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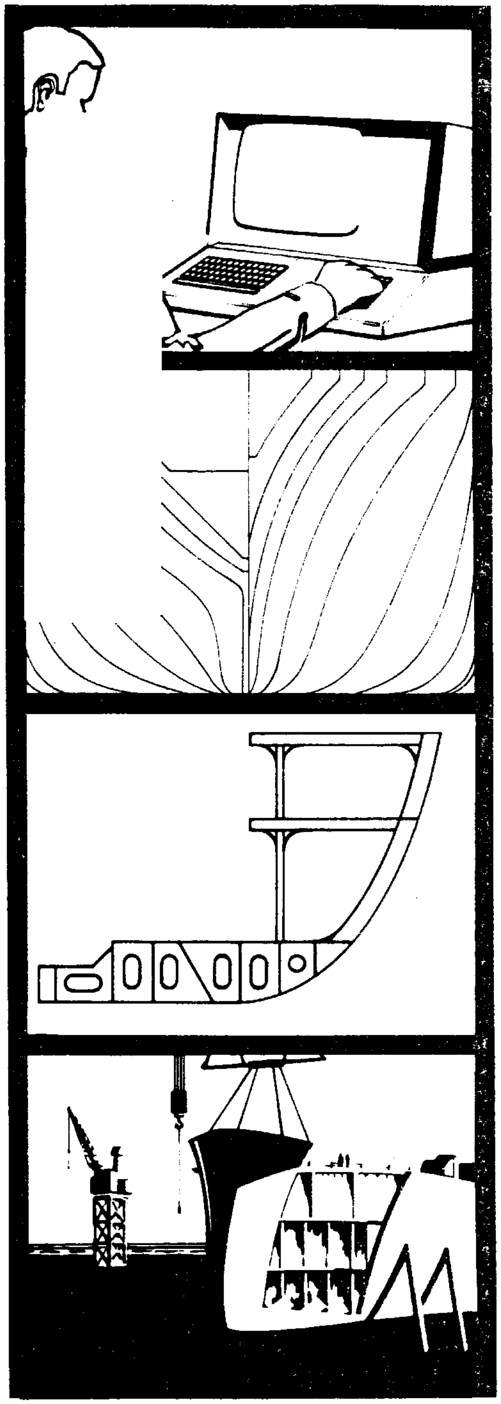

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SPADES AS AN AID IN SHIP DESIGN

Jan Ulsteen

Cali and Associates

Metairie, Louisiana

At Cali and Associates, Mr. Ulsteen is responsible for data base management, program development and hull technical calculations. He has nine years' experience in development of computer software for ship design and N/C production. Mr. Ulsteen has a B.Sc. degree in Naval Architecture from the University of Strathclyde, Glasgow, Scotland.

INTRODUCTION

The use of computers has made a tremendous impact on the ship design and the ship building processes in recent years. Designers utilize special programs to optimize their design according to economic and performance requirements. for a certain type of vessel in a certain type of service. From this iterative process, the optimum parameters are obtained and the preliminary design carried out .

The ship builders have sophisticated computer software available to them for Numerical Control of cutting machines and machine tools. Thus, the generation of parts and other manufacturing aids through the use of computers has been widely accepted for saving costs and production time, and for increasing the accuracy of the parts.

In order to properly describe a vessel with its complicated form and structural design, numerical hull fairing and structural description programs have been designed and extensively refined. The main objective of these programs is to generate a mathematical description of the hull surfaces and associated structural details with as great an accuracy as is feasible. This description is stored on a permanent data base which is accessible to all the N/C and production related programs within the shipbuilder's computer environment.

But, separating the design analyzing programs and the N/C production programs is a large void, partially filled with miscellaneous ' stand alone' and unrelated programs for the various detail design and engineering tasks to be performed, either by the designer or the builder. These programs have usually been written in order to solve a particular problem, and do not offer an extensive comrnunication link with other programs or systems.

This paper is intended to demonstrate how an existing N/C system, such as the 'SPADES' System, can benefit design and engineering work during the design cycles prior to the production oriented N/C lofting. Because of the system's large data storage capability and the use of a common Data Base for storage and retrieval of all hull geometry and structural related data, such a use will not only benefit engineering through reduced amount of input required at each stage during the design, but will also reduce considerably the amount of work that would otherwise have to be done downstream during the final engineering and lofting process.

HULL FORM DEFINITION AND PRELIMINARY DESIGN CALCULATION

It is assumed that at the beginning of this phase, the naval architect has already established a set of preliminary lines representing his first approximation of the hull form to meet the economic and performance requirements of the ship. He is now ready to start the iterative process between hull forrn and calculations to refine this first approximation.

The numerical FAIRING Program is utilized to define the initial lines of the hull without performing an actual fairing. A discreet number of offset points are selected from the preliminary lines in order to define the boundary control lines and the main design stations. From these data, a number of waterlines or diagonal planes is selected, and the lines generated and stored on the Data Base. The check drawing of these lines and stations is ins petted for reasonable fairness for calculation purposes, and the original offsets changed, if necessary.

A numerical fairing of the lines will normally not be performed at this stage, as detailed definitions and accurate fairness for lofting purposes are not required yet. However, we do have the basis for the final fairing and hull definition already stored for later use.

From these preliminary computer lines, any number of stations and frames can now be interpolated and stored on the Data Base. The usual number of "Simpson" stations and additional frames, if required, are selected for calculation and the Curves of Form calculations carried out by the HULLCAL Program Module. A drawing of the hydrostatic curves, as well as a tabular printout, is provided by the program. By checking and comparing these with the desired properties from the design requirements, it can now be established what changes will have to be made to the original lines in order to satisfy the design requirements.

The necessary changes can be made to the main dimensions of the vessel, the boundary control lines, and the preliminary station offsets that were originally supplied to the FAIRING Program. The new lines and stations are generated and the Curves of Form calculations are repeated. These steps are repeated as necessary until the results are satisfactory within the established design tolerances.

Other design criteria, such as intact stability and floodable length requirements, can also be checked simultaneously or as a next step in the design procedure. Usually, the main watertight decks are described through the HULLOAD Program and stored on the Data Base at this time. The cross curves of stability and floodable lengths can now be computed for the portion of the hull below the specified decks. If the results are not acceptable, the original lines are changed and the steps repeated as before. In the case of floodable lengths, the watertight subdivision bulkheads can be relocated to meet the requirements for compartmentalization.

At some stage during this design cycle, the naval architect might want to verify that the design will meet the performance requirements as far as cargo and tank capacities are concerned, as well as the damage stability requirements. Some additional frames in way of the tanks, cargo compartments and engine room, if necessary, are generated and stored. Through the HULLOAD Program, the main internal decks and bulkheads are described and loaded to the Data Base. Tank and compartment descriptions based on these bulkheads and decks as boundaries are given to the HULLCAL Program, and preliminary capacities are computed.

The same compartment descriptions can be used individually or combined when computing the damage stability for various critic al cases and vessel conditions. Thus, shortcomings in the design relating to capacities or compartment locations can be corrected at an early stage with very little effort. The necessary changes are made, and the same steps are then repeated.

Since the damage stability calculation is available through the system, this should be used as the tool for determining the allowable maximum compartment sizes and bulkhead locations, rather than floodable lengths. This program will calculate not only the sinkage, but also the stability after flooding for all types of operating conditions and damage cases.

As in the preliminary fairing step, we have now established most of the basic definitions and program input instructions that will be required at a later stage when the final calculations are to be performed. Only a few more detailed descriptions might be necessary to add at that time.

When the preliminary design is completed to the satisfaction of all the outlined requirements, the detailed hull definition of all necessary control lines is given to the FAIRING Program. At this time, the actual hull fairing will be performed, taking into account the details required for the lofting process.

All the construction frames, as well as the final design stations, are generated and stored on the Data Base. The major decks and bulkheads are also defined and stored; and at this time, the final Mold Loft Offsets for control lines, water-lines, buttocks, deck and bulkhead traces can be printed. A complete lines plan and a body plan on frames is extracted through the DRAWING Program.

The detail touches, if any, are added to the HULLCAL input instructions, and the final calculations including Bonjean curves are rerun, generating the tabular printouts and corresponding drawings, as required.

