly the case for detailed structural models that are constructed in a model shop far removed from the engineering, drafting and planning departments. If such models are delivered *after* the technical groups have completed working drawings and work scopes on those sections, and their attentions are elsewhere, the models will have little more than check value. The ideal situation occurs when detailed structural models are built in close proximity to the departments for whose use they are intended, and their construction coincides with the ship sections being designed in those departments. In this situation, the questions that arise on model construction can be answered immediately, the model's revelation of inconsistencies and errors in working drawings can be resolved and corrected on the spot, and the model can be used to aid the actual design process. Thus, the model becomes an on-going, working tool, accruing time-saving benefits on a daily basis.

Where immediate proximity is not possible, but where the model is being constructed in a shop within the yard, close, formal liaison must be maintained for the structural model to produce its full potential as a time-saving device. This can be accomplished by regularly scheduled — daily if possible — liaison between the using departments and the model shop. One yard using this method also has developed an information flow system on prepared forms that are transmitted daily between the model shop and the using disciplines. The forms briefly present the problem — whether it be an interference, a plan inconsistency, a structural interface problem, etc. — and call for a resolution by a target date. In addition, of course, the model shop must be supplied with change orders, revision notices and new drawings as soon as they are published.

The construction of detailed structural models by an outside model builder, at a location removed from the shipyard, is least desirable. It was found during the project that, while some questions on the drawings could be answered by phone, the lack of constant contact with the departments greatly decreased the usefulness of the model being constructed. It was also found that because engineering does not have the model constantly available they cannot recognize areas needing changes as they occur. Other types of models such as mechanical models or display models may well be constructed by an outside shop and delivered on the date requested. In these cases, the model will probably fulfill the use intended.

One of the major conclusions of the research that became most evident throughout the investigation was that the request for a model should originate from the using department. If, for example, the engineering department requests a detailed structural model to be built, they will most surely derive great value from the use of that model. If, however, engineering is presented with a model they did not re-

	SHIPYARD										
	A	B	C	D	E	F	G	H	I	J	K
MODEL TYPES USED											
Display Models			x	x	x	x					
Scientific Test Models	x	x						x			x
Shell Plating Models		x						x			x
Detailed Structural Models		x	x	x	x	x		x	x	x	x
Erection Unit Models		x		x			x				
Fluid and Electrical Systems Models (Machinery Space)	x				x			x		x	x
Mechanical Models		x			x			x			
Facilities Models		x	x	x	x			x			x
FACILITIES AVAILABLE											
Full-Time Model Shop	x	x	x		x						
Part-Time Model Shop				x				x		x	
Models Built In Engineering, Loft, or Planning Departments		x				x	x	x			x
Use of Outside Model Firm				x							x
Models Built by Design Agent		x								x	x

Figure VI-1: Table Showing Model Types Used And Model Making Facilities Available In Various U.S. Shipyards quest, the value derived will probably be greatly diminished.

Among shipyards who make little use of models, or whose model programs have not succeeded, a number of reasons are highlighted below:

- Lack of funding approval from top management.
- Lack of time.
- The philosophy that skilled, experienced personnel do not need the aid of a model.
- Late engineering (more the rule than the exception) negates the usefulness of modeling.
- Lack of awareness among technical personnel of of the potential of modeling.
- Lack of management backing and control.
- Low priority for transfer of engineering information to the model builder.
- Reluctance to change.

Figure VI- 1 provides an overview of the use currently being made of the various types of models in ten major shipyards, plus a brief overview of their model making facilities.

The following sections of this chapter describe specific examples of the use of models in the shipyards. Where appropriate, the use of models in other industries is also described.

A. *Display Models*

As described in Chapter II of this manual, the decision to construct a display model may originate with either the shipbuilder, the owner, or through an agreement between the two. In one case, a Government agency requested that a model of a special ship be built for a permanent display.

1. While most display models are constructed by outside modeling firms, one shipyard which maintains a full-time model shop, signed a contract to construct a cargo ship model in its shop, at a cost of more than $6,000. Outside of its public relations value, little practical benefit accrued to the yard.

2. Another shipyard has a unique, informal method of producing display models of ships under contract. They employ the skills of several in-house people interested in this work, to produce the models on an "as-time-permits" basis. The results are relatively crude but adequate display models. The yard is considering having this work done by an outside firm, as it probably would be less expensive and the results certainly better.

3. Another yard also has much experience in building display models in-house by its highly qualified model shop. However, they, too, for cost reasons, suggest that in the future they may use outside firms for this work.

4. Another yard in conjunction with the owners in two separate shipbuilding contracts, had display models constructed for public relations use in its lobby. These models have also been transported to special events in the local area upon the request of special interest groups. Outside model makers were contracted to build the models and duplicates were made in each case, one for the owner and one for the shipbuilder. The costs ranged from $3,000 to $4,300 per model. An unusual benefit resulted when the shipyard's steel buyer found that photographs of one of these models became very helpful in his discussions with the mill representative on steel requirements for the ship.

B. *Scientific Test Models*

1. During the early stages of production planning for one shipyard's RO/RO cargo ship contract, consideration was given to erecting the ship in 96 foot sections. One of the major questions was whether or not excessive torsional deflections would occur in deck and/or innerbottom panels of this length. To resolve this question, it was decided to build a simple scientific test model of both the innerbottom and deck panels to determine deflections under their own weight using various means of support. Exact answers were not required; only an order of magnitude was desired. The innerbottom was modeled in greatly simplified form. Since torsion was the major problem, all small stiffeners were omitted and the plating cross section to which they were attached was increased by the omitted stiffener cross section. The model, then, consisted of one flat deck panel, one flat shell panel, two longitudinal girders and six web frames. It took about eight hours to build.

The model was supported several ways and deflections were observed under its own weight. The scaling equations described in the article entitled "Prognosis With Plastic Models" referenced in Chapter VII, Section

B, indicated that for the scale chosen (3/4" = 1') and materials used, the scale deflections observed would be about half of what they should be. This fact was kept in mind. The result of the analysis showed that the 96 foot sections would be acceptable from a torsional deflection point of view.

C. Shell Plating Models

Little needs to be said for the purposes of this manual regarding shell plating models, beyond their description in Chapter II, and the novel construction technique described in Chapter V. Plating models are not new to the shipbuilding industry and, if anything, their use is diminishing. The task of shell plating development is being accomplished now through the use of computerized lofting programs. Since the fairing capabilities of a computerized system are quicker and less expensive, the need for a model to develop sight edges or lift steel has been generally reduced.

D. Detailed Structural Models

It was found that most shipyards have used some form of structural models with varying degrees of cost and success. Since structural models are of major concern in this study, more emphasis will be placed on the descriptions in this section.

1. Even though the shipyard in this example maintains a full-time, comprehensive model shop, all detailed structural models are constrútted as a function of the planning department. A photo of one of these models is shown in Figure VI-2. They are constructed of inexpensive template cardboard and Duco cement. In general, these models are constructed early, from contract plans, and many assumptions regarding interface details are made. As detailed working drawings become available, the models are refined. The major result is that the planning function of the shipyard can make timely inputs to the detailed design with significant effect on producibility. One specific example observed was a midbody erection unit for a specialized tanker. The model was 3/8" =1'0" scale, and the unit modeled was approximately 200 tons in weight. The model represented approximately two man-weeks of time. Much detail was shown although, wherever possible, stiffeners were represented by flat strips of cardboard or ink lines. It was felt by the yard that the model paid for itself after the first welding problem was identified. Other details such as attachment of flat bar stiffeners on the top versus bottom of cofferdam platforms for ease in welding were identified. A side benefit of this yard's cardboard modeling program was that injured shipfitters are often employed as model builders, under the direction of the planning department, thus making efficient use of their talents. Little modeling skill was required since parts were simply traced with carbon paper from drawings. In some cases, the finished models were spray painted, resulting in increased durability, visibility and presentability.

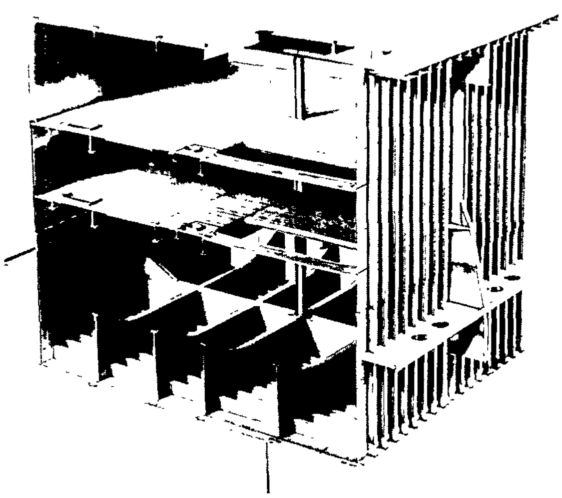

Figure VI-2: Example of Detailed Structural Model Constructed from Cardboard as a Function of the Planning Department

The exact magnitude of benefits derived from these cardboard structural models was difficult to assess since the benefits were not limited to one shipyard function. There was no doubt among the using departments, however, that such models were extremely valuable and saved the yard a great number of manhours.

2. Another shipyard makes extensive use of detailed structural models as a basic tool to evaluate construction procedures and to determine the most cost effective methods.

The large model observed was constructed to a scale of 3/8" = 1' and was fabricated from plastic. One interesting variation in technique was that angle stiffeners were milled out of solid plastic stock rather than being built up or broken out of plastic sheet. Extensive use of colored plastic for different types of structure was made.

