#0116

NATIONAL SHIPBUILDING RESEARCH PROGRAM

U.S. DEPARTMENT OF COMMERCE

MARITIME ADMINISTRATION

in cooperation with

BATH IRON WORKS CORPORATION

NOVEMBER 1, 1980

NATIONAL SHIPBUILDING STANDARDS PROGRAM

STATUS REPORT NO. 2

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NATIONAL SHIPBUILDING RESEARCH PROGRAM

SHIP PRODUCIBILITY PROGRAM

Subj: National Shipbuilding Standards Program - Status Report No. 2

Gentlemen:

This report updates the data contained in the National Shipbuilding Standards Program Status Report No. 1, issued June 1, 1980. It reflects significant accomplishments, current progress, and future plans as indicated by the achievements of Panel SP-6 and ASTM Committee F-25 on Shipbuilding. As important plans are developed, new objectives defined and stated, priorities determined and agreed upon, and schedules detailed, the changes in the standards program will be chronicled and documented in subsequent status reports.

Management control of the program by Panel SP-6 and ASTM Committee F-25 remains effective because of the clear-cut assignment of responsibility and functional application of the activities of each organization. The concensus procedure provides a forum for the exchange of ideas and the resolution of problems as viewed by the various segments of the industry. The interface between the various SNAME Panels, ASTM Committee F-25, Government Agencies, and the Regulatory Bodies, is part of the process required to achieve the goals and objectives of the standards program.

The accomplishment of many projects, both current and contemplated, depends largely on the participation and support of each individual and organization involved in the standards program.

The active cooperation of everyone is necessary to ensure the success of the standards program, whose potential for savings can be of considerable benefit to the industry.

A corrected distribution list is included with Status Report No. 2 for information. Requests for additional changes should be referred to:

Samuel Wolkow
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Very truly yours,

BATH IRON WORKS CORPORATION

Samuel Wolkow
Secretary, Panel SP-6

STATUS REPORT NO. 2

EXECUTIVE SUMMARY

Recent Developments

Since the issuance of Status Report No. 1 on June 1, 1980, significant events in the National Shipbuilding Standards Program have transpired.

Of primary importance was the signing of a contract with the Maritime Administration on Sept. 30, 1980 for the continuation of the Ship Producibility Research Program. This agreement provides for cost reimbursement to Bath Iron Works Corporation as Manager of the Ship Producibility Program to administer the ongoing shipbuilding standards and specifications program, and includes funding for the following tasks:

Task S-28, "Standard Specifications for Piping Systems"
Task S-29, "U.S. Shipbuilding Standards Long Range Plan"
Task S-30, "Mechanical Design/Construction Standards-Group III"
Task S-31, "Consensus QA/QC Acceptance Standards" and
"FY-80 Special Project Funding"

Accomplishments

A high point in standards development was reached on July 3, 1980 when the first ASTM shipbuilding Standards (F670-80) for a 5 and 10 gal. dispensing tank was issued. This standard is scheduled to be published in the 1981 edition of the ASTM Book of Standards, Part 46 (Sub. 07) .

Other standards which have progressed to the society ballot stage include, "Practice for Use of Branch Connections," and "Specification for Wrought Carbon Steel Sleeve Type Pipe Couplings." Additional standards are expected to advance through the due process balloting procedure and be published as society standards by the end of the year.

ASTM's Committee on Publications proposes to restructure the Annual Book of Standards from 48 to 63 parts by 1982. By that time it is anticipated that Committee F-25 will have completed a sufficient number of standards to meet the Society's minimum requirements for having its own Book of Standards on Shipbuilding assigned.

Long Range Plan

Of notable interest was the development of the specifications for the long range plan which was presented to the members of Panel SP-6 at the meeting held in Sturgeon Bay on Sept. 10-11, 1980. As a result of consensus recommendations a revised preliminary proposa was drafted and resubmitted for the Panel’s review and approval on Oct. 10, 1980, and a Request for Proposal to IHI. Marine Technology as a sole source respondent was forwarded on Nov. 1, 1980. The primary emphasis of the long range plan is to set near-term (2-3 year) priorities. Secondary emphasis is directed on the developmen of longer term (10-20 year) goals.

SP-6 Slide Presentation

A slide presentation has been prepared to provide an overview of the standards program interface between Panel SP-6 and ASTM Committee F-25 on Shipbuilding, and to indicate the latest status of all projects currently in development. A written text accompani the slide show. Duplicate copies of the slides are available for u as a public relations aid to foster industry awareness of the work being done by the Panel and to highlight the resulting benefits.

Summary

The results of past accomplishments indicates that Panel SP-6 has gained sufficient procedural experience to move on to new approaches to standards development, e.g. zone outfitting pre-outfitting, accuracy and dimensional control, etc., where standards surface as the primary factor, while still recognizing the need to develop shipyard unique type mechanical design and construction standards ‘which are intended to provide maximum near term benefits to shipyards.

The work of SNAME Panel SP-6 and ASTM Committee F-25 in advancing standards development continues to receive added expressi of industry encouragement and acceptance. As a result, more intere is being generated within the shipbuilding community leading to a greater level of effort and participation in accelerating the progress of the National Shipbuilding Standards Program.

An indication of this fact is the increase in membership on Panel SP-6 from nine to fifteen shipyards by the addition of the following firms:

Peterson Builders, Inc.
Marinette Marine Corp.
Bay Shipbuilding Corp.
Tacoma Boatbuilding Co., Inc.
General Dynamics Corp./Electric Boat Division
General Dynamics Corp./Quincy Shipbuilding Division

Industry awareness is further stimulated by the application of completed standards in new shipbuilding contracts even prior to formal acceptance and publication by ASTM Committee F-25. As a result, more shipyards are implementing internal standards organizations in order to benefit from achievements of the standards program.

NATIONAL SHIPBUILDING STANDARDS PROGRAM

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PART I - MARAD/SNAME SPONSORED STANDARDS PROGRAM

SNAME Panel SP-6

Almost all the tasks subcontracted under the FY-79 program are substantially completed as indicated on the lists attached to this report as appendices (A) and (B).

Notably among these was the publication of the "Weld Defect Tolerance Study" which was distributed to the industry on June 1, 1980. This report received both national and international acclaim and has generated several ongoing activities. Of special importance is the "Fitness for Service in Shipbuilding" conference which was held at the National Bureau of Standards in Boulder, CO on Oct. 23-24, 1980 under the co-sponsorship of Panels SP-6 and SP-7 (Welding). The goal of this conference was to formulate a U.S. Shipbuilding Industry policy position on new weld acceptance standards. To attain this objective it was proposed to establish a task group representing a comprehensive cross-section of the industry functioning under the direction and guidance of Panel SP-7.

Furthermore, in acknowledgement of the "Weld Defect Tolerance Study," the British Welding Institute in conjunction with the American Welding Society is sponsoring an international conference to be held in London, England on Nov. 17-19, 1981 on the subject, "Fitness for Purpoase Validation of Welded Construction." The fitness for purpose philosophy represents an important advancement over present weld acceptance standards which are considered overly conservative and predominantly workmanship based, when taking into account recent improvements in the state of the art. The concept expressed in the "Weld Defect Tolerance Study" has created intense industry interest, both here and abroad, and is intended to provide the basis for near term initiatives to substantially reduce unnecessary ship weld repair costs. The report concludes that $ 500,000 to $ 1 million can be saved per ship by eliminating repair of innocuous defects.

It was specifically intended that most of the tasks listed on appendices (A) and (B) should reflect mechanical design and construction standards which have immediate application in shipbuilding contracts and can be used in advance of final ASTM acceptance and publication.

Membership

Since the last status report (June 1, 1980), there has been a marked increase in the membership of Panel SP-6 as reflected on the membership list attached hereto as appendix (C) . Fifteen major shipyards are now represented on the panel in additio to the Navy (NAVSEA) and the Maritime Administration.

The high degree of government participation as evidenced by Navy and MarAd participation in the activities of the standards program is readily apparent and efforts are underway to rekindle U.S. Coast Guard's interest and cooperation in the National Shipbuilding Standards Program. In September, 1980, the U.S. Coast Guard appointed Mr. Robert E. Williams, Chief of Design of the Naval Engineering Division, as official representative to Committee F-25.

In view of certain Design Agents having previously volunteered panel support, invitations will be extended to selected representat firms to join in the work of the panel, particularly in regard to lending their expertise in developing the concept of functional design and detail design standards as well *as* standards material lists for steel and outfit equipment.

The idea of making panel membership available to all segments of the industry (owners/operators, design agents, regulatory agenci is meeting a measure of resistance since it is the opinion of some members that the purpose in reactivating the panel was to have it act in the capacity of a shipbuilding forum. Others interpret the scope of Panel SP-6 as a steering committee intended to act upon the industry's concerns and priorities in the standards program. Clarification and resolution of this question will be addressed at the next panel meeting.

Future Plans

FY- 80

The current Shipbuilding Standards Program includes the follow technical tasks:

Task S-30, Mechanical Design/Construction Standards-Group III To continue the development of detailed mechanical design/construct standards based on composite priority recommendations of the SNAME Panel SP-6 member shipyards.

Task S-31, Consensus QA/QC Acceptance Standards - To develop/ adapt industry quality acceptance standards based on the priority consensus recommendations of SNAME Panel SP-6.

Task - FY-80 Special Project Funding - To provide funding for special short-term, high priority efforts such as studies, standard development, surveys, workshops, special consulting, public relations activities, etc., in support of standard program objectives.

Task s-29, Standards Program Long-Range Plan - To develop a roadmap for U.S. shipbuilding standards development for the 1980's with specific goals and indication of actions required and responsibilities assigned.

Task S-28, Standard Specifications for Piping Systems - To develop standard specifications for piping joints, valves, fittings and symbols which can be used with confidence by the industry.

FY-81

With the Fy-80 program approved and funded in part by the Maritime Administration, the panel's work is now being directed towards identifying high priority candidate tasks for the FY-81 prospectus. Key event target dates for the FY-81 proposal are as follows:

• November, 1980	Submittal of suggested tasks to Panel SP-6 for consensus.
• January, 1981	Complete Panel's review
• March, 1981	Present consensus recommendation to Ship Production Committee/MarAd for concurrence.
• September, 1981	Receive MarAd funding and authorization to proceed.

Some pilot projects suggested for the FY-81 program include the following:

- Standardized Bid Response Sheets - To provide standard format for review and analysis of bid responses.
- Standard Purchase Specifications - To provide standard parameters for defining operating and performance characteristics of main and auxiliary equipment.
- Inspection Standards - Primarily for establishing acceptance criteria for surface preparation for paint application; weld acceptance criteria; hull construction tolerance standards, etc.
- Repair Standards - To define regulatory agency requirements for repair work and also for upgrading materials and systems to U.S. Flag standards.

- Functional Design Standards - Development of key drawings for H. M, E systems including standard machinery arrangements, piping system diagrammatics~ modular power system standards, structural midship standards, and standard zone packages, etc.

- Plan Approval/Submittal Cycle Standards - Particularly in regard to USCG NVC-679 which emphasizes the need to establis uniform practices, uniformly applied, to expedite plan appro procedures.

- Public Relations Program - To promote and publicize the activities of the panel's work in the standards program.

- Executive Management Briefings - To describe the scope and objectives of the National Shipbuilding Standards Program and Panel SP-6'S interface with ASTM, ASNI and ASA.

- Mechanical Design/Construction Standards Group IV - To provide short term benefits by being immediately available for implementation in advance of formal acceptance and publication by the standards organizations.

In preparing the FY-81 plan, panel members are encouraged to propose projects which will address both near-term and long-range objectives and provide for an ongoing development effort which wil articulate an organized and disciplined approach to standards technology.

FY-82

The major area of activity for this period is expected to be the implementation of consensus priorities generated by the Standar Program Long Range Plan (Task S-29).

Summary

In retrospect, the work under Panel SP-6 can be summarized as addressing the following requirements:

- The need for developing a central long range industry plan with specific goals and responsibilities clearly defined.

- The need to encourage and support near-term efforts to develop functional design and engineering standards for unit construction.

- The need to continue development of detailed design and construction standards.

- The need to differentiate between industry consensus and individual shipyard standard requirements.

PART II

ASTM COMMITTEE F-25 VOLUNTARY STAND DEVELOPMENT

Membership

Membership "in ASTM Committee F-25 currently corn-prises approximately 170 individuals representing all parts of the shipbuilding industry. The Government's commitment to the Committee is evidenced by the recent assignment of several Maritime Administration personnel to the technical subcommittees of the organization. The Navy's deputation to the group remains forceful and effective in accomplishing the objectives of the committee. Most encouraging was the recent appointment of Mr. Robert E. Williams of U.S. Coast Guard Headquarters to the Committee. This is particularly noteworthy because of the USCG'S duties as shipbuilding inspector and plan approval authority for all commercial ship construction. These functions are directed by their Office of Marine Inspection and Merchant Marine Technical Divisions, respectively. In documenting and certificating commercial vessels for delivery by the shipbuilder to the owner, such action cannot be consummated without the issuance of the USCG Certificate of Inspection.

The participation of the USCG in the National Shipbuilding Standards Program will provide major input on policy positions on such matters as plan approval cycles, inspection procedures, material and equipment standards, etc.

Organization

F-25 Officers

Chairman	R. J. Taylor, EXXON International Co.
1st Vice Chairman	E. A. Schorsch, Bethlehem Steel Co.
2nd Vice Chairman	Radm. E. J. Otth, USN, NAVSEA
3rd Vice Chairman	H. F. Greiner, Sealol, Inc.
Secretary	*Samuel Wolkow, Bath Iron Works Corp.

*Effective Jan. 1, 1981.

Technical Subcommittees & Chairmen

	Materials
F-25.01	J. C. West, Bethlehem Steel Corp., Beaumont
	Coatings
F-25.02	Open
	Outfitting
F-25.03	N. M. Stiglich, Eness R & D Corp.
	Hull Structure
F-25.04	W. M. Hannan, ABS
	Ship Control & Automation
F-25.06	F. J. Kennedy, NAVSSES, PHILA
	General Support Requirements
F-25.07	S. H. Bailey, Avondale Shipyards, In
	Deck Machinery
F-25.08	D. G. Pettit, NAVSEA
	Electrical/Electronics
F-25 .10	Open
	Machinery
F-25.11	B. J. Walsh, NAVSEA
	Welding
F-25.12	Open
	Piping
F-25.13	Open

It is critical to the effectiveness of the subcommittees that the chairmanships of F-25.02, F-25.10, F-25.12, and F-25.13 be occupied to ensure continuity in the performance of these units. Hopefully this situation will be remedied by the time of the Decemb meeting in Orlando, FL.

Progress to Date

The first Committee F-25 standard was approved by the Society' Committee on Standards on July 3, 1980. This standard (F670-80) is for a 5 and 10 gallon dispensing tank and will be published in the 1981 edition of the ASTM Book of Standards, Part 46 (Sub. 07).

Several other standards are in the process of being balloted as Society standards and final approval is expected by the end of December, 1980. They include:

- Use of branch connections
- Welded joint design for shipboard practice
- Modular gage boards
- Design & installation of rigid pipe hangers
- Gage piping assembly
- Selection application of thermal insulation on piping and machinery
- Selection of bolting lengths for piping system flanged joints
- Funnels
- Sleeve type pipe couplings
- Vertical steel ladders

Various task groups organized within the strucutre of the parent technical subcommittees are involved in the development of draft standards and/or are investigating other areas of research pertaining to their fields of expertise.

Standards Development

Panel SP-6, acting in its capacity as the steering committee for the Industry's standards program, has been able to accelerate the progress of draft standards through ASTM's due process ballot procedure. For the period from June 1, 1980 to Nov. 1, 1980, the following SNAME/Industry consensus standards were referred to the cognizant ASTM technical subcommittees for ongoing development:

Task S-21, "Line Shaft Installation Standard"

- Geared Steam Turbine, Inboard System
- Geared steam Turbine, Outboard System
- Direct Drive Diesel System

Task S-24, "Mechanical Design/Construction Standards, Group II"

- Commercial Hydropneumatic Potable Water Tank
- Commercial Steel Air Receiver

Copies of the draft standards noted above are included in this report as appendices (D) through (H) .

Future Plans

Following up on the successful Shipbuilders' Workshop which was held in May, 1980 at the Denver meeting, a similar workshop for Owners is planned for the December meeting to be held in Orlando, FL.

The purpose of the workshop is to provide a forum for the Owners to inform the Committee of specific industry standards which would be most beneficial to them. Essentially, the standards should satisfy the owners' requirements and be economically feasible for the shipbuilders to implement, while complying with the rules and regulations of the regulatory agencies.

To stimulate interest in this workshop, a briefing on the standards program was presented at the New York Port Engineers meeting on Sept. 17, 1980. In addition, the assistance of Radm. W. M. Beckert of the American Institute of Marine Shipping has been offered to ensure the success of the workshop.