Although the type of programs that are utilized in the above demonstration are oriented towards the final lofting and engineering phases of the design and are not intended to be "automatic design programs", they lend themselves to the naval architect as very useful tools in performing the design iteration. Another advantage of using such a production oriented system during the design is that the majority of the input instructions and definitions are made at an early stage, thus saving lead time and manpower in performing the final design and hull definition.

There are, of course, factors other than mentioned above which affect the finalization of the hull form. However, the introduction by the naval architect of these factors in the design iteration will not reduce the validity of the procedure described above.

STRUCTURAL DESIGN AND SCANTLING DEFINITION

At some stage during the preliminary design, the scantlings of the hull structure must be determined. A typical production oriented N/C system such as the 'SPADES' System is not intended to compute the scantling requirements. While there are a number of special programs available to the designers for various stress and strength analysis, some means are needed to transfer the determined scantlings and structural data to engineering drawings and subsequently working drawings, and to the Data Base for lofting purposes.

In this process, as for the preliminary design cycles, the 'SPADES' System can be a very useful tool for the design engineers. If utilized during this phase of the design, the system will, in the process, create and load the bulk of the data needed in the Data Base during the subsequent lofting and production phases of the shipbuilding process.

The following procedure assumes a longitudinally framed vessel. In the case of a transversely framed ship, or a combination of longitudinal and transverse frames, the sequence of the various steps may have to be altered. This sequence is to a certain extent arbitrary and will generally be determined to suit each design and the specific practices of each engineering organization. The main objective, however, will always be the same: store as much of the data as possible in the Data Base, and let the computer do the time-consuming and repetitive work.

As soon as the naval architect has the preliminary computer lines generated, a discreet number of frames are interpolated and stored on the Data Base. Based on the scantling requirements, the HULLOAD Program is used to define and load all shell traces from the midship area and extended toward the bow and stern. Although these can be defined by specific locations, the use of relative spacings such as stiffener spacing and plate widths may be more useful at this stage. Some selected references such as the main deck trace at the shell, the bilge area, or the keel, are used as the basis for the relative trace definitions.

The DRAWING Program is now used to extract a preliminary shell expansion drawing and a body plan of frames with the shell traces, as well as the traces of all decks and bulkheads that have been defined. With these drawings as guidance, the traces are now modified and extended toward the ends to suit structural requirements, plating widths and curvature of the bow and stern sections. The changes are made by redefining and adding to the existing HULLOAD data. This way, the Data Base will always be up to date and new drawings can be extracted at any time as the design is progressing.

In parallel with the above steps, the traces of stiffeners and seams on decks and longitudinal bulkheads are defined and loaded through the HULLOAD Program. As for shell traces, the definition is started in the midship area. By reviewing the preliminary drawings extracted from the Data Base, the traces are modified and extended towards the ends as best suited to each particular deck and bulkhead and the overall structural configuration.

Through the use of the PARTGEN Program, or the DEMO Program, if available, the image of each entire deck or bulkhead is created and stored on the Data Base as a complete drawing. Thus, by using the "window" capability of the system, or in some cases, the "Part Separation" feature, any portion of each image can be extracted and drawn to the proper scale as needed for the scantling or general arrangement drawings.

The design of transverse bulkheads, deep web frames, and transverse girders is handled in the same manner. By utilizing the data loaded through HULLOAD and additional detailed information, the PARTGEN or DEMO Program creates all necessary scantling drawings for the transverse structures.

At some time during the design state, it is necessary to determine the required plate sizes for the bill of material. As steel mills and warehouses throughout the country need more lead time to fill a particular order, it is important to have a fairly accurate estimate of the steel requirements as early as possible. In the case of complex hull forms, a shell expansion drawing may not be accurate enough for determining the proper plate sizes. For this purpose, a preliminary shell plate development through the PLATDV Program is obtained in the critical areas of the hull. From the results of this program, the best suited plates can be determined, the shell seams or butts relocated, or additional seams defined, if necessary. If this is done at an early stage of the design, there will be no impact on steel delivery or production schedules by last minute changes.

At the most appropriate time during the above process of scantling definition, the HULLCAL Program is used to run the Longitudinal Strength Calculations for the various operating conditions of the vessel. This will point out any weaknesses in the structural design, which can be corrected before the design is completed. By using the N/C computer system as a tool in the structural design phase, the design engineers are less affected by design changes in the lines or arrangement of bulkheads and decks. As soon as the naval architect has altered the lines or relocated any of the main structures, the already established input definitions for the structural data can be reloaded onto the altered Data Base. Only slight modifications may be necessary, and the new drawings can be extracted almost immediately. This is due mainly to the 'ISPADES' System's use of symbolic names for all structures and associated details. All references are made by these names, or if dimensions are used, they are relative to established structures. Therefore, by building up the Data Base during the designing phase, the amount of work involved in recreating or altering drawings and structural data as the design is altered, is reduced to a very minimum.

DETAIL WORKING DRAWINGS

Within the context of this paper, these drawings can be divided into two basic groups:

A. Detail structural drawings to be used for hull construction.
B. Record and information drawings, such as compartment and access drawings, arrangement drawings, and composite drawings.

Because of the different purposes, and in order to obtain the maximum benefit from the use of 'SPADES' in generating these drawings, the two groups will be treated separately.

It is assumed that the structural definitions from the scantlings have been loaded on the Data Base, as well as detailed information such as standard cut-outs or notches for penetrating stiffeners and longitudinal. The stiffeners' size and characteristics have also been defined and loaded on the Data Base.

A. Structural Drawings

The format of these types of drawings has traditionally been the one most suitable for submittal to the regulatory bodies for structural evaluation. But the format most suitable for construction would be that corresponding to the work units, such as sub-assemblies, assemblies, modules, etc.

This conflicting requirement has been solved in some shipyards by creating another set of drawings or sketches geared to work units. This solution, besides increasing the drafting man-hours, has also the problem of maintaining two duplicate sets of drawings. The procedure suggested herein should satisfy both requirements with one set of drawings.

The majority of drawings in this group deals With flat surfaces, such as bulkheads, platforms, flats, floors, girders, etc. All these drawings must be generated as if the structure, regardless of the size, were a single part to be processed in the N/C cutting machine. Then, through the use of the part separation procedure in the PARTGEN Program, smaller parts can easily be extracted.

These drawings relating to non-flat surfaces, such as a deck with sheer and/or camber, will be generated following the same procedure. But they will not be utilized ultimately to extract the actual parts to be cut.

The following sequence of steps covers the case of generating the drawings necessary for a flat deck with or without sheer. The same procedure with slight variations would be applicable to any other ship's structure.

By utilizing the Data Base with its information about the deck geometry and structural details, a "part" comprising the entire deck is generated through the PARTGEN Program. Using the part separation feature, the deck is then divided into the various portions associated with each work unit. As many illustrative details as needed are also generated during this step. Each portion and details are plotted in separate sheets. The welding details, lettering and general notes are finished by hand. These sheets are issued as a multiple sheets drawing for submittal to the regulatory bodies and the owner.

When this process is repeated for other drawings, the various sheets from each drawing can be used to make up a muitiple sheets drawing with all the information necessary to build a work unit. With the existence of these individual structures within each work unit already defined and stored on the Data Base as "parts”, the Mold Loft can now, through the use of the part separation feature, further divide each portion of each structure into the actual pieces needed for nesting and N/C cutting.

B. Record and Information Drawings

These types of drawings will not be utilized by the Mold Loft to obtain parts for construction. They can therefore be generated by taking into account only the engineering needs.

As for the structural drawings, "master" drawings of large areas in the ship are generated from the existing Data Base information through the PARTGEN Program. These drawings are stored on the Data Base, covering each entire deck. They will generally include all boundaries, bulkhead traces, stiffener layout, and cross-section, and all access openings.

Through the use of the "window" capability of the system, or the part separation feature, any portion of any drawing can be extracted in the desired scale. These drawing portions are used by the various Engineering groups for different applications. In the process of extracting the desired portions, additional details pertaining to the intended purpose of the drawings can be added.

It is implied by the use of the above procedures that the Engineering Department assumes full control and responsibility for the loading and maintenance of the 'SPADES' Data Base as far as the structural data and details are concerned. This assures the integrity and compatibility of all the data applicable to the structural design of the vessel. All parties involved can then utilize the Data Base fully for what its name implies: the common source for all hull and structural related data.