The model was used primarily to make major structural and construction procedure decisions on erection breaks, welding sequences, plate standardization, lift sizes and the use of angles versus channels. Erection breaks were drawn on the model rather than actually making cuts at their proposed locations. An example of a construction detail developed through use of the model was the decision to make plating sight edges parallel to the baseline rather than parallel to the shear line.

It was strongly felt that the major advantage of the model was that it provided a common reference at production meetings, insuring that all parties understood exactly what was being discussed. These meetings are held at a high management level, being attended by the general manager, project engineer, chief planner and, at times, the trade foremen. The importance of having the model available very *early* in a contract could not have been more strongly emphasized.

3. Another yard, which maintains a complete and versatile model shop, makes excellent use of structural models. The yard's model shop is operated in conjunction with the loft, and personnel are interchangeable. This system has great merit in its cost effectiveness. Generally, models are constructed on a "rush, as-needed" basis. at the request of either Hull Engineering or Production Planning. High-level conferences are held around the structural models to solve problems. Use is made of various materials including plywood, wood, plastic, PVC tubing, aluminum, cardboard and sheet metal.

In addition to aiding in decision making on erection breaks, welding sequences, etc. these models have also been used in launch planning. In one case, the model made it apparent that scantlings had to be increased for launch purposes. The yard, which also constructs drill rigs, professes heavy savings by building plastic structural models of complicated drill rig sections, such as large structural elbow joints. In one case, savings were estimated at 1,100 manhours per elbow as a result of problem solving through the use of the models.

This yard derives many side benefits from their models after they have served their primary function as a design, engineering or production management tool. For example, they are frequently used right in the shops and working areas as a visual aid to the tradesmen. This is done at the discretion of the particular superintendents based on their judgment of the time-saving value. The models are also used as tools to teach shipbuilding nomenclature to new draftsmen and other workers.

4. Another shipyard, which has no regular or formal modeling operation, does, in certain instances, construct cardboard structural models for the purpose of determining erection breaks and lifting pad placement. The work is done in the structural engineering department and, the method used is simply to glue drawings to cardboard and cut the parts out. While the workmanship and accuracy of the assembled sections were admittedly very crude, the models were considered quite adequate for the purpose intended.

The same yard also saw need to construct a plywood scale model to prove to the designer that his plans did not show a satisfactory connection between a box girder and the deck edge coaming. Again, this example demonstrates the usefulness in certain cases of a three-dimensional representation for information and communications purposes.

Some in the shipyard have seen that modeling can be a most useful tool to solve problems quickly or to avert an error that would later become a costly problem. Others feel that there is seldom enough time to use models as a tool. Funding of models, even if the cost is modest, is a problem.

5. Another yard, primarily a repair yard, had signed a new construction contract calling for the construction of a semi-submersible drill-rig. One of the first steps taken was to build a 1/10 scale wooden model for the purpose of planning construction sequences and erection breaks. In addition, the model was to be used for educational purposes as most personnel were ship-repair oriented and unfamiliar with new construction work, particularly drill-rigs. While no assessment of cost saving benefits is possible because issues became resolved through use of the model *before* they became real problems, the model was judged by the yard as having been invaluable as a management tool.

6. Another shipyard, which does not have a full-time shop to build structural models, does make extensive use of structural models, built primarily from cardboard. Most of the modeling activity is performed by a structural leadman and a shipfitting foreman, both of whom have good modeling skills and have proved to management the benefits of modeling.

Structural models are constructed as soon as the first plans are available, generally in a scale of 3/8" = 1'. The actual choice of scale, particularly for curved sections, is determined by whatever scale is used on the majority of drawings. The method used is to trace by prick punching holes directly through drawings into cardboard and then to cut the shapes with knives. After assembly, the different erection units are painted with different colors and extensive labelling of units, frames, etc. is done. Because of the peculiar skill of the builder, the results are highly accurate and professional. They are used for assembly sequence, turning studies, lifting pad locations, erection breaks, etc.

It is worth noting that this shipyard has a very positive philosophy toward the use of models. Because of management's realization of the great problem-solving and cost-saving benefits that have accrued, decisions to use models are automatic and no formal approval is necessary.

7. BIW utilized two kinds of detailed structural models on its 25,000 DWT tanker tanker program. The usage made of each type presents an interesting comparison:

a. Very early in the contract, long before working drawings were available, a planning team for the five-ship program was established. The supervisor of this group, who was actually an assembly area supervisor on loan to the planning team, decided that one of his first steps should be to construct simple cardboard models of various sections of the tanker. He felt they would be most helpful in getting the production planning job done quicker and more efficiently. In addition, since the yard had not built tankers before, he saw the modeled sections as an excellent educational tool to familiarize personnel with tanker construction. The models were constructed from template cardboard using preliminary contract plans as a basis of information, and the scale selected was 3/8" = 1'. Actual building of the models was assigned to a first-class shipfitter, also on loan to the planning team. Typical sections constructed were tank sections, stern sections, rudder horn, etc. One such model is shown in Figure VI-3. The models were used to great advantage as a communications and educational tool primarily by lead men and ship-fitting mechanics. These personnel were brought in from the yard to view the models and familiarize themselves with what they were going to build. In addition, the planning group made early determinations of erection breaks and construction methods, using the models. These models were also loaned to the Hull Engineering group for use in determining lifting pad locations, lifting and turning procedures and verifying centers of gravity. They were particularly useful in this regard where a unit was of an obtuse shape. This group also found the models most useful in gaining the confidence of the rigging department that certain lifting and turning procedures were feasible. The riggers were much more receptive to physical, three-dimensional demonstrations, then to verbal explanations of sketches.

Figure VI-3: Cardboard Model of Tanker Section Built By A Shipyard Planning Department. Scale 3/8" = 1'

Overall, these cardboard models were a great aid in planning the job, because they were done on the initiative of the group who would use them, and they were available to that group when they were needed.

b. By way of comparison, the detailed structural models of the 25,000 DWT tanker built as part of the study project (Figure VI-4), were not used to the same degree as the cardboard models, even though they were infinitely more accurate and detailed. The prime reasons were as follows:

Figure VI-4: Plastic Model of 25,000 DWT Tanker Section, Built as Part of Study Project. Scale 3/4" =1'

Ž They were constructed by a subcontracted model firm at a location removed from the shipyard and, therefore, could not be used as a “working” tool during their construction. This again verifies the conclusion that the most beneficial modeling is that which is done in the very department which will use the models.

Ž Even though they were constructed from working drawings, thus enchanting their completeness and accuracy, their availability to various potential users was not timely. By the time they were delivered to the shipyard, engineering, lofting and production planning had completed most of their work on the particular sections involved. The feeling of these groups was that the models would have been useful if they had been available two months sooner. Here again, a basic conclusion of the study — that the model must be available early — was verified. Had circumstances been such that the project plastic models were available early, the tanker planning team would have had no need to construct cardboard models except for special sections.

Ž The models built for the research project were, of course, not requested by any specific shipyard group such as engineering or production planning. Therefore, there was little initiative to make extensive use of them.

Among the specific examples of benefits that did accrue from the use of the plastic structural models were the following

Ž Shortly after the modeled tank section was delivered to the planning group, the piping planner saw that a piping line, if installed as drawn, would pass through the rungs of a vertical ladder. The problem was corrected on the plans.

Ž Since portions of the tankers were to be blasted and painted after erection on the ways, much planning was needed for the necessary access, stage building, lighting, heating and ventilation required to accomplish the task. By using the 3/4" = 1' scale rule supplied with the model, and seeing the webs, frames, brackets and other structure in three dimensions, the paint department foreman was very readily able to accomplish the planning. He maintained that it would have been a tedious and time consuming task to do the same planning from normal two-dimensional plans.

Ž During the construction of the various sections in the model maker’s shop, the construction process itself revealed dimensional inconsistencies and interface errors. This information was quickly transmitted to the yard and corrections made. Examples were: a stiffener on a bulkhead was found to be located in the middle of a manhole, and no ladders were specified for the manholes between two frames.

- First line supervision, the leadingmen, found it helpful for overall understanding, to bring their people in to view the models.
- An unusual usage came to light when the material handling foreman revealed that he had been using the models on a continuing basis. In the sequence of events in the tanker program at that time, there occurred a time lag between the completion of certain units in the assembly building and their erection on the ways. During this time lag, the units had to be stored outdoors in appropriate locations and positions for future transport to the ways. For certain units, an intermediate stop at the blast and paint facility was necessary. By viewing the three-dimensional scale models, seeing the shape peculiarities of the units and using the 3/4" = 1' scale rule, the materials handling foreman was readily able to ascertain where best each of the many units should be stored. A great deal of time was saved by this usage.
- The tanker program Project Manager and appropriate foreman used the model to determine the necessary staging required for both general construction and paint work.

In general, the plastic structural models of the 25,000 DWT tanker served many useful purposes, but their overall application as a shipbuilding tool was limited. Their construction and usage verified certain conclusions of the study worth repeating here:

- The model must be available *early* in the sequence of events of a ship construction contract.
- The structural model need not be overly elaborate, detailed or accurate for most uses.
- The model should be constructed in the shipyard, preferably in close proximity to the using department such as engineering or planning.
- The model should be built only if potential users are convinced as to its benefits or if it is probable that a discipline for use of the model can be maintained.
- An overriding usage of structural and all other three-dimensional models, in addition to any specific intended use, is as a communication device.

E. *Erection Unit Models*

While there is often considerable overlap in usage between detailed structural models and erection unit models, some examples were seen of a model being constructed strictly to determine erection units and how they related to available shipbuilding facilities.