Several papers have been offered for the joint ASTM/SNAME Shipbuilding Standards Symposium scheduled to be held the week of Oct. 19, 1981 in Arlington, VA. A copy of the call for papers is included at the end of this report for ready reference for those who may be interested in contributing.

Long range goals which have been established for Committee F-25 include:

- Developing a policy position regarding the Government's participation in the voluntary standards program.
- Formulating a joint long range plan in conjunction with SNAME Panel SP-6.
- Increasing emphasis on public relations activities.

Part III - Conclusions

Conclusions

As the National Shipbuilding Standards Program continues to grow, it is apparent that in prioritizing standards development as an ongoing effort, it is necessary to redirect the industry's production concept from one of a high labor ivtensive process to that of an organized and"coordinated approach to a disciplined standards technology which in its application has proven successful in reducing costs, shortening schedule durations, and improving productivity.

Recommendations

As previously stated:

(1) Shipyards which are not actively involved in the National Shipbuilding Standards Program should discuss this report internally, obtain further information as necessary, and establish a top management position on the subject. All shipyards are welcome as active members of SNAME Panel SP-6.

(2) Every organization comprising the shipbuilding industry which is not active in the work of ASTM Committee F-25 should review this report, obtain further information as necessary, and again establish a top management position on participation. Every organization and individual with an interest in developing and using shipbuilding standards is encouraged to become a member of the committee.

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INSTALLATION OF PROPULSION SHAFTING FOR A SHIP WITH A GEARED DRIVE AND SHAFTING EXTENDED TO AN OUTBOARD STRUT

1. Scope

1.1 This procedure describes a method for the direction and documentation of the installation and alignment of the propulsion shafting for a marine propulsion system composed of the power units, a main reduction gear unit, line shafting with either one or two stern tube bearings, and outboard shafting supported by one or more struts.

1.2 The power units may be either steam turbine, or high-speed diesel engines, or medium-speed diesel engines, or gas turbine engines.

2. Summary of Method

2.1 The stern tube is fixed first in its structural position and a centered line-of-sight through the tube is used to locate the strut position and to position the reduction gears. A reference centerline is then established from the reduction gear shaft flange through the stern tube to the strut bore.

Design calculations are performed to determine the proper displacement and alignment of each shaft bearing, in relation to the reference centerline, which will give the design bearing load distribution and acceptable shaft deformation. The propeller and stern tube bearings are considered fixed, and the line bearings and reduction gear bearings are each positioned at their individual design displacements from the reference centerline, in both the vertical and horizontal directions. Special checks are made to insure that the journals of the line and gear bearings have proper contact over the bearing surface.

After the ship is waterborne, and the shaft sections completely coupled, and the reduction gear chocked in position, the bearing reactions are measured to determine compliance with the design reactions. The line and gear bearing positions may be finally adjusted, by a calculated displacement,. to improve the compliance.

2.2 The basic steps in the installation and alignment procedure are given in Table 1.

TABLE 1

Procedure of Operations	Reference Section
Establish initial shaft centerline	7
Machine shaft to final length dimension	8
Bore the strut and stern tube for bearing shells	9
Install the strut and stern tube bearings	10
Align the reduction gear and line shaft bearings	11
Measure bearing reactions	12
Documentation	13.

3. Significance of Installation Standard

3.1 An installation standard for propulsion shafting which includes adequate documentation will minimize the change of out-of-tolerance in shaft alignment and will permit the identification of events which may have caused an out-of-tolerance.

3.2 An installation standard for propulsion shafting will ensure that all parties concerned with the process are aware of the necessary steps and the objectives of the alignment procedure.

4. Definitions

centered telescope - the condition of the optical alignment telescope, mounted on a shaft flange, when the telescope is in the center of the gear flange and perpendicular to the face. A line of sight from a centered telescope maintains a constant target position as the mounting flange is rotated.

cross hair position - the position of optical target cross hairs relative to the cross hairs of the optical alignment telescope, as viewed through the telescope. The designation "up" means that the target cross hairs are above the telescope cross hairs; "starboard" means that the target cross hairs are to starboard of the telescope cross hairs, etc.

drop - vertical or transverse position of one flange relative to a mating flange, measured at the flange rims. A drop reading designated positive means that the forward flange is either above, or to starboard, of the aft flange. Same as "sag", or "rim".

gap - opening between mating flange faces at the top, bottom and sides of the flange perimeters.

gap-drop method - the method of aligning shafting using relative positions of mating flanges. Same as the "gap-sag" method.

gear flange - the output flange of the second reduction gear shaft; as a reference point, the aft face of the flange.

hydraulic jacking method - a method of measuring the vertical force on each bearing. Also called the bearing method, the shaft weighing method, and the method of measured bearing reactions.

key chock - one of the fitted chocks below the low speed gear bearings and the corners of the lower gear case which are sued to align the gear shaft to the line shaft.

line bearing - journal bearing supporting a line shaft section, located between the gear flange and the stern tube.

propeller bearing - the shaft bearing immediately forward of the propeller.

propulsion shafting - shafts used to transmit power from second reduction gear wheel (bull gear) to the propeller, including the second reduction gear shaft, the inboard and outboard line shafts, the stern tube shaft, and the tail shaft.

shaft centerline - an axial centerline through the shaft centers at the supporting positions. The bearing centerlines are above the shaft centerline by 1/2 the bearing clearance.

stern tube bearing - the bearings, which are enclosed within the stern tube and support the tail shaft.

tail shaft - the section of propulsion shafting which mounts the propeller. Same as the propeller shaft.

5. Apparatus

5.1 Optical alignment telescope with right angle eyepiece and built in optical micrometers for measuring displacements from the line-of-sight along two orthogonal axes (two-plane micrometer). Maximum tolerances for the telescope are one part of 200,000 for measurements along the line-of-sight and 0.5 seconds (0.000139 deg). of arc for measurements at right angles to the line-of-sight.

5.2 Bracket for mounting and adjusting the position of the telescope on the face of the shaft flange.

5.3 open optical alignment targets with cross hairs mounted within adjustable target holders.

5.4 Hydraulic *jack* and pressure gauge combination, calibrated to ± 2% of full-scale, capable of raising the shafting completely off each individual bearing.

5.5 Dial gauges for measuring shafting displacements in the hydraulic jacking procedure, accurate to ±0.(1005 in ±0.0127xLuu)_~ with mounting fixture to hold the gauge firmly.

5.6 Laser beam as an alternate to optical alignment telescope.

5.7. Strain gauges for deriving bearing loads from shaft strain measurements; alternate procedure to the sue of hydraulic jack and pressure gauge.

5.8 Hydraulic jack and load cell as an alternate to hydraulic jack and pressure gauge combination.

6. Alignment Requirements and Supporting Data

6.1 The shaft installation design and the alignment specifications are developed to meet certain objectives with respect to bearing loads, shaft stresses, and vibration response. These objectives are outlined in Annex Al. After the shafting design has been developed, engineering calculations are made to establish "the design bearing positions relative to a reference centerline. Calculations are also made *as* required for the determination of the actual position of the bearings during the alignment operation. The design bearing positions and the alignment calculations may be compiled in a document of propulsion shafting installation data. The document should also include alignment data, such as that suggested in Tables Xl through X5 of the Appendix, which would be useful for any realignment of the shafting in service.

6.2 Calculations for Alignment

6.2.1 The calculations required for the installation and alignment procedure are outlined in the following sub-sections.

6.2.2 Bearing Load Calculation. An analysis of the shafting as a beam on multiple supports.

Input - Shafting design information.

journals for selected bearing reactions, as shown in Table Xl.

6.2.3 Influence Number Calculation. A supplementary analysi to that of 6.2.2.

Input - shaft design information.

Determination - the change in each bearing reaction for a given change *in* the position of one bearing. Done for each bearing of the system and used to correct bearing positions, see 12.4.

6.2.4 Gap-Drop Calculation. A calculation of the deflection of each shaft section, uncoupled, as a simple beam on two supports.

Input - Shafting design information, plus the location of supports, see 11.1.2.

Determination - design values of gap and drop at each coupling connection, which are used to align the shafting and gear, see 11.6.

6.2.5 Hydraulic Jacking Calculations. Analysis of hydraulic force versus deflection readings.

Input - hydraulic pressure, or load cell readings, and deflection readings from 12.2.

Determination - bearing reaction forces for comparison with design requirements of Table Xl.

6.2.6 Strain Gage Analysis. An analysis of strain measurements on the shaft surface to determine the corresponding bearing reactions.

Input- strain gage data from 12.3.

Determination - bearing reaction forces for comparison with design requirements of Table Xl.

Procedure of Operations

7. Establish Initial Shaft Centerline

7.1 Position of the Stern Tube

7.1.1 For a ship stern configuration with outboard shafting, the stern tube is positioned within the structural frames of the shell and skeg; the convential vertical sternframe structure is not present. The stern tube would be welded within the supporting frames, based on design dimensions, before the reduction gear and strut are ready for positioning.

7.1.2 The stern tube is relatively long in an open water stern configuration because of the low angle of intersection with the shell surface. Center optical targets at the forward end, the midpoint, and the aft end of the stern tube. Position an optical alignment telescope at the forward end of the stern tube and set a line-of-sight on the forward and aft targets of the stern tube.

7.2 Position the Outboard Strut

7.2.1 Rig the outboard strut into an approximate position on the line-of-sight. Check the longitudinal position of the strut.

7.2.2 Final positioning of the strut should be made when the aft hull structure is reasonably complete, when major hull components are in place, and when radiant heating from the sun is a minimum, see Note 1.

7.2.3 Center optical targets at the forward and aft ends of the strut bearing bore. Using the supporting chainfalls, bri the strut bore target centers onto the line-of sight established from the forward end of the stern tube. Secure the strut leg connection to the supporting hull “structure. After the rigging has been slacked-off, take a set of optical readings on the three stern tube targets and, the two strut bore targets with the teles cope set as in 7.1.2, and record in Table X2 for reference.

7.3 Position the Main Engine

7.3.1 Land the main reduction gear and the turbines and condenser, or the diesel engines, on their foundations using either jacking screws or taper wedges for support, but without permanent chocking. Establish the preliminary position of the components at their design locations relative to hull reference lines. Do not secure the support connections between the reduction gear and the main engine and do not install the high-speed flexible couplings.

7.3.2 Position the second reduction gear (bullgear) in a longitudinal location within the gear casing as defined by the gear manufacturer and hold this position mechanically until all shafting is coupled in 11.7.

7.4 Establish Preliminary Gear Alignment

7.4.1 Center an optical alignment telescope on the gear flange. Confirm the centered telescope position by the procedure given in Annex A2. Center optical targets at the forward end, the midpoint, and the aft end of the stern tube, as in 7.1.2.

7.4.2 Adjust the position of the gear using either jacking screws, or tapered wedges, such that the line-of-sight from the centered telescope on the gear flange coincides with the centers of the aft and forward targets in the stern tube. The reduction gear position has to permit use of alignment chocks with adequate thickness, otherwise the centerline through the stern tube and strut bores has to be repositioned accordingly.

7.4.3 A line-of-sight may now be established from the centered - telescope on the gear flange, through the three targets in the stern tube, to the two targets in the strut bore.

Record in Table X2 the stern tube and strut target cross-hair positions, with the gear flange in the 0° and 180° positions.

Record in Table X3 the position of the gear casing base flange relative to the gear foundation plate.

7.5 Monitor Hull Distortion

7.5.1 The machinist may use the centered alihnment telescope and the stern tube targets (7.4.1 to periodically repear the readings of 7.4.3 while the welding end machinery installation are being completed. Consisten readings will indicate that hull distortion has leveled off.

7.5.2 Proceed to stern tube and strut boring (Section 9) when hull welding and installation of heavy components have been completed to the criteria established by the engineering department

NOTE 1 - Readings taken with the optical alignment telescope will be definitely effected by distortion of the ship hull due to temperature of the air, solar radiation, and weight loading. For comparable readings, the telescope should be used at the same time of the day, preferably at night, and under similar ship conditions.

NOTE 2 - In this procedure, and in following sections, a line-of-sight established by a *laser* beam may be used in lieu of an optical alignment telescope.

8. Machine Shaft to Final Length Dimension

8.1 After the strut has been secured in position, measure the distance between the gear flange and the aft face of the strut boss.

8.2 One section of the line shafting may serve as a make-up section with excess thickness at one flange face. From the overall length measurement of 8.1, and the finished lengths of the other sections," determine the required length of the make-up section. Determine the amount of material to be machined from the face of the over-size flange, with tolerances.

8.3 Finish machine the flange face of the make-up section to give the required length. Confirm the shaft length by measurement.

9. Bore the Stern Tube and Strut for Bearing Shells

9.1 Position the Boring Bar for the Stern Tube Aft Bearing

9.1.1 Mount the boring bar in the aft bearing position of the stern tube using the optical alignment telescipe centered on the gear flange, as in 7.4.1, establish the line-of-sight which is the reference centerline. Adjust the position of the boring bar to bring its target cross-hairs to the design positions, relative to the reference centerline given in Table XI. See Note 3.

9.1.2 Measure the position of the boring bar centerline relative to the rough bore of the stern tube. The machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the shell.

9.1.3 If a forward stern tube bearing is not provided, proceed to 9.3.

NOTE 3 - The reference centerline represents the center of the shaft at the bearing locations. The optical telescope centered on the gear shaft flange is located on the reference centerline. The design position for the boring bar centerline would be located above the reference centerline by 1/2 the diametral clearance of the bearing to be installed at that location. The-design posiiton for the bearing bore, as given in Table Xl, may be further displaced from the reference centerline by an amount selected to achieve as design “fair curve” alignment.

9.2 Verify the Position to be Taken by the Stern Tube Forward Bearing

9.2.1 Use the design position for the stern tube forward bearing, given in Table Xl, as the position to be used for the boring bar at the forward position in the stern tube, relative to the line-of-sight from the gear flange established in 9.1.1.

9.2.2 Center two optical targets at the forward and aft-ends of the stern tube forward bearing position. Record the cross-hair positions of the targets, relative to the line-of-sight, in Table x2.

9.2.3 Using the reference line-of-sight from the gear flange of 9.1.1 and the design position of 9.2.1, and the actual stern tube position of 9.2.2, the machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the forward bearing.

9.3 Bore the Stern Tube for the Aft Bearing

9.3.1 Position the complete boring machine at the stern tube ready for boring. The boring bar has been set in 9.1.1 at the design position given in Table Xl relative to the reference centerline.

9.3.2 Bore for the aft stern tube bearing according to the applicable shipyard drawings. Do not move the boring bar in any way during the boring process by readjustment of any supporting device for either the boring bar or the boring machine. While boring,the machinist should check the location of the boring bar relative to the design position, using a telescope aligned to the reference centerline, to insure that the proper boring line is being maintained, especially before the final finish cut.

9.3.3 Measure the finish bore for the aft bearing. The measurements are to be taken at 4 to 6 in. intervals along the bearing bore within the stern tube on diameters at 0°, 45°, 90° and 135° from vertical. If possible, take measurements in the early morning or evening when temperature conditions are more stable. Record time, temperature, and measurements of the machine bore in Table X4. Also record the location and type of any other work executed on the stern tube after the bore” machining.

9.4 Bore the Stern Tube for the Forward Bearing

9.4.1 Establish the reference centerline of 9.1.1 at the forward bearing location.

9.4.2 Although the bore is shorter than the aft bearing bore the boring procedure duplicates that of steps 9.3.1 to 9.3.3.

NOTE 4 - The measurements of the aft stern tube bores, and the bearing outer diamters, Table X4, should be completed by the same machinist. Similarly, the measurements for the forward bearing fit should be completed by the same machinist.

9.5 Position the Boring Bar for the Strut Bearing

9.5.1 Position optical alignment targets in the forward and aft ends of the stern tube. Using the alignment telescope centered on the gear shaft flange, as in 7.4.1, establish the reference centerline through the stern tube targets to the strut bore. Position the boring bar in the strut bore at the design position given in Table Xl, See Note 3. The bore design position given in Table Xl may be based on either a bearing parallel to the reference centerline or on a bearing sloped in relation to the reference centerline.

9.5.2 Measure the position of the boring bar centerline relative to the rough bore of the strut. The machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the shell.

9.6 Bore the *Strut* Boss for the Strut Bearing

9.6.1 Position the complete boring machine at the strut boss. The boring bar has been set in 9.5.1 at the design position.

9.6.2 Bore for the strut bearing according to the applicable shipyard drawings. Do not move the boring bar during the boring process by readjustment of the supports for either the boring bar or the boring machine. During the boring operation the machinist should check the location of the boring bar relative to the disign position, using a telescope aligned to the reference centerline, to ensure that the proper boring line is being maintained, especially before the final finish cut. Because of unavoidable gradual movements of the stern structure relative to the established reference centerline through the stern tube bore, it may be more practical to locate the alignment telescope aft of the strut boss. The boring operation may be monitored by sighting forward to the stern tube targets.

