4.0 EXECUTING

4.1 Self Check

A/C includes a *self-check* system which workers and their immediate leaders execute. Self checks are crucial. Workers have not completed a job until they have checked their work to assure compliance with written accuracy instructions. Thus, self checks are regarded as work just as much as any other work task. Subsequently, work leaders, one for approximately every eight workers, check the same work and *record* the pertinent final data accordingly. Very important check points and lines, i.e., control items, are again checked and *recorded* by the next higher level of supervision. If such data is unreliable or not available there is no point in having A/C.

4.2 A/C Group

Where A/C is successfully applied, people having responsibilities to execute A/C procedures are assigned in the hull construction department. All are members of a yard-wide A/C group, have 8 to 9 years of varied shipbuilding experiences and were carefully selected on the basis of their aptitude for and commitment to improving productivity. Their responsibilities are:

- to check items which are so crucial that they should not be just dependent on the self-check system.
- trouble shooting,
- A/C of subcontracted items,
- further development of the A/C system,
- analysis of information collected by the self-check system, and
- convening a monthly A/C group meeting, chaired by the senior operations manager and attended by the managers and deputies of the major divisions of the operations department, for discussion of productivity matters.

As participation in A/C provides an excellent overview of planning, executing and evaluating, A/C group experience is prerequisite for higher managerial responsibilities. And, because increased productivity is dependent on more managers acquiring a complete overview of the entire shipbuilding process, memberships in an A/C group are rotated.

4.3 When and What to Check

Usually, schedules are posted for starting and finishing dates at each control station for part fabrication, sub-block assembly and block assembly. Summary sheets for future work loads are also posted. Self checks, subsequent checks and recordings are regarded as work processes that must adhere to these schedules. A blackboard in each division of production shows the day-to-day status.

Normally, the master schedule for block erection, weekly progress sheets and a schedule for erection checks based on the master schedule are posted in an erection office. The day-to-day status of block erection is maintained on a blackboard.

Accuracy checks are performed daily in accordance with schedules that are revised weekly, if necessary. Basically, the items checked for conformance with accuracy standards are:

- for template preparation - overall dimensions including excess allowances and marks required for fabrication, assembly and checking work,
- for part fabrication - overall dimensions of cut plates or shapes, edge preparations, deformation, and the curvature of bent parts,
- for sub-block and block assembly - the positioning of parts or sub-blocks, their fit, gaps for welding, distortion and overall dimensions, and
- for erection - fit up, gaps for welding and maintenance of hull alignment.

4.4 Information for Check Sheets

In accordance with work instructions issued by designers and based on information provided by A/C planners, members of an A/C group in a hull-construction department prepare check sheets. These designate check points and lines, checking methods, responsible personnel for measuring, and required frequency for measuring. Typical examples of check sheets are incorporated in Appendix A.

Preparing check sheets for curved blocks is usually difficult because the dimensions included in normal working drawings, while sufficient for assembly work, are not suitable for checking purposes. The simplest example are the two diagonals required for verifying the rectangularity of a panel. The A/C group advises loftsmen to calculate numerous other special dimensions that facilitate accuracy checks; examples of these are also shown in Attachments 4, 5 and 6 of Appendix A.

Actual measurements are *mainly* performed as specified by the check sheets. However, check sheets cannot practically provide for all dimensions for all hull parts and assemblies. There has to be some dependence on supplementary routine checking of other dimensions by workers. This helps insure that the dimensions required by check sheets will satisfy accuracy standards. Typically, check sheets address dimensions and measuring methods as briefly illustrated in Figures 4-1 and 4-2.