1. In order to determine optimal erection sequences to suit existing facilities, one shipyard constructed, in its model shop, a scale model of their building basin and proposed tanker (Figure II-6, Chapter II). The model was built primarily from balsa wood in a scale 1/20" = 1'0". Each proposed erection unit was made from a separate block of balsa and all units were connected by means of brass pins. The model was constructed and used in a very early time frame, actually before contract signing. The shipyard's evaluation was that, while the model was invaluable in planning erection sequences, its primary value was in identifying potential problem areas regarding how best the ship could be built in the yard's facilities. This was a good example of the usage of a model very early in a procurement for planning purposes.

2. Another shipyard also has made valuable use of rough erection break models on both of its recent commercial contracts for new ship types. The models, representing primarily shell and bulkhead configurations, were constructed from plywood and joined with metal pins. Here again, they were used to identify problem areas of constructing the new vessels in the facilities available.

F. *Distributive Systems Models*

Machinery space models are among the most valuable types of models used by shipbuilders and are often required contractually by the owner, particularly for multiple-ship programs. Chapters II-F and III-B-5 provide general descriptions of such models and an insight into their usefulness. Following are specific examples of machinery space models investigated during this study.

1. The design office of one shipyard decided to employ a 1½"= 1' scale model, built primarily from plastic, for design and design control in the main and auxiliary machinery spaces of a new class naval ship. Some 25% of the actual detail design was accomplished using the model, after composite drawings had been used as a planning tool. In its use as a design tool, representatives from the piping, ventilation, and electrical departments provided their inputs to the model and appropriate changes were made by the model builder.

First, a general arrangement model was built. Port and starboard had different configurations to reflect the dissimilar types of main machinery. As a side benefit at this point, the model was used to help choose suppliers of machinery.

Next, the detail model was constructed. Transparent, colored acrylic plastic was chosen for rapid assembly and to enable the viewer to see the inner parts of the model. The clear colored plastic also represented as closely as possible the color scheme recognized aboard ship in marking up the various systems such as piping. Machinery items were generally made from wood and painted the appropriate color. All major designing was done on the model, and junior draftsmen made their drawings directly from the model. In many cases, routing decisions were made by the model builder with schematic inputs and changes coming from the engineers.

In addition to space allocations and interference control, examples of major design problems whose solutions were directly attributable to the model were as follows:

Ž To allow access, a way was found to eliminate airborne noise shielding over the upper reduction gear.

Ž The lube oil pumps as hung from the reduction gear would not fit and could not be maintained or replaced without dry docking and cutting through the hull. Working directly with the model, major changes in the lube oil system were made to solve the problem.

Ž The firemain system was simplified through the use of the model.

After the design was completed, the model was transported to the shipyard at their insistence and per the instructions of the owner, for use in planning actual installations and educating tradesmen.

With the construction period of this model being spread over a 3½ to 4 year period, considerable forethought and planning went into the erection sequence of the various sections. Any part or subsection of the model had to be readily removable at any given time for access to other sections. Since this was a most successful venture into modeling as a design and design control tool, it would be in order to briefly outline the erection sequence used:

a. Construction of a strong plywood box-type base.

b. Datum marks representing framing, longitudinal etc., were scribed on the base.

c. The main structure was erected, including framing, bulkheads, stiffeners, deckheads, major foundations and tanks forming part of the main structure. This whole structure was suitably supported.

d. Main and auxiliary machinery was then installed and thoroughly examined by all parties concerned from a point of view of accessibility, maintenance, shipping and unshipping, etc. Any desired changes are proposed and those that are agreed upon are finalized at this stage. The result should be an optimum layout of machinery and equipment.

e. Principal walkways, ladders and gratings were then installed to at least reserve desirable space for these items.

f. Major piping systems, cable trays, engine air intake and exhaust ducting, etc. were installed next.

g. Minor systems, such as light fixtures were installed last.

It was felt that literally hundreds of installation difficulties that were encountered on previous programs were, for this program, resolved on the model with proportionate cost savings.

While the actual model costs over a 3½ year period were high — 21,000 manhours plus approximately $4,000 in materials — there was no question that the benefits resulting from its use were many times its cost.

2. BIW, through its design agent on a commercial shipbuilding contract for 25,000 DWT tankers, constructed machinery space models of the ships' engine room and pump room (See Figure IV-10, Chapter IV). As in the previous example, a scale of 1½" = 1' was employed and plastic was the principal material used. In addition to allowing the user to view the inner parts of the model, plastic parts had the advantage of coming apart easier when revisions were necessary. Moreover, factory made plastic pipe fittings were readily available and attached to the model structure very easily.

This was an extremely successful usage of a machinery space, piping and electrical system model and the following evaluation recounts key chronological factors that should be noted:

- During the early stages of detail design, the model was used as an aid toward the the selection of equipment sized to fit within the machinery space. Proper distribution of equipment from an operability and specific utilization aspect became evident when viewed on the model.
- The detail design development was a joint effort on the part of the designers and the model maker, culminating in an engine room arrangement best suited to meet the operator's requirements.
- As the engineering effort progressed, the model began to take shape, making available the opportunity for representatives from the shipbuilder and the ship operator to review arrangements and discuss the model with the designers. Using the model, determinations were made for relocation of some equipment to suit the individual requirements of the shipbuilder's practices or the operator's preferences. The model maker was capable of making the required changes while the representatives were present so that complete agreement could be reached with all of the interested parties.
- Following agreement on the engine room arrangements, the installation of the detailed system designs were commenced. This was by far the most time consuming phase because it involved a production function and all the stumbling blocks encountered therein. It was found that the closer the working relationship that could be established between the designers and the model maker, the better was the design and the faster the work was completed, trouble free, for issuance by the shipbuilder to the installation trades.
- The plan schedule was developed to support the shipbuilder's construction schedule. The model as a miniaturized version became the proving ground for each system and the relationship of each component to its respective piping. Logically, the shipbuilding schedule for the machinery space identifies, locates and establishes foundations for the main engines, reduction gears, pumps, coolers, heaters, filters and other system supporting equipment. In similar fashion, the model construction follows the same pattern.
- The shipbuilder was next interested in the main piping systems with emphasis on the larger sizes which must be given space priority **and** which were located in the lowest level of the machinery spaces. The model maker worked to the same sequence modified to facilitate fabrication from outside the shell and subject to working area within the shell dependent on the scale chosen. The model maker had to consider installing inboard piping as a priority to that which was run closer to the shell. This, of course, presented an accessibility problem to the model maker. The shipbuilder, of course, would be interested in installing piping near the shell first, leaving the center of the space available for later work.
- Volumetrically, the ventilation and wireways occupy a sizable space

which must be assigned for the primary runs so that the smaller piping can be routed accordingly. To the model maker, these systems represent a major space consideration, because they again restrict working area within the model. It is to his advantage to install a substantial portion of these systems and leave the remaining portions for later installation where accessibility for working becomes a controlling factor. The ship-builder, on the other hand, although he may pre-fabricate and assign space, will find it necessary to "leave loose" certain areas to permit shipboard installation of piping which otherwise becomes inaccessible.

Ž It was impossible to consider installing each system completely prior to commencing work on systems running adjacent to each other. The designer had to consider other systems and herein lies a major cost saving benefit in the role of the model. Relatively speaking, it requires minutes versus days to fabricate the identical piping on the model versus on the actual ship. A three-dimensional picture immediately reveals interferences, clearances, drainage considerations, venting considerations, head room infringements, passageway clearances and any other requirements real or potential — and many such difficulties indeed were revealed. Realistically, if all of the piping systems designed to pass through an area within a space were detailed concurrently and presented to the model maker in preliminary sketch form, he would be able to install interference free runs in a short period of time. The designer then corrects his details as required and all system designs can proceed until another such area is encountered. In practice, not all systems are detail designed at the same time. Priority is given to the larger piping anticipating that the smaller sized piping can be rerouted to avoid interference. In this regard, small piping/tubing that is within the capability of the building trade to bend and shape as being run, is not installed in the model. Interference resolution is not as compelling a factor here. Moreover, the sheer volume of such small piping would only make the model unnecessarily complicated.

Ž Another possible approach to be considered is to give the model maker the diagram and let him run the piping on the model. Then the designer/draftsman can lift dimensions from the model and transfer them to the plan. This can only be adopted if the model maker is experienced with the piping systems. In many instances on this program, such an approach was used for interference areas. Moreover, the designer always has to be called in to determine if other considerations not known to the model maker had been violated. The advantage to be gained by using this technique is time on the part of the designer reviewing other systems plans and developing composite overlays for isolated areas. When this can be superseded by the action of viewing the problem on a model and resolving it by adjustments in place, the assurance of a satisfactory installation is realized. Dimensioning from the model is within the range of acceptability.

3. Another yard, in conjunction with its supportive efforts in this research project, constructed a systems model of the deckhouse for the 25,000 DWT tankers it has under contract (Figure VI-5). This after deckhouse model consisted of all levels 01 through 05 and included internal structure, joinery bulkheads, piping of 1" diameter and greater, vent systems, electrical wire ways and all electrical systems components. Other items of outfit were also included in order to determine the optimum level of detail.

