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NAVY DEPARTMENT

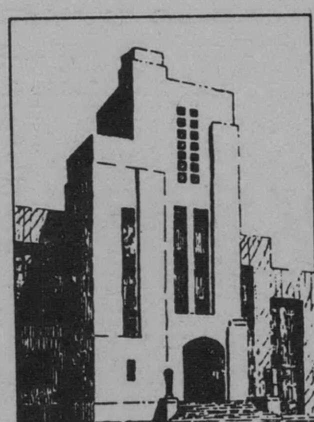
THE DAVID W. TAYLOR MODEL BASIN

WASHINGTON 7, D.C.

WAX MODEL CONSTRUCTION AT THE DAVID W. TAYLOR MODEL BASIN

by

Jacques B. Hadler and
Werner B. Hinterthan



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ABSTRACT

This report gives an account of the development of a satisfactory wax blend for the manufacture of ship models at the David Taylor Model Basin. The blend selected consists of 30 percent refined paraffin (Aristowax), 32.5 percent hydrogenated castor oil (Opalwax), and 37.5 percent n-butyl methacrylate (Lucite 44). This blend is suitable for use in the Washington, D.C. climate for the manufacture of models up to 33 feet in length. Its use results in model costs which are about 55 percent of those for similar wood models, and in a reduction in manufacturing time of almost two weeks. The manufacturing methods in use with this wax blend are also outlined in some detail in this report.

INTRODUCTION

Until 1948 all ship models for the David Taylor Model Basin were constructed of wood. Because of the rising costs of wood model construction, the staff of the Model Basin proposed at that time to develop wax model manufacturing facilities to supplement the wood model shop. It was known that European model basins used wax almost exclusively for ship model manufacture. Although wax model construction at the Taylor Model Basin had been discussed in the past, it was believed that the high temperatures prevailing in Washington, D.C. during the summer months would preclude its use because of softening and distortion of the models. However, with the general development of synthetic products it was considered probable that a wax composition could be developed which would stand high temperatures without distortion and be strong enough for all practical purposes. A suitable blend was finally obtained and it was then decided that there was enough to be gained in time and cost of model construction to warrant the equipping of a wax model shop.

WAX VERSUS WOOD

Wax as a material for the manufacture of ship models has many advantages. Wood today is extremely expensive and often not well seasoned. Although wax is expensive too, it can be used over and over again and therefore rapidly compensates for any initial higher outlay. Wax models can be made much more quickly and easily. They require no paint and do not deteriorate when immersed in water. In addition, any alterations in the hull form which may be considered desirable can be much more easily incorporated in a wax model than in one of wood.

Paraffin models are generally used in European model basins. The disadvantages of possible change in shape, such as sagging, are considered secondary to the advantages of the lower cost and shorter time in producing the original model, the facility with which the shape can be altered, and finally the possibility of re-use of the material. Moreover, there is no trouble due to leakage, no painting is necessary, and the model need not be stored if the waterline plan from which it was cut is retained. From the European point of view, the use of wood is justified only for special purposes, such as:

a. Models which must be stored for some time in proper condition for re-use.

b. Higher speed models for maneuvering tests, where physical damage is likely.

c. Models for tests at very light displacements.

d. Models larger than 23 feet in length which are to be tested in artificially created waves. The law of similitude demands similar mass distribution between the model and full-scale ship. Such weight distribution may cause strength troubles in tests with wax models.

While wood models of large size have an advantage compared with wax models, paraffin has also been used for models up to 36 feet in length which were tested in waves. Casting difficulties were overcome by casting the model in two sections which were joined amidships by long bolts through bulkheads about one foot thick which provided additional strength reinforcement. Such paraffin models proved to be strong enough to prevent cracking even when running in artificially created waves.

CHARACTERISTICS REQUIRED OF WAX

The major properties desired for a wax-type composition which is to be a suitable substitute for wood are the following:

a. The material should be reasonable in cost and readily obtainable.

b. It should be hard enough for handling without marring the surface, yet be soft enough for easy hand or machine working with ordinary woodworking tools.

c. It should be free from distortion or plastic flow at air and water temperatures up to at least 100 F.

d. It should be easily melted at reasonable temperatures and readily poured into the mold with a minimum of shrinkage and porosity. It should form a watertight smooth body which will separate cleanly from the mold.

e. The finished surface must be equivalent to that obtained with smooth sanded, varnished, or painted wood.

f. The strength of the material should be such that 30-foot models can be handled with canvas strap slings or pad eyes supporting the model at two points, and a ballasted model afloat should not hog or sag appreciably.

g. The thermal coefficient of expansion should not be greater than 3×10^{-4} per degree F, and the variation in dimensions due to absorption or loss of water or change in structure should not exceed 0.1 percent over a period of six months.

h. The wax should be capable of being remelted and re-used without loss of the above characteristics.

i. The materials should be nontoxic.

j. The blend must have good patching qualities.

k. Special precautions to the underwater surface should not be necessary before using the finished model, such as careful brushing of the bottom when immersed to remove air bubbles, or immersing in water for three days before it is ready to run.

WAX DEVELOPMENT

In initiating the wax development program, the experience of the European tanks with the use of paraffin and beeswax in model construction was examined. This indicated that models manufactured of these materials would probably sag, if not specially supported, in the temperature range above 70 F.

As a first step, wax manufacturers and suppliers were contacted and requested to supply samples of material suitable for conducting physical and chemical laboratory tests. More than 50 different natural and synthetic waxes and plastics were tested individually and in about 80 different combinations. These tests, made on small samples, included tests for strength, melting temperature, shrinkage, distortion, saponification, hardness, workability, and smoothness of the finished surface.

As a result of these tests, it was found that a composition of 35 percent n-butyl methacrylate (Lucite 44), 27.5 percent hydrogenated castor oil (Opalwax), and 37.5 percent refined paraffin (Aristowax, 140 M.P.) met most of the characteristics of the desired wax compound. At this time n-butyl methacrylate was not commercially available and varied in composition between orders. This wax mixture was stronger than the paraffin compound used in Europe, especially at comparatively high temperatures. However, it was found that it was difficult to melt and mix properly. When cast into a mold, it required careful cooling to avoid excessive hardness. It also tended to separate in the mold, the heavy n-butyl methacrylate settling to the bottom. Subsequently, a number of 12- and 20-foot models were cast. The difficulty of cutting these models on the waterline cutting machine in use at that time and the difficulties outlined above indicated the desirability of trying other basic materials and mixtures.

Polythene, for instance, one of the lightest and simplest of the plastics, has been the subject of intensive research by the Du Pont chemists. Polythene is a thermoplastic resin. It is odorless, and, since it is a paraffinic hydrocarbon, it is nontoxic. It is very flexible although it does not possess the limp, rubbery quality that characterizes most nonrigid plastics. It is outstanding for its low water absorption and has the advantage of a low specific gravity, 0.92 at 77 F.

A number of models were made of paraffin blended with 4 percent of Polythene (Alathon D). The cores were left in these models in order to provide additional strengthening. This was not entirely satisfactory, as the wood in the core tended to swell if the models were stored in water. Furthermore the inside of the model had to be kept dry when testing, a difficult problem for a self-propelled model with a shaft stuffing box extending through the core. The permanent type core also increased the cost of the models.

About this time, a number of samples of Alathon D in combination with natural waxes were made and tested. This mixture held promise. Alathon D blended well with natural waxes and was easily shaped. About 32 models were made of compositions of Aristowax (98 to 90 percent) and Alathon D (2 to 10 percent). In manufacturing these models, it was found that the Alathon D blends were subject to severe shrinkage, had a high thermal coefficient of expansion, and some pitting of the surface. Small temperature changes would frequently crack the model and break it into numerous pieces.