9.6.3 Measure the finish bore for the strut bearing, following the procedure for the stern tube bore, see 9.3.3.

10. Install the Stern Tube and Strut Bearings

10.1 The machinery foreman and engineering personnel will establish the machined dimension, with tolerances, for the outer diameter of the bearing shells for the stern tube and strut. The dimension values will be based on the measured bore dimensions of 9.3.3, 9.4.2, and 9.6.3, plus an allowance to give the design interference fit, and plus an allowance for the difference between metal temperatures in the hull and in the machine shop.

10.2 Record the required dimensions for the stern tube bearings and the strut bearing in Table X4.

10.3 Machine the bearing shell outer diameters to the required dimensions of Table X4.

10.4 After finish machining, measure the bearing outer diameters at 4 to 6 inch intervals along the bearing length, on diameters at Oo, 450, 900 and 1350 from the vertical. To confirm concentricity, measure the bearing radial wall thickness at the forward and aft ends of each bearing and record in Table x4.

10.5 Record machined dimensions and ambient temperature in Table X4. Determine the interference fit at each interval, at the ship hull temperature conditions, and record in Table X4.

10.6 Install the stern tube and strut bearings with a drive fit. Complete the installation conditions listed in Table X before and after the bearing installation. Record the hydraulic force required to drive each bearing.

10.7 Center a telescope on the gear flange as in 7.4.1 and Annex A2. Mount optical targets in the bore of the aft stern tube bearing, at the aft and forward ends, each positioned to the center of the shaft to be installed.

10.8 Reposition the reduction gear, if necessary, to bring the target centers in the stern tube aft bearing bore to the design position of Table Xl. This operation may be combined with that of 11.5.1. Record the new gear position in Table X3. This line-of-sight, from the centered telescope to the finished bore of the installed aft bearing becomes the final reference centerline.

10.9 Mount optical targets centered in the bore of the strut bearing, at the aft and forward ends, and measure the bearing position in relation to the new reference centerline of 10.8. Record the target positions in Table Xl.

10.10 Mount optical targets in the bore of the forward stern tube bearing, if fitted, and measure the bearing position in relation to the new reference centerline of 10.8. Record target positions in Table Xl.

10.11 Before installation of the shafting, the final measured position of the stern tube and strut bearings, as recorded in 10.9 and 10.10, should be reviewed by engineering personnel for conformance with design requirements. The design position of the gear bearings and inboard line shaft bearings may be adjusted to suit the installed positions of the stern tube and strut bearings for the purpose of improving contact at the bearings and improving bearing load distribution.

10.12 Using the reference centerline of 10.8, establish the horizontal and vertical planes of the centerline and record the centerline position by permanent markings on the aft peak bulkhead on either side of the shaft seal housing. Provide a temporary reference bracket, welded to the bulkhead in the vertical plane, to permit micrometer measurements to the top surface of the shaft. Establish the position of the reference surface above the reference

11. Align. the Reduction *Gear* and Line Shaft Bearings

11.1 Preparation for Alignment

11.1.1 The preceding sections have established a final reference centerline from the installed position of the aft stern tube bearing to the center of the gear flange, and normal to that flange. This section outlines the procedures for positioning the line and gear bearings at their design positions, vertically and horizontally, relative to the reference centerline. For some ships the design position of the shaft at the bearings may be on the reference centerline, with the possible exception of the forward line bearing. For higher power ships with machinery aft, th design position of the shaft at all the bearings may be displaced for the reference centerline along *a* fair-curve which establishes acceptable bearing loads.

Positioning the bearings may be accomplished either by optical methods or by the gap-drop method described in 11.4 and 11.6 respectively. The gap-drop method is not readily adaptable to shafting with internal piping for controllable pitch propeller systems.

11.1.2 If the gap-drop method is to be used, engineering personnel should examine the structural details and arrangement of piping and auxiliary machinery beneath the line of inboard shafting and select locations for temporary shaft supports which will provide two points of support for each section of shafting. After the temporary supports have been installed, engineering personnel will verify the longitudinal position of the center of each temporary support and each bearing from a known frame statio and record the locations in Table x5. These positions become the design positions for the gap-drop calculation.

11.2 Installation of Shafting

11.2.1 Install the tail shaft and outboard shaft and the out board seals at the strut and stern **tube**. Place the inboard shaft seal around the shaft but do not bolt the seal to the bulkhead. Mount the propeller. At this time the line bearing foundations and the temporary supports would be in place. Place the line shafting and line bearings in position. In the usual construction sequence, the ship would be launched after these installations have been completed.

11.2.2 With the line shafting and line bearings in place, position the shafting roughly to the reference centerline by use of jacking screws in the bearing base flanges and by wedges or chocks under temporary supports.

11.2.3 Temporarily chock the upper casing of the main thrust bearing to provide clearance around the shaft. A tight casing may impose a downward force on the uncoupled shaft which would distort the measured gap-drop values.

11.3 Bearing Surface Contacts

11.3.1 Either the optical method or the gap-drop method of alignment will position the line bearings at the design vertical and horizontal positions to provide the design load reactions. However the methods do not insure that there is not a skew angle between the bearing and shaft centerlines which would reduce the load capacity of the bearing.

11.3.2 Remove caps of line bearings, wherever possible, for measurement of clearances between the shaft journals and bearing surfaces in a horizontal plane. Maintain equal clearances during the following alignment operations. Also use feeler gages to check vertical clearances between the shaft journal and the bearing surface at the forward and aft ends of each line bearing to insure that there is contact over the length of the bearing.

11.4 Optical Alignment of Line Bearings

11.4.1 If the line bearings are to be installed before the shafting, they may be positioned optically at their design positions from the reference centerline established in 10.8.

11.4.2 If the line bearings are installed integral with the shafting, it will be necessary to establish an offset line-of-sight parallel to the reference centerline and in the same vertical plane . Using targets mounted on the shaft, adjacent to the bearings, the bearings can be positioned at their design positions relative to the established line-of-sight. The targets must be accurately centered and vertical in order to achieve accurate horizontal alignment; alternately a line-of-sight may be established in the horizontal plane of the reference centerline to position the bearings in the horizontal direction.

11.5 Alignment of the Reduction Gear

11.5.1 If the design positions of the low-speed gear bearings as given in Table Xl, are displaced from the reference centerline established in 10.8, the gear may be positioned by a calculated change in the vertical measurements from the foundatic plate as recorded in Table X3. The calculated change should account for the design vertical offset and angularity of the gear shaft relative to the reference centerline, plus the correction for the fore and aft distance between the bearing centerline and the position of the vertical' measurement. The gear can also be positioned in the athwartship direction by the centerline marks recorded in Table X3. This operation may be combined with that of 10.8.

11.5.2 The gear may be positioned by an alternate technique using an optical telescope sighting to optical targets mounted on the gear case. The displacements and angularity may then be measured directly in the plane of each gear bearing.

11.5.3 In the above procedures for aligning the low-speed gear to the line shafting, the gear is positioned primarily by the jacking screws in the area of the key chocks under the two gear bearings and the corner points of the lower gear case. The other jacking screws around the gear case flange are adjusted to reduce the distortion of the casing. The final alignment of the gear case, relative to the low speed gear bearing positions, is done by either pin gauge, proof staff, or tight wire measurements and by tooth contact checks. That procedure is performed later and is outside the scope of this standard, see reference (1).

11.6 Gap-Drop Alignment

11.6.1 The gap-drop method uses the uncoupled sections of shafting as alignment gages to locate the line and gear bearings at the design displacements from the reference centerline. An engineering calculation is performed to determine the gap and drop values that would exist between each set of flanges when the bearings are at their design position from the reference centerline. The calculation includes the effect of the deflection, or "droop", of each section of shafting under its own weight and supported at the two specified points of 11.1.2. The calculated gap and drop values are prepared by the Engineering Department and presented in Table X5. The values apply only under the conditions stated: Bearings and temporary supports in the positions given by

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(1) "Guide to Propulsion Reduction Gear Alignment and Installation", SNAME T & R Bulletin 3 - 10. September 1972.

Table X5, propeller either mounted or not mounted, and ship either waterborne or on dry dock.

11.6.2 Maintain the longitudinal position of the bearings and temporary supports established in 11.1.2 within a tolerance of +0.5 inches (12.7 mm) during the alignment operation.

11.6.3 Move line bearings and temporary supports vertically and transversely, either by jacking screws or by wedges, to achiev the gap and dropmeasurer,ents specified in Table X5 within +0.001 inches (±0.0254 mm). When measuring gaps and drops at a coupling, push the mating flanges together to make the gap and drop measurements more accurate.

11.6.4 Record in Table X5 the final gap and drop measuremen taken when the bearings and temporary supports are in the positions given in Table X5. Indicate in the table whether or not the prope was mounted and whether or not the ship was waterborne. The Engineering Department will signify acceptance of the gap and drop measurements of Table X5, if they are suitable for proceeding to bearing and gear chocking.

11.6.5 The gap-drop method of alignment will give the best results with the hull waterborne and the propeller mounted. The procedure will give least reliable results if the ship is in a dry dock because the hull deflection may differ radically from a normal waterborne deflection line. The design gap-drop values must be calculated for the conditions that will exist at the time of measurement.

11.7 Coupling of the Shafting

11.7.1 All of the shaft coupling connections either flanged, muff-coupling, or hydraulic sleeve type must be made-up complete before the following alignment checks can be performed. Make-up of the gear shaft coupling should be deferred until step 11.8.2 is completed. The mechanical stops on the longitudinal position of the gear shaft should be removed, see 7.3.2.

11.7.2 The forward stern tube seals may be mounted on the bulkhead.

11.7.3 The ship should be waterborne and the propeller in place.

11.8 Gear Shaft Bearing Check

11.8.1 Bending moments and shear forces imposed on the gear shaft by the line shafting can cause a tipping, or skewing of the low speed gear within its bearings with serious consequences to the gear tooth contact. Although many shipyards measure the vertical bearing reactions, the alignment of the gear bearings in the horizontal plane is often not checked.

11.8.2 Before the coupling between the line shaft and gear shaft is made-up, a set of gap and drop readings should be taken at the gear coupling flanges. The calculated gap and drop values for this check will differ from those of 11.6.1 because they would be based on a continuous (coupled) shaft up to the gear flange. This check is a valuable reference to ensure that excess moments will not be imposed on the gear shaft.

11.8.3 A complete check on the alignment of the low-speed gear bearings under the influence of the forces imposed by the line shaft may be accomplished by the following optional procedure. With the shafting coupled, remove the bearing caps of the low-speed gear bearings (No. 1 and No. 2). Set dial indicators at zero reading to record the vertical and horizontal movement of the forward journal (No. 1) . Roll out the forward bearing, leaving the gear shaft supported by the aft bearing and the coupled lineshaft. Record the movement of the journal measured by the dial indicators

11. 8.4 The centralization of the journal may be determinec by gap measurements between the journal and the seating bore for the lower bearing shell. Mark locations for measurements at the horizontal split at the forward end, midpoint, and aft end of the bearing length. Gap measurements should be taken with a micromete on both sides of the journal at these locations, and also at the vertical (6 o'clock). position at the forward end of the bearing. Additional *readings* may be taken at the 4, 5, 7 and 8 o'clock posi tions at the forward end. The measured total thickness of the bearing shell minus the gap measurement at the 6 o'clock position the sag of the shaft, which should agree with the vertical dial indicator reading of 11.8.3.

11.8.5 The gap measurements described above should be made at four rotational positions of the shaft: 0°, 90.°, 180°, 270° ar again at O°. At each rotational position, the shaft should be rot ahead on the turning gear to the position? the gap measurements ma the shaft rotated ahead through. a small angle and then reversed tc approach the same position from the opposite direction? and the ga measurements re-checked.

11.8,6 Hydraulic jacking of the No. .1 bearing may be conve iently accomplished when the bearing is removed. See Section 12.2 A load versus vertical displacement curve can be established which should check the influence number calculation of 6.2.3. The bear: reaction at operating conditions is the jacking force existing whe the shaft is restored to its original dial indicator position of 1

11.8.7 Replace the forward bearing and mount the dial indi cators at the aft bearing (No. 2) . Roll out the aft bearing and record the movement of the aft journal. Repeat the procedures of

11. 8.3 to 11. 8.5 at the aft bearing location.

11.8.8 The gap and dial indicator measurements at the forward and aft journals provide data for the following determinations:

(a) The normal central position of the shaft.

(b) Whether or not there is a permanent bend or crank effect in either the low-speed gear shaft *or* the line shaft.

(c) Rotating ahead and astern should indicate any parasitic torque in the rotating system.

(d) Forces on the gear journals can be determined from the measured radial displacements multiplied by the influence numbers. The operating position of the gear can then be determined to decide whether or not the existing displacements of the journals are acceptable.

11.8.9 The above procedure must be performed with close coordination of the gear manufacturer. Specifically, the procedure can't be used if either low-speed gear bearing would be overloaded when the opposite bearing is removed. The load limit should be checked for both the static and the turning gear rotation conditions.

11.8.10 The position of the low-speed gear journals may be determined under full load operating conditions by the use of proximity probes mounted in the upper bearing shells. That procedure would be a special investigation beyond the normal procedures of shaft alignment.

11.9 Chocking of Gear and Line Bearings

11.9.1 The shipyard may elect to chock the reduction gear and the line bearings after these bearings have been positioned by the procedures of 11.3 to 11.8. There is a risk that the gear may have to be re-chocked after the final measurement of bearing reactions. If the above procedures have been completed successfully, the final measurement of reactions will usually result in only a readjustment of the line bearings.

Performing the chocking after the measurement of the bearing reactions results in production schedule delays for securi the connections to the main engine and for operating the engine on dock trials.

11.9.2 Make an inspection of the gear position relative to the foundation supports and structural clearances. Request the approval of engineering and the gear manufacturer's representative to proceed with fitting of chocks under the gear bearings.

11.9.3 Measure the vertical distance between the gear base plate and the tapered liner welded to the gear foundation plate, at each of the four corners of each chock of the gear. If a tapered foundation plate is used, the measurement would be directly to the foundation plate. Machine a chock to fit each chock location.

11.9.4 Install the machined chocks of the gear. Check each chock for contact on top and bottom surfaces. Refit a chock if the contact on either surface is less than 80%. Record the contact area in Table X3.

11.9.5 Fit gear case foundation bolts and back-off the jacking screws.

11.9.6 Measure the vertical distance between the bearing foundation and the bearing base for each line bearing at the locations where chocks are to be fitted. Machine chocks to fit each location. Check each chock for contact on both surfaces and refit if the contact is less than 80%.

11.9.7 In the case of the forward line bearing, the chocks should be machined 0.050 inches (1.270 mm) less than the required thickness. In fitting the chocks a standard .050 shim is included. The contact area requirement of 80% still applies. If the bearing position has to be changed after hydraulic jacking (see 12.2), the standard shim is replaced by another single shim, rather than removal and refit of the chocks. The forward line bearing is the bearing most likely to be repositioned to achieve the design bearing reactions.

11.9.8 In the case of a thrust bearing in a housing separate from the gear, the housing should be chocked to give uniform radial clearance at the shaft seals when the shaft sections are coupled.

12 Measurement of Bearing Reactions

12.1 Conditions for Measurement

12.1.1 After the journal bearings of the shafting system have been positioned by either the optical or gap-drop methods described in 11.4 to 11.6, the bearing reactions should be actually measured. The measurements may be accomplished by either the hydraulic jacking method (shaft weighing) or by the strain gage method. Some shipyards use one method as the principal procedure and use the alternate method on occasion to check critical bearings.

The measurements should be made with the ship waterborne and the propeller in place. The ideal conditions for measurements would be normal hull loading and the reduction gear at operating temperature. Actually, the measurements have to be made at the light displacement existing during outfitting. Measured reactions at the gear and forward line bearings may be corrected for the themal growth from actual gear temperature to full operating temperature.

12.1.2 The internal alignment of the reduction gear for proper tooth contact should have been completed because that procedure may involve adjustment of the gear case chocks:

12.1.3 Any support connections between the reduction gear and the power units should be coupled and carrying load, with temporary supports unloaded. Installation of the high-speed flex- ible couplings does not affect the procedure.

12.2 Hydraulic Jacking of bearings

12.2.1 Engineering will select the location at which the hydraulic jack will be applied for measuring each line bearing reaction by the hydraulic jacking method. Measure the axial distance from the jack location to the corresponding bearing and record these data in Table x6. The jack is to be supported on solid steel sturcture which carries the jack load to a frame or longitudinal number; wooden blocks or posts are not adequate. Assign numbers to each jack position and to the corresponding bearing.