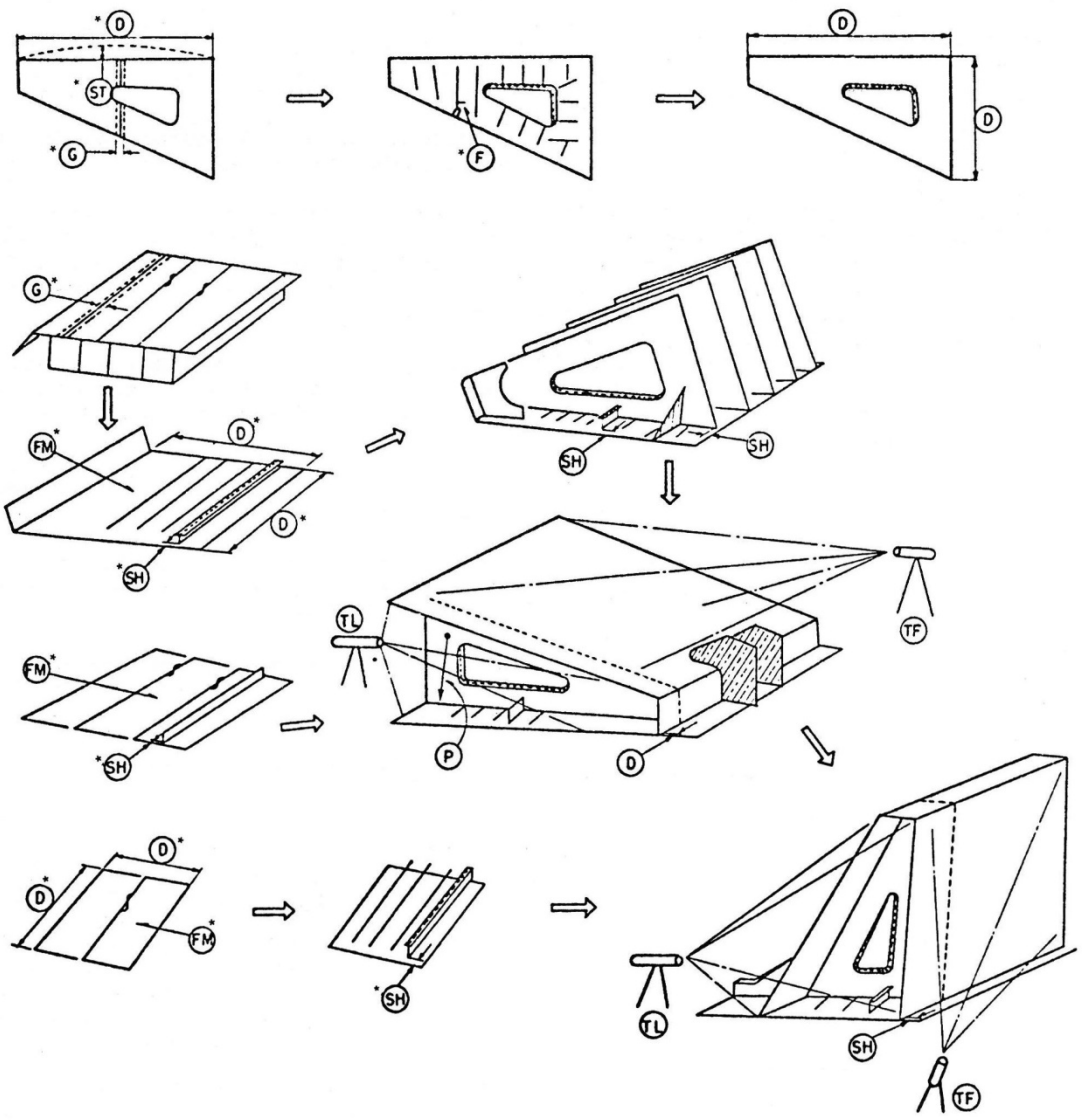