Finally, after attempting to remedy this difficulty by reducing the quantity of Alathon D, it was decided to reinvestigate the n-butyl methacrylate mixtures, despite the previous difficulties in blending and working this material. N-butyl methacrylate was now uniform in composition, and commercially available under the name "Lucite 44." The Lucite acrylic resins include a series of poly-methacrylate esters which have excellent physical properties. Data on available Lucite resins will be given in later Model Basin reports now in preparation. About 12 samples were made with Lucite 44 in combination with four varieties of natural and synthetic waxes. A number of 7-foot models were cast of the most promising mixtures. From this experience it appeared that a mixture of 37.5 percent Aristowax, 25 percent Opalwax, and 37.5 percent Lucite 44 would give very satisfactory results. Eight 20-foot models were successfully manufactured to this formula. In the meantime, tests were being run on samples with small modifications to this blend. It was found that a mixture of 30 percent Aristowax, 32.5 percent Opalwax, and 37.5 percent Lucite 44 was still better. It could be used the whole year around, had good machinability, a very smooth marble-like surface, and no saponification.

A number of models were constructed of this material, and all were successful. It was then decided to try casting a 25-foot model using the normal handling procedures. This model also proved to be quite successful and did not require any unusual handling techniques. With this model placed in water, a hogging test was run over a 100-hour period, and a hog of approximately 5/8 inch was recorded. The largest portion of this hog occurred within the first few hours. It has since been concluded from test specimens that some of this hogging was due to the thermal differences in the basin air and water temperatures. The remainder of the hogging was due to the normal weight versus buoyancy distribution of the model.* The removal of the hogging from the model by a tension device will be discussed later. Since this model was satisfactory, it was decided to construct a 30-foot model of a fine-lined hull; this was also successful.

It was decided that this wax compound met most of the requirements of the Model Basin. Its cost, 50 cents per pound, is acceptable. For use in the Washington, D.C. climate, its strength and dimensional stability are superior to waxes previously used in model testing.**

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*It should be noted that this particular model had a rather unusual hull shape with the buoyancy concentrated amidships while the ends, particularly the stern, were abnormally heavy.

**Still, the high linear coefficient of thermal expansion and the density of 0.987 at 60 F are not entirely satisfactory.

The disadvantages of the compound are considered secondary to the advantages of the marble-like smooth surface, low saponification values, good patching properties, and great toughness. Consequently, sufficient quantities of material were ordered for routine wax model construction. Table 1 gives the prices and the manufacturers of the constituents used in the Model Basin blend. Figure 1 shows samples of these materials.

TABLE 1

Constituents of the Wax Blend Presently Used at the Taylor Model Basin

Trade Name	Manufacturer	Proportion in Percent	Price per lb
Lucite 44	Polychemical Department E.I. du Pont de Nemours & Co. Wilmington, Delaware	37.5	$0.92
Aristowax (MP 143-150)	Petroleum Specialties Co. New York, N.Y.	30	0.12
Opalwax (Hydrofol Glycerides 200)	Archer Daniels Midland Co. 2191 West 110th St. Cleveland 2, Ohio	32.5	0.38
	Model Basin Blend	100	$0.50

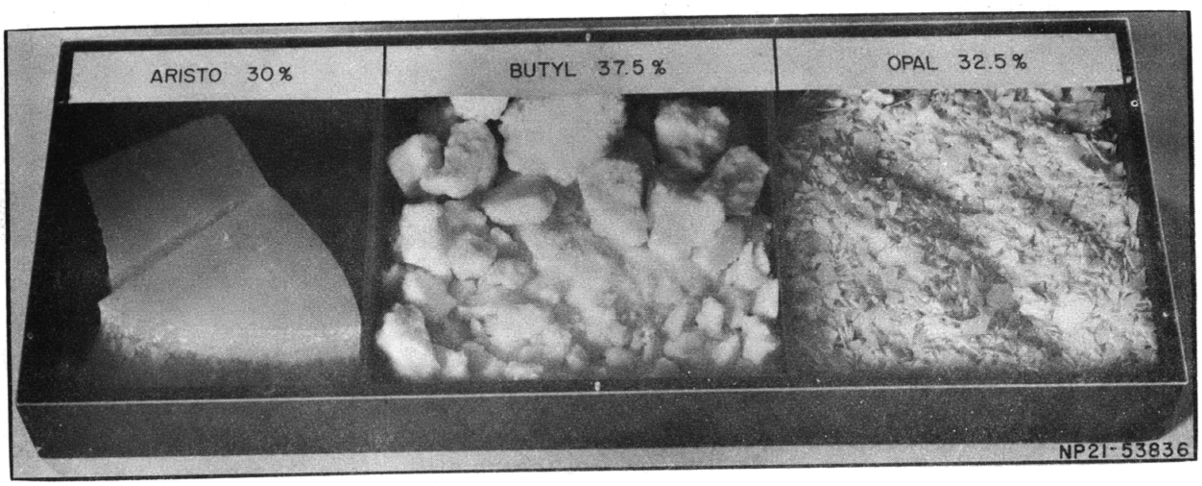

Figure 1 - Samples of Materials Used in Model Basin Wax Blend

WAX MODEL MANUFACTURING

THE MODEL CUTTING MACHINE

In 1948, a model cutting machine capable of cutting either wood or wax was ordered from the British firm of R.W. Munro Ltd., London, England, which specializes in the design and manufacture of model basin equipment. This machine cuts a waterline by means of two rotating knives, which are positioned to the proper half-breadth, port and starboard of centerline, by means of a "feeler" manually controlled by the operator, while the carriage of the machine travels past the feeler in synchronism with the model's motion past the knives. Waterlines are varied by vertical positioning of the knives before each cut. This machine was installed and put into operation in 1949.* In the same year, a wax shop was fitted out with clay bins for casting wax models, electrically heated wax melting tanks, and miscellaneous handling equipment and small tools. Figure 2 gives a general view of the major facilities of the wax shop.