32.2.2 The strut bearing and stern tube bearing reactions cannot be conveniently measured by jacking. The aft bearing of the gear shaft may be measured usually by a jack between the bearing and the gear flange.' The forward gear bearing is difficu and usually requires some special fixture on the shaft. As a lesser option, the load may be assummed to be the weight.of the low-speed gear and shaft, minus the measured load of the aft bear ing. If the gear shaft bearings are checked by the procedure of 11.8.3- 11.8.7, the gear bearings may be accurately jacked as part of that procedure.

12.2.3 Engineering personnel shall conduct the hydraulic jacking procedure at each available bearing. All bearings should be done in the same time period shortly after dock trials when the bearing and gear temperatures are close to actual service conditions. A decision to forego jacking for a particular bearing reaction is the responsibility of the engineering department. A second set of jacking measurements may be taken after sea trial and also under different conditions of vessel loading.

12.2.4 At each bearing, progressive sets of readings (either hydraulic pressure or hydraulic force versus shaft displacement) are taken as the shaft is raised and lowered by the hydraulic jack. A mean line, plotted through the data reflecting elastic deflection, will indicate the jack reaction pressure at zero displacement. Record the ambient temperature, the lube oil temperature, and the reduction gear sump temperature. A variation in the procedure is to roll out the bearing and measure the jacking force required to nestore the shaft to its operating position.

12.2.5 An alternate method for measuring bearing reactions is to use a load cell to measure the reaction force on the hydraulic jack. This method eliminates the hysteresis effect in the hydraulic fluid pressure. Also it may be conveniently used to measure a bearing reaction plus the simultaneous change in the reactions on adjacent bearings.

12.2.6 It is often difficult, for practical reasons, to get a complete set of hydraulic jacking measurements with the reduction gear case at full operating temperature. Before the shaft can be stopped for the jacking operation, the engine will have been progressively reduce in power and then rotated on the turning gear. An optional procedure to obtain a set of bearing reactions under a simulated “hot gear” condition is to raise the low-speed gear shaft and insert shims under the forward and aft bearing journals. The shim thickness should be the calculated thermal growth of the reduction gear foundation and lower case. This procedure is a particular benefit for properly locating the first line shaft bearing.

12.2.7 The engineering department will convert the hydrau- lic force figure of 12.2.4 - 12.2.5 for each bearing to a bearing reaction force by calculating a correction for the axial displace- ment of the jack from the bearing center plane. Record the corrected bearing reactions in Tables x6 and Xl.

12.3 Load Determination by Alternate Strain Gage Techni

12.3.1 An alternate to the hydraulic jacking procedure is the use of strain gages mounted on the surface of the shaft at selected stations to determine shaft strains. By calculation procedures, the strains are converted to bending moments which lea to the determination of the bearing reactions. Strain measurement are made with the shaft in several rotational positions.

12.3.2 The data needed for this method are the weight of the shafting components, such as propeller and gear the shaft diameter at all sections, and the longitudinal position of the bearings.

12.3.3 The application of the strain gages, the strain re ings, and the determination of the bearing reactions are accomplis by the engineering department. The bearing reactions are tabulate in Table Xl.

12.3.4 The particular advantage of the strain gage method is that once the strain gages have been applied to the shaft, a complete set of strain readings may be taken in a short period of time. This makes it possible to take a complete set of readings before the reduction gear casing has cooled; also readings may be taken at different hull loading conditions during trials if the schedule permits operating the main engine on turning gear for a short period. Another advantage is that the method gives the horizontal reactions on each bearing in addition to the vertical reactions.

12.4 Corrections to Bearing Positions

12.4.1 The measured bearing reactions of either section 12.2 or 12.3 are compared with the design bearing loads of Table xl. If the compliance with the design load is not acceptable to the engineering department, a change in the vertical position of the bearing will be recommended by the engineering department. By the calculated values of influence numbers, see section 6.2.3, the amount of change in the vertical position of the bearings to correct the loadings can be quickly dytermined. Reconunended changes should generally be in multiples of 0.005 inches (0.127 mm) . If changes are not recommended in cases of marginal compliance, the fact should be noted in Table Xl.

12.4.2 Changes in the vertical position of the bearings are accomplished by refitting of the chocks. In the case of the first line bearing, the change may be made by substituting an alternate shim for each of the original 0.050 inch shims.

12.4.3 If significant changes are made in the chocking, the engineering department will require another measurement of the bearing reactions to confirm the proper bearing positions, either by hydraulic jacking or by the strain *gage* method. If no changes are required, the alignment procedure is complete. The final measured bearing reactions should be recorded in Table xl.

13. Documentation

13.1 The record of the shaft installation alignment should be assembled in a "Propulsion Shafting Installation Data" document. The purpose of the document is to describe the results of the shafting alignment and to provide enough information so that the shafting may be readily re-aligned in the future. The document should include at least the following information:

Design bearing positions and reactions, plus the final measure positions and reactions, as suggested by Table Xl.

Angle of the tailshaft in the strut bearing as given in Table Xl.

Measured position of the reduction gear above the foundation plate, similar to the data of Table X3.

Force fit requirements for the stern tube bearings, similar to that of Table X4.

The calculations for alignment, particularly the influence number and the gap-drop values, see 6.2.

13.2 The tables of the Appendix present typical data tabulations for the purpose of illustrating the alignment process. Some-sections will not be applicable for the selected method of alignment. Also the data format may have to be adjusted to suit the shaft and reduction gear arrangement, special features of a ship design and practices of individual shipyards.

To reduce the number of tables, they have been designed to be used by either engineers or machinists on different occasions. The user must define the location and conditions by checking the appropriate box in the heading format.

Annex Al

Objectives of the Shafting Alignment Design

All The bearing reactions of the low-speed gear under normal running conditions shall satisfy the requirements of the gear manufacturer. The requirements are usually given as a limiting difference between the two reactions in the vertical direction, either as an absolute value or a percentage. The gear manufacturer may *also* limit the horizontal reaction, from the line shafting, at each of the gear bearings. The limitations on the line shaft effect on the gear shaft may be also specified as maximum allowable bending moments at the gear shaft flange in the vertical and horizontal planes. The intent of the limitations is to insure that proper pinion-to-gear alignment is maintained under the combined effect of line shaft moments, gravity forces, and gear tooth mesh forces'.

Al. 2- The low-speed gear running position should not be unduly influenced by changes in the position of the first line bearing realtive to the gear bearings. The change in position may be caused by hull deflection or by thermal growth of the gear. case. To reduce the influence of the first line bearing, it is usually positioned at 10-12 shaft diameters from the aft gear bearing. The Allowable Setting Error (ASE) of the first line bearing should be determined. The ASE is the amount of change in the first line bearing position which will cause the gear bearing reaction differential to be exceeded. An ASE of

10 roils is a minimum value; the value should be significantly higher for large, flexible hulls, particularly those subject to large displacement changes. High influence numbers for the first line bearing would be indicative of a low value of ASE.

A1.3 The spacing of the line shaft bearings shall be set to maintain the bearing reactions within the manufacturer's limits. Typical maximum unit loads are 150 psi for gear bearings, 50 psi for line bearings, and 100 psi for stern tube bearings. Minimum load to be at least 20% of sum of adjacent shaft span weights.

A1.4 The spacing of the line shaft bearings shall be set with consideration of the lateral modes of shaft vibration. The position of the bearing forward of the propeller bearing will have a major influence on the lateral critical. The position of the first line bearing will influence the ASE, see A1.2. Within these constraints, the use of a minimum number of bearings should be favored.

A1.5 The design alignment of the shafting should be optimized to give acceptable bearing loads under the normal service conditions of hull deflection. This is particularly significant for ships with short shafting and subject to operation under very different draft conditions.

A1.6 The design alignment should consider all steady forces acting on the shafting system including deadweight loads, propeller buoyancy, and the off-center thrust of the propeller. The resolution of forces and bearing reactions should be made in the vertical and horizontal planes.

A1.7 Positioning the shafting system bearings on a common centerline, or line-of-sight, offers the most simple installation

Procedure. A centerline alignment, however, may not be satisfactor for high power ships with short shaft lines. The bearings must be displaced, or offset, from a reference centerline along a fair curv of alignment to obtain,the desired bearing loads and to give proper bearing contacts, particularly at the propeller bearing.

Al. 8 The propeller bearing reaction is usually assumed be located at 0.33 to 0.5 x shaft diameter, from the aft end of the bearing, in the case of oil-lubricated bearings. The contact angle between the shaft line and the bearing should not exceed 0.3×10^{-3} radians, as a typical value for bearings with an L/D - 2, in order to maintain a load-bearing oil film. The angle of contact should be checked for the possible range of indicating contact at the for-ward end of the bearing. To achieve the desired angle of contact it may be necessary either to lower the design position of the bearings forward of the propeller bearing, or to position the propeller bearing with a fixed slope relative to the reference centerline. To ensure a satisfactory oil film, the diametral c ante should be .0013 - .0017 x shaft diameter.

A1.9 The strength of the shafting shall comply with the rules of the Regulatory Bodies. Bending and torsional stresses shall be carefully considered at *local* areas of stress concentratic

Al. 10 In the determination of the cold alignment positi of the shaft bearings, the thermal growth of the reduction gear lower case, the gear foundation structure to the double bottom, an the local thermal distortion within the double bottom should be considered and calculated, based on available data and reasonable assumptions. The difference in thermal growth between the reducti gear support structure, compared to the first line bearing pedestal, has a significant effect on the low-speed gear bearing reaction difference.

A1.11 The alignment of the shafting is made with the shaft at rest. The oil film thickness under operating condition should be included in the calculation of the cold alignment offsets. Also the weardown of the propeller bearing in service should be included in the calculation of the fair curve of alignment.

A1.12 In the design of the shafting system for a ship with an outboard shaft and strut configuration, the strut and aft stern tube bearings should have low influence numbers to insure that these bearings will not be sensitive to overloading caused by deflection of the hull under cargo loading and seaway conditions.

Annex A2

Centering an Optical Alignment Telescope

A2. 1 Mount an optical alignment telescope on the gear flange. Confirm the centered telescope position using the following steps:

A2.2 Place optical targets at the forward and after ends of the stern tube such that the two target cross-hair positions can be measured using the built-in optical micrometers of the telescope. Note that the targets need not be centered within the stern tube.

A2.3 Take telescope readings in the horizontal and vertical directions for both targets.

A2.4 Rotate the gear flange 180°. If the target cross-hair positions are within the telescope field after the flange rotation, take telescope readings in the horizontal and vertical directions for both targets and continue to A2.5. If the target cross-hair positions are not within the telescope field after the flange rotation, adjust the position of the targets, or the telescope, or both, without changing the longitudinal locations of the targets, such that the target cross-hair positions can be measured before and after a 180° gear flange rotation. If the target or telescope positions are changed, “return to A2.3.

A2.5 Compare the readings of A2.3 and A2.4. For each targe the horizontal readings at zero rotation must be identical (within telescope accuracy) to the horizontal readings of the same target at 180° rotation. Similarly, for each target, the vertical readings must be identical (within telescope accuracy) at each rotated position. The telescope is centered only if these readings are equivalent for both targets. If the readings are not equivalent, adjust the telescope position and return to A2.3 Note that the readings for the two different targets need not be equivalent.

NOTE 5 - After rotation the shaft, joggle the gear shaft to ensure that it is resting at the bottom center of its bearings.

APPENDICES

XI Design Alignment Requirements and Installation Results.

X2 Alignment Readings.

X3 Reduction Gear Position Measurements.

X4 Stern Tube Bearing Fit.

X5 Gap-Drop Alignment.

X6 Hydraulic Jacking of Bearings.

Geared, Outboard

TABLE XI

DESIGN ALIGNMENT REQUIREMENTS
AND INSTALLATION RESULTS

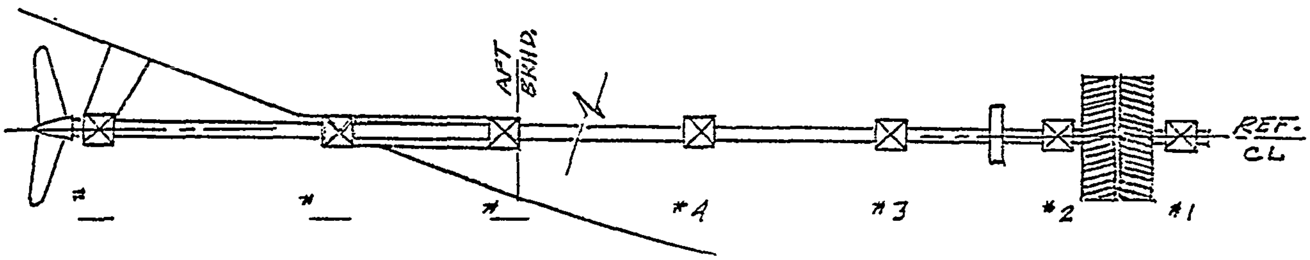
HULL NO.______ DATE______________

PROCEDURE		Ref. Sec. of Std.
DESIGN BEARING REACTIONS AND BEARING POSITIONS	☐	6.2.2
MEASURED BEARING REACTIONS	☐	12.2.7/12.3.3

CONDITIONS

REDUCTION GEAR OPERATING CONDITION - COLD ☐ OIL TEMP_____°F
- HOT ☐ OIL TEMP_____°F
- SIMULATED HOT ☐ OIL TEMP_____°F

SHIP HULL CONDITION - LIGHT SHIP ☐ DRAFT FWD______ AFT______
- LOADED ☐ DRAFT FWD______ AFT______



BRG. NO.	DESIGN SHAFT POS. FROM REF. CL* VERTICAL inches	DESIGN SHAFT POS. FROM REF. CL* HORIZ. inches	MEASURED FINAL SHAFT POSITION FROM REF. CL* VERTICAL inches	MEASURED FINAL SHAFT POSITION FROM REF. CL* HORIZ. inches	DESIGN BEARING REACTION pounds	FINAL MEASURED REACTION pounds
1						
2						
3						
4						
5						
6						
7						
8						
C.L. POSITION ON A.P. BKHD.					(See 10.12)	

PROPELLER BEARING DESIGN CONTACT ANGLE______________________________radians

*Positive values indicate position above, or to starboard, of reference centerline.

ENGINEER____________________ DEPT.______________

Geared, Outboard

TABLE X2 ALIGNMENT READINGS

HULL NO.______ DATE______________

STERN TUBE AFT BEARING ☐ , or FORWARD BEARING ☐ , or STURT BEARING ☐

OPERATION (Ref. Sec. of Std. 7.2.2, 7.4.3, 9.1.1, 9.2.4, 9.3.3, 9.6.2, 10.9)

INITIAL LINE-OF-SIGHT ☐

BORING BAR POSITION - AFT BRG. BORE ☐

STERN TUBE CENTER POSITION - FWD BRG. BORE ☐

FINAL BORING BAR POSITION - FWD BRG. BORE ☐

INSTALLED BEARING POSITION - FWD BRG. ☐

BORING BAR POSITION-STRUT BORE ☐

STRUT BORE CENTER POSITION ☐

FINAL BORING BAR POS.-STRUT BOR

INSTALLED BEARING POSITION-STRU

CONDITIONS

SIGHTING: FROM GEAR FLANGE TO STERN TUBE ☐ FROM STERN TUBE TO STRUT ☐

FROM STERN TUBE TO GEAR ☐ FROM STRUT TO STERN TUBE ☐

INSTRUMENT: CENTERED OPTICAL TELESCOPE ☐

LASER BEAM ☐

WEATHER: CLOUDY______ FAIR______ AIR TEMP.______ °F

INCOMPLETE HULL STRUCTURE, AFT______________________________

OPTICAL ALIGNMENT READINGS

TARGET POSITION	DISTANCE OF TARGET TO SCOPE	TELESCOPE READINGS* INITIAL SHAFT ROTATION		SHAFT ROTATED 180°	
		VERTICAL	HORIZ.	VERTICAL	HORIZ.
AFT					
FORWARD					
CENTER					

TIME OF DAY______

AFT					
FORWARD					
CENTER					

TIME OF DAY______

AFT					
FORWARD					
CENTER					

TIME OF DAY______

*Positive readings indicate target cross hairs are above, or to starboard, of telescope line-of-sight.