As the yard had never built such a model before, this example can be most helpful to those yards contemplating model work as a management tool. Necessarily

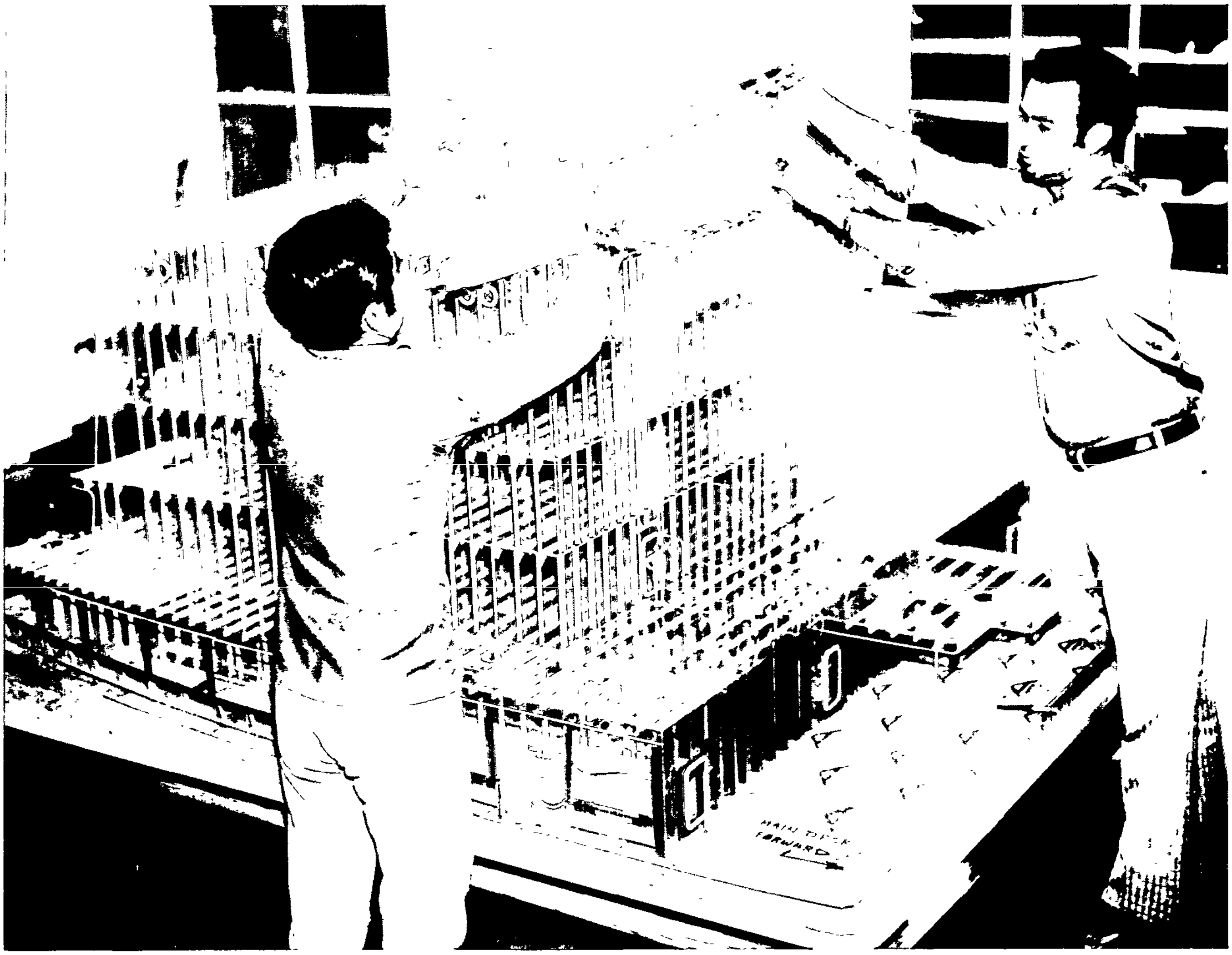

Figure VI-5: Systems Model of 25,000 DWT Tanker Deckhouse Scale 3/4" = 1'.

a model shop was installed and outfitted, tools acquired and personnel trained. Salesmen and model shops were consulted on available material which suited the shop's needs.

In assigning personnel to the project, capable men were chosen from the joiner trades, among them a shipwright quarterman, a pattern and cabinet maker and a shipwright/joiner layout man. While none had significant modeling experience, all knew and understood tools, shop practices, and most importantly, were able to read the usual shipyard drawings.

Initial structural work proceeded very satisfactorily due largely to the simple geometry of the deckhouse. During the installation of various systems, some problems arose owing to the lack of accurate drawings, and the interferences that became apparent in the model. Immediate benefits, of course, resulted from these discoveries. The actual physical task of modeling the piping, ventilation, wireways and fixtures was found to be relatively simple.

Approach: It was decided that the model would be built using a variety of materials, such as plexiglass, wood, plastic, metal and cardboard as best suited to clearly and accurately depict the physical installation configuration.

In order to construct a model small enough to be easily moved and large enough to show sufficient details, a scale of ¾" = 1' was selected. This scale was also convenient for interpolation as it represented the house in 1/16 scale. Additionally, this scale had an economic advantage in that many ready made components were available quickly from model part suppliers who can provide a wide variety of pre-formed, pre-cast shapes, pipes, valves, pipe connections, ladders and gratings to this scale. With all of these precision made aids available from the model industry, it was possible to achieve close tolerances in overall accuracy.

The model was constructed in such a way that it could be easily moved when completed. In order to take advantage of the model as a production aid and to disseminate the information to workmen involved, it was found that ideally, the model should be located convenient to an area where the actual ship construction work is to be performed.

The place in fact selected for the construction of the deckhouse model was a room separate from but adjacent to the joiner shop of the yard. This area was selected because not only all wood working machines would be readily available there, but the model makers selected were employees of that shop. In retrospect, this location was not ideal as the disadvantages outweighed the advantages. Since there must be a very close relationship between the model shop, engineering and planning, the model shop should have been located as close to the engineering department as possible in order to expedite resolution of interferences and solve other problems as they developed. It is also desirable because the proper direction from the various engineering disciplines to coordinate the optimum installation arrangement and to insure that the drawings are revised accordingly can be obtained. The model maker must not “free hand” the installation or the purpose of the model will be sacrificed. It was concluded that every detail must be per the drawing lest the benefits to reducing ship construction costs be diluted or even wasted.

Construction Sequence and Procedures: In the early stage of model planning, considerable forethought and planning had to be given to the erection methods and sequence of construction from the point of view of access and portability since each section of the model must be readily removable at all times for access to internal systems. The configuration of the section erection and assembly sequence should, to the greatest extent possible, represent the planned fabrication and erection sequence of that of the actual ship.

In order to achieve the goal of accessibility to the interior portions of the model, it was decided to build each deck level independently with each level split into sections as would be. done later in assembling the actual superstructure. Thus, bulkheads were cemented to the decks above, in keeping with the actual practice of upside down fabrication to minimize overhead welding.

The construction sequence of the superstructure model then, was briefly as follows:

Ž First, the model base was made out of 3/4" plywood, the top representing the main deck. The entire base was designed as a kind of box and was painted a flat white.

Ž Using pencil line layout, the centerline, framing, longitudinals, supporting structure, etc. were marked.

Ž The structure was then fabricated in sections and erected on the main deck. Each section consisted of the exterior and interior bulkheads and stiffeners as well as stanchions and decks, including deck beams, girders and brackets.

Ž Joiner bulkheads, lining and sheathing were fabricated next and cemented together forming boxes which were fitted inside the structural sections.

Ž Large outfitting items such as ladders, rails, doors were then added.

Ž Piping systems, ventilation trunks and ducts, wire and cableways and light fixtures were then fabricated, fitted and installed in the model sections.

Benefits: A model as outlined above can be a very helpful tool for everyone involved in the production and planning of the actual construction of the structure, provided the model is built early enough. In the design and planning, the engineer wants to solve possible interference problems of the different systems installed, the planner tries to arrange the erection units and the sequence of erection, the superintendent hopes to get a picture of the work load involved, and the foreman intends to allocate and arrange his manpower to preclude interferences with other crafts as well as to finish the construction in the time frame targeted. All of these goals can be achieved if the right model is available at the right time. Therefore, the earlier certain information is available and can be modeled, the more valuable the model will be. Rough sketches and verbal direction are all that are needed to get the modeling of systems started. The systems model is supposed to be an engineering aid, thus it can only be valuable if drawings are developed *from* it and not for it.

The construction status of the deckhouse model was about equal with the status of the assembly work of the actual superstructure in the yard. From this respect not too many benefits were gained from this research model. However, it should be mentioned that several meetings were held with the various trades, using the model as the basis for discussing erection problems. These meetings resulted in significant changes to the originally planned erection breaks and sections of the superstructure. The changes were due to lifting and handling problems of the large units. It was further established that the yard may gain time in outfitting the main deck as a unit, rather than being outfitted after joining.

Personnel from engineering and production engineering consulted the model frequently to solve interference problems.

4. In industries other than shipbuilding, process engineering, power engineering and heavy construction firms have developed the use of fluid and electrical systems models to a highly sophisticated degree. So well has this tool paid off that modeling departments have become an integral part of the organization of most major process and power engineering companies over the past ten years. It is the existence of such model programs which has fostered the creation and growth of model parts supply companies and the American Engineering Model Society.

The actual model construction techniques employed are not unlike those employed in constructing machinery space models for ships. In fact, many of the manufactured model parts designed for process models are used with great success by marine machinery space modeling firms. The important aspect of process modeling programs is their interface with the engineering disciplines. To a large extent, process engineering firms have overcome the natural resistance of engineering personnel to this new method of performing and representing a design. Unlike the shipbuilding industry which rarely uses the model as more than a design check tool, some process engineering companies have gone so far as to do *all* their designing of piping, cabling and ducting runs on the model. Many times, working drawings are eliminated entirely so that the only record of a design consists of system schematics and the model. Piping sketches are made directly from the model as the model is used directly in the field. Due to lead time problems, such extensive use of the fluid and electrical systems model may not be possible in shipbuilding but much can be learned from the process industry to increase the benefits derived from machinery space models in the shipbuilding industry. It should be highly beneficial to any marine designer using a machinery space model to study the papers presented at the annual (starting in 1970) seminars of the American Engineering Model Society. Many of these papers are referenced in Chapter VII of this manual and all are available from the Society (referenced in Appendix A).