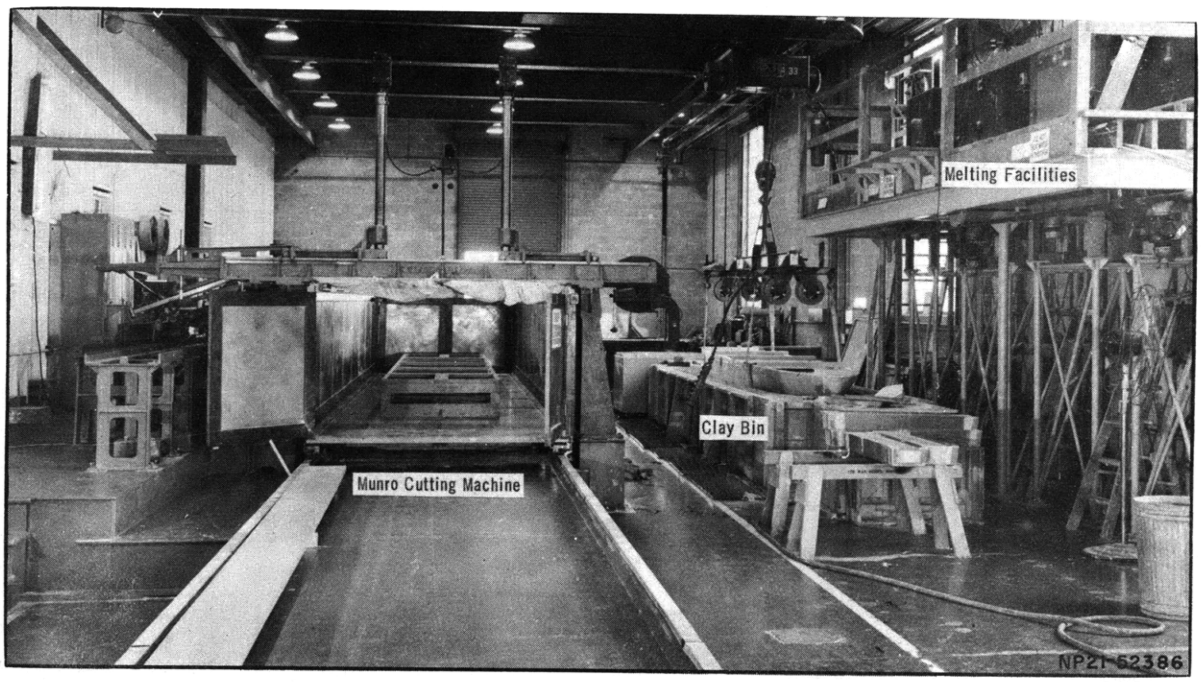

Figure 2 - General View of Wax Shop Showing Munro Cutting Machine, Clay Bin, and Melting Facilities

*The cutting machine is equipped with a set of changeable gears in the connection between the main carriage drive and the drive for the table on which the cutting plan is mounted. This ratio is normally set at 2:1 so that the customary one-half longitudinal scale of the drawing is re-expanded to 1:1 at the model. Other drive ratios are used in special cases.

PREPARATION OF PLANS

The method of preparing plans for use in the wax shop has an important influence on the efficiency of later operations. At the Model Basin, upon receipt of the lines plan from the design agent, the scale of the model is first determined and the body plan is expanded to model size by hand or photographic means. Each station is then outlined in red pencil outside the mold line to indicate the size and shape of the clay mold, and in blue pencil inside the mold line to indicate the size and shape of the core. The red line is 3/8 inch outside the mold line to provide a cutting allowance, plus 1/2 inch at the upper edge of the model where the sides are vertical in order to provide a "draw," or taper to facilitate removal of the casting from the clay mold. The blue line is held inside the mold line 2 1/4 inches at the sides and 2 3/4 inches at the bottom to allow those wall thicknesses in the finished model at the sides and bottom, respectively (see Figure 3). These lines are usually carried to a level 6 inches above the designed LWL of the model, except in special cases where additional freeboard may be required.

The spacing of the stations is also included in the drawing for use by the shop in preparing longitudinal battens, one for spacing stations in the clay mold and one for the core. The mold batten is marked so as to space each station an additional inch away from the midship section in order to insure a full 3/8-inch cutting allowance where the hull has a large taper. This is necessary because the 3/8-inch allowance on the body plan is measured perpendicular to the centerline and not to the surface of the model so that the resulting allowance on the casting would be less than 3/8 inch if the station were not displaced. After preparation of this body plan, the shop can begin construction of the clay mold and core.

Meanwhile, the drafting room prepares the cutting plan which consists primarily of a waterline plan with the waterlines spaced about one inch apart on model scale. The scale in the longitudinal direction for a 20-foot model is generally set at one-half scale. The scale in the transverse direction is usually model scale to avoid interferences between the closely spaced waterlines. These waterlines are drawn on tempered masonite, painted white, and normally drawn with different colors of ink as an aid to the cutting machine operator. In models with deadrise, three or four parallel longitudinal lines are added, which divide the half-breadth into equal intervals and are used in making longitudinal cuts in the deadrise area.

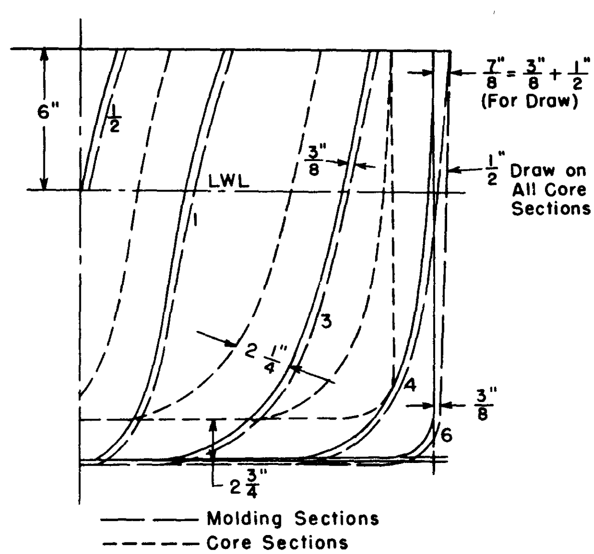

Figure 3 - Mold and Core Sections

The drafting room also prepares bow and stern outboard and inboard profiles and a depth scale. The depth scale provides the proper scale for vertical spacing of the waterlines and the lines for deadrise mentioned in the previous paragraph.

THE CORE AND THE MOLD

Upon receipt of the mold and core plans, work is started in the shop on manufacture of the core of the model. This consists of a series of stations, cut from inexpensive wood, on which are mounted wood lathing, 3/16 to 1/4 inch thick and widely spaced, to get the general shape of the inside of the hull. High accuracy is not required here since only the outside of the model is to be cut to accurate shape. The inside shape is unimportant so long as the thickness is reasonably uniform. The lathing is covered with a waterproof rubberized cloth. Figure 4 shows a partially completed core for a 20-foot model. Wood blocks which are to be cast into the model for later attachment of lifting, towing, and dynamometer pads are attached to the bottom of the core in order to position them properly in the mold.

Figure 4 - Fabrication of Core for a 20-Foot Wax Model

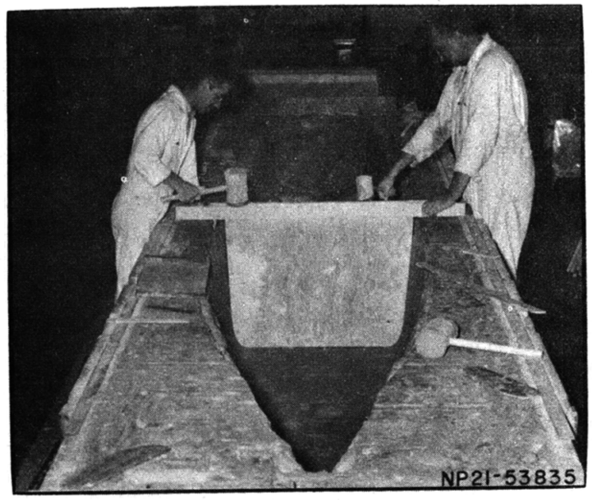

Figure 5 - Molding Clay Bin in Preparation for Casting 20-Foot Wax Models

While the core is under construction, the clay bin is also prepared. Templates are made from the mold plans at each station and the bow and stern profiles. These are used to obtain the desired mold shape, as in Figure 5. The clay used is a fine "Cornwall China Ball Clay" imported from England. After the mold has been completed, a batten is placed across the mold in the bin at the midship section, and a plumb bob is used to mark the centerline and the midship station as a cross on the bottom of the mold. This is grooved into the clay and appears as a raised cross on the bottom of the solidified wax model. It is valuable in helping to set the model in the cutting machine.

The core is then inserted (Figure 6) and aligned, and the wall thickness is checked. At this point the mold is ready for the casting operation, see Figure 7.