MACHINIST__________________ DEPT.______________

TABLE X3 REDUCTION GEAR POSITION MEASUREMENTS

HULL NO.______ DATE______________

OPERATION
INITIAL GEAR POSITION ☐
FINAL GEAR POSITION ☐
LOW-SPEED GEAR BEARING ALIGNMENT ☐
GEAR CHOCK CONTACT ☐

Ref. Sec. of Std.
7.4.3
10.8/11.5.1
11.8.2/11.8.4
11.9.4

CONDITIONS
SHIP ON WAYS ☐
SHIP WATERBORNE ☐
PROPELLER MOUNTED ☐
PROPELLER OFF ☐

VERTICAL POSITION OF GEAR CASE
measured between gear case flange face and foundation base plate at four locations.
AFT END OF AFT KEY CHOCKS:
STARBOARD CHOCK______inches
PORT CHOCK ______inches
FORWARD END OF FWD. KEY CHOCKS:
STARBOARD CHOCK______inches
PORT CHOCK ______inches

ATHWART SHIP POSITION OF GEAR CASE
measured as an offset from scribed centerline on foundation base plate to scribed line on gear case flange.
OFFSET AT AFT FLANGE OF CASING______________inches, GEAR TO STBD./PORT
OFFSET AT FWD FLANGE OF CASING______________inches, GEAR TO STBD./PORT

LOW-SPEED GEAR BEARING ALIGNMENT
low-speed gear supported by coupled line shafting.
low-speed gear bearings rolled out.
VERTICAL DEFLECTION OF JOURNAL: FWD BRG.__________ AFT BRG.__________
GAP MEASUREMENTS FROM BEARING BORE TO GEAR SHAFT JOURNAL:
FORWARD BEARING: FWD END, STBD. __________ PORT__________ VERT.__________
MIDPOINT, STBD.__________ PORT__________
AFT END, STBD. __________ PORT__________
AFT BEARING: FWD END, STBD. __________ PORT__________
MIDPOINT, STBD.__________ PORT__________
AFT END, STBD. __________ PORT__________ VERT.__________

GEAR CHOCK CONTACT
Area contact as % of total bearing surface, determined by blueing.
KEY CHOCKS AFT, STBD.________%
PORT ________%
KEY CHOCKS FWD, STBD.________%
PORT ________%

OUTBOARD CHOCKS, STARBOARD SIDE:
#1________%, #2________%, #3________%, # 4________%, # 5________%. # 6________%,
#7________%, #8________%, #9________%, #10________%, #11________%, #12________%

OUTBOARD CHOCKS, PORT SIDE:
#1________%, #2________%, #3________%, #4________%, #5________%, #6________,
#7________%, #8________%, #9________%, #10________%, #11________%, #12________

MACHINIST______________________ DEPT.____________________

TABLE X4 **BEARING FIT FOR STERN TUBE OR STRUT**

HULL NO.______ DATE___________

STERN TUBE AFT BEARING ☐, or FORWARD BEARING ☐ , or STRUT BEARING ☐

OPERATION		Ref. Section of Std.
STERN TUBE OR STRUT BORE MEASUREMENT	☐	9.3.3/9.4.2/9.6.3
REQUIRED BEARING SHELL O.D.	☐	10.2
FINISHED SHELL O.D. MEASUREMENT	☐	10.4
BEARING INSTALLATION	☐	10.6

CONDITIONS
STERN TUBE OR STRUT METAL TEMP. _____ °F AIR TEMP______ °F
BEARING SHELL METAL TEMP.______ °F AIR TEMP______ °F

BORE I.D. AND SHELL O.D. MEASUREMENTS

DISTANCE FROM AFT END OF BORE OR SHELL	DIAMETERS, AT ANGLES FROM VERTICAL, LOOKING FORWARD: 0°	45°	90°	135°	INTERFERENCE, BRG. SHELL O. MINUS BORE I.
L_0 @ 0 inches					
L_1 @ __ inches					
L_2 @ __ inches					
L_3 @ __ inches					
L_4 @ __ inches					
L_5 @ __ inches					
L_6 @ __ inches					
L_7 @ __ inches					
L_8 @ __ inches					
L_9 @ __ inches					
L_{10} @ __ inches					

BEARING CONCENTRICITY

RADIAL WALL THICKNESS (shell plus babbitt)	ANGULAR POSITIONS, LOOKING FORWARD 0°	90°	180°	270°
AFT END				
FORWARD END				

BEARING INSTALLATION
HYDRAULIC FORCE REQUIRED TO DRIVE BEARING: _______ TONS
BEARING LENGTH INSERTED WHEN FORCE REACHES MAXIMUM: _______ % APPROX.

MACHINIST ________________________ DEPT.__________________
ENGINEER ________________________ DEPT.__________________

TABLE X5

GAP - DROP ALIGNMENT

HULL NO.________

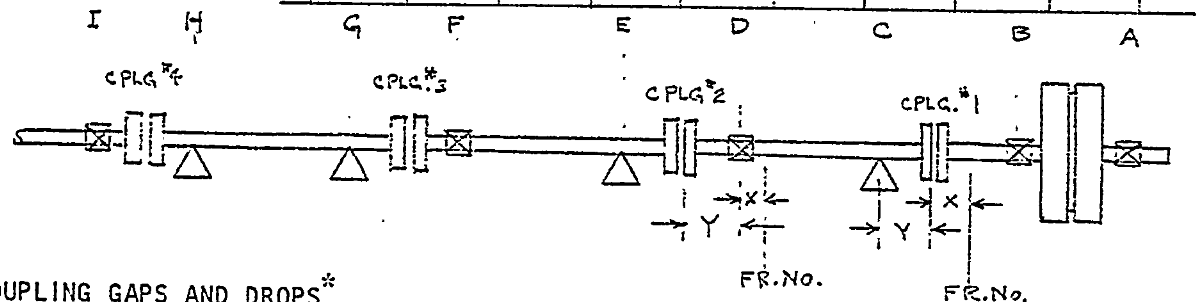
DATE______________

OPERATION
LOCATION OF SHAFT SUPPORTS ☐
GAP - DROP DESIGN VALUES ☐
GAP - DROP MEASUREMENTS ☐

Ref. Sec. of Std.
11.1.2
11.6.1
11.6.4

CONDITIONS
SHIP CONDITION: BUILDING WAY ☐ DRY DOCK ☐ WATERBORNE ☐
PROPELLER MOUNTED ☐ OFF ☐

SUPPORT POSITIONS	A	B	C	D	E	F	G	H	I	-
TYPE (Temp. or Brg.)										
FRAME NO.										
DIST. AFT OF FRAME ~ X										
CPLG. NO.										
DIST. FROM CPLG. — Y										



COUPLING GAPS AND DROPS*

CPLG. NO.________

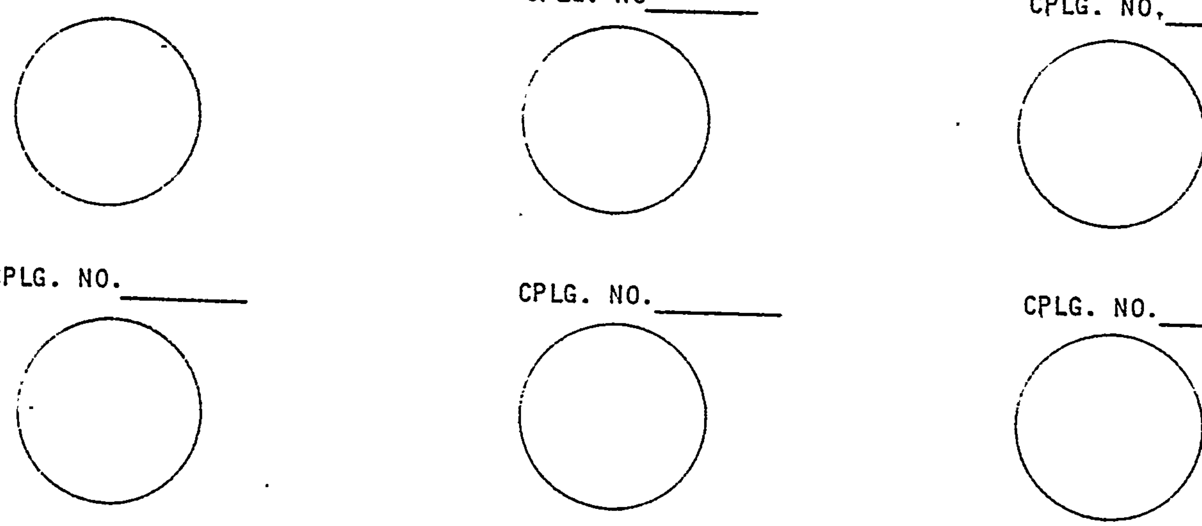
CPLG. NO________

CPLG. NO.________

CPLG. NO.________

CPLG. NO.________

CPLG. NO.________



*A positive drop indicates fwd. flange is above, or to stbd., of after flange.

ENGINEER____________________ DEPT.______________

MACHINIST____________________ DEPT.______________

TABLE X6 HYDRAULIC JACKING OF BEARINGS

HULL NO._____ DATE___________

CONDITIONS Ref. Section 12.2 of Std.

REDUCTION GEAR OPERATING CONDITION - COLD ☐ OIL TEMP. _______ °F
- HOT ☐ OIL TEMP. _______ °F
- SIMULATED HOT ☐ OIL TEMP. _______ °F

SHIP HULL CONDITION - LIGHT SHIP ☐ DRAFT FWD___, AFT___
- LOADED ☐ DRAFT FWD___, AFT___

FORCE MEASUREMENT BY HYD. PRESSURE ☐ BY LOAD CELL ☐

BEARING NO._____ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:

HYD. PRESS.										
LOAD CELL RDG.										
DIAL GAUGE RDG.										

JACKING DOWN:

HYD. PRESS.										
LOAD CELL RDG.										
DIAL GAUGE RDG.										

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT__________
CONVERSION FACTOR FOR PRESSURE TO FORCE__________
JACK LOAD__________POUNDS
CORRECTION FACTOR FOR JACK POSITION__________

BEARING REACTION__________POUNDS

BEARING NO._____ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:

HYD. PRESS.										
LOAD CELL RDG.										
DIAL GAUGE RDG.										

JACKING DOWN:

HYD. PRESS.										
LOAD CELL RDG.										
DIAL GAUGE RDG.										

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT__________
CONVERSION FACTOR FOR PRESSURE TO FORCE__________
JACK LOAD__________POUNDS
CORRECTION FACTOR FOR JACK POSITION__________

BEARING REACTION__________POUNDS

ENGINEER____________________________ DEPT.____________________

September 1, 1980

INSTALLATION OF PROPULSION SHAFTING FOR A SHIP WITH A GEARED, INBOARD SHAFTING SYSTEM

1. Scope

1.1 This procedure describes a method for the direction and documentation of the installation and alignment of the propulsion shafting for a marine propulsion system composed of the power units, a main reduction gear unit, line shafting completely inboard, and either one or two stern tube bearings.

1.2 The power units may be either steam turbines, or high-speed diesel engines, or medium-speed diesel engines, or gas turbine engines.

2. Summary of Method

2.1 A line-of-sight is established from the center of the reduction gear shaft flange, with the gear in an initial design position, to the center of the aft end of the stern tube. This reference centerline is later corrected. to the installed position of the stern tube bearing.

Design calculations are performed to determine the proper displacement and alignment of each shaft bearing, in relation to the reference centerline, which will give the design bearing load distribution and acceptable shaft deformation. The stern tube bearings, line bearings, and reduction-gear are each positioned at their individual design displacements from the reference centerline, in both the vertical and horizontal directions. Special checks are made to insure that the journals of the line and stern. tube bearings have proper contact over the bearing surface.

After the ship is waterborne, and the shaft sections completely coupled, and the reduction gear chocked in position, the . bearing reactions are measured to determine compliance with the "design reactions. The line and gear bearing positions may be finally adjusted, by a calculated displacement,to improve the compliance.

2.2 The basic steps in the installation and alignment procedure are given in Table 1.

TABLE 1

Procedure of Operations	Reference Section
Establish initial shaft centerline	7
Machine shaft to final length dimension	8
Bore the stern tube for bearing shells	9
Install the stern tube bearings	10
Align the reduction gear and line shaft bearings	11
Measure bearing reactions	12
Documentation	13

3. Significance of Installation Standard

3.1 An installation standard for propulsion shafting whic includes adequate documentation will minimize the chance of out-of tolerance in shaft alignment and will permit the identification of events which may have caused an out-of-tolerance.

3.2 An installation standard for propulsion shafting will ensure that all parties concerned with the process are aware of the necessary steps and the objectives of the alignment procedure.

4. <u>Definitions</u>

centered telescope - the condition of the optical alignment telescope, mounted on a shaft flange, when the telescope is in the center of the gear flange and perpendicular to the face. A,line of sight from a centered telescope maintains aconstanttargetposition as the mountaing flange is rotated.

cross hair position - the position of optical target cross hairs relative to the cross hairs of the optical alignment telescope, as viewed through the telescope. The designation "up " means that the target cross hairs are above the telescope cross hairs; 'starboard" means that the target cross hairs are to starboard of the telescope cross hairs, etc.

drop - vertical or transverse position of one flange relative to a mating flange, measured at the flange rims. A drop reading designated positive means that the forward flange is either above, or to starboard, of the aft flange. Same as ''sag " or''rim".

gap - opening between mating flange faces at the top, bottom and sides of the flange perimeters.

gap-drop method - the method of aligning shafting using relative positions of mating flanges. Same as the ''gap-sag"method.

gear flange - the output flange of the second reduction gear shaft; as a reference point, the aft face of the flange.

hydraulic jacking method - a method of measuring the vertical force on each bearing. Also called the bearing method, the shaft weighing method, and the method of measured bearing reactions.

key chock-oneofthe fitted chocks below the low speed gear bearings and oorners of the lower gear case which are used to align the gear shaft to the line shaft.

line bearing - journal bearing supporting line shaft sections, located between ' the gear flange and the stern tube.

propeller bearing - the shaft bearing immediately forward of the propeller.

Propulsion shafting - shafts used to transmit power from the second reduction gear wheel (bull gear) to the propeller, including the second reduction gear shaft, line shafts and tail shaft.

shaft centerline - an axial centerline through the shaft at at the supporting positions. The bearing centerlines are above the shaft centerline by 1/2 the bearing clearance.

stern tube bearing - the aftermost bearing, or bearings, which are enclosed within the stem tube and support the tail shaft.

tail shaft - the section of propulsion shafting which mounts the propeller Same as the propeller shaft.

5. Apparatus

5.1 Optical alignment telescope wit h right angle eyepiece and built in optical micrometers for measuring displacements from the line-of-sight along two orthogonal axes (two-plane micrometer). Maximum tolerances for the telescope are one part in 200,000 for measurments along the line-of-sight and 0.5 seconds (0.000139 deg) of are for measurements at right angles to the line-of-sight.

5.2 Bracket for monting and adjusting the position of the telescope on the face of the shaft flange.

5.3 Open optical alignment targets with cross hairs mounted within adjustable target holders.

5.4 Hydraulic jack and pressure gauge combination, calibrated to ±2% of full-scale, capable of raising the shafting completely off each individual bearing.

5.5 Dial gauges for measuring shafting displacements in the hydraulic jacking procedure, accurate to ±0.0005 in (±0.0127 mm), with mounting fixture to hold the gauge firmly.

5.6 Laser beam as an alternate to optical alignment telescope.

5.7 Strain gauges for deriving bearing loads from shaft strain measurements; alternate procedure to the use of hydraulic jack and pressure gauges.

5.8 Hydraulic jack and load cell as an alternate to hydraulic jack and pressure gage combination.

6. Alignment Requirements and Supporting Data

6.1 The shaft installation design and the alignment specifications are developed to meet certain objectives with respect to bearing loads, shaft stresses, and vibration response. These objectives are outlined in Annex Al. After the shafting design has been developed, engineering calculations are made to establish the design bearing positions relative to a reference centerline. Calculations are also made as required for the determination of the actual position of the bearings during the alignment operation. The design bearing positions and the alignment calculations may be compiled in a document of propulsion shafting installation data. The document should also include alignment data, such as that suggested in Tables XI through X5 of the Appendix, which would be useful for any realignment of the shafting in service.

6.2 Calculations for Alignment

6.2.1 The calculations required for the installation and alignment procedure are outlined in the following sub-sections.

6.2.2 Bearing Load Calculation. An analysis of the shafting as a beam on multiple supports.

Input - Shafting design information.

Determinations - bearing positions and slope of bearing journals for selected bearing reactions, as shown in Table Xl.

6.2.3 Influence Number Calculation. A supplementary analysis to that of 6.2.2.

Input - shafting design information.

Determination - the change in each bearing reaction for a given change in the position of one bearing. Done for each bearing of the system and used to correct bearing positions, see 12.4.

6.2.4 Gap-Drop Calculation. A calculation of the deflection of each shaft section, uncoupled, as a simple beam on two supports.

Input - Shafting design information, plus the location of supports, see 11.1.2.

Determination - design values of gap and drop at each coupling connection, which are used to align the shafting and gear, see 11.6.

6.2.5 Hydraulic Jacking Calculations. Analysis of hydraulic force versus deflection readings.

Input - hydraulic pressure, or load cell readings, and deflection readings from 12.2.

Determination - bearing reaction forces for comparison with design requirements of Table XI.

6.2.6 Strain Gage Analysis. An analysis of strain measurements on the shaft surface to determine the corresponding bearing reactions.