G. *Mechanical Models*

As described in Chapter II, mechanical models can be very useful in developing or verifying the mechanical aspects of a particular ship subsystem. While anchor handling models are included in this category, their use is well established and, in fact, often specified contractually. No attempt was made to observe specific examples of anchor handling models. For reference, however, it can be said that such models are generally made to a scale of 1-1/2 " = 1 ', and the material used is normally wood and plywood plus, of course, metal for the anchor and chain. From these models, the orientation and shape of the hawsepipe and bolsters can be determined. One of the objectives of making the model is to shape the shell bolster so that the anchor will not lock before turning over when the flukes come up facing inboard. From the model, the drawing room can prepare lines for the bolster castings.

Examples of other kinds of mechanical models follow:

1. A vendor to one shipyard constructed a working model of a plate turning mechanism they wished to sell to the shipyard. The idea was a good example of where one picture was worth a thousand words as the actual process could be demonstrated completely and convincingly using the model. While the actual model work was relatively crude, it served the purpose and was a major factor in an eventual contract award for the equipment to the vendor.

2. Because of the complex nature of a stern elevator system on a new ship type under contract, one shipyard made a decision to construct a large scale working model of the mechanism as an aid in its construction and assembly (See Figure II-IO, Chapter II). Wood and plywood were the basic materials used. The models overall dimensions were approximately 5' high, 5' wide and 7' long, and the cost of building the model approximately $3,700. The shipyard was convinced that this cost was recovered after the first few production problems were identified. The entire welding sequence was written using the model as a guide. As a result of building the model first, construction of that complex portion of the actual ship proceeded very well.

H. *Facilities Models*

Even though facilities models were not of primary concern during the investigation, it was concluded that those shipyards who do model their facilities find them extremely useful as a shipbuilding management tool, and their use is to be highly recommended. Chapter II-H and III-F describe facilities models and their benefits in general. Following are some specific examples of the current use of such models in shipyards.

1. One shipyard, in contemplating a new steel fabrication and assembly facility, decided to build a model of the proposed facility (Figure VI-6). The scale used was 1/4 " = 1'0". The basic technique used was to simulate the building itself using wooden stanchions and girders. Machinery and equipment was modeled in blocks from balsa wood. Machinery locations and work in process flow could be seen at a glance, analyzed and adjusted by merely moving the blocks and this was actually done many times throughout the design process. As a result, a great deal of the planning and decision making was accomplished through the model's use, as management could quickly visualize the configurations and settle upon the layout that would optimize the new facility. In addition, the company maintained that considerable savings were realized in drawings, as so much of the facility could actually be designed on the model.

Here again, the value of a model as a' communication medium — ***keeping the purpose of a decision-making meeting right on target with uniform understanding*** should be emphasized. While the cost savings realized by reducing the amount of time top management must give to a problem cannot be accurately quantified, the benefits are obvious.

Other facilities models used to advantage by the same shipyard were a shipways and gantry crane model and a turning jig model.

2. Another shipyard has constructed a 1/100 scale model of an entirely new shipyard facility being contimplated. The model is being used as a major tool in designing and planning the shipyard layout. Building and machinery locations, steel process flow, and equipment size can be visualized in three-dimensional scale form and potential problems easily recognized.

3. Another yard constructs facilities models as a matter of routine when the need arises. The yard has no question as to their necessity and usefulness. These models are generally built from wood in a scale of 1/16" = 1'. Among specific models built and used as a basis for design were a panel shop, a fabrication shop, and a plate burning shop. A special jig for building tanker bottoms was designed exclusively by model.

4. Another shipyard constructed a layout of its entire shipbuilding facilities in a scale of

1" = 30' for use as a day-to-day planning tool by its production engineering and producting planning departments (See Figure II-11, Chapter II). The model is kept current in accordance with actual situations in the yard, including ships on the ways and in the water. By using ship models in different combinations on the facilities model, time-phased situations can be created to physically illustrate in three dimensions proposed contract schedules. The model is used also to solve the continuing problem of movement flow and space allocation within the shipyard. In general, then, the model makes it possible for the yard to be accurately aware of present conditions and to foresee future needs. The yard feels that the major benefit of its facilities model is in the *prevention* of mistakes.

The same yard has also completed a model of a newly approved blast and coat facility. It is being used primarily as a control tool for the development of the actual construction schedule (See Figure II-12, Chapter II.)

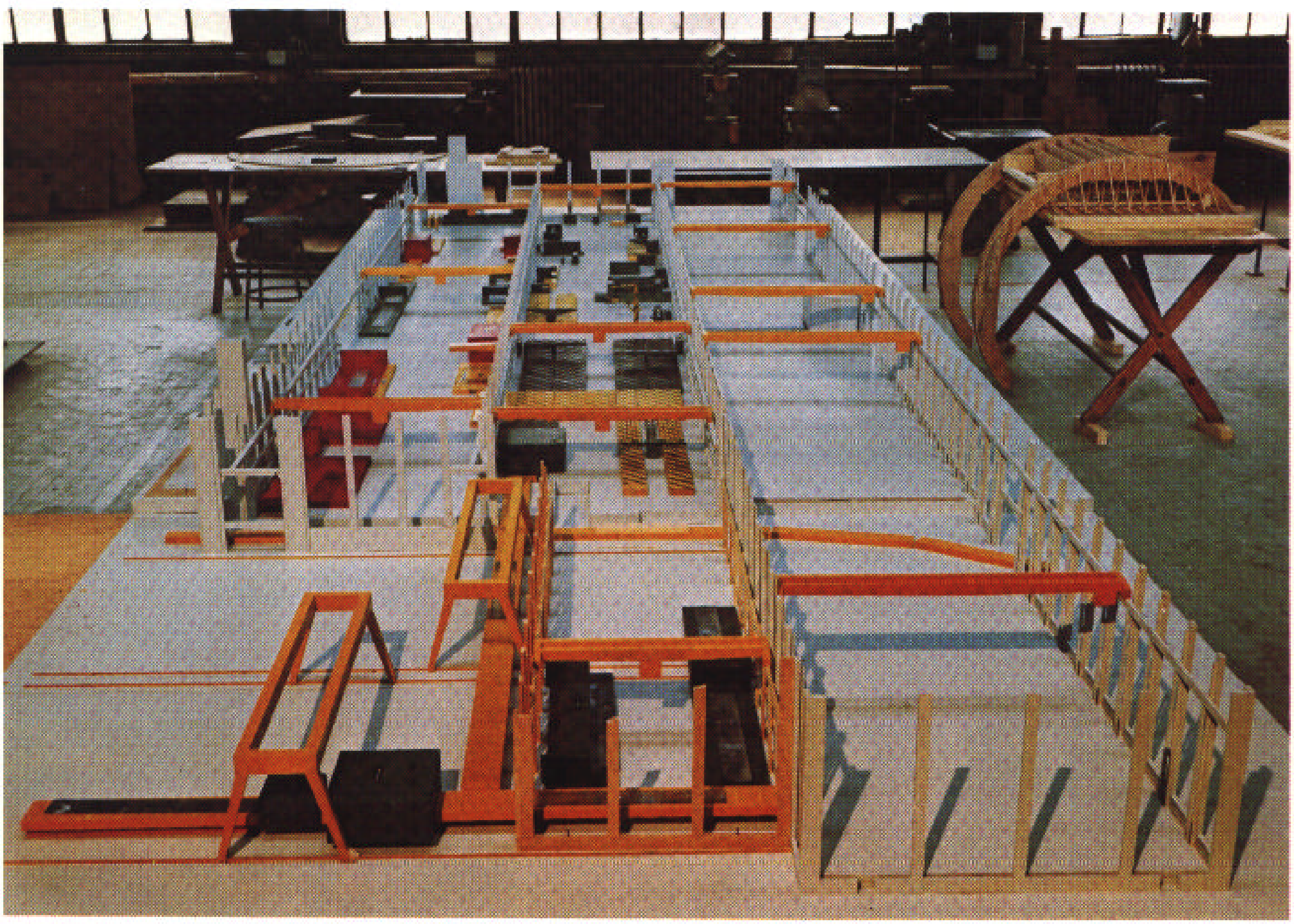

Figure VI-6: Facilities Model Built to Plan New Steel Fabrication and Assembly Facility.