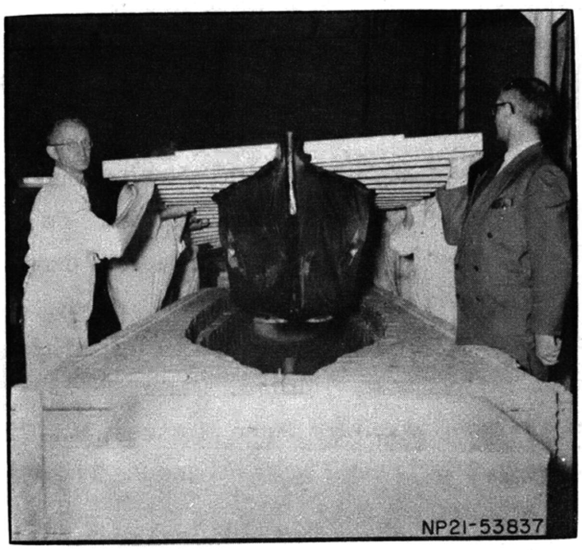

Figure 6 - Inserting Core into Clay Bin

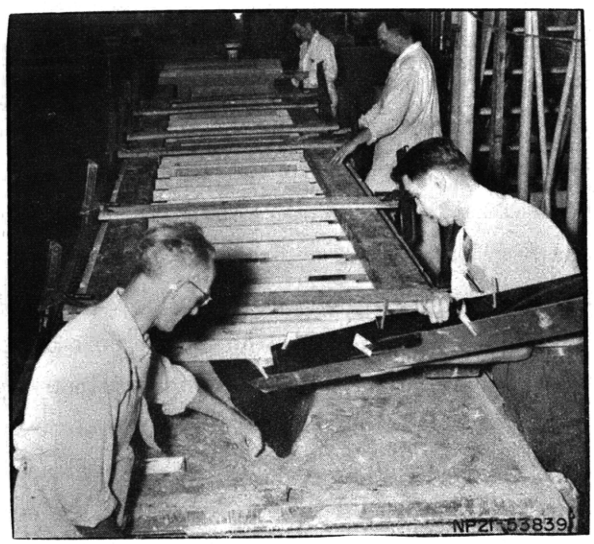

Figure 7 - Preparing for Pouring of Wax for 20-Foot Model

MELTING, BLENDING, AND CASTING PROCESSES

The process of melting and blending the wax mixture requires approximately 18 hours. The blending of the natural with the synthetic materials is carried out very carefully by following a specially developed technique in heat treatment. The melting equipment must be properly designed with exact temperature controls because the blending temperature of Lucite 44 is near its decomposition point. Excessive temperature, even for short periods, tends to impair its physical properties. Localized overheating may cause serious breakdown of the material in contact with the immediate overheated wall area.

Each model to be cast from remelted material should be composed of approximately 70 percent used material from broken-up models, 25 percent clean shavings from the cutting bin, and 5 percent new material to allow for losses.*

When new material is used for blending, the oven is filled with the appropriate amounts of new Opal and Aristowax. The temperature is brought up to 260 to 280 F until melting is completed. At this point the new Lucite 44 is added and the temperature raised to 345 F. When the Lucite 44 is added, mechanical stirring is started and continued until all of the Lucite has dissolved. When the temperature has reached 345 F, the heaters are turned off and the mixture permitted to cool to about 280 F, the pouring temperature. The viscosity of the blend while adding Lucite 44 is such that it would be difficult to achieve a homogeneous blend without power stirring. A further advantage of vigorous agitation during the melting and blending cycle is to reduce markedly the temperature gradient in electrically heated ovens and thereby reduce the decomposition of the material at points of local overheating.

In casting the model, the molten wax is cleaned by passing it through a gravity-type filter. This filter uses steel wool as the filtering material, is electrically heated, and handles approximately 40 pounds of molten wax per minute. The pour is made from both sides of the model, usually at the bow, and the bottom is filled as rapidly as possible. When the wax has reached the turn of the bilge, the rate of pour is reduced and water at about 130 F is added to the core to control the rate of cooling and to provide uniform pressure on both sides of the waterproof cloth covering the core. During casting, special attention must be devoted to the control of temperature in the wax and in the water added to the core. To assist in controlling and refining the technique, a data sheet is provided and filled out carefully during the casting procedure. Rapid casting is stopped when the wax level is about 3 inches below the deck line. From here on, a slow feeding is started to make up for shrinkage. This feeding has to be done continuously until the wax has solidified. During this period the model builds up some internal stresses. In order to relieve these stresses, it is important to remove the core of the model as soon as practical; see Figures 8 and 9. The curing time of a model after removal of the core is about one day.

Athwartship metal reinforcing bars are cast into the wall just below the deck line. They provide support for the side walls and prevent damage when turning the models. The center portion of these bars between the side walls is detachable from the socket portion which is imbedded in the wax.

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*I.e., losses incurred in cutting and finishing the model and the small amount of decomposition of material during melting operations.

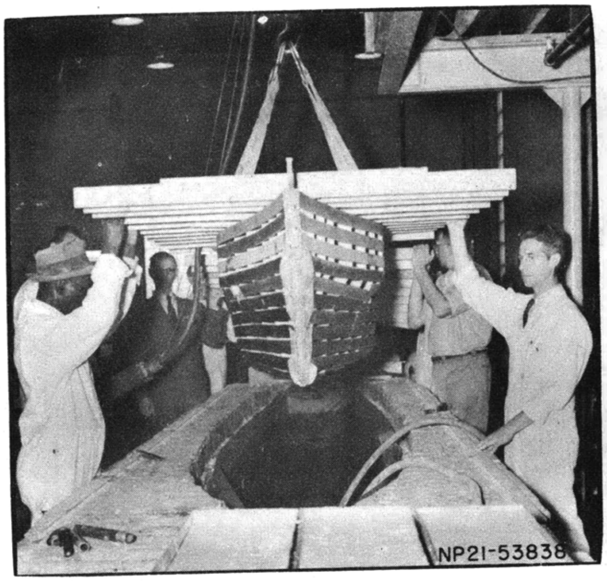

Figure 8 - Removing Core from Model

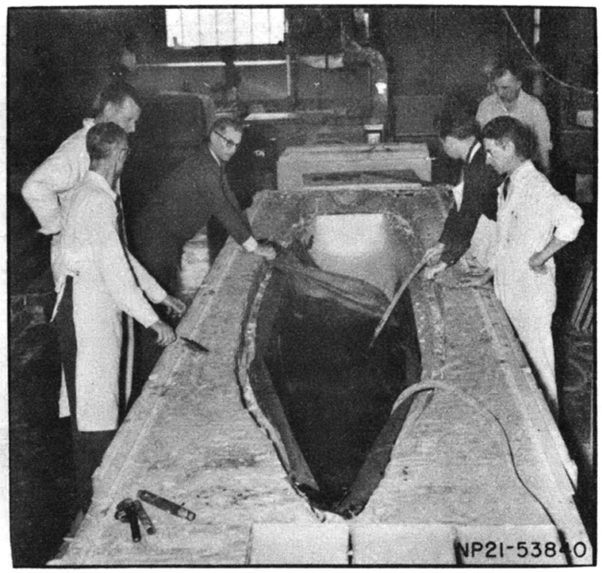

Figure 9 - Removing Rubberized Cloth from Model

CUTTING PROCESS

Prior to removal from the clay bin, the top of the model is surfaced with portable power equipment to a datum plane. The interior of the bottom is also planed in way of the towing brackets and dynamometer bed. Transverse wood beams are secured on the deck line by hot screws. Each beam has a central hole by which it is dowelled to a template corresponding to the bed of the cutting machine. The template insures that the beams are correctly spaced and aligned along the centerline of the model so that the model can be easily and rapidly centered in the machine. Upon completion of this work, eye bolts are screwed onto the wood lifting pads, water is introduced between the model and its clay mold, the model is floated out of the clay bin and lifted with a crane, as shown in Figure 10. The model is then placed on pads on the wax shop floor and is turned over by means of the crane slings and a strongback. The model is now ready to be placed in the cutting machine where the transverse wood beams will center it.