Input - strain gage data from 12.3.

Determination - bearing reaction forces for comparison with design requirements of Table XI.

Procedure of Operations

7. Establish Initial Shaft Centerline

7.1 Position the Main Engine

7.1.1 Land the main reduction gear and the turbines and condenser, or the diesel engines, on their foundations using either jacking screws or taper wedges for support, but without permanent chocking. Position the components at their design positions relative to hull reference lines. Do not secure the support connections between the reduction gear and the main engine and do not install the high-speed flexible couplings.

7.1.2 Position the second reduction gear (bullgear) in a longitudinal location within the gear casing as defined by the gear manufacturer and hol d this position mechanically until all shafting is coupled in 11. 7.

7.2 Establish Preliminary Stern Tube Position .

7.2.1 Center an optical alignment telescope on the gear flange. Confirm the centered telescope position by the procedure given in Annex A2. Center optical targets at the forward end, the midpoint, and the aft end of the stern tube.

7.2.2 The position of the three targets relative to the line-of-sight from the centered telescope should be measured with the gear flange in the 0° and 180° positions. Recordd the target positions in Table X 2. Make a priliminary assessment of whether or not the stern tube and reduction gear are aligned within the limits of normal alignment adjustments:

Record in Table X3 the position of the liner gear casing base flange relative to the gear foundation plate.

7.3 Monitor Hull Distrotion

7. 3.1 The machinist may use the centered alignment telescope and the stern tube targets to periodically repeat the readings of 7.2.2 while the welding and machinery installation are being completed. A history of consistent readings will indicate that hull distortion has leveled off.

7.3.2 Proceed to stern tube boring (Section 9) when hull welding and installation of heavy camponents have been completed to the criteria established by the engineering department.

NOTE l- Readings taken with the optical alignment telescope will. be definitely effected by distortion of-the ship hull due to temperature of the air, solar radiation, and weight loading. For comparable readings, the telescope should be used at the same time of the day, preferably at night, and under similar ship conditions.

NOTE 2 - In this procedure, and in following sections, a line-of-sight established by a laser beam may be used in lieu of an optical alignnent telescope.

8. <u>Machine Shaft to Final Length Dimension</u>

8.1 Measure the distance between the gear flange and the aft face of the stern tube.

8.2 One section of the line shafting may serve as a make-up section with excess thickness at one flange face. From the overall length measurement of 8.1, and the finished lengths of the other sections, determine the required length of the make-up section. Determine the amount of material to be machined from the face of the over-size flange, with tolerances.

8.3 Finish machine the flange face of the make-up section to give the required length. Confirm the shaft length by measurement.

9. Bore the Stern Tube for Bearing Shells

9.1 Position the Boring Bar for the Aft Bearing

9.1.1 Mount the boring bar in the aft bearing position. Using the optical alignment telescope centered on the gear flange, as in 7.2.1, establish the line-of-sight which is the reference centerline. Adjust the position of the boring bar to bring its target cross-hairs to the design position, relative to the reference centerline, given in Table XI, See note 3. The bore design position fiven in Table Xl may be based on a bearing parallel to the reference centerline or on a bearing sloped in relation to the reference centerline.

9.1.2 Measure the position of the boring bar centerline relative to the rough bore of the Stern tube. The machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the shell.

9.1.3 If the boring bar positio n is too far off-center to give a complete peripheral fit, it will be necessary to reposition the bar to a new reference centerline and reposition the reduction gear accordingly. The reductio n gear position has to permit use of alignment Chocks with adequate thickness. Re-establish the boring bar positio n as in 9.1.1 and record the new gear position in Table X3.

9.1.4 In the procedures of 9.1.1 to 9.1.3, the optical telescope may be alternately positioned at the aft end of the stern tube with line-of-sight perpendicular to, and centered on, a target on the gear flange.

9.1.5 If a forward stem tube bearing is not provided, proceed to 9.3.

NOTE 3 - The reference centerline represents the center of the shaft at the bearing locations. The optical telescope centered on the gear shaft flange is located on the reference center line. The design position for the boring bar centerline would be located above the reference centerline by 1/2 the diametral c1earance of the bearing to be installed at that location. The design position for the bearing bore, as given in Table Xl, may be farther displaced from the reference centerline by an amount selected to achieve as design “fair curve” alignment.

9.2 Verify the Position to be Taken by the Stern Tube Forward Bearing.

9.2.1 Use the design position for the forward stern tube bearing, given in Table Xl, as the position to be used for the boring bar at the forward position in the stern tube, relative to the line-of-sight from the gear flange established in 9.1.1.

9.2.2 Center two optical targets at the forward and aft ends of the stern tube forward bearing position. Record the cross-hair positions of the targets, relative to the line of sight, in Table X2.

9.2.3 Using the reference line-of-sight from the gear flange of 9.1.1, and the design position of 9.2.1, and the actual stern tube position of 9.2.2, the machinist will confirm that the boring for the bearing shell will provide a a complete peripheral fit for the forward bearing.

9.2.4 I a complete fit will not be provided, reposition the reference line-of-sight by repositioning the gear and repeat steps 9.1.1 to 9.1.3 and 9.2.1 to 9.2.3.

9.3 Bore the stern Tube for the Aft Bearing

9.3.1 Position the complete boring machine at the stern tube ready for boring. The boring bar has been set in 9.1.1 at the design position given in Table Xl relative to the reference centerline.

9.3.2 Bore for the aft stern tube bearing according to the applicable shipyard drawings. Do not move the boring bar in any way during the boring process by readjustment of any supporting device for either the boring bar or the boring machine.

while boring, the machinist should check the location of the boring bar relative to the design position, using a telescope aligned to the reference centerline, to insure that the proper boring line is being maintained, especially before the final finish cut.

9.3.3 Measure the finish bore for the aft bearing. Ihe measurements are to be taken at 4 to 6 in. internals along the bearing bore with the stern tube on diameters at 0°, 45°, 90° and 135° from vertical. If possible, take Measurements in the early morning or evening when temperature conditions are more stable. Record time, temperature, and measurements of the machined bore in Table X4. Also record the location and type of any other work executed on the stern tube after the bore machining.

9.4 Bore the Stern Tube for the Forward Bearing

9.4.1 Establish the reference centerline of 9.1.1 at the forward bearing location.

9.4.2 Although the bore is shorter than the aft bearing bore, the boring procedure duplicates that of steps 9.3.1 to 9.3.3.

NOTE 4 - The measurements of the aft stern tube bores, and the bearing outer diameters, Table X4, should be completed by the same machinist. Similarly, the measurements for the forward bearing fit should be completed by the same machinist.

10. Install the Stern Tube Bearings

10.1 The machinery foremen and engineering personnel will establish the machined dimension, with tolerances, for the outer diameter of the stern tube bearing shells. The dimension values will be based on the measured bore dimensions of 9.3.3 and 9.4.2, plus an allowance to give the design interference fit, and plus an allowance for the difference between metal temperatures in the hull and in the machine shop.

10.2 Record the required dimensions for the stern tube bearings in Table X4.

10.3 Machine the bearing shell outer diameters to the required dimensions of Table X4.

10.4 After finish machining, measure the bearing outer diameters at 4 to 6 inch intervals along the bearing length, on diameters-at 0°, 45°, 90° and 135° from the vertical. To confirm concentricity, measure the bearing radial wall thickness at the forward and aft ends of each bearing and record in Table X4.

10.5 Record machined dimensions and ambient temperature in Table X4. Determine the interference fit at each interval, at the ship hull temperature conditions, and record in Table X4.

10.6 Install the stern tube bearings with a drive fit. Complete the installation conditions listed in Table X4 for the aft and forward bearings, before and after the bearing installation. Record the hydraulic force required to drive each bearing.

10.7 Center a telescope on the gear flange as in 7.2.1 and Annex A2. Mount optical targets in the bore of the aft stern tube bearing, at the aft and forward ends, centered in the bore.

10.8 Reposition the reduction gear, if necessary, to bring the forward and aft target centers in the aft bearing bore to *the* design position of table Xl.. This operation may be combined with that of 11.5 .1. Record the new gear position in Table X3. This line-of-sight, from the centered telescope to the finished bore of the installed aft bearing, becomes the final reference centerline.

10.9 Mount optical targets centered in the bore of the forward stern the bearing, if fitted, and measure the bearing position in relation to the new reference centerline of 10.8. Record the target positions in Table Xl.

10.10 Using the reference centerline of 10.8, establish the horizontal and vertical planes of the centerline by permanent markings on the aft peak bulkhead on either side of the shaft seal housing. Provide a temproary reference bracket, welded to the bulkhead in the vertical plane, to permit micrometer measurements to the top surface of the shaft. Establish the position of the reference surface above the refernce centerline of 10.8 and record in Table Xl.

11. Align the Reduction Gear and Line Shaft Bearings

11.1 Preparation for Alignment

11.1.1 The preceeding sections have established a final reference centerline from the installed position of the aft stern tube bearing to the center of the gear flange, and normal to that flange. This section outlines the procedures for positioning the line and gear bearings at their design positions, vertically and horizontally, relative to the reference centerline. For some ships the design position of the shaft at the bearings may be on the reference centerline, with the possible exception of the forward line bearing. For higher power ships with machinery aft, the design position of the shaft at all the bearings may be displaced from the reference centerline along a fair curve which establishes acceptable bearing loads.

Positioning the bearings may be accomplished either by optical methods or by the gap-drop method described in 11.4 and 11.6, respectively. The gap-drop method is not readily adaptable to shafting with internal. piping for contollable pitch propeller sytems.

11.1.2 If the gap-drop method is to be used, engineering personnel should examine the structural details and arrangement of piping and auxiliary machinery beneath the line of shafting and select locations for temporary shaft supports which will provide two points of support for each section of shafting. After the temporary supports have been installed, engineering personnel will verify the longitudinal position of the center of each temporary support and each bearing from a known frame station and record the locations in Table X5. These positions become the design positions for the gap-drop calculation.

11.2 Installation of Shafting

11.2.1 Install the tail shaft and outboard shaft seal. Place the inboard shaft seal around the shaft but do not bolt the seal to the bulkhead. Mount the propeller. At this time the line bearing foundations and the temporary supports would be in place. Place the line shafting and line bearings in position. In the usual construction sequence, the ship would be launched after these installations have been completed.

11.2.2 With the line shafting and line bearings in place, position the shafting roughly to the reference centerline by use of jacking screws in the bearing base flanges and by wedges or chocks under temporary supports.

11.2.3 The uncoupled tail shaft becomes a special case because the forward end may tip upwards if the propeller is mounted. If a forward bearing is not provided, a temporary support is used to hold (downward force) the tail shaft centerline at the design position given in Table Xl at the plane of the aft peak bulkhead, relative to the reference centerline as established in 10.10.

If a forward bearing is provided, a temporary support may be required to seat (downward force) the shaft journal in the forward bearing. If the propeller is not mounted, and there is no forward bearing, a temporary support is used to hold (upward force) the forward end of the tail shaft at the design position give n in Table Xl.

11.2.4 Temporarily chock the upper casing of the main thrust bearing to provide clearance around the shaft. A tight casing may impose forces on the uncoupled shaft which would distort the measured gap-drop values.

11.3 Bearing Surface Contacts

11.3.1 If a forward stern tube bearing is not provided, the bearing contact over the length of the aft stern tube bearing may be checked physically by the following optional procedure before the shafting is coupled. The forward end of the tail shaft is raised and lowered, the jacking force versus the shaft vertical position is recorded, and the total range of physical angularity between the shaft journal and the aft bearing surface is thereby determined. The force will rapidly change when the surface of the journal contacts the forward edge of the bearing surface, top or bottom. The shaft may then be set in the position of design angularity, give n in Table Xl, within the measured total range of angularity. The corresponding shaft centerline position, vertically and horizontally, at the plane of the aft peak bulkhead may then be recorded in Table Xl.

11.3.2 Either the optical method or the gap-drop method of alignment will position the line bearings at the design vertical and horizontal positions to provide the design load reactions. However the methods not insure that there is not a skew angle between the bearing and shaft centerlines which would reduce the load capacity of the bearing.

11.3.3 Remove caps of line bearings, wherever possible, for measurement of clearances between the shaft journals and bearing surfaces in a horizontal plane. Maintain equal clearances during the following alignment operations. Also use feeler gages to check vertical clearances between the shaft journal and the bearing surface at the forward and aft/ ends of each-line bearing to insure that there is contact over the length of the bearing.

11.4 Optical Alignment of Line Bearings

11.4.1 If the line bearings are to be installed before the shafting, they may be positioned optically at their design positions from the reference centerline established in 10.8.

11.4.2 If the line bearings are installed integral with the shafting, it will be necessary to establish an offset line-of-sight parallel to the reference centerline, and *in* the same vertical plane. Using targets mounted on the shaft, adjacent to the bearings, the bearings can be positioned at their design positions relative to the established line-of-sight. The targets must be accurately centered and vertical in order to achieve accurate horizontal alignment; alternately a line-of-sight may be established in the horizontal plane of the reference centerline to position the bearings *in* the horizontal direction.

11.5 Alignment of the Reduction Gear

11.5.1 If the design positions of the low-speed gear bearings as given in Table Xl, are displaced from the reference centerline established in 10.8, the gear may be positioned by a calculated change in the vertical measurements from foundation plate as recorded in Table X3.

The calculated change should account for the design vertical offset and and angularity of the gear shaft relative to the reference centerline, plus the correction for the fore and aft distance betweem the bearing centerline and the position of the vertical measurement. The gear can also be positioned in the athwartship direction by the interline marks recorded in Table X3. This operation may be combined with that of 10.8.

11.5.2 The gear may be positioned by an alternate technique using an optical telescope sithting to optical targets mounted on the gear case. The displacements and angularity may then be measured directly in the plane of each gear bearing.

11.5.3 In the above procedures for aligning the low-speed gear to the line shafting, the gear is positioned primarily by the jacking screws in the area of the key chocks under the two gear bearings and the corner points of the lower gear case. The other jacking screws around the gear case flange are adjusted to reduce the distortion of the casing. The final aligrmnt of the gear case, relative to the low speed gear bearing positions, is dbne by either pin gauge, proof staff, or tight wire measurements and by tooth contact checks. That procedure is perfomed later and is outside the scope of this Standard, see refernce (1).

1.1.6 Gap-Drop Alignment

11.6.1 The gap-drop method uses the uncoupled sections of shafting as alignment gages to locate the line and gear bearings at the design displacements from the reference centerline. An engineering calculation is performed to determine the gap and drop values that would exist between each set of flanges when the bearings are at their design position from the reference centerline.

(1) "Guide to Propulsion Reduction Gear Alginment and Installation", SNAME T & R Bulletin 3-10. september 1972

The calculation includes the effect of the deflection, or “droop” of each section of shafting under its own weight and supported at the two specified points of 11.1.2. The calculated gap and drop values are prepared by the Engineering Department and presented in Table X5. The values apply only under the conditions stated: bearings and temporary supports in the positions given by Table X5, propeller either mounted or not mounted, and ship either waterborne or on dry dock.

11.6.2 Maintain the longitudinal position of the bearings and temporary supports established in 11.1.2 within a tolerance of +0.5 inches (12.7 mm) during the alignment operation.

11.6.3 Move line bearings and temporary supports vertically and transversely, either by jacking screws or by wedges, to achieve the gap and drop measurements specified in Table X5 within ±0.001 in; (±0.0254 mm). When measuring gaps and drops at a coupling, push the mating flanges together to make the gap and drop measurements more accurate.

11.6.4 Record in Table X5 the final gap and drop measurements taken when the bearings and temporary supports are in the positions given in Table X5. Indicate in the table whether or not the propeller was mounted and whether or not the ship was waterborne. The Engineering Department will signify acceptance of the gap and drop measurements of Table X5, if they are suitable for proceeding to bearing and gear chocking.

11.6.5 The gap-drop method of alignment will give the best results with the hull waterborne and the propeller mounted. The procedure can also be performed without the propeller in place, however there will be some loss in accuracy because the propeller is a major weight item. The procedure will give least reliable results if the ship is in a dry dock because the hull deflection may differ radically from a normal waterborne deflection line. The design gap-drop valure must be =lculated for the conditions that will exist at the time of measurement.

11.7 Coupling of the Shafting

11.7.1 All of the shaft coupling connections either flanged, muff-coupling, or hydraulic sleeve type be made-up complete before the following alignnent checks can be performed. Make-up of the gear shaft coupling should be deferred until step 1-1.8.2 is completed. Ihe mechanical stops on the longitudinal position of the gear shaft should be removed, see 7.1.2.

11.7.2 The forward Stern tube seals may be mounted on the bulkhead.

11.7.3 The Ship should be waterborne and the propeller in place.

11.8 Gear Shaft Bearing Check

11.8.1 Bending moments and shear forces imposed on the gear shaft by the line shafting can cause a tipping, or skewing, of the low speed gear within its bearings with serious consequences to the gear tooth contact. Although many shipyards measure the vertical bearing reactions, the alignment of the gear bearings in the horizontal plane is often not checked.