The initial task of generating a drawing, whether scantling or detail, is done in an iterative mode. The data on the Data Base is altered or more data added, and to a certain extent, the coding is modified and a new drawing is plotted on the N/C drafting machine. These steps are repeated until the desired result is obtained. At that point, the drawing is finished by hand, adding any necessary details and lettering. When the final drawings have been issued, it will generally be more economical to handle the revision activity by conventional methods. It is, however, of the utmost importance that the Data Base is changed accordingly whenever a revision is made. A manually revised drawing will not have the direct reflection of the Data Base information as a validation feature. But issue of the revised drawing must imply that the Data Base has been revised accordingly if the above procedure is used.

CONCLUSION

Although the 'SPADES' System is basically production oriented towards hull form definition, calculations, structural data, N/C part generation and flame cutting, it has been shown how it can be a very useful tool for the naval architect and the structural engineer during the design phases. The various tasks of the design and engineering procedures can be performed simultaneously, with a few exceptions, with very little additional work and loss of time due to changes and additions to the basic design.

The main reason for this is, of course, the extensive use of the common Data Base by all programs. By building up and maintaining as comprehensive a Data Base as possible, the amount of input data, and thus, the work involved in preparing each computer run, is greatly reduced. In most cases, a program may be re-executed with the changes or additional data included automatically without having to alter the original input data. As the design is progressing, the latest information will always be available to everyone involved as soon as it has been defined through the system.

With the benefits the designers and engineers can obtain from the use of the N/C system, the man-hours and the lead time required to complete the design will be reduced. But the most important item is the fact that the "mathematical Ship" as defined on the Data Base is as complete as possible prior to starting the actual lofting and N/C production process. This reduces considerably the amount of work and time involved in the lofting process, as well as the possibilities of difficulties or errors in the design or the lofting during the production phase. Any possible errors or shortcomings will have been discovered and corrected at a much earlier stage. To a certain extent, the Data Base can be compared to a prototype of the vessel, not unlike the full size mock-ups and prototypes used in the aircraft and automobile industries.

The following pages show some examples of the type of drawings obtained from the 'SPADES' System during a Hull Form and Preliminary Design procedure. These are intended strictly as examples and do not reflect any attempt to perform an actual design.

The vessel in the examples is based on the Mariner class design as published in the "Principles of Naval Architecture".

A. Hull Definition

Based on the published set of offsets, the required control lines were defined and loaded through the FAIRING Program. This produced the drawings shown in Figure 1 for the 528 Ft. LBP Vessel. The control lines consist of stem and stern profiles, bottom and side tangents, upper waterlines for forward and aft body, midship station, and station No. **0** (F. P.) for the tangent of the forward waterline endings. The offsets were not faired, and in areas lacking definitions, estimated values were used.

The given basic station offsets were used to define the actual hull form. The set of fairing lines for a discrete number of pre-selected diagonal planes was then produced by the program, as shown in Figure 2. Again, no fairing was performed, only curve fitting and interpolation. The lack of definition of the stern profile is obvious by the shape of the produced lines towards the stern. But this is sufficient for a first approximation of the design calculations.

For calculation purposes, the basic 20 Simpsons Stations were selected, including half stations forward and aft. These were interpolated from the fairing lines and control lines, and the result from the FAIRING Program is shown in Figure 3 for the 528 Ft. LBP Vessel.

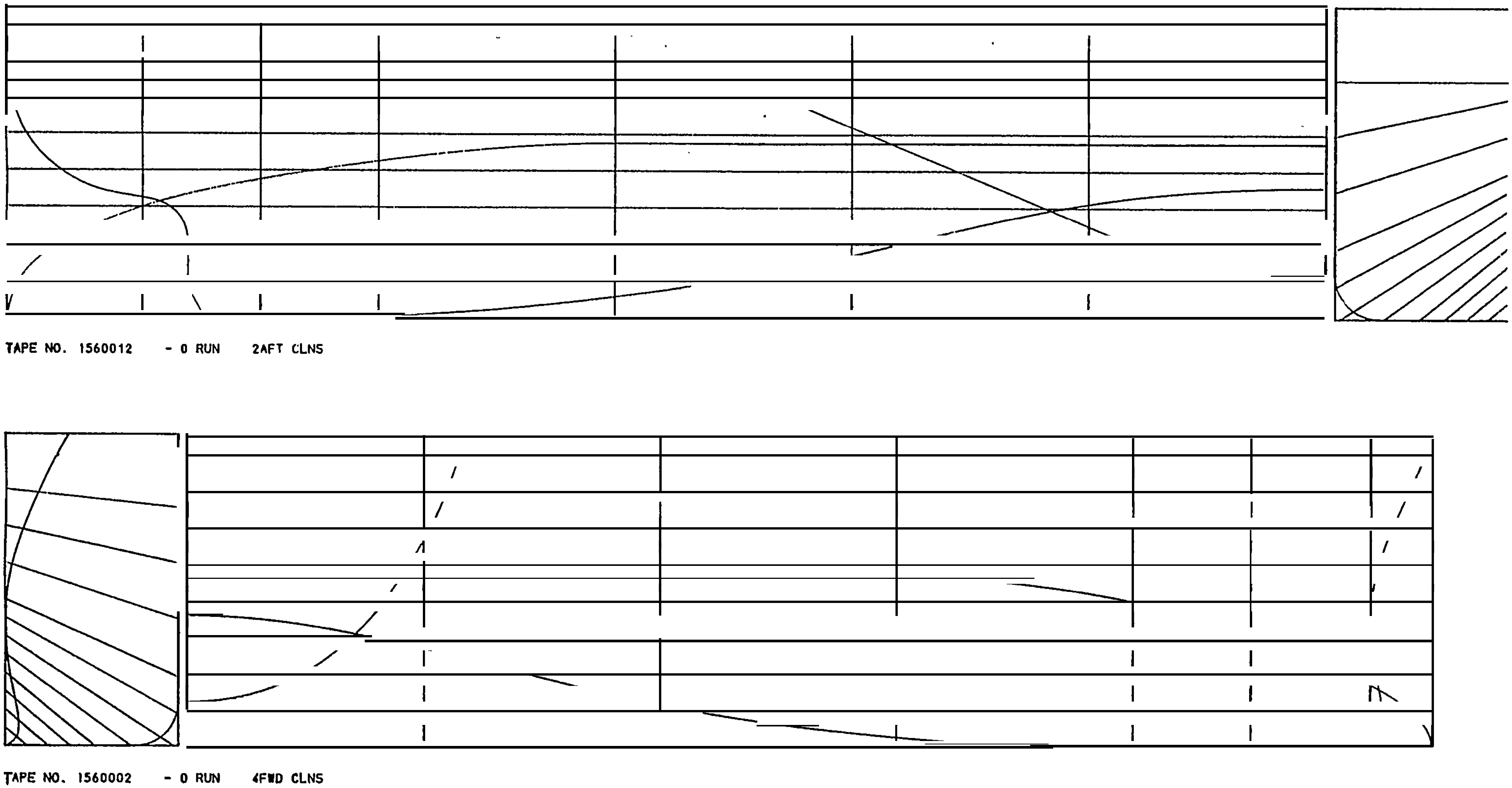
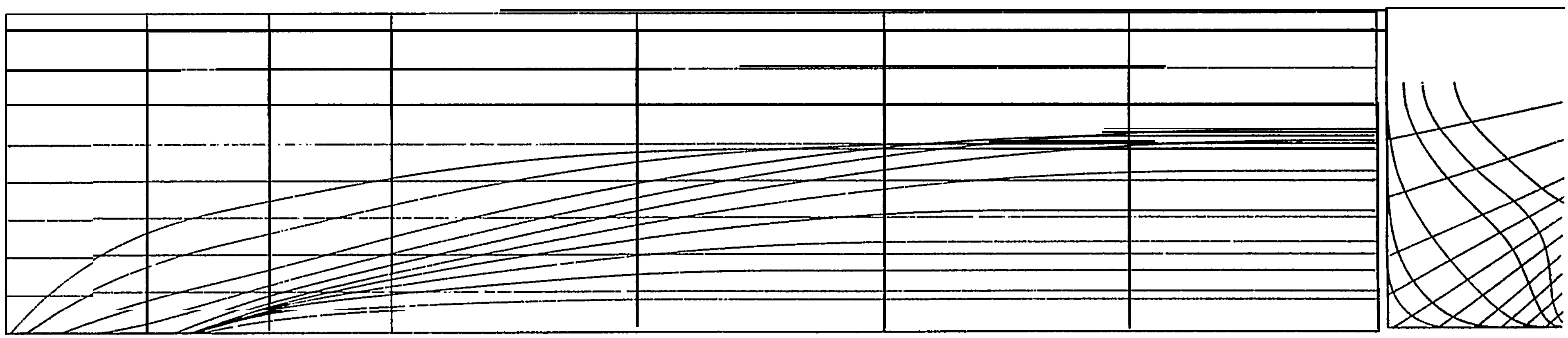