The waterline drawing board is placed on the table and set with its centerline parallel to the centerline of the machine. This is checked all along the length by running the table past the feeler. When this has been done, the drawing table is locked in position so that the midship station is in line with the feeler. The carriage is set so that the cross mark on the bottom of the model is in line with the centerline of the cutter. The pantagraph is now set to the correct ratio for the transverse scale of the drawing. The feeler is then set to the centerline of the drawing, at which point the cutting knives should just touch one another. To eliminate backlash in the equipment, the feeler and knives are always moved from outboard towards the centerline when approaching a setting. The feeler, and consequently the knives, are then set to maximum beam and the distance between knives checked to make certain that

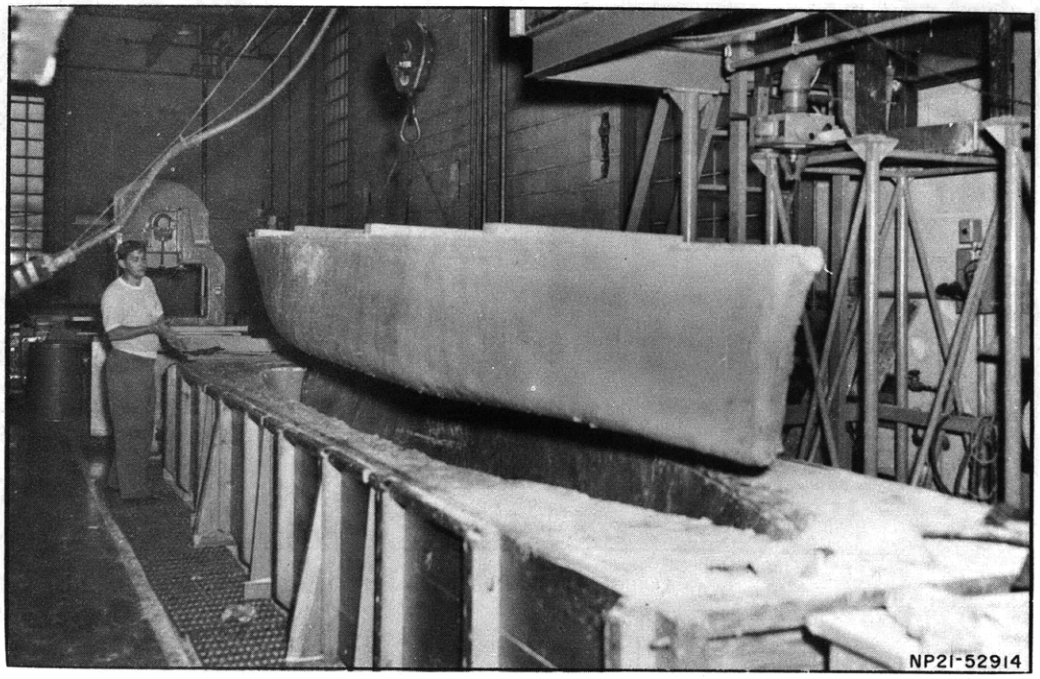

Figure 10 - Lifting 20-Foot Model Out of Clay