11.8.2 Before the coupling between the line shaft and gear shaft is made up, a set of gap and drop readings should be taken at the gear coupling flanges. The calculated gap and drop values for this will differ from those of 11.6.1 because they would be based on a continuous (coupled) shaft up to the gear flange. This check is a valuable refernce to ensure that excess moments will not be imposed on the gear shaft.

11.8.3 A complete check on the alignment of the lowspeed gear bearings under the influence of the forces imposed by the line shaft may be accomplished by the following optional procedure, which may be recommended by the gear manufacturer.

With the shafting coupled, remove the bearing. caps of the low-speed gear bearings (No. 1 and No. 2) . Set dial indicators at zero reading to record the vertical and horizontal movement of the forward journal (No. 1) . Roll out the forward bearing, leaving the gear shaft supported by the aft bearing and the coupled lineshaft. Record the movement of the journal measured by the dial indicators.

11.8.4 The centralization of the journal may be determined by gap measurements between the journal and the seating bore for the lower bearing shell. Mark locations for measurements at the horizontal split at the forward end, midpoint, and aft end of the bearing length. Gap measurements should be taken with a micrometer on both sides of the journal at these locations, and also at the vertical (6 o'lock) position at the forward end of the bearing. Additional readings may be taken at the 4, 5, 7 & 8 o’clock positions at the forward end. The measured total thickness of the bearing shell minus the gap measurement at the 6 o’clock position is the sag of the shaft, which should agree with the vertical dial indicator reading of 11.8. 3.

11.8.5 The gap measurements described above should be made at four rotational positions of the shaft: 0°, 90°, 180°, 270° and again at 0°. At each rotational position, the shaft should be rotated ahead on the turning gear to the position, the gap measurements made, the shaft rotated ahead through a small angle and then reversed to approach the same position from the opposite direction, and the gap measurements re-checked.

11.8.6 Hydraulic jacking of the No. 1 bearing may be conveniently accomplished when the bearing is removed. See Section 12.2. A load versus vertical displacement curve can be established which should check the influence number calculation of 6.2.3. The bearing reaction at operating conditions is the jacking force existing when the shaft is restored to its original dial indicator position of 11.8.3.

11.8.7 Replace the forward bearing and mount the dial indicators at the aft bearing (No. 2) . Roll out the aft bearing and record the movement of the aft journal. Repeat the procedures of 11.8.3 to 11.8.5 at the aft bearing location.

11.8.8 The gap and dial indicator measurements at the forward and aft journals provide data for the following determinations:

(a) The normal central position of the shaft.

(b) Whether or not there is a permanent bend or crank effect in either the low-speed gear shaft or the line shaft.

(c) Rotating ahead and astern should indicate any parasitic torque in the rotating system.

(d) Forces on the gear journals can be determined from the measured radial displacements multiplied by the influence numbers. The operating position of the gear can then be determined to decide whether or not the existing displacements of the journals are acceptable.

11.8.9 The above procedure must be performed with close coordination of the gear manufacturer. Specifically, the procedure can’t be used if either low-speed gear bearing would be overloaded when the opposite bearing is removed. The load limit should be checked for both the static and the turning gear rotation conditions.

11.8.10 The position of the low-speed gear journals may be determined under full load operating conditions by the use of proximity probes mounted in the upper bearing shells. That procedure would be a special investigation beyond the normal procedures of shaft alignment.

11.9 Chocking of the Gear and the Line Bearings.

11.9.1 The shipyard may elect to chock the reduction gear and the line bearings after these bearings have been positioned by the procedures of 11.3 to 11.8. There is a risk that the gear may have to be re-chocked after the final measurement of bearing reactions. If the above procedures have been completed successfully, the final measurement of reactions will usually result in only a readjustment of the line bearings;

Performing the chocking after the measurement of the bearing reactions results in schedule delays for securing the connections to the-main engine and for operating the engine on dock trials.

11.9.2 Make an inspection of the gear position relative to the foundation supports and structural clearances. Request the approval of engineering and the gear manufacturer's representative to proceed with fitting of chocks under the gear bearings.

11.9.3 Measure the vertical distance between the gear base plate and the tapered liner welded to the gear foundation plate, at each of the four corners of each chock of the gear. If a tapered foundation plate is used, the measurement would be directly to the foundation plate. Machine a chock to fit each chock location.

11.9.4 Install the machined chocks of the gear. Check each check for contact on top and bottom surfaces. Refit a chock if the contact on either surface is less than 80%. Record the contact area in Table X3.

11.9.5 Fit gear case foundation bolts and back-off the jacking screws.

11.9.6 Measure the vertical distance between the bearing foundation and the bearing base for each the bearing at the locations where chocks are to be fitted. Machine chocks to fit each location. Check each chock for contact on both surfaces and refit if the contact is less than 80%.

11.9.7 In the case of the forward line bearing, the chocks should be machined 0.050 inches (1.270 mm) less than the required thickness. In fitting the chocks a standard .050 shim is included. The contact area requirement of 80% still applies. If the bearing position has to be changed after hydraulic jacking (see 12.2), the standard shim is replaced by another single shim, rather than removal and refit of the chocks. The forward line bearing is the bearing most likely to be repositioned to achieve the design bearing reactions.

11.9.8 In the case of a thrust bearing in a housing separate from the gear, the housing should be chocked to give uniform radial clearance at the shaft seals when the shaft sections are coupled.

12. Measurement of bearing Reactions

12.1 Conditions for Measurement

12.1.1 After the journal bearings of the shafting system have been positioned by either the optical or gap-drop methods described in 11.3 to 11.8, the bearing reactions should be actually measured. The measurements may be accomplished by either the hydraulic jacking method (shaft weighing) or by the strain gage method. Some shipyards use one method as the principal procedure and use the alternate method on occasion to check critical bearings.

The measurements should be made withe the ship water-borne and the propeller in place. The ideal conditions for measurements would be normal hull loading and the reduction gear at operating temperature. Actually, the measurements have to be made at the light displacement existing during outfitting. Measured reactions at the gear and forward line bearings may be corrected for the thermal growth from actual gear temperature to full operating temperature.

12.1.2 The internal alignment of the reduction gear for proper tooth contact should have been completed because that procedure may involve adjustment of the gear case chocks.

12.1.3 Any support connections between the reduction gear and the power units should be coupled and carrying load, with temporary supports unloaded. Installation of the high-speed flexible couplings does not affect the procedure.

12.2 Hydraulic Jacking of Bearings

12.2.1 Engineering will select the location at which the hydraulic jack will be applied for measuring each line bearing reaction by the hydraulic jacking method. Measure the axial distance from the jack location to the corresponding bearing and record these data in Table X6. The jack is to be supported on solid steel structure which carries the jack load to a frame or longitudinal member; wooden blocks or posts are not adequate. Assign numbers to each -jack position and to the corresponding bearing.

12.2.2 The stern tube bearing reactions cannot be measured by jacking. The aft bearing of the gear shaft may be measured usually by a jack between the bearing and the gear flange. The forward gear bearing is difficult and usually requires some special fixture on the shaft. As a lesser option, the load may be assumed to be the weight of the low-speed gear and shaft, minus the measured load the aft bearing. If the gear shaft bearings are checked by the procedure of 11.8.3-11.8.7, the gear bearings may be accurately jacked as part of that procedure.

12.2.3 Engineering personnel shall conduct the hydraulic jacking procedure at each available bearing. All bearings should be done in the same time period shortly after dock trials when the bearing and gear temperatures are close to actual service conditions. A decision to forego jacking for a particular bearing reaction is the responsibility of the engineering department. A second set of jacking measurements may be taken after sea trial and also under different conditions of vessel loading.

12.2.4 At each bearing, progressive sets of readings (either hydraulic pressure or hydraulic force versus shaft displacement) are taken as the shaft is raised and lowered by the hydraulic jack.

A mean line, plotted through the data reflecting elastic deflection, will indicate the jack reaction pressure at zero displacement. Record the ambient temperature, the lube oil temperature, and the reduction gear sump temperature. A variation in the procedure is to roll out the bearing and measure the jacking force required to restore the shaft to its operating position.

12.2.5 An alternate method for measuring bearing reactions is to use a load cell to measure the reaction force on the hydraulic jack. This method eliminates the hysteresis effect in the hydraulic fluid pressure. Also it may be conveniently used to measure a bearing reaction plus the simultaneous change in the reactions on adjacent bearings.

12.2.6 It is often difficult, for practical reasons, to get a corn- plete set of hydraulic jacking measurements with the reduction gear case at full operating temperature. Before the shaft can be stopped for the jacking operation, the engine will have been progressively reduced in power and then rotated on the turning gear. An optional procedure to obtain a set of bearing reactions under a simu- lated "hot gear" conditions to raise low-speedgearshftandinsert shims under the forward and aft bearing journals. The shim thick- ness should be the calculated thermal growth of the reduction gear foundation and lower case. This procedure is a particular benefit for properly locating the first line shaft bearing.

12.2.7 The engineering department will convert the hydraulic force figure of 12.2.4 - 12.2.5 for each bearing to a bearing reac- tion force by calculating a correction for the axial displacement of the jack from the bearing center plane. Record the corrected bearing reactions in Tables X6 and Xl.

12.3 Load Determination by Alternate Strain Gage Technique

12.3.1 An alternate to the hydraulic jacking procedure is the use of strain gages mounted on the surface of the shaft at selected stations to determine shaft strains. By calculation procedures, the strains are converted to bending moments which lead to the determination of the bearing reactions. Strain measurements are made with the shaft in several rotational positions.

12.3.2 The data needed for this method are the weight of the shafting components, such as propeller and gear, the shaft diameter at all sections, and the longitudinal position of the bearings.

12.3.3 The application of the strain gages, the strain readings, and the determination of the bearing reactions are accomplished by the engineering department. The bearing reactions are tabulated in Table Xl.

12.3.4 The particular advantage of the strain gage method is that once the strain gages have been applied to the shaft, a complete set of strain readings may be taken in a short period of time. This makes it possible to take a complete set of readings before the reduction gear casing has cooled; also readings may be taken at different hull loading conditions during trials if the schedule permits operating the main engine on turning gear for a short period. Another advantage is that the method gives the horizontal reactions on each bearing in addition to the vertical reactions.

12.4 Corrections to Bearing Positions

12.4.1 The measured bearing reactions of either section 12.2 or 12.3 are compared with the design bearing loads of Table Xl. If the compliance with the design load is not acceptable to the engineering department, a change in the vertical position of the bearing will be recommended. By the calculated values of influnce numbers, see section 6.2.3, the amount of change in the vertical position of the bearings to correct the loadings can be quickly determined. Recommended changes should generally be in multiples of 0.005 inches (0.127 mm). If changes are not recommended in cases of marginal compliance, the fact should be noted in Table Xl.

12.4.2 Changes in the vertical position of the bearings are accomplished by refitting of the chocks. In the case of the first line bearing the change may be made by substituting an alternate shim for each of the original 0.050 inch shims.

12.4.3 If significant changes are made in the chocking, the engineering department will require another measurements of the bearing reactions to confirm & proper bearing positions, either by hydraulic jacking or by the Strain gage method. If no changes are required, the alignment procedure is complete. The final measured bearing reactions should be recorded in Table XL.

13. Documentation

13.1 The record of the shaft installation alignment should be assembled in a "Propulsion Shafting Installation Data" document. The purpose of the document is to describe the results of the shafting alignment and to provide enough information so that the shafting may be readily re-aligned in the future. The document should include at least the followinq information:

Design bearing positions and reactions, plus the final measured positions and reactions, as suggested by Table Xl.

Angle of the tailshaft in the aft stern tube bearing as given in Table Xl.

Measured position of the reduction gear above the foundation plate, similar to the data of Table X3.

Force fit requirements for the stern tube bearings, similar to that of Table X4.

The calculations for alignment, particularly the influence number and the gap-drop values, see 6.3.

13.2 The tables of the Appendix present typical data tabulations for the purpose of illustrating the alignment process. Some sections will not be applicable for the selected method of alignment. Also the data format may have to be adjusted to suit the shaft and reduction gear arrangement, special features of a ship design, and practices of individual shipyards.

To reduce the number of tables, they have been designed to be used by either engineers or machinists on different occasions. The user must define the location and conditions by checking the appropriate box in the heading format.

September 1, 1980

Annex Al

Objectives of the Shafting Alignment Design

A1.1 The bearing reactions of the low-speed gear under normal running conditions shall satisfy the requirements of the gear manufacturer. The requirements are usually given as a limiting difference between the two reactions in the vertical direction, either as an absolute value or a percentage. The gear manufacturer may also limit the horizontal reaction, from the line shafting, at each of the gear bearings. The limitations on the line shaft effect on the gear shaft may be also specified as maximum allowable bending moments at the gear shaft flange in the vertical and horizontal planes. The intent of the limitations is to insure that proper pinion-to-gear alignment is maintained under the combined effect of line shaft moments, gravity forces, and gear tooth mesh forces.

A1.2 The low-speed gear running position should not be unduly influenced by changes in the position of the first line bearing relative to the gear bearings, The change in position may be caused by hull deflection or thermal growth. To reduce the influence of the first line bearing, it is usually positioned at 10-12 shaft diameters from the aft gear bearing. The Allowable Setting Error (ASE) of the first line bearing should be determined. The ASE is the amount of change in the first line bearing position which will cause the gear bearing reaction differential to be exceeded. An ASE of 10 mils is a minimum value; the value should be significantly higher for large, flexible hulls, particularly those subject to large displacement changes. High influence numbers for the first line bearing would be indicative of a low value of ASE.

A1.3 The spacing of the line shaft bearings shall be set to maintain the bearing reactions within the manufacturer’s limits. Typical maximum unit loads are 150 psi for gear bearings, 50 psi for line bearings, and 100 psi for stern tube bearings. Minimum load to be at least 20% of sum of adjacent shaft span weights.

A1.4 The spacing of the line shaft bearings shall be set with consideration of the lateral modes of shaft vibration. The position of the bearing forward of the propeller bearing will have a major influence on the lateral critical. The position of the first line bearing will influence the ASE, see A1.2. Within these constraints, the use of a minimum number of bearings should be favored.

A1.5 The design alignment of the shafting should be optimized to give acceptable bearing loads under the normal service conditions of hull deflection. This is particularly significant for ships with short shafting and subject to operation under very different draft conditions.

A1.6 The design alignment should consider all steady forces acting on the shafting system including deadweight loads, propeller buoyancy, and the off-center thrust of the propeller. The resolution of forces and bearing reactions should be made in the vertical and horizontal planes.

A1.7 Positioning the shafting system bearings on a common centerline, or line-of-sight, offers the most simple installation procedure. A centerline alignment, however, would not be satisfactory for high power ships with short shaft lines. The bearings must be displaced, or offset, from a reference centerline along a fair curve of alignment to obtain the desired bearing loads and to give proper bearing contacts, particularly at the propeller bearing.

A1.8 The propeller bearing reaction is usually assumed to be located at 0.33 to 0.5 x shaft diameter, from the aft end of the bearing, in the case of oil-lubricated bearings. The contact angle between the shaft line and the bearing should not exceed 0.3×10^{-3} radians, as a typical value for bearings with an L/D = 2, in order to maintain a load-bearing oil film. The angle of contact should be checked for the possible range of hull deflections to insure that the angle doesn't become negative, indicating contact at the forward end of the bearing. To achieve the dssired angle of contact it may be necessary either to liner the design position of the bearings forward of the propeller bearing, or to position the propeller 'bearing with a fixed slope relative to the reference centerline. To ensure a satisfactary oil film, the diametral-clearance should be .0013-.0017 x shaft diameter.

A1.9 The strength of the shafting shall comply with the rules of the Regulatory Bodies. Bending and torsional stresses shall be carefully considered at local areas of stress concentration.

A1.1O In the determination of the cold alignment position of the shaft bearings, the thermal growth of the reduction gear lower case, the gear foundation structure to the double bottom, and local thermal distortion within the double bottom should be considered and calculated, based on available data and reasonable assumptions. The difference in thermal growth between the reduction gear support structure, compared to the first line bearing pedestal, has a significant effect on the low-speed gear bearing reaction difference.

A1.11 The alignment of the shafting is made with the shaft at rest. The oil film thickness under operating condition should be included in the calculation of the cold alignment offsets. Also the weardown of the propeller bearing in service should be included in the calculation of the fair curve of alignment.

Annex A2

Centering an Optical Alignment Telescope

A2.1 Mount an optical alignment telescope on the gear flange. Confirm the centered telescope position using the following steps:

A2.2 Place optical targets at the forward and after ends of the stern tube such that the two target cross-hair positions can be measured using the built-in optical micrometers of the telescope. Note that the targets need not be centered within the stern tube.