Fig. 1 Control Lines



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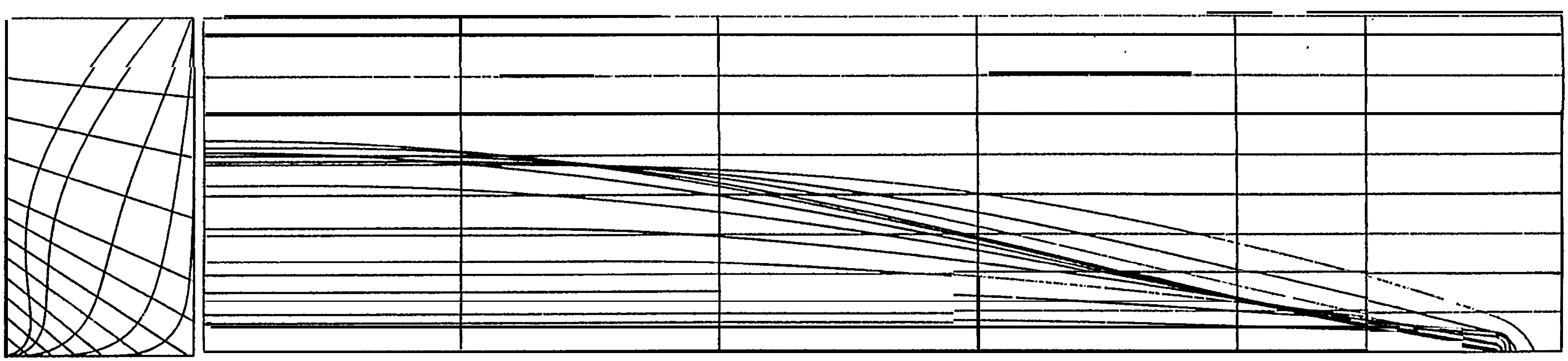

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Fig. 2 Fairing Lines

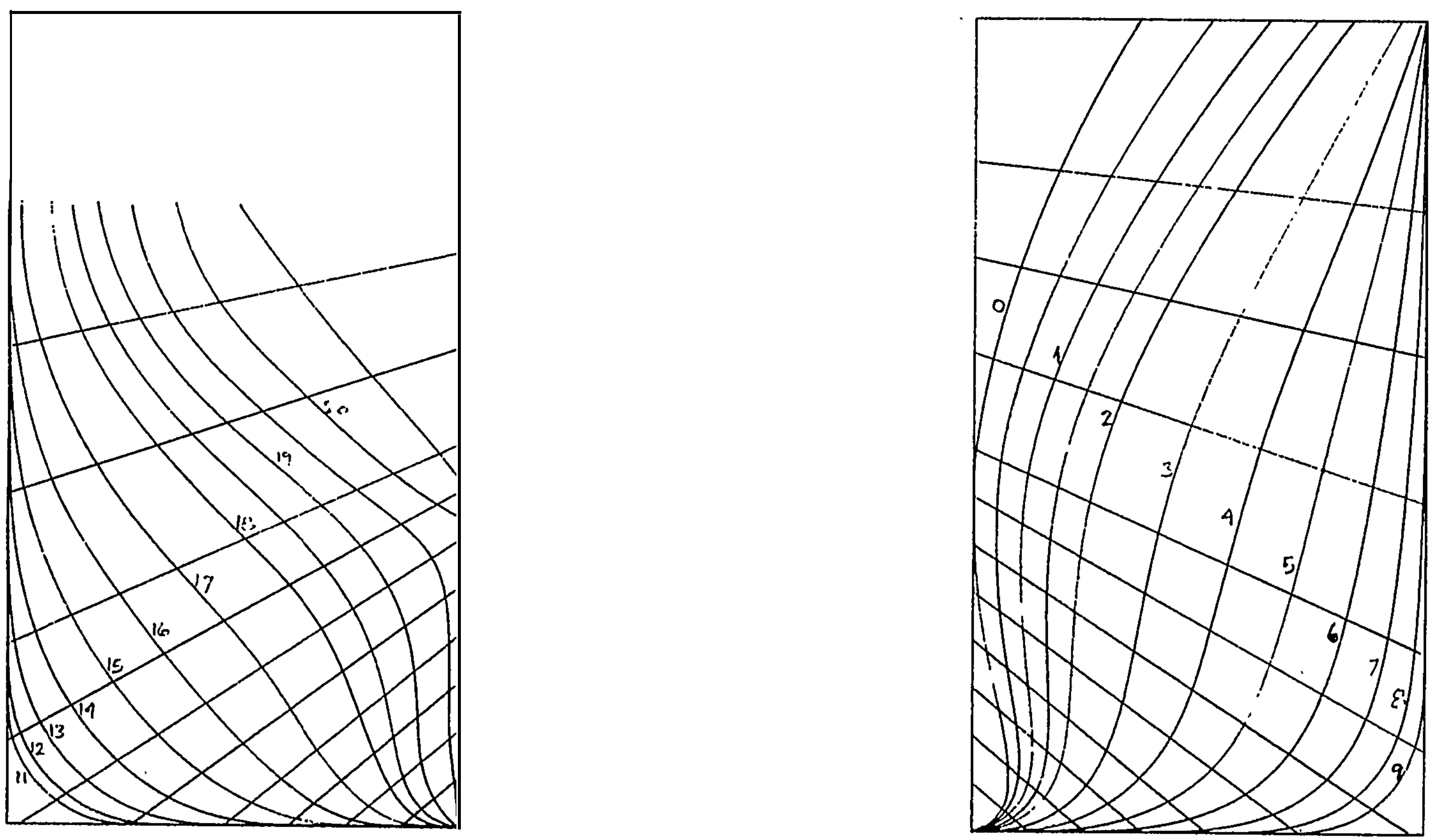

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Fig. 3 Stations. Run 1

B. Design Calculations

By using the Simpson integration rule through the HULLCAL Program, the set of Curves of Form shown in Figure 4 was obtained. The calculation was performed for the molded lines only, using the previously generated stations and waterlines four feet apart. No allowance for appendages, such as rudder, propeller, etc. , nor shell plate thickness was included at this time.

The corresponding Cross Curves of Stability are shown in Figure 5. These were based on a reference VCG of O feet and calculated for the portion of the hull below the main deck only. The main deck was loaded through the HULLOAD Program. A set of Bonjean curves was also generated and drawn by the HULLCAL Program, as shown in Figure 6. Every other station was used in order to clarify the drawing.

Finally, a set of floodable length curves was calculated and plotted against the profile of the vessel, as shown in Figure 7. These were based on a margin line three inches below the main deck, and a subdivision draft of 29'10".