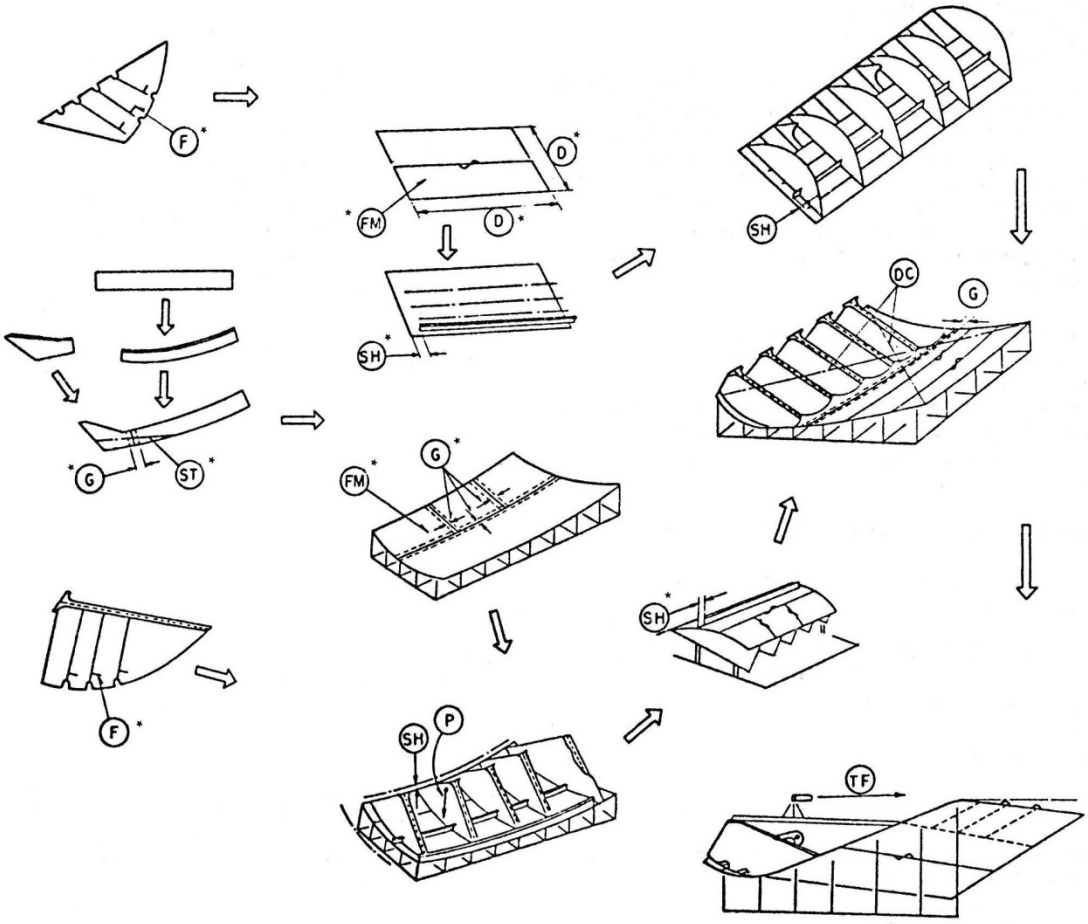