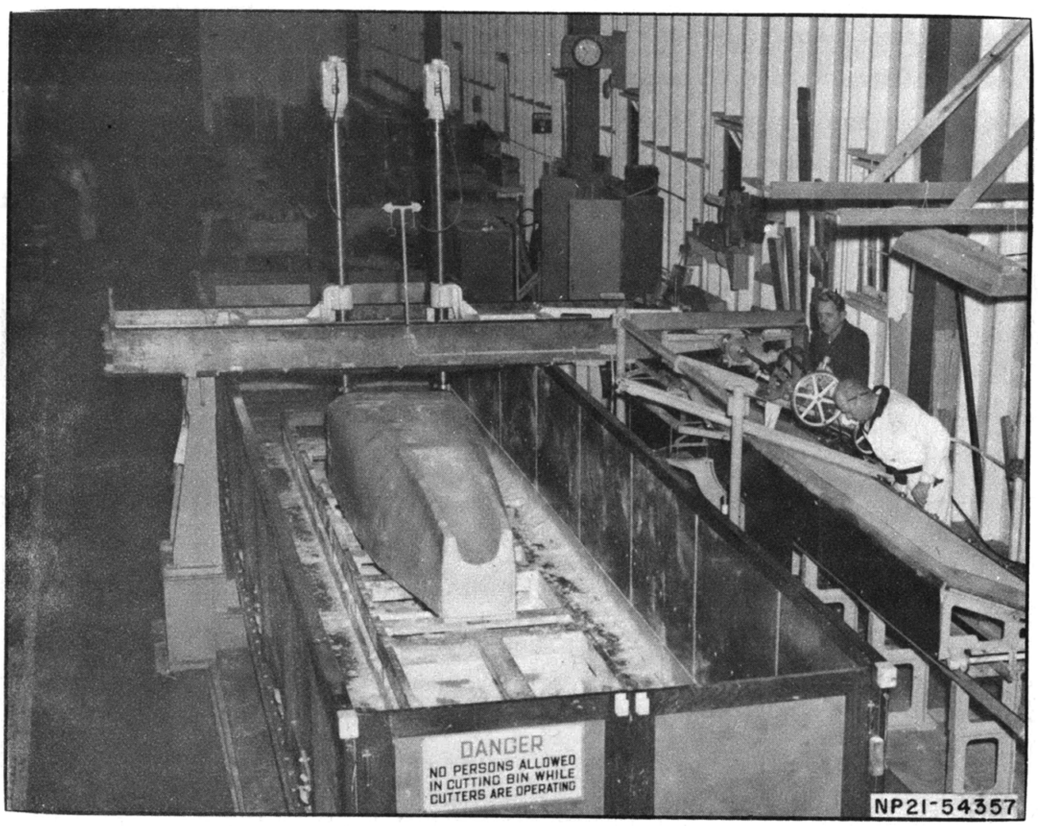

Figure 11 - Munro Cutting Machine

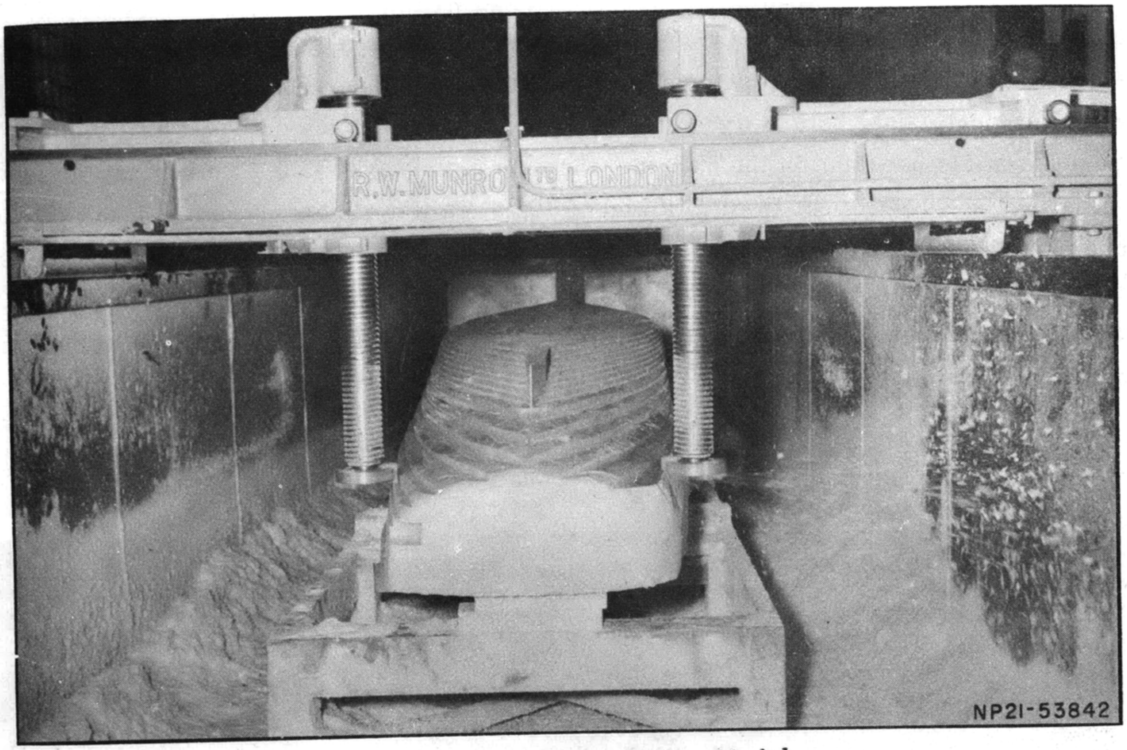

Figure 12 - Cutting the Wax Model

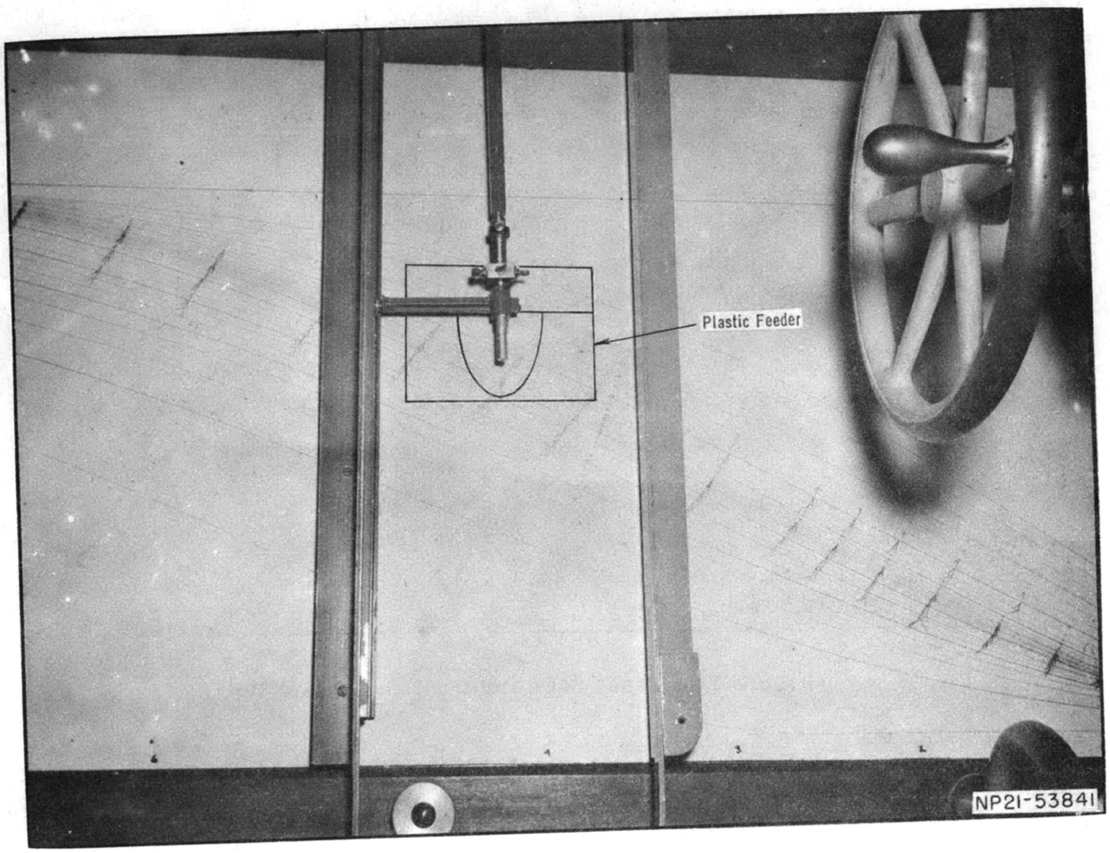

Figure 13 - Wax Model Cutting Machine Feeler

the correct beam is cut on the model. If the beam is not correct, the pantagraph fulcrum is adjusted and the whole process repeated. The bottom is then planed. In vessels with deadrise, the longitudinal bottom lines are cut first, starting with the outboard longitudinal. Because of the backlash in the machine, the cuts are always started amidships; the bow waterlines are usually cut first, followed by the stern waterlines. Figures 11 and 12 show two different 20-foot models being cut. Figure 13 shows the feeler in position on the cutting plan. Upon completion of the cutting operation, the model is moved to the scraping bin. The midship station is marked on the bottom and the deckline. These lines are never quite removed in scraping.