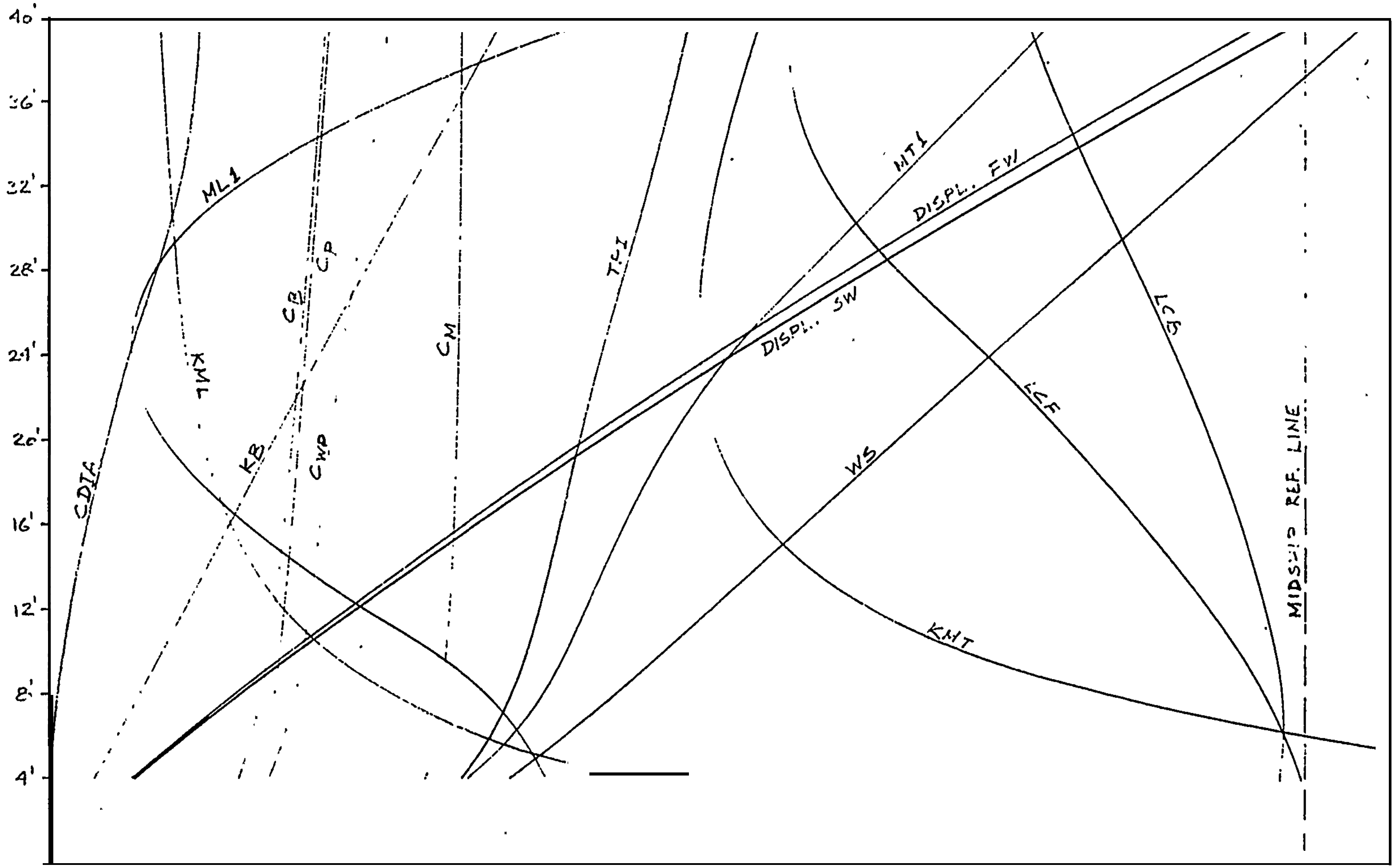

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Fig 4 Curves of Form, Run 1

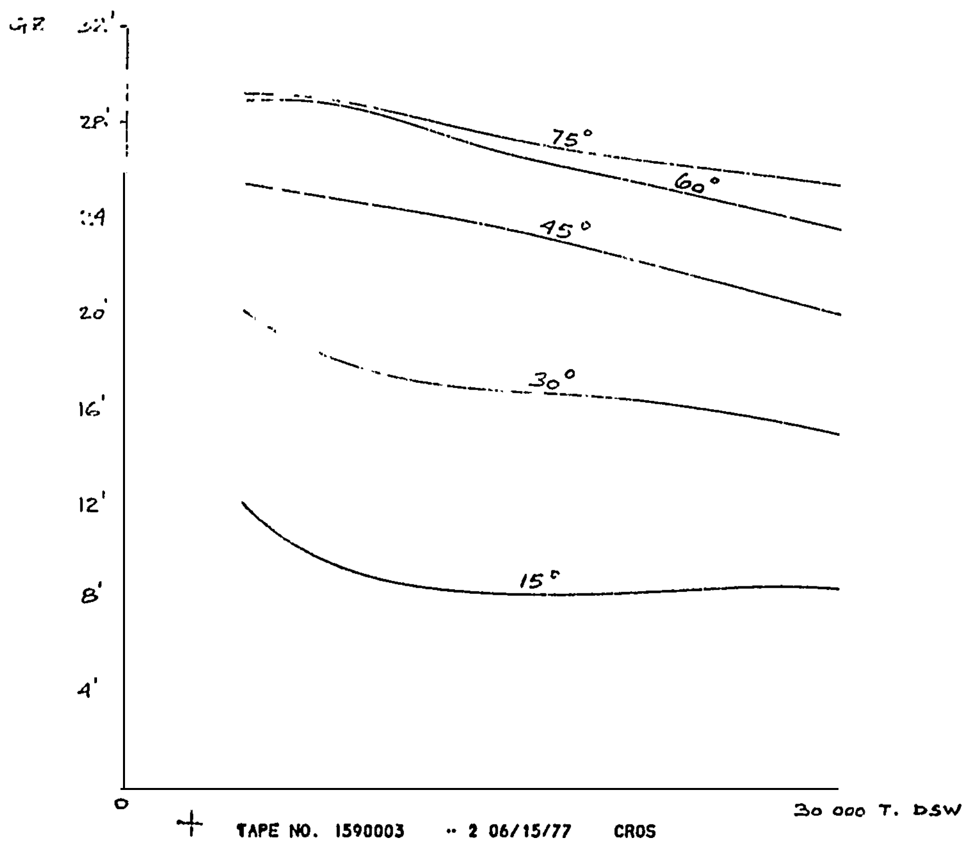

Fig. 5 Cross Curves of Stability, Run 1

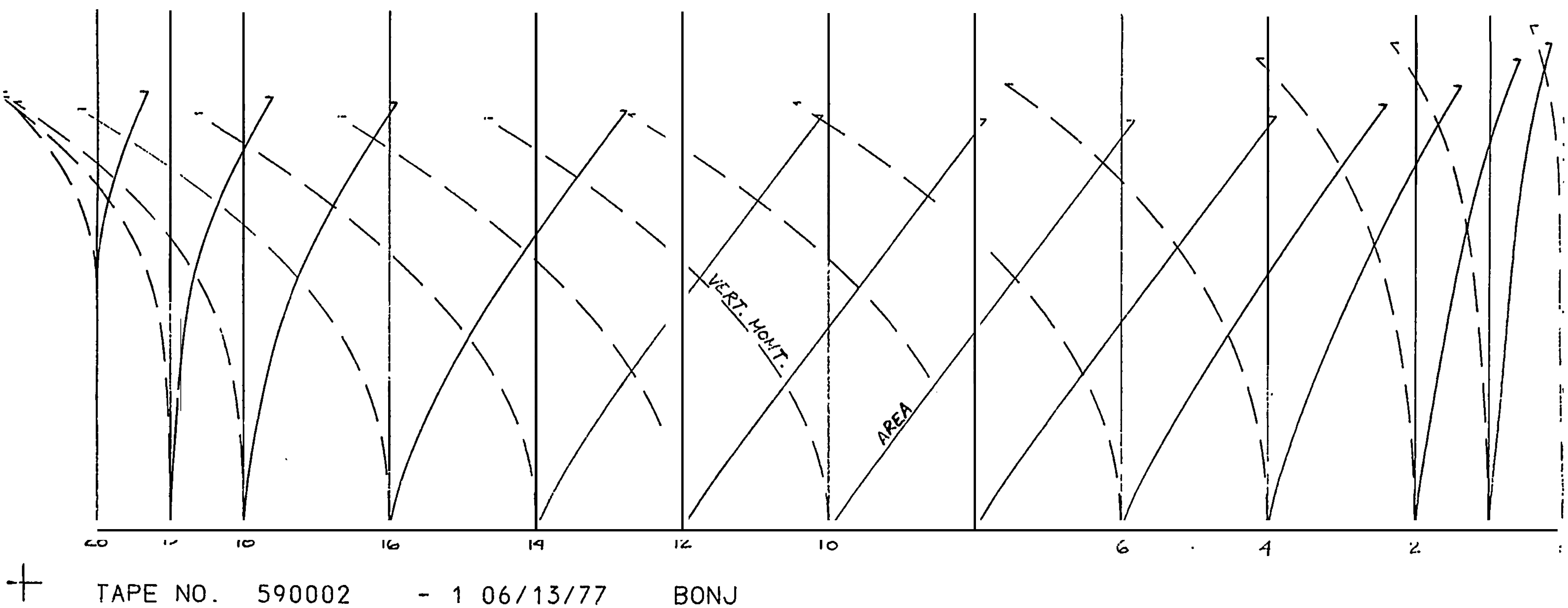

Fig. 6 Bonjean Curves, Run 1

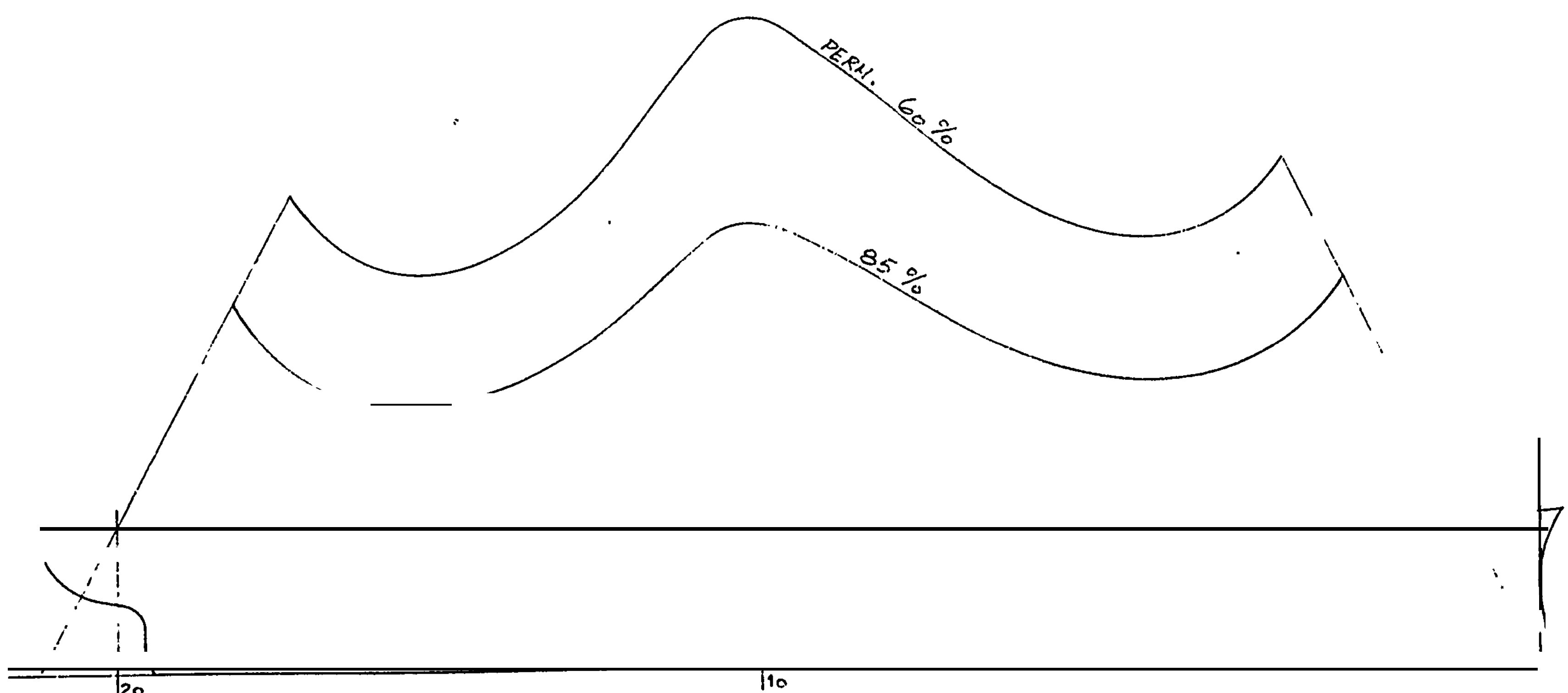

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Fig. 7 Floodable Length Curves, Run 1

C. Design Alteration

It was now decided to add an 80 ft. section of parallel middle body to the vessel to increase the length to 608 ft. LBP. All other offsets were to remain the same. The "jumboizing" was accomplished by adding 80 ft. to all longitudinal (Z) coordinates of the aft body control lines and given basic stations. The resulting fairing lines did not change, except for their relative location. The Simpson station spacing was increased, of course, and the results of the new station interpolation are shown in Figure 8. Stations 9 through 11 became identical now to the midship station.

The new Curves of Form drawing is shown in Figure 9 and the corresponding Cross Curves of Stability in Figure 10.

As can be expected, these new curves have the same general characteristics as before, except for a considerable increase in displacement. The stability increased slightly, while the largest increase can be seen in the Moment to Trim 1 inch (MT 1).