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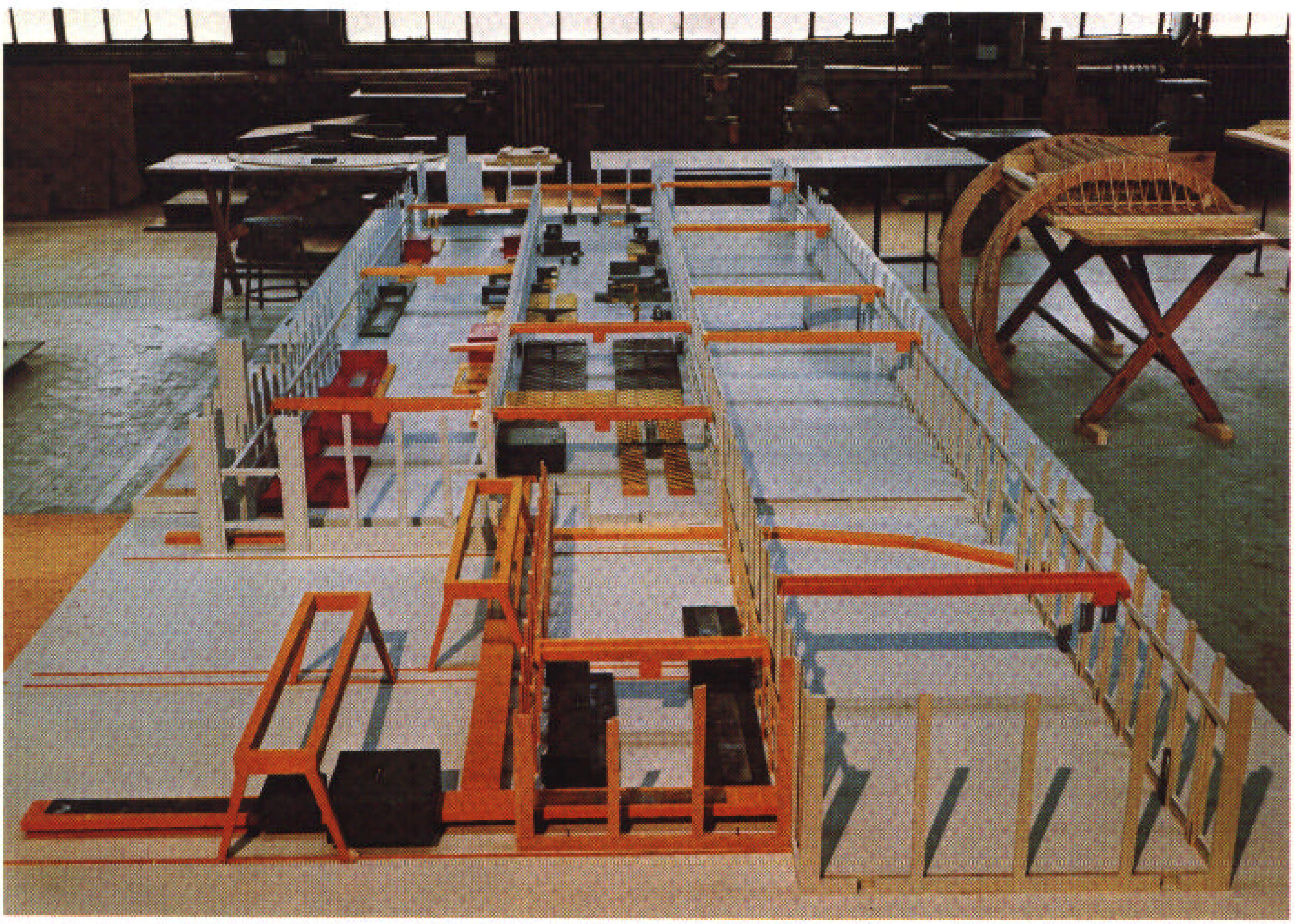

Figure VI-6: Facilities Model Built to Plan New Steel Fabrication and Assembly Facility.

CHAPTER VII
LITERATURE REVIEW

The following list of articles represents the results of a continuing review of literature with respect to the use of models in design, engineering and construction applications. Although many of the articles are not directly applicable to the shipbuilding industry, they contain fabrication and modeling techniques that would be of interest to anyone concerned with the establishment of an "in-house" modeling program. Many of the following abstracts were condensed from the *Journal of the British Ship Research Association* from 1950 to mid-1973.

To facilitate the reader in using this chapter, the review list of articles has been arranged in the six categories as follows: A. Scientific Test Models; B. Structural Models; C. Distributive Systems Models; D. Model Building Methods and Materials; E. Model Studies; and F. Cost Benefits from Establishing and Managing Model Programs. Although some of the articles may contain information on more than one of the above categories, it was placed in the most relevant category at the discretion of the authors. It is not known whether English translations are or can be made available for the foreign articles (indicated in parenthesis following the article's title).

A. *Scientific Test Models*

Colloquium on USE OF MODELS AND SCALING IN SHOCK AND VIBRATION, American Society of Mechanical Engineers, Winter Meeting, 19 November 1963.

The following two papers were among the many presented:

> A MODEL FOR THE SIMULATION OF WAVE-IMPACT LOADS AND RESULTING TRANSIENT VIBRATION OF A NAVAL VESSEL, by J. Andrews and J. W. Church. Pg. 16.
>
> Using a 1:136 scale model of an aircraft carrier hull with a large flared bow, tests are being conducted at the David Taylor Model Basin to investigate the whipping effect that occurs in heavy seas. The model, instrumentation and tests are described.
>
> SOME MODERN DEVELOPMENTS IN THE APPLICATION OF SCALE MODELS IN DYNAMIC TESTING, by H. N. Abramson and G. E. Nevill. Pg. 1.
>
> The theory of models and the general principles of dynamic similarity are briefly presented. Application to dynamic problems is described with special consideration for coupling between the structure and surrounding. medium.

FABRICATION OF A LARGE SCALE MODEL FRIGATE (for Experiments on the Transverse Strength of Ships) by Kingston, E.A.W. *British Welding Journal* (April, 1965). Pg. 152.

This paper describes construction and testing of a large scale steel frigate model which was then subjected to various loadings to determine the transverse strength.

DYNAMIC MODELS OF VIBRATING ROTOR STAGES, by Stargardter, H. American Society of Mechanical Engineers. Paper No. 66-WA/GT-8. December 1, 1966.

The fabrication and testing of models cast of flexible silicone rubber, known as R.T.V., is described and evaluation of the various models is made.

MARINE DIESEL-ENGINE EXHAUST NOISE. PART II SCALE MODELS OF EXHAUST SYSTEMS by Buiten, J. and Janssen, J. H. *International Shipbuilding Progress.* October, 1968. Pg. 353.

Scale model tests of sound levels on the wing of a ship's bridge indicated that proper modeling procedures yield good ship-model correlation of results. The construction and scaling is explained and the test results are evaluated.

USE OF PLASTIC MODELS TO EVALUATE THERMAL STRAINS IN DIESEL-ENGINE PISTONS by Lawton, B. *Journal of Strain Analysis.* July, 1968. Pg. 176.

STRESSES IN THE BLADES OF A CARGO SHIP PROPELLER by Keil, H. G., Blaurock, J. J. and Weitendorf, E. A. *A. I.A.A. Journal* (January, 1972). Pg. 2.

THE LAUNCHING OF THE TSC HAMBURG EXPRESS: MODEL TESTS AND THE LAUNCHING OF THE SHIP by Brix, J. and Limbach, K. (In German) *Schiff u. Hafen* (April, 1972). Pg. 235.

Using a 1:60 scale model of the hull and the launching environment a West German yard simulated the launching of the container-ship Hamburg Express. From the results of the tests, they were able to determine that the ship would safely clear all of the possible obstacles in the launching vicinity.

ON MODEL INVESTIGATIONS PERTAINING TO SCAVENGING IN TWO-STROKE DIESEL ENGINES by Kannappan, A. American Society of Mechanical Engineers. Paper No. 7 I-DGP-8 (20 April 1971). Presented at the Diesel and Gas Engine Power Conference and Exhibit, Toronto.

SCALE MODEL EXPERIMENTS ON MACHINERY NOISE IN SHIPS by Wolde, T. Ten. Symposium on Applications of Experimental and Theoretical Structural Dynamics. South Hampton University (Institute of Sound and Vibration Research). April, 1972.

This paper deals with the application of 1:10 scale models toward investigation of machinery noise levels. Practical discussion of scaling for damping, modeling of welded connections, and the materials used for the model engine was included.

MODEL TEST FOR INVESTIGATING THE SAFETY OF DAMAGED PASSENGER SHIPS AGAINST CAPSIZING IN REGULAR AND IRREGULAR WAVES by Stahlschmidt, E. (In German) Schiff u. *Hafen* (November, 1972). Pg. 826.

Model tests were undertaken at Hamburg University using a 1:30 scale model to determine the safety of a damaged passenger ship from capsizing. The model and the test procedure were described and the results of the tests were given.

B. *Structural Models*

NEW TECHNOLOGICAL METHODS IN SHIPBUILDING by Burghart, H. (In German) *Schiffbautechnik. (September, 1954)* Pg. *289.*

Cardboard structural models were used in an East German shipyard to aid in the construction of a series of 150' motor coasters. The models proved to be quite valuable for the planning of the structural construction sequences as well as planning and production control of assembly fabrication.

CONSIDERATIONS IN THE DESIGN OF STRUCTURAL MODELS by Ralphael, C. *Engineering Review.* February, 1955. Pg. 52.

In this article, the author makes note of some considerations that should be noted in the design and manufacture of structural models.

STRUCTURAL MODEL TECHNIQUES AND THEIR APPLICATION TO OIL ENGINE DESIGN by Morland, G. W., Ganguly, S. and Atkin, T. *Institute of Mechanical Engineers*, Applied Mechanics Group. (1965)

This paper deals with the use of scale models to aid in the structural analysis of engine components. It includes dicussion of the advantages of different types of modeling materials.

USE OF MODELS IN THE DESIGN OF ENGINE STRUCTURES by Flear, B. S. Engineering Design and Application. April, 1965, Pg. 34.

This article deals with the application of models in the design and development of a diesel engine and showed acceptable stresses could be obtained for engine structures.

INVESTIGATION ON A STRUCTURAL MODEL OF THE S. S. OCEAN VULCAN by Chapman, J. D. and Taylor, P. F. *Royal Institute of Naval Architects.* 30 October 1969.