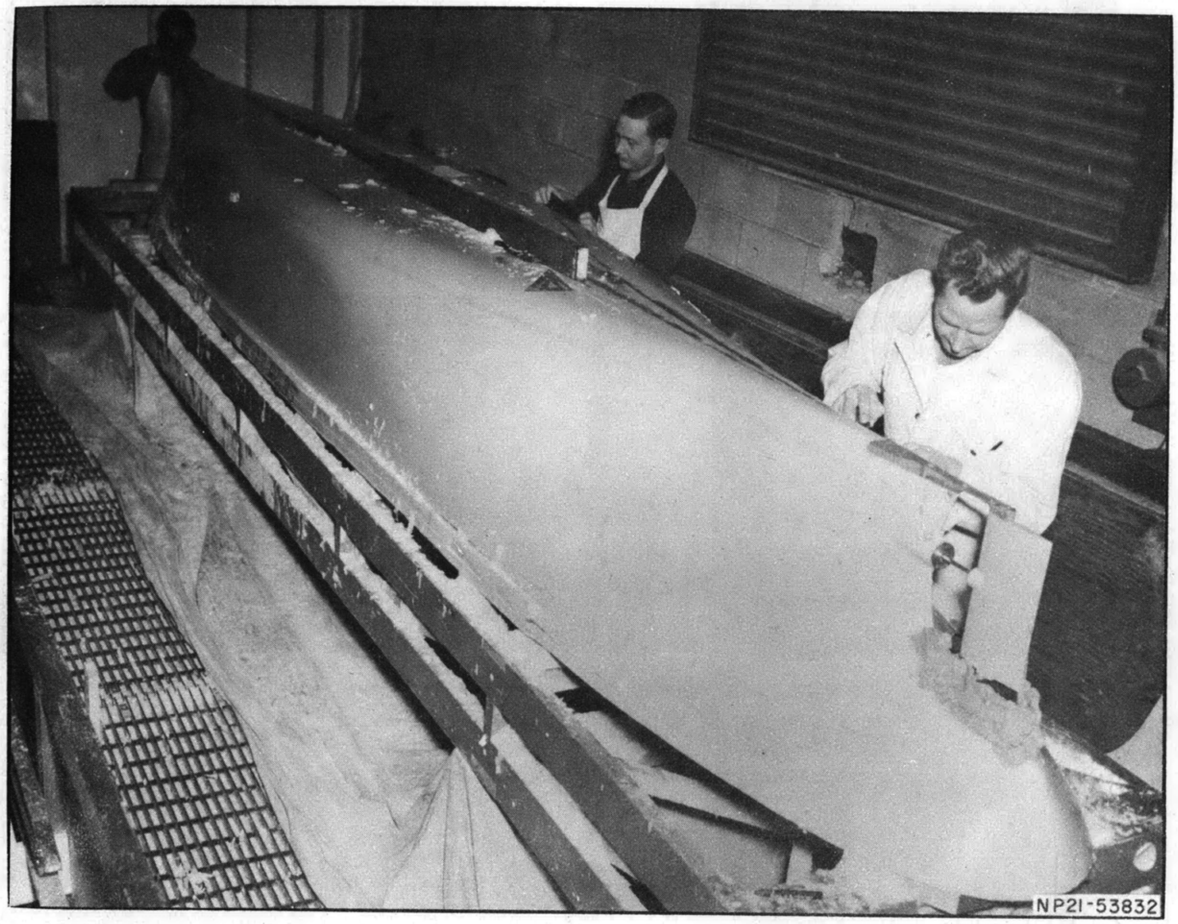

Figure 14 - Final Scraping on a 20-Foot Model

FINISHING PROCEDURE

The bow and stern templates are now used to cut away superfluous wax at the ends. All excess wax is removed by hand, using spokeshaves, scrapers, and specially developed tools, until the waterlines marked by the corner of the cutting knives are just faintly visible. Figure 14 shows the final scraping operation. When all scraping work is completed, the hull is rubbed down with steel wool to obtain as smooth a surface as practicable. The model is now ready for bare-hull testing.

Appendages to wax models are fitted in the same manner as to wood models. Some of the appendages, such as bossings, can be made of wax.

SPECIAL CONSIDERATIONS

In equipping the models for test, there are some operations which are different from those with wood models. The towing brackets require the casting of wood blocks into the bottom of the model in order to obtain an adequate fastening for wood screws. These blocks are attached to the bottom of the core and are made an integral part of the model as it is cast. The installation of blocks for the attachment of the propulsion dynamometers is accomplished in the same manner.

HOGGING

Experience in the testing of the 20-foot models with a large length-beam ratio and of all 30-ft models built to date has shown that there is a tendency for these models to hog. This hog is presently removed by the use of so-called "hog wires," which consist of two tension wires anchored to the bow and the stern and led over two sets of fulcrums located at approximately the one third points of the model. By increasing the tension of the wires all of the hog can be removed. Figure 15 shows the hog wires installed on a 20-foot model.

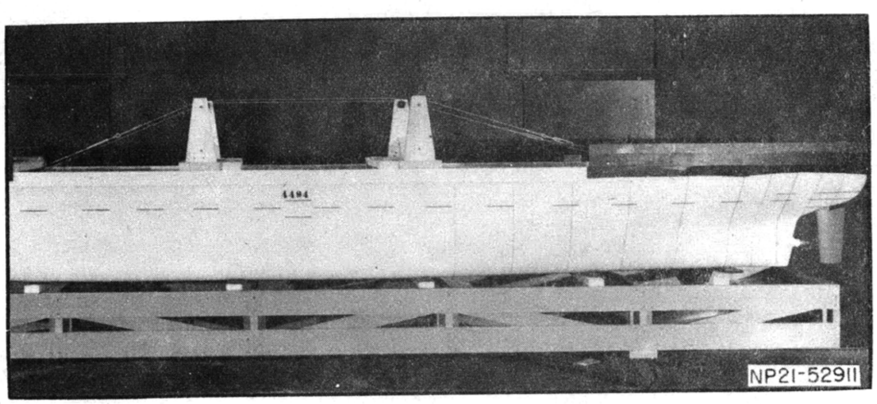

Figure 15 - Hog Wires Installed on Model

HANDLING OF WAX MODELS

The experience of the European basins has indicated that special care is needed in the handling of models constructed of paraffin. The low tensile strength of the paraffin models requires that the models be turned in water. The strength of the Model Basin mixture is indicated by a test that was performed on one of the earlier models. A 20-foot model weighing 1800 pounds was lifted by one canvas sling at the midship section and then dropped from a height of 3 feet to the concrete floor. The only damage that occurred was a local *spalling* of the wax at the point of initial impact. The hull was undamaged in all other respects. This test proved the strength of the Model Basin blend to be sufficient to permit turning models on shore. At the present time, all models whose over-all length does not exceed 23 feet are turned on shore, as shown in Figure 16. Adequate turning equipment for models of greater length has not been manufactured, and they are presently turned in water.

Techniques have been developed for lifting wax models by means of pad eyes in the bottom, similar to techniques used for wood models. The use of pad eyes in the bottom permits the lifting of the models by a crane without the use of slings and a strongback. This