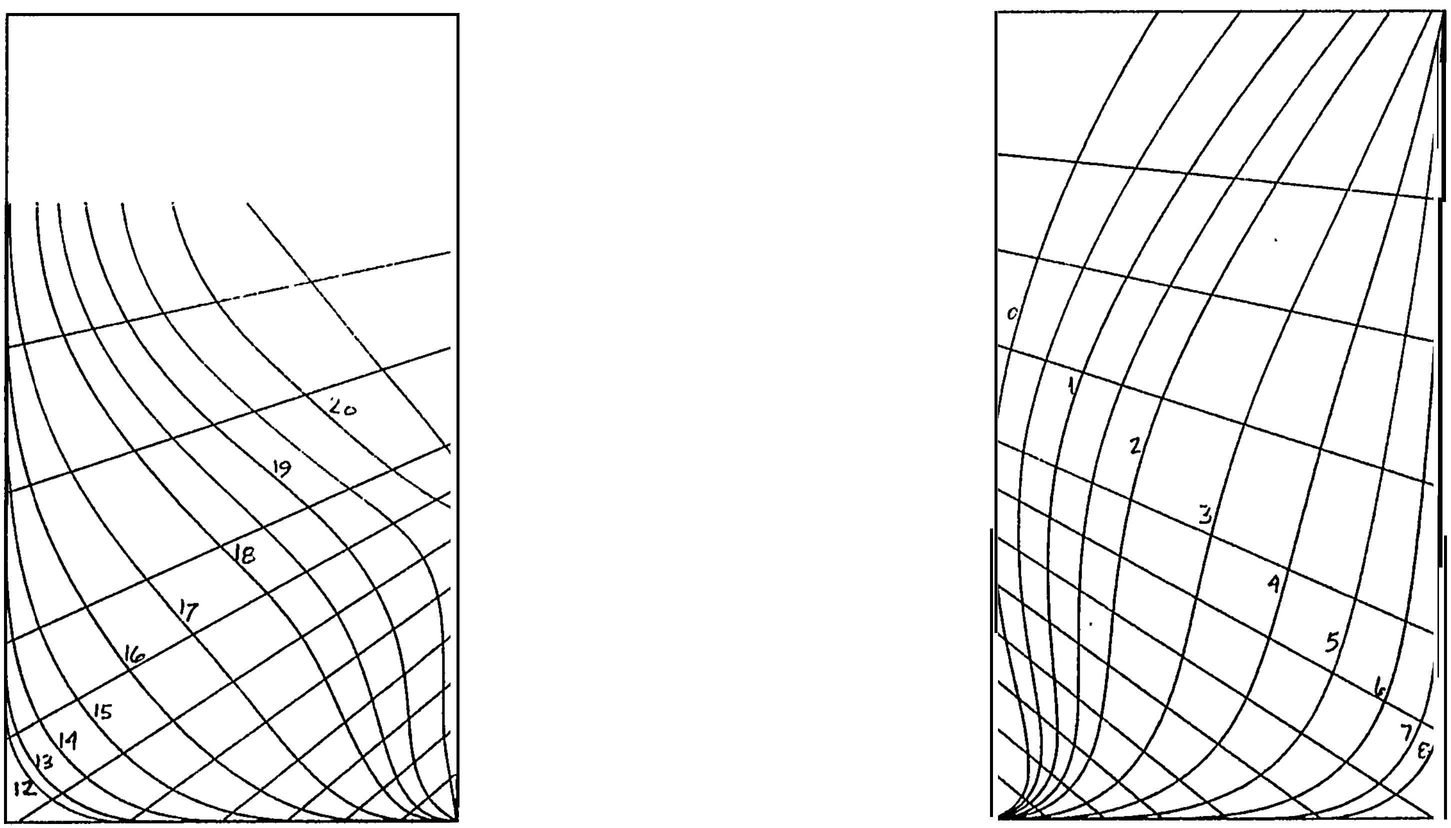

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Fig. 8 Stations, Run 2

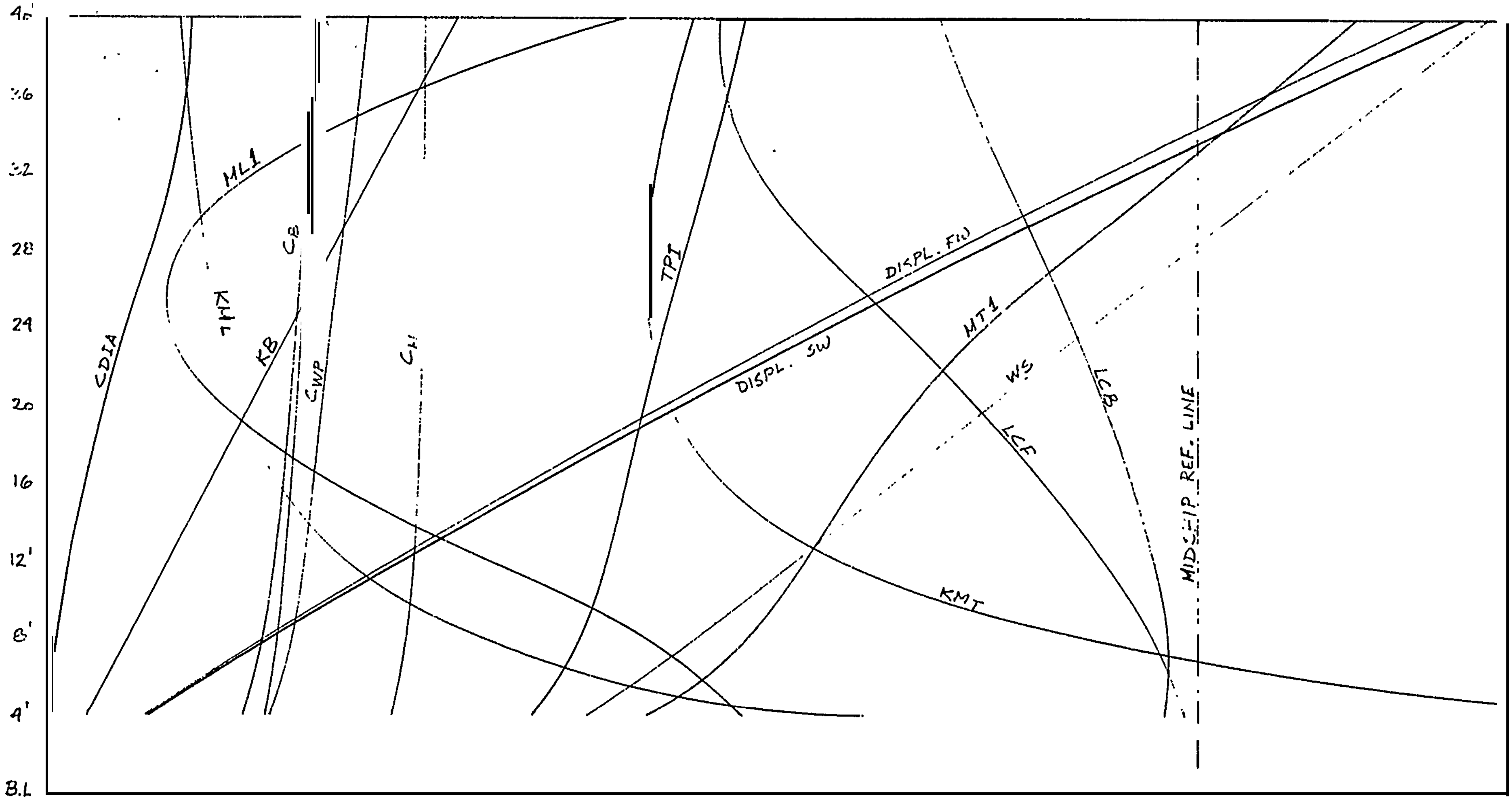

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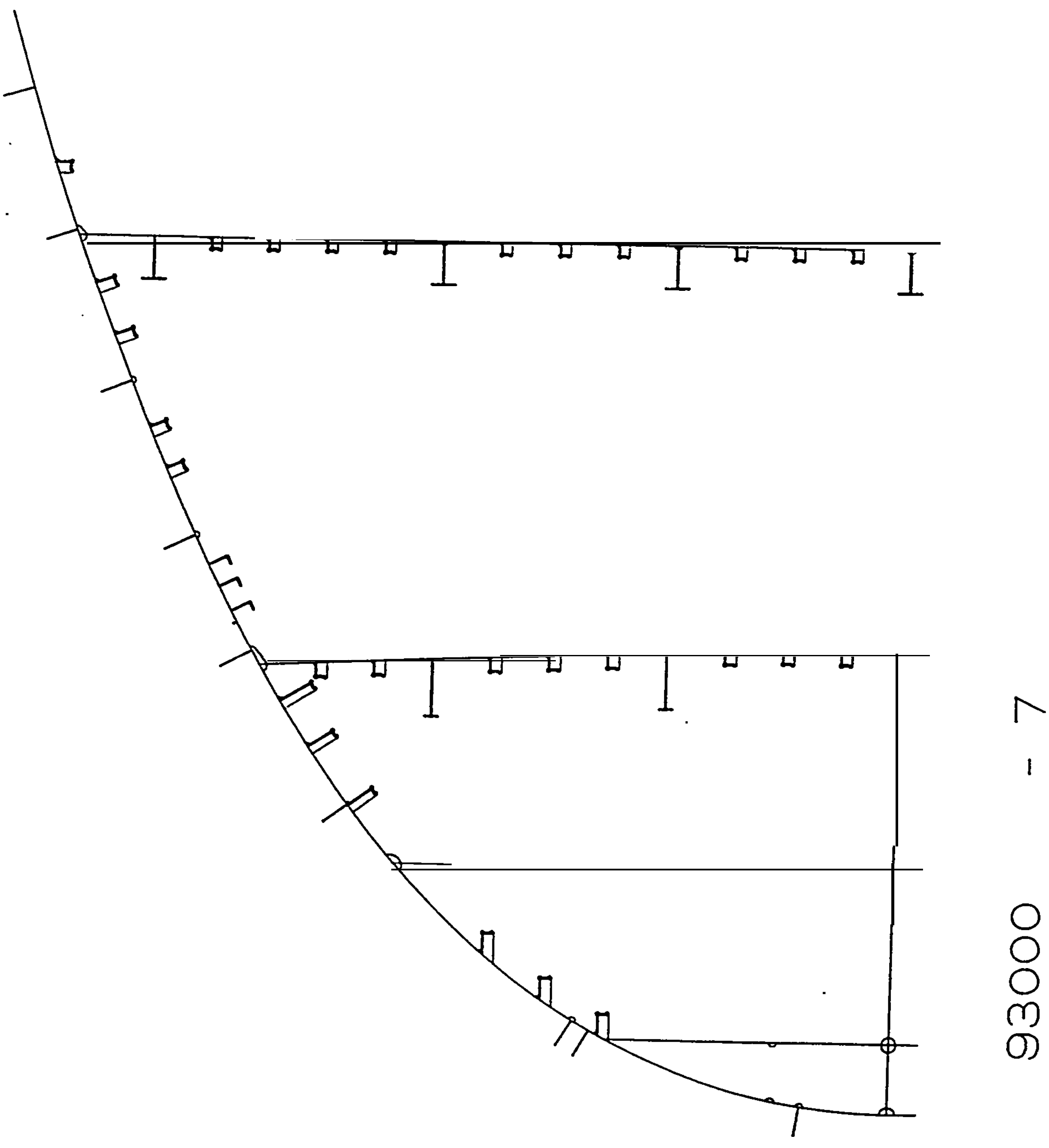
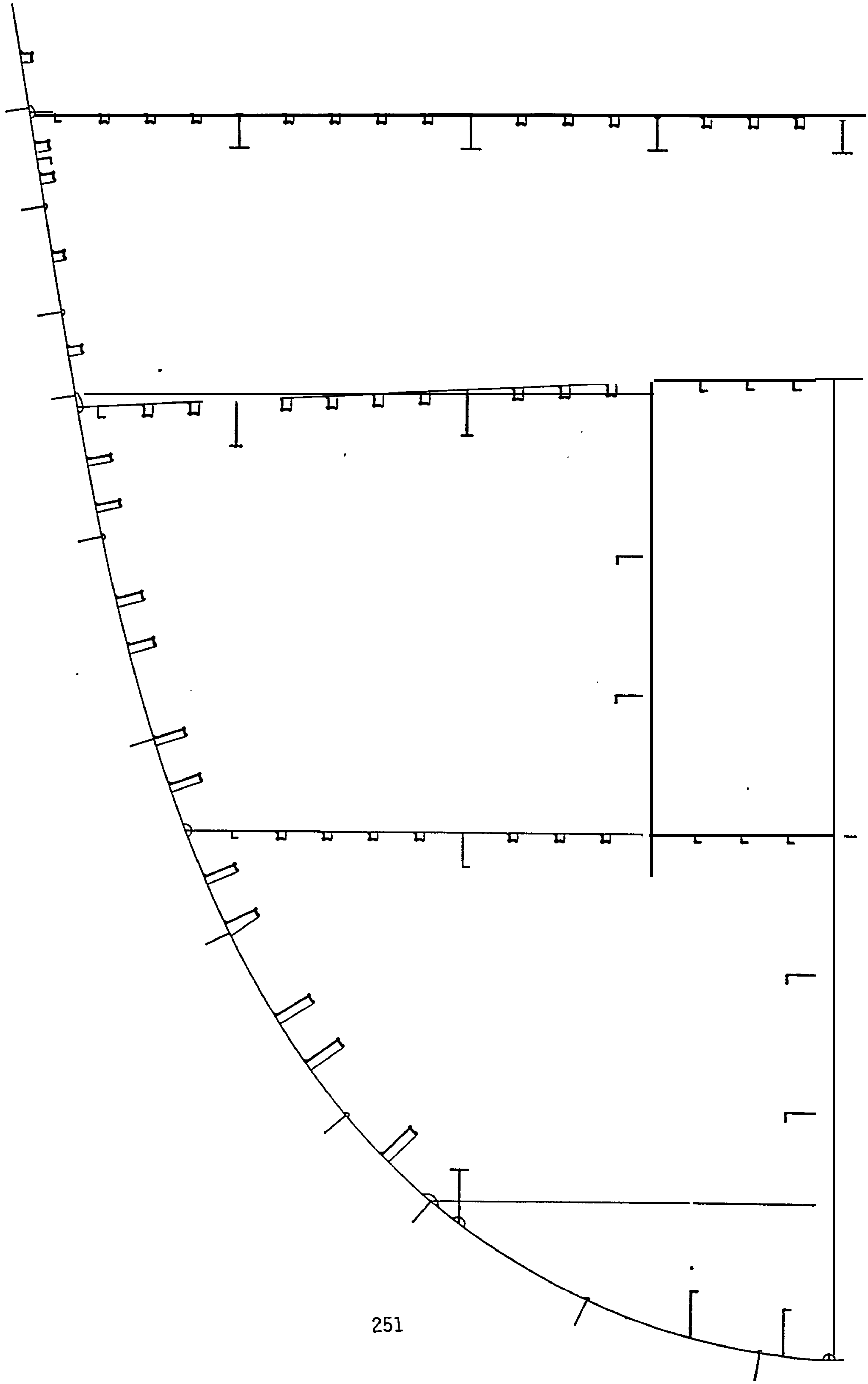
Fig. 9 Curves of Form, Run 2

Fig. 10 Cross Curves of Stability, Run 2

D. Structural Design

The following figures are included to demonstrate some typical drawings generated by the DEMO