The main purpose of this investigation was to establish a structural modeling procedure which would be directly applicable towards the analysis of a ship's structures. The *S.S. Ocean Vulcan* was chosen for modeling purposes since many experiments had been performed on the fill-size ship. The techniques and materials used in the model construction are described and results of the tests are favorably compared with the ship data.

DESIGN OF MODELS OF HYDRODYNAMICALLY LOADED SHELLS by Murphy, G. International Association for Shell Structures. 10-15 October 1971. Paper No. 8-2.

LARGE ENGINES - ANALYZE BEFORE FABRICATING by Mesloh, R., Brill, W. A. and others. American Society of Mechanical Engineers. Paper No. 71-DGP-7. 18-22 April 1971.

Construction of a physical model is described and the benefits from such testing are given.

MODEL TESTS FOR A DECK-LASHING SYSTEM FOR CONTAINERS. Ship

Research Institute of Japan. December, 1970. Pg. 242.

This paper describes the results of model tests undertaken to establish the forces and stresses in a deck lashing system for containers.

FINITE - ELEMENT AND EXPERIMENTAL STRESS ANALYSIS OF MODELS OF SHIP DECKS WITH LARGE OPENINGS by Beck, A. W. van and Stapel, Jr. (In Dutch) Netherlands Ship Research Centre TND. March 1972. Communication No. 275.

A scale model was used for experiments to determine the influence of large deck openings.

PROGNOSIS WITH PLASTIC MODELS by Wright, D. V. and Bannister, R. L. *Machine Design.* (In three parts)

Part 1: *VIBRATION AND DEFLECTION STUDIES*
August, 1969. Pg. 134.

Part *2: SCALING AND FABRICATION*
4 September 1969, Pg. 136.

Part *3: INSTRUMENTATION FOR DYNAMIC TESTING*
2 October 1969. Pg. 138

This article written in three parts represents one of the most concise reports on the use of plastic structural models for dynamic studies.

C. Distributive Systems Models

PLASTIC PLANNING IN SHIPBUILDING. (In German) *Schiff u. Hafen.* November, 1963. Pg. 1063.

A German company, the Rud. Otto Meyer firm, has experimented with the use of scale models for planning ship engine room layouts. The article briefly describes the procedure followed and advantages of the model versus the complicated drawings of the same layout.

THE ADVANTAGES OF (LAYOUT) MODELS FOR DESIGN PURPOSES by Muller, W. (In German) *Shiffbautechnik.* April, 1965. Pg. 196.

This article contains a good description of the use of scale models in an East German yard for engine room layouts in a trawler. It also includes information on the model shop established, the people involved and the building techniques they used.

NEW METHODS FOR THE DESIGN AND PRODUCTION OF SHIPS' MACHINERY INSTALLATIONS (Layout Models) by Grossman, G. (In German) *Schiff u. Hufen.* November, 1952. Pg. 928.

Model layouts of the engine room of an 83,400 DWT tanker, done in 1:20 scale were considered to be quite advantageous in improving the layout for reduced manning purposes. Pictures of the layout were circulated with the prints of simple isometric pipe drawings to aid in the fabrication and construction of the ship.

THE USE OF LAYOUT MODELS AT THE PRELIMINARY DESIGN STAGE by Lingreen, P. (In German) *Schifbautechnik.* February, 1968. Pg. 212.

The use of 1:20 scale models at the preliminary design stage to determine the position of major machinery items is discussed with reference to technique-s of construction and the advantages of such investigations.

THE DESIGN AND FABRICATION OF PIPE WORK WITHOUT DRAWINGS, BY DIGITAL COMPUTER AND MODELS by Redding, R. J. Institution of Chemical Engineers. 16-17 June 1966. Pg. 50.

A modeling machine, linked with a digital computer automatically bends, shapes and cuts polystyrene pipe parts which can then be assembled to form a model of the system being designed by the computer. The advantages of using this system versus the normal methods are discussed and show very significant savings.

PIPING LAYOUT RATIONALISM BY MEANS OF DESIGN MODELS by Kayser, P. (In German) *Hansa. No. 24.* December, 1967. Pg. 2126.

This article describes the use of 1:10 or 1:20 plexiglas scale models for obtaining improved and less costly engine room designs, particularly with respect to piping. Techniques of the model construction and graphical representation by photographs and simple isometric drawings are presented.

PIPEWORK PRODUCTION FOR SHIPS' MACHINERY INSTALLATIONS WITH AID OF DESIGN MODELS by Nonse,

L. (In German) *Jahrbuck der Shiffbautechnischen Gesellschaft. 1968.* Pg. *269.*

This article contains information on the use of scale models in lieu of the conventional design drawings. Design models enable simple isometric drawings and photographs to be used. An example is cited where several modules of a 4,000 horsepower refrigerated ship were built directly from the models without using the conventional drawings.

D. *Model Building Methods And Materials*

STEEL OR PLASTIC? THE CHOICE OF A MATERIAL FOR SMALL-SCALE MODELS OF NAVAL STRUCTURES by Clarkson, J. *European Shipbuilder. No. 4. 1962.* Pg. *78.*

FABRICATION AND TESTS OF STRUCTURAL MODELS by Breen, J. E. American Society of Civil Engineers, *Journal of the Structural Division.* June, 1968. Pg. 1339.

This article contains details of the fabrication of models and includes a brief dicussion on various materials suitable for elastic and inelastic models. The author uses the majority of the paper to discuss loading, testing and evaluating the results.

MATERIALS FOR STRUCTURAL MODELS by Roll, F. American Society of Civil Engineers, *Journal of the Structural Division.* June, 1968. Pg. 1353.

This article is a comparison of the various types of materials commonly used in structural model applications. The author presents the materials with a minimum amount of actual physical properties but attempts to point out the advantages and disadvantages in normal applications.

MODEL ENGINEERING - NEW APPLICATION FOR THE DRAUGHTING MACHINES IN SHIPYARDS. Kongsberg Electronics N. C. Systems News. No. 2. 1971.

An automatic milling tool has been developed and is briefly described in connection to its use when attached to a draughting machine for cutting accurate model parts from plastic up to 4 m.m. thick. It is numerically controlled and uses data developed for numerical control for steel plates.

STRUCTURAL MODELS FOR ARCHITECTURAL AND ENGINEERING EDUCATION by Pahl, P. J. and Soosaar, K. MIT, Department of Civil Engineering, TA1-M41 - C58, R64 -03.

This research project covers the subject of structural modeling in great detail. The section on materials gives physical properties and advantages or disadvantages of each material for various applications. The section on fabrication presents methods and techniques generally found to be acceptable in structural modeling. A brief section is also included on planning model studies.

SCALE MODELS IN ENGINEERING AND DESIGN. *American Engineering Model Society.*

The following two papers were among the many presented at the 1972 seminar:

- HOW TO DO IT by Lance, H. Pg. 160.

  This paper presents the basics of model construction including discussion on the scale, base materials and dimensions, structural shapes, equipment and tagging methods.

- HOW TO DO IT by Carter, D. Pg. 173

  The basics of model construction are again presented with special emphasis on the six areas of piping, electrical and instrumentation, heating, ventilating and air conditioning ducts, tagging, color coding, and shipping the model.

PLASTICS FOR THE CRAFTSMAN by Newman and Newman. Crown Publishers, Inc., New York.

This publication represents another major source of plastic modeling "know-how" used in this project. It also contains some exotic uses of plastics.

PLEXIGLAS DESIGN AND FABRICATION DATA. Rohm and Haas Company, Independence Mall West, Philadelphia, Pennsylvania 19105.

This book is considered an excellent source of plastic modeling technology and is considered a necessary tool in any model shop. It was a major source of information in this model project.

MODEL BUILDING FOR ARCHITECTS AND ENGINEERS by Taylor, Jr. American Institute of Architects. McGraw-Hill Book Company, New York.

This book describes the techniques of model building for facilities and architectural models.

FLOATATIONAL MODELS by Farmer, W., N. A. in *The National Fisherman,* Camden, Maine. February and August, 1973.

These two articles describe how to build and test small models made of inexpensive materials with particular reference to small craft such as yachts and fishing vessels.

E. *Model Studies*

THE USE OF SHIP MODELS IN THE EXPERIMENTAL STUDY OF THE HYDRAULIC PROBLEMS ARISING FROM NAVIGATION by Greslon, L. (In French) *Nouvenauter Techniques Maritimes* en 1957. Pg. 61.

Ship behavior patterns in canals, harbors and at moorings have been studied by the French at the Sogreah hydraulic laboratory. The techniques used and the measurements taken are described.

MODERN AIDS TO DESIGN AND DRAUGHTING. Papers from one-day Symposia, 1967. Ministry of Technology, National Engineering Laboratory Report No. 347. March, 1968.

The three following papers were among those presented

C 1 - THE USE OF MODELS IN THE DESIGN PROCESS by Saunders, A. Pg. 93.

C2 - MODELS AS AN AID TO DESIGN AND COMMUNICATION by Crousdale, K. R. Pg. 122.

C3 - THE USE OF MODELS AS AIDS TO DESIGN by Holmes, E. Pg. 144.

SOME PROBLEMS IN THE DEVELOPMENT OF MODELS OF THE DESIGN PROCESS by Werler. (In German) *Kammer der Technik.* Presented at Autumn Shipbuilding Meeting Rostock. October, 1969.