FIGURE 4-1: Dimensions and check methods that are typically the subject of check-sheet instructions for upper-wing tank parts in parallel midbody. See legend in Figure 4-2.



D DIMENSION CHECK
FM ASSEMBLY FINISHED MARKING
G CHECK LINE FOR GAS CUTTING
F GUIDE LINE FOR FITTING STIFFENERS
ST CHECK LINE FOR DISTORTION
SH CHECK SHIFT DIMENSION
P PERPENDICULARY CHECK
TF CHECK FLATNESS BY TRANSIT
DC CHECK DIAGONAL LENGTH
TL CHECK ALIGNMENT AT THE END BUTT OR END FRAME

* SELF-CHECK BY WORKER

NOTE: END BUTTS CHECKED ARE ALL NEAT CUT BEFORE ERECTION

FIGURE 4-2: Dimensions and check methods that are typically the subject of check-sheet instructions for curved blocks (bilge).

4.4.1 *Part Fabrication*

In order to achieve specified accuracy during assembly work, each of many parts must be fabricated within specified accuracy standards. As measuring every dimension of every part is impractical, random sampling is employed to monitor accuracy tendencies. However, special or large structural parts, such as girder or transverse web assemblies are exceptions. Each should be measured meticulously per check sheet instructions with particular attention to deformation. When cutting machines, such as N/C, are employed, their maintenance is a significant factor in the uniform working circumstances which are the bases for a valid random sampling. Maintenance checks on cutting machines should be frequent and regular.

The accuracy of bent parts is critical for achieving the accuracies specified for assemblies. Inaccurately bent parts are frequently forced to fit and are the sources of internal stresses which cause deformation when welding. Thus, all curved shell parts should be checked using sight-line templates and other information provided by loftsmen in order to establish for each plate as required:

- degrees of inclination for setting the templates,
- matches of the plate edges with seam marks on the templates,
- clearances between the template edges and plate surfaces,
- transverse and longitudinal curvatures,
- twisting, and
- straightness of the sightline (see Figure 4-3).

Analogous techniques and checks apply to other parts such as twisted longitudinals.

4.4.2 *Sub-block Assembly*

Typically, what is important for A/C of sub-blocks is the fit of stiffeners, brackets and face plates such as on a web plate, and how to prevent and/or deal with deformation and shrinkage caused by welding. Therefore, measuring activity during sub-block assembly should concentrate on:

- checking fitting dimensions,
- checking for deformation and shrinkage by using a reference line on a web plate and/or a straight edge of the web plate, and
- measuring other dimensions as indicated on a check sheet.

4.4.3 *Block Assembly*

Achieving specified accuracy in an assembled block is most important because the block assembly process offers the last opportunity to deal with variations that otherwise have to be considered during erection.

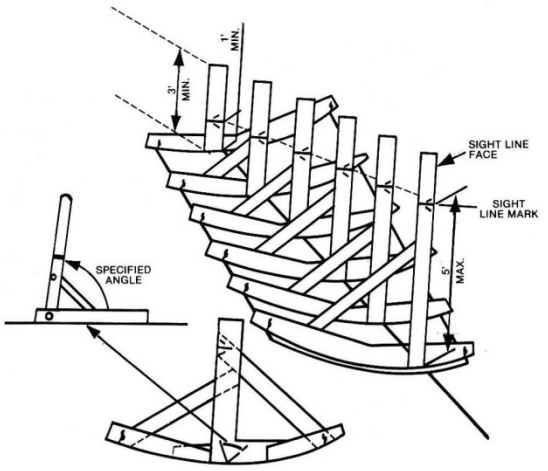


FIGURE 4-3: As shown, each template is set at a specified station and angle with its edge marks matching plate edges. Sight line marks, relative to a taut string, determine the accuracy of longitudinal curvature. Inclination of the sight line is an aspect of human engineering required as an A/C measure. A checker maintains an efficient, relaxed stance. Such techniques when repeated many times, significantly contribute to increased productivity.

Regardless of their shapes, blocks are categorized by the panel upon which they are assembled, i.e., flat or curved. Typically the former are assembled on flat platens and the latter on pin jigs. Measurement methods for the two types are necessarily different.

Flat-block check sheets should include the following requirements:

- measurements of width, length and diagonals to be made just after the base panel is assembled,
- twisting,
- locations of sub-blocks and internal parts fitted after the base panel is completed, and
- special measurements as shown in Figure 4-4 to check unique aspects of flat blocks which incorporate some curved shell.