Program. These are the basis for the structural drawings of various transverse bulkheads and deep webframes for a large bulk barge. The drawings were generated after the definition of decks and longitudinal bulkheads, longitudinal stiffeners and girders, shell seams and detailed cut-outs and notches were defined and loaded on the Data Base.





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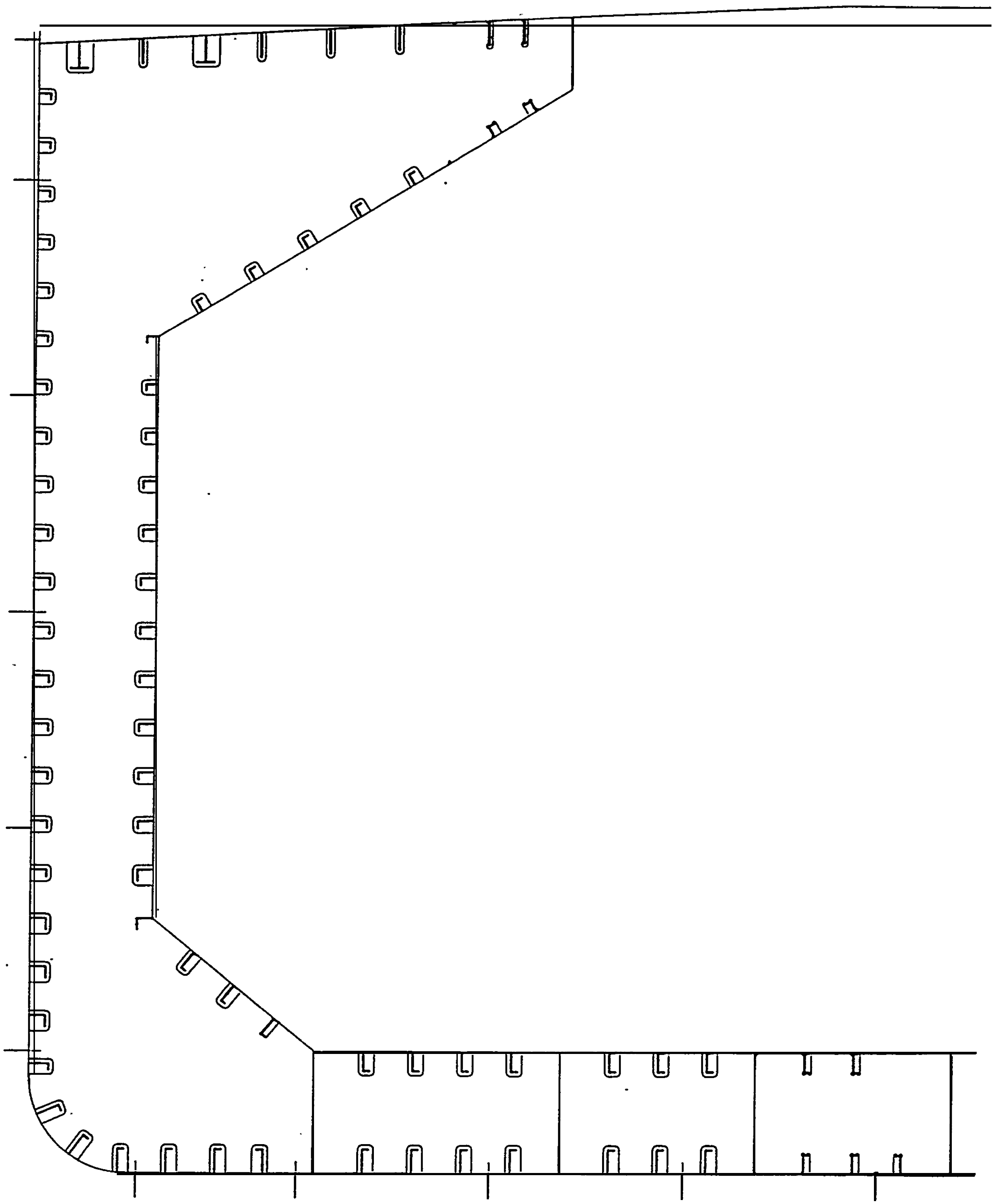

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