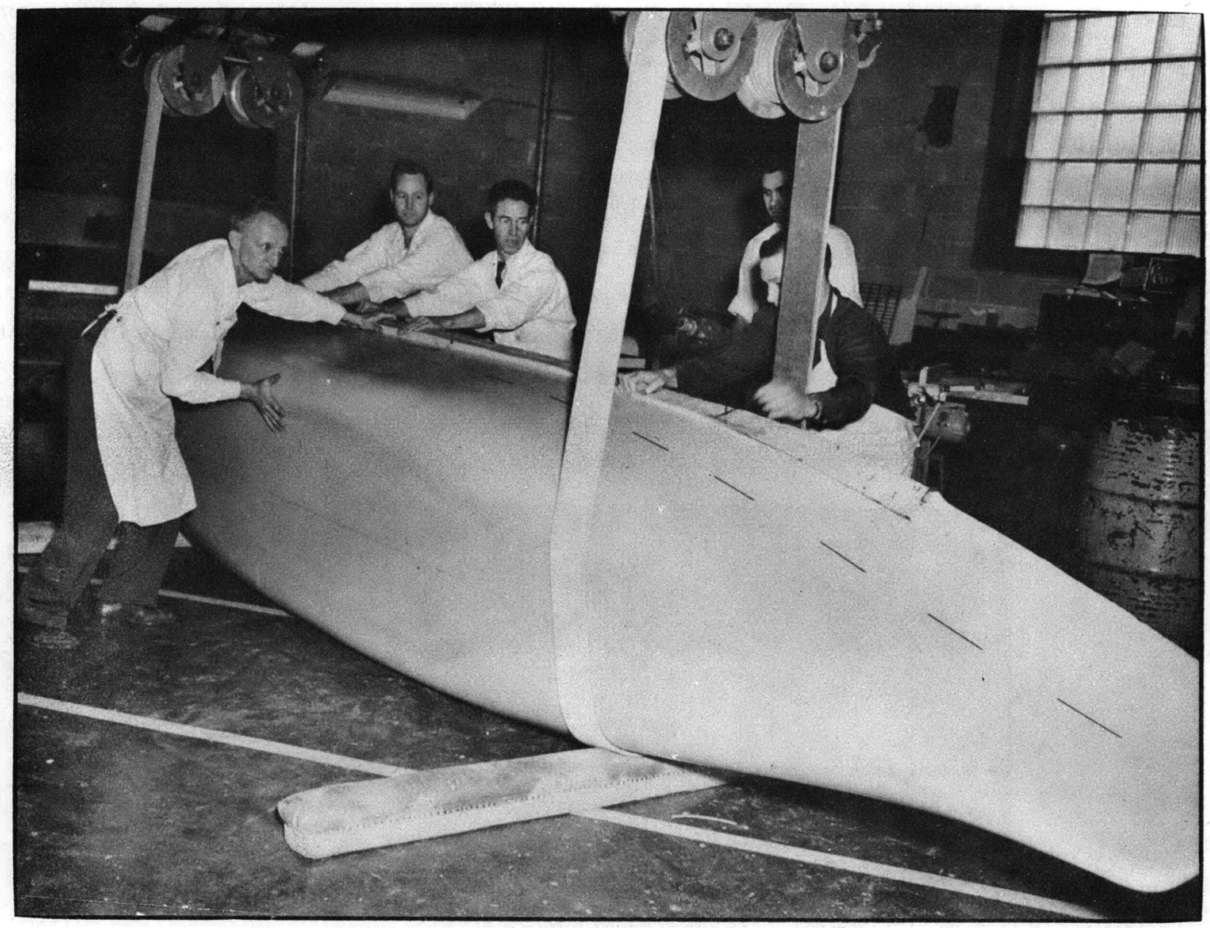

Figure 16 - Turning of a 20-Foot Model

is important in moving models into the circulating water channel at the David Taylor Model Basin. Wood blocks approximately 6 × 30 inches are cast into the bottom of the model. Four pad eyes are installed, one in each piece of wood. Tests have shown that the screws which hold the pad eyes will fail before the wood blocks will pull out of the wax.

SIZE OF MODELS

In the past, the length of models constructed of wax has generally been limited to 20 feet. This limitation was due to the nature of the material used as well as the testing facilities available. In developing a wax compound suitable for the Washington area, it was also desired to obtain one which would have sufficient strength for the construction of 30-foot models. The present compound meets this requirement. To date, four 30-foot models have been constructed, a Great Lakes ore carrier (Figure 17) and three low-block-coefficient ships. The construction of wax ship models is now entirely routine.

Half models or bulkheaded models may be as readily constructed of wax as of wood. The bulkheads are about 6 inches thick and are bolted together with four or five through bolts. The hogging problem with these models has been no more severe than with solid models.

As indicated previously, the specific gravity of wax is approximately 60 percent greater than that of wood. This property of the wax blend prevents its use when light displacement tests are desired on certain types of models. Extremely shallow draft vessels, such as ferry

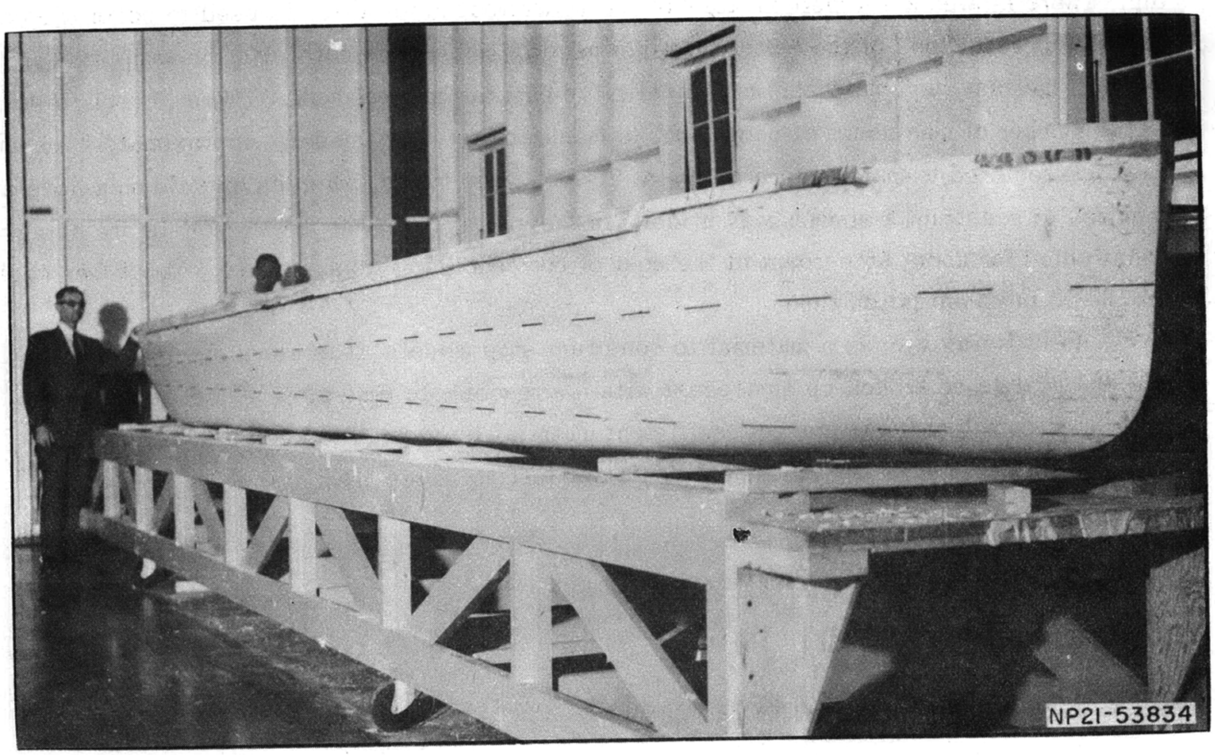

Figure 17 - The 30-Foot Model of a Great Lakes Ore Carrier on Handling Frame

boats or bulk carriers, which are to be tested at light displacement, usually cannot be built of wax unless the usual test procedure is modified.

In order to continue the development of construction techniques, the manufacture of a 20-foot wax submarine model was recently undertaken. The model was cast in the clay bin by means of four copes filled with wax. The core had to be broken up after solidification to make room for the measuring instruments installed in the model. The only reinforcement provided in the model was mesh wire around the corners of the strut attachment points. The cooling procedure differs somewhat from the usual methods and has to be carefully specified.

Subsequent to the construction of the 20-foot submarine model, an alternate method was tried. A bow was built of wax to be fitted to an existing wooden submarine stern. In this case two half castings were made and welded together along a longitudinal parting line at the half-depth level. This latter method for constructing submarine models appears to be somewhat preferable to the one-piece casting method. However, final selection must await further experience with both methods.

ECONOMIC ASPECTS

The major economy accruing from the construction of wax models is the repeated use of the wax blend. This in itself represents a saving of approximately $400.00 in material for a typical 20-foot model. There is some loss of material in the construction of a wax model. It is assumed that two percent of the wax blend will be lost in the process of cutting and scrapping. There is also a 100 percent loss of the waterproof cloth which is used to cover the core and a 25 percent loss of the wood materials used in making the core and the templates for molding the clay bin, but these are a negligible part of the total cost. There is a large saving in the number of man-hours of shop labor to manufacture a wax model. Approximately 55 man-days are required to manufacture a typical 20-foot wood model, whereas only 30 man-days are required to construct a similar wax model. In the aggregate, 20-foot wax models are being constructed for about 55 percent of the cost of corresponding wood models. About two weeks are saved in construction time.

In utilizing wax as a material to construct ship models, it is necessary for economy that the models be broken up and recast within a reasonable time after all scheduled tests have been completed. At present, sufficient material is on hand to keep each model about three months after this in case repeat or further testing is required.

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