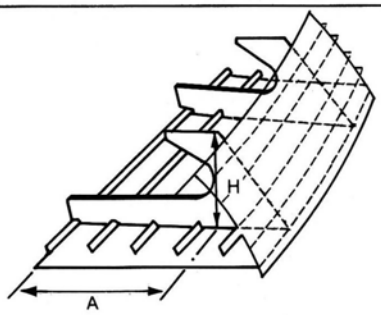


FIGURE 4-4: A and H are typical vital dimensions which A/C engineers require. Usually they are provided for in work instructions prepared by designers; loftsmen calculate their actual values.

Curved-block check sheets should include the following requirements:

- measurements to check guides for precisely locating curved plates for a base panel on a pin jig,
- measurements of width, length, diagonals and chord lengths to be made just after a base panel is assembled,
- use of marked steel-tapes prepared by loftsmen for checking assembly finished-marking, i.e., the locations of sub-blocks and internal parts on a curved panel,
- means to verify the fitting angle of internal structure,
- instructions on how to detect and correct deformation caused by welding, and
- meticulously checking required dimensions between panel edges and the edges of internal structure particularly near erection joints.

Checking blocks as described in the foregoing is important because many are neat cut along erection joints during the final phase of block assembly.

4.4.4 Hull Erection

During the erection stage, the object is to at least achieve end-product accuracy standards specified by regulatory societies and owners for hull depth, breadth, length and straightness. A/C group members monitor vital points and dimensions by measuring and recording periodically per check sheet instructions during the entire period between keel laying and launch; see Figure 4-5 and Appendix A.

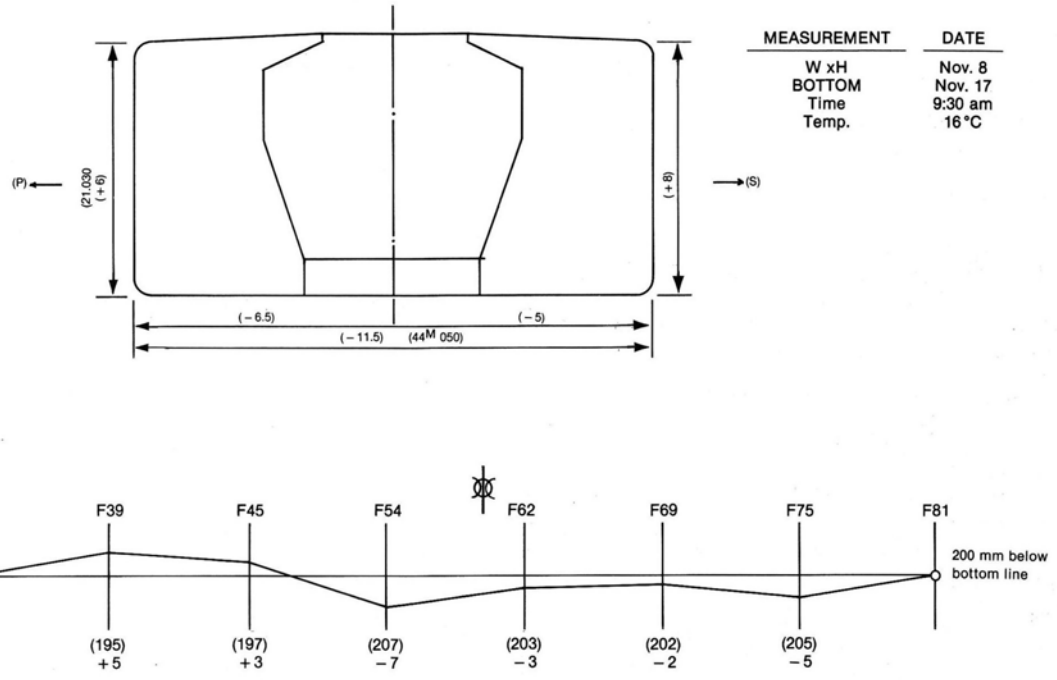


FIGURE 4-5: In order to achieve end-product accurancy, A/C engineers carefully monitor the alignment of assembled blocks throughout the entire hull erection period. Usually, regulatory and/or owner representatives witness these activities.

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