USING ENGINEERING MODELS IN THE DESIGN AND CONSTRUCTION OF INDUSTRIAL PIPING INSTALLATIONS. 1970 Seminar, the *American Engineering Model Society.*

The following two papers were among those presented

- THE CONCEPT, PRINCIPLES AND FUNCTION OF THE ENGINEERING MODEL APPROACH by Rowland, J. R. Pg. 2.

  This paper deals with the basic ideas behind engineering modeling including a brief discussion of past history and justification of the modeling approach.

- THE DEVELOPMENT AND USE OF ENGINEERING MODEL by Lewis, H. Pg. 39.

  The use of models as a design tool is discussed and a brief outline of the cost and economies associated with model engineering is presented.

SCALE MODELS IN ENGINEERING AND DESIGN. *American Engineering Model Society.*

The following five papers were among those presented at the Society's 1971 seminar:

- BRITISH PIPING MODEL PRACTICE by O'Reilly, J. Pg.31.

  This paper presents a brief review of the pipe modeling techniques as developed in Britain with a brief mention of their applications to the British shipbuilding industry.

- EUROPEAN MODEL PRACTICES by Visser, J. Pg. 37.

  This paper presents a brief review of current European practices — with particular reference to the industries in each country which employ model engineering as part of their design procedure.

- USE OF MODELS ON SMALL PROJECTS by Miller, R. E., Jr. Pg. 79.

  Model engineering for small projects can also lead to significant cost reductions. The benefits of optimimum layout and a good communication tool are still quite valid for smaller projects.

Ž CENTERLINE MODEL PIPING by Elich, J. P. Pg. 113.

Centerline model piping is that where only the centerlines of pipe runs are represented by wire or string and occasional discs of paper or plastic show true model pipe diameter. This paper presents the centerline piping techniques and the advantages of such a method.

Ž FULL-SCALE MODEL PIPING by Kaplan, H. H. Pg. 123.

Full-scale model piping incorporates piping of the properly scaled diameter and all parts are represented by accurate scale pieces. Although more costly than centerline model piping, its use is sometimes justified where possible interferences and clearances are of importance.

The following three papers were among those presented at the Society's 1972 seminar:

Ž USE OF MODELS DURING THE CONSTRUCTION PHASE by McCoy, G. T. Pg. 66.

The use of models during the construction phase proved to yield the greatest benefits for any project. The author presents some of the rationale for efficient application of models to job site engineering.

Ž THE USE OF MODELS IN THE SHIPBUILDING INDUSTRY by Phillips, R. A. Pg. 80.

This paper describes the experience of a Canadian design office with models in ship design. These include display models, engine room layouts, anchor stowage models, shell plating models and others.

Ž .THE USE OF MODELS IN THE DRAWING OFFICE by Brown, E. A. Issued by Draughtsman's and Allied Technicians Asso.

This booklet describes many types of models and their usefulness to aiding design. It includes discussion of planning and construction details, the training of personnel and fabrication checks during construction.

USING ENGINEERING MODELS ON SMALL PROJECTS by Miller, R. E. Jr., *Engineering Graphics.* April, 1972. Pg. 6.

MODEL MAKING: A PRICELESS TOOL. Bechtel Briefs. February, 1970. Pg. 10.

F. *Cost Benefits From Establishing And Managing Model Programs*

USING ENGINEERING MODELS IN THE DESIGN AND CONSTRUCTION OF INDUSTRIAL PIPING INSTALLATION.

American Engineering Model Society.

The following three papers were presented at the Society's 1970 seminar:

Ž MODEL COSTS VERSUS VALUE RECEIVED by Downer, H. D. Pg. 19.

This article presents some of the advantages of using scale models for engineering and design in terms of savings to the contractor and the future owner.

Ž GETTING THE NECESSARY INFORMATION TO CONSTRUCT THE MODEL by Tronsen, W. Pg. 27.

This paper presents the rationale used for obtaining information for various model construction steps.

GETTING THE DESIGN FROM THE MODEL TO THE CONSTRUCTION PERSONNEL by Walker, E. A., Jr. Pg. 35.

This brief article describes the function of a model as a design tool to aid the contractors in actual construction. The model is normally used in conjunction with simple isometric drawings depicting layouts and the location of the individual parts of the system.

SCALE MODELS IN ENGINEERING AND DESIGN.

American Engineering Model Society.

The following four papers were presented at the Society's 1971 seminar:

● INTEGRATING A MODEL PROGRAM INTO THE ENGINEERING DEPARTMENT by Brown, M. K. Pg. 1.

This article presents the reasoning and steps for integrating a model engineering program into existing engineering facilities. Subjects covered include costs, time, need for training programs and model usage in construction.

- PIPING DESIGN MODELS — MANAGEMENT AND OPERATION OF THE PROGRAM by Lewis, H. A. Pg. 15.

The author presents some of the steps for managing a model program. Particular emphasis was made that the model program is not an additional step in design but a replacement for some of the more complicated orthographic drawings.

- AN IN-HOUSE PROGRAM OF ENGINEERING MODELING by Hale, R. J. Pg.41.

This article presents an in-house modeling program as employed by a laboratory. The author presents prerequisites for establishing a program which includes a dependable work volume, management support, selection of personnel and economic evaluation of benefits.

Ž ADVANTAGES OF MODEL CONSULTANT SERVICES by McCoy, A. D. Pg. 67.

This author presents the possible benefits realized by using the expertise of established model organizations and consultants for organizing and executing an engineering model program.

The following five papers were presented at the Society's 1972 seminar:

- PROBLEMS OF STARTING A PIPING DESIGN MODEL PROGRAM by Burns, W. R. Pg. 14.

This paper presents the problems that one can expect to encounter in establishment of model programs and how to handle them. Particular emphasis was made to problems encountered in the model fabrication schedules.

- PROBLEMS OF STARTING A PIPING DESIGN MODEL PROGRAM by Bliss, C. Pg. 37.

This article presents the problems encountered by a modeling firm in establishing their own program, how they overcame them and the benefits they expect to receive.

- VOCATIONAL TRAINING PROGRAM — MODEL BUILDING TECHNICIAN by Neklason, N. C. Pg. 49.

This article describes a course developed in the West Valley Community College in California for the training of model building technicians. A brief history of how the course was developed and descriptive list of the required courses is included.

Ž TRAINING by Pennock, J. O. Pg.58.

This paper is a brief presentation of the rationale used for training personnel for model building programs.

- MODEL INFORMATION SYSTEMS AND PROCEDURES by Willstein, L. Pg. 125.

This paper describes several significant steps in the modeling design work including preliminary model review, tagging and identification of parts, final model reviews and the production of isometric drawings from the model.

MODEL DESIGN TRAINING PROGRAM: OUTLINE.
Bechtel Model Shop, Bechtel Corporation.

This outline presents a good description of a working training program and includes fabrication ideas that can save on fabrication costs.

EMPLOYMENT OF CONSTRUCTION MODELS RATIONALIZES PIPE FITTING by Kayser, P. Lubeck (A German Firm).

APPENDIX A

SUPPLIERS, MANUFACTURERS AND MODELING COMPANIES, SOCIETIES

The Following Companies Specialize In Model Construction:

United Scale Models
Division CGS Scientific Corporation
P.O. Box 222
Concordville, PA 19331

Jay S. Hanna
Hanna Associates
Spear Street
Rockport, ME 04856

Bechtel Corporation
P.O. Box 3965
50 Beale Street
San Francisco, CA 94119

I.E.A. Models
733 King Street, East
Hamilton, Ontario, CANADA

Scale Models, Inc.
1220 West Sixth Street
Cleveland, Ohio

Model Builders
284 Campbell Road
Brockport, NY 14420

"Visual"
"Visual" Industrial Products, Inc.
Indianola, PA 15051

NAVAC, Inc.
Naval Architect Visual Aid Company
P.O. Box 781, Manor Branch
New Castle, DE 19720

The Following Companies Specialize in Scale Model Parts:

Engineering Model Associates
1621 N. Indiana Street
Los Angeles, CA 90063
(Plastic Structural and Piping Parts)

Model Parts Incorporated
La Crue Street
P.O. Box 214
Concordville, PA 19331
(Plastic Structural and Piping Parts)

Industrial Model Supplies
7 North Mary Street
Wilmington, DE 19804
(Plastic Structural and Piping Parts)

Rohm & Haas Company
P.O. Box 584
Bristol, PA 08046
(Plexiglass and Plastics)

E.M.A. Model Supplies, Ltd.
74 A The Centre
Feltham, Middlesex, ENGLAND

Gerard Metal Craftsman, Inc.
151 W. Rosecrans Avenue
Gardena, CA 90701
(Aluminum Shapes and Expanded Metal Sheets)

James Bliss and Company, Inc.
Route 128
Dedham, MA 02026
(Shipfittings, Lifeboats, and Deck Equipment)

Northeastern Model Company
99 Cross Street
Methuen, MA
(Wooden Structural Shapes)

The Following Companies Have Special Tools That Can Be Adapted To Model Building:

Rockwell Manufacturing Company
400 N. Lexington Avenue
Pittsburg, PA 15208
(Power Tools)

Milwaukee Heat-Blo-Gun Model 750X
Milwaukee Lock and Manufacturing Company
5024 N. 37th Street
Milwaukee, WI 53209
(Heat Guns)

Brookstone Company
14 Brookstone Building
Peterborough, NH 03458
(Small Modeling Tools)

Fast Form
Wing Manufacturing
P.O. Box 33
Crystal Lake, IL 60014
(Vacuum Forming Machine)

The Following Society Has Records Of Model Builders And Suppliers For Further Information:

American Engineering Model Society
P.O. Box 177
Ross, OH 045061