A2.3 Take telescope readings in the horizontal and vertical directions for both targets.

A2.4 Rotate the gear flange 180°. If the target cross-hair positions are within the telescope field after the flange rotation, take telescope readings in the horizontal and vertical directions for both targets and continue to A2.5. If the target cross-hair positions are not within the telescope field after the flange rotation, adjust the position of the targets, or the telescope, or both, without changing the longitudinal locations of the targets, such that the target cross-hair positions can be measured before and after a 180° gear flange rotation. If the target or telescope positions are changed, return to A2.3.

A2.5 Compare the readings of A2.3 and A2.4. For each target the horizontal readings at zero rotation must be identical (within telescope accuracy) to the horizontal readings of the same target at 180° rotation. Similarly, for each target, the vertical

Readings must be identical (witin telescope accuracy) at each rotated

The telescope is centered only if these readings are equivelent for both targets. If the readings are not equivalent, adjust the telescopy position and return to A2. 3. Note that the readings for the two different targets need not be equivalent.

NOTE 5 - After rotating the shaft, joggle the gear shaft to ensure that it is resting at the bottom center of its bearings

APPENDICES

X1 Design Alignment Requirements and Installation Results.

X2 Alignment Readings.

X3 Reduction Gear Position Measurements.

X4 Stern Tube Bearing Fit.

X5 Gap-Drop Alignment.

X6 Hydraulic Jacking of Bearings.

TABLE X1

DESIGN ALIGNMENT REQUIREMENTS
AND INSTALLATION RESULTS

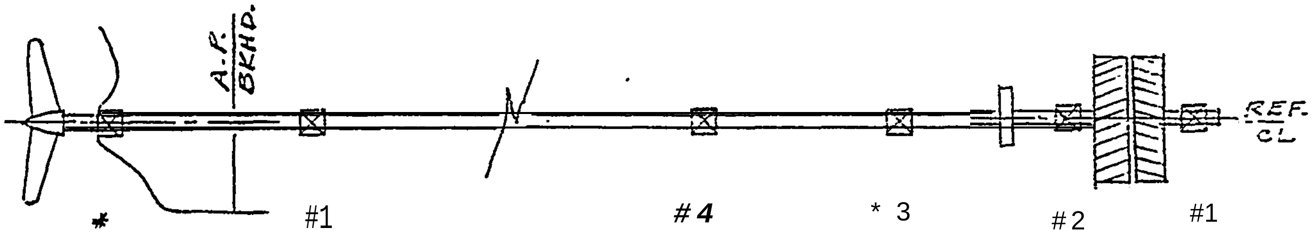
HULL NO. ______ DATE ______________

PROCEDURE		Ref. Sec. of Std.
DESIGN BEARING REACTIONS AND BEARING POSITIONS	☐	6.2.2
MEASURED BEARING REACTIONS	☐	12.2.7/12.3.3

CONDITIONS

REDUCTION GEAR OPERATING CONDITION - COLD ☐ OIL TEMP _____ °F
- HOT ☐ OIL TEMP _____ °F
- SIMULATED HOT ☐ OIL TEMP _____ °F

SHIP HULL CONDITION - LIGHT SHIP ☐ DRAFT FWD AFT
- LOADED ☐ DRAFT FWD AFT



BRG. NO.	DESIGN SHAFT POS. FROM REF. CL* VERTICAL inches	HORIZ. inches	MEASURED FINAL SHAFT POSITION FROM REF. CL* VERTICAL inches	HORIZ. inches	DESIGN BEARING REACTION pounds	FINAL MEASURED REACTION pounds
1						
2						
3						
4						
5						
6						
7						
8						
C.L. POSITION ON A.P. BKHD.					(See 10.10/11.2.3)	

PROPELLER BEARING DESIGN CONTACT ANGLE ______________________ radians

MEASURED LIMITS OF CONTACT ANGLE AT A.P. BULKHEAD (See 11.3.1):

UP POSITION, MEASURED FROM REF. CENTERLINE ________ inches

DOWN POSITION, MEASURED FROM REF. CENTERLINE ________ inches

CALC. POSITION REL. TO REF. CL TO GIVE DESIGN ANGLE inches above
inches below

*Positive values indicate position above, or to starboard reference centerline,

ENGINEER DEPT..

TABLE X2 ALIGNMENT READINGS

HULL NO. ______ DATE ______________

STERN TUBE AFT BEARING ☐ or FORWARD BEARING ☐

OPERATION	Ref. Sec. of Std.
INITIAL LINE-OF-SIGHT	7.2.3/7.3.1
BORING BAR POSITION - AFT BRG.. BORE ☐	9.1.2
STERN TUBE CENTER POSITION - FWD BRG~BORE ☐	9.2.3
FINAL BORING BAR POSITION - FWD BRG. BORE ☐	9.4.2
INSTALLED BEARING POSITION - FWD BRG.	10.9

CONDITIONS

SIGHTING: FROM GEAR FLANGE TO STERN TUBE
FROM STERN TUBE TO GEAR

INSTRUMENT: CENTERED OPTICAL TELESCOPE
LASER BEAM ☐

WEATHER: CLOUDY ______ FAIR ______ AIR TEMP. ______ °F

INCOMPLETE HULL STRUCTURE, AFT ______________________________

OPTICAL ALIGNMENT READINGS

TARGET POSITION	DISTANCE OF TARGET TO SCOPE	TELESCOPE READINGS* INITIAL SHAFT ROTATION VERTICAL	HORIZ.	SHAFT ROTATED 180° VERTICAL	HORIZ.
AFT					
FORWARD					
CENTER					

TIME OF DAY

AFT					
FORWARD					
CENTER					

TIME OF DAY

AFT					
FORWARD					
CENTER					

TIME OF DAY

*Positive readings indicate target cross hairs are above, or to starboard, of telescope line-of-sight.

MACHINIST DEPT.

TABLE X3 REDUCTION GEAR POSITION MEASUREMENTS

HULL NO. ______ DATE ______________

OPERATION

INITIAL GEAR POSITION

FINAL GEAR POSITION

LOW-SPEED GEAR BEARING ALIGNMENT

GEAR CHOCK CONTACT

Ref. Sec. of Std.

7.2.3

10.8/11.5.1/11.5.2

11.9.4

11.8.2/11.8.4

CONDITIONS

SHIP ON WAYS

SHIP WATERBORNE

PROPELLER MOUNTED

PROPELLER OFF

VERTICAL POSITION OF GEAR CASE

measured between gear case flange face and foundation base plate at four locations.

AFT END OF AFT KEY CHOCKS:

STARBOARD CHOCK inches

PORT CHOCK

FORWARD END OF FWD. KEY CHOCKS:

STARBOARD CHOCK ______ inches

PORT CHOCK ______ inches

ATHWART SHIP POSITION OF GEAR CASE

measured as an offset from scribed centerline on foundation base plate to scribed line on gear case flange.

OFFSET AT AFT FLANGE OF CASING ______________ inches, GEAR TO STBD./PORT

OFFSET AT FWD FLANGE OF CASING ______________ inches, GEAR TO STBD./PORT

LOW-SPEED GEAR BEARING ALIGNMENT

low-speed gear supported by coupled line shafting.

low-speed gear bearings rolled out.

VERTICAL DEFLECTION OF JOURNAL: FWD BRG. ________ AFT BRG. ________

GAP MEASUREMENTS FROM BEARING BORE TO GEAR SHAFT JOURNAL:

FORWARD BEARING: FWD END, STBD. ________ PORT ________ VERT. ________

MIDPOINT, STBD. ________ PORT ________

AFT END, STBD. ________ PORT ________

AFT BEARING: FWD END, STBD. ________ PORT ________

MIDPOINT, STBD. ________ PORT ________

AFT END, STBD. ________ PORT ________ VERT. ________

GEAR CHOCK CONTACT

Area contact as % of total bearing surface, determined by blueing.

KEY CHOCKS AFT, STBD. ________% KEY CHOCKS FWD, STBD. ________%

PORT ________% PORT ________%

OUTBOARD CHOCKS, STARBOARD SIDE:

________%, #2________%, #3________%, # 4________%, # 5________% . # 6________%,

: ;________%, #8________%, #9________%, #10________%, #11________%, #12________%

OUTBOARD CHOCKS, PORT SIDE:

#1 ________%, #2________%, #3________%, #4________%, #5________%, #6________

#7________%, #8________%, #9________%, #10________%, #11________%, #12 ________

MACHINIST DEPT.

TABLE X4 STERN TUBE BEARING FIT

HULL NO. ______ DATE ____________

STERN TUBE AFT BEARING [ ] or FORWARD BEARING [ ]

OPERATION		Ref. Section of Std.
STERN TUBE BORE MEASUREMENT	[ ]	9.3.3/9.4.2
REQUIRED BEARING SHELL O.D.	[ ]	10.1
FINISHED SHELL O.D. MEASUREMENT		10.4
BEARING INSTALLATION		10.6

CONDITIONS

STERN TUBE METAL TEMP. ______°F AIR TEMP °F

BEARING SHELL METAL TEMP. ______°F AIR TEMP ______°F

BORE I.D. AND SHELL O.D. MEASUREMENTS

DISTANCE FROM AFT END OF BORE OR SHELL	DIAMETERS, AT ANGLES FROM VERTICAL; LOOKING FORWARD: 0°	45°	90°	135°	INTERFERENCE, BRG. SHELL O.D. MINUS BORE I.D.
L_0 @ O inches					
L_1 @ inches					
L_2 @ inches					
L_3 @ inches					
L_4 @ inches					
L_5 @ inches					
L_6 @ inches					
L_7 @ inches					
L_8 @ inches					
L_9 @ inches					
L_{10} @ inches	!				

BEARING CONCENTRICITY

RADIAL WALL THICKNESS (shell plus babbitt)	ANGULAR POSITIONS, LOOKING FORWARD 0°	90°	180°	270°
AFT END				
FORWARD END				

BEARING INSTALLATION

HYDRAULIC FORCE REQUIRED TO DRIVE BEARING: ________ TONS

BEARING LENGTH INSERTED WHEN FORCE REACHES MAXIMUM: ________ % APPROX.

MACHINIST DEPT.

ENGINEER DEPT.

TABLE X5

GAP - DROP ALIGNMENT

HULL NO.________

DATE______________

OPERATION

LOCATION OF SHAFT SUPPORTS ☐

GAP - DROP DESIGN VALUES ☐

GAP - DROP MEASUREMENTS ☐

Ref. Sec. of Std.
11.1.2
11.6.1
11.6.4

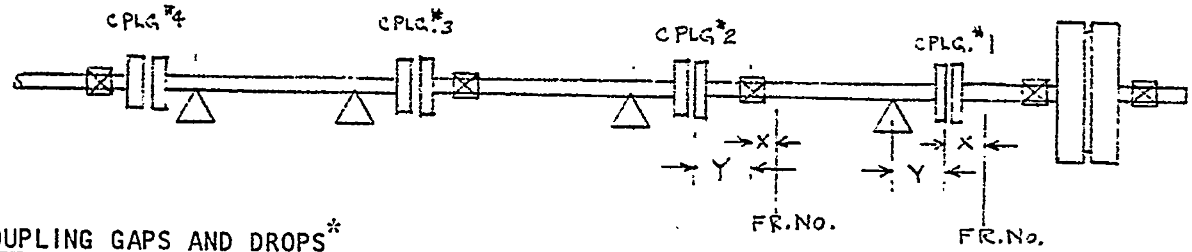
CONDITIONS

SHIP CONDITION: BUILDING WAY ☐ DRY DOCK ☐ WATERBORNE ☐

PROPELLER MOUNTED ☐ OFF ☐

SUPPORT POSITIONS	A	B	C	D	E	F	G	H	I	-
TYPE (Temp. or Brg.)										
FRAME NO.										
DIST. AFT OF FRAME-X										
CPLG. NO.										
DIST. FROM CPLG. - Y										

I H G F E D C B A



COUPLING GAPS AND DROPS*

CPLG. NO.________

CPLG. NO________

CPLG. NO.________

CPLG. NO.________

CPLG. NO.________

CPLG. NO.________

*A positive drop indicates fwd. flange is above, or to stbd., of after flange.

ENGINEER______________________ DEPT.________________

MACHINIST_____________________ DEPT.________________

TABLE x6 HYDRAULIC JACKING OF BEARINGS

HULL NO.______ DATE____________

CONDITIONS Ref. Section 12.2 of Std.

REDUCTION GEAR OPERATING CONDITION - COLD - OIL TEMP. °F
- HOT - OIL TEMP. °F
- SIMULATED HOT - OIL TEMP. °F

SHIP HULL CONDITION - LIGHT SHIP - DRAFT FWD____, AFT____
DRAFT FWD____, AFT____

FORCE MEASUREMENT BY HYD. PRESSURE BY LOAD CELL

BEARING NO.______ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:

HYD. PRESS.	
LOAD CELL RDG.	
DIAL GAUGE RDG.	

JACKING DOWN:

HYD. PRESS.	
LOAD CELL RDG.	
DIAL GAUGE RDG.	

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT__________
CONVERSION FACTOR FOR PRESSURE TO FORCE__________
JACK LOAD__________POUNDS
CORRECTION FACTOR FOR JACK POSITION__________

BEARING REACTION__________POUNDS

BEARING NO.______ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:

HYD. PRESS.			
LOAD CELL RDG.			
DIAL GAUGE RDG.			

JACKING DOWN:

HYD. PRESS.					
LOAD CELL RDG.					
DIAL GAUGE RDG.					

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT__________
CONVERSION FACTOR FOR PRESSURE TO FORCE__________
JACK LOAD__________POUNDS
CORRECTION FACTOR FOR JACK POSITION

BEARING REACTION POUNDS

ENGINEER DEPT.

September 9, 1980

INSTALLATION OF PROPULSION SHAFTING FOR A SHIP WITH A DIRECT DRIVE DIESEL ENGINE

1. Scope

1.1 This procedure describes a method for the direction and documentation of the installation and alignment of the propulsion shafting for a marine propulsion system composed of the main diesel engine, line shafting completely inboard, and either one or two stern tube bearings.

1.2 The pcwer unit is a slow-speed diesel engine, directly connected to the line shaft.

2. Summary of Method

2.1 A line-of-sight is established from the center of the engine output flange, with the engine in an initial design position, to the center of the aft end of the stem tube. This reference centerline is later corrected to the installed position of the stem tube bearing.

Design calculations are performed to determine the proper displacement and alignment of each shaft bearing, in relation to the reference centerline, which will give the design bearing load distribution and acceptable reactions at the engine coupling. The stern tube bearings and line bearings are each positioned at their individual design displacements from the reference centerline, in both the vertical and horizontal directions. Special checks are made to insure that the journals of the line and stern tube bearings have proper contact over the bearing surface.

After the ship is waterborne, and the shaft sections completely coupled, and the main diesel engine chocked in position, the bearing reactions are measured to determine compliance with the design reactions. The line bearing positions may be finally adjusted, by a calculated displacement, to improve the compliance.

2.2 The basic steps in the installation and alignment procedure are given in Table 1.

TABLE 1

Procedure of Operations	Reference Section
Establish initial shaft centerline	7
Machine shaft to final length dimension	8
Bore the stem tube for bearing shells	9
Install the stern tube bearing	10
Align the main engine and the line shaft bearings	11
Measure bearing reactions	12
Documentation	13

3. Significance of Installation Standard

3.1 An installation standard for propulsion shafting which includes adequate documentation will minimize the chance of out-of-tolerance in shaft alignment and will permit the identification of events which may have caused an out-of-tolerance.

3.2 An installation standard for propulsion shafting will ensure that all parties concerned with the process are aware of the necessary steps and the objectives of the alignment procedure.

4. Definitions

centered telescope - the condition of the optical alignment telescope, mounted on a shaft flange, when the telescope is in the center of the flange and perpendicular to the face. A line of sight from a centered telescope maintains a constant target position as the mounting flange is rotated.

cross hair position - the position of optical target cross hairs relative to the cross hairs of the optical alignment telescope, as viewed through the telescope. The designation “up” means that the target *cross* hairs are above the telescope cross hairs; “starboard” means that the target cross hairs are to starboard of the telescope cross hairs, etc.

drop - vertical or transverse position of one flange relative to a mating flange, measured at the flange rims. A drop reading designated positive means that the forward flange is either above, or to starboard, of the aft flange. Same as "sag" or "rim".

engine chock - one of the fitted chocks under the main engine which are used to align the main engine crankshaft.

engine flange - the output flange of the main engine crankshaft; as a reference point, the aft face of the flange.

gap - opening between mating flange faces at the top, bottom and sides of the flange perimeters.

gap-drop method - the method of aligning shafting using relative positions of mating flanges. Same as the "gap-sag” method.

hydraulic jacking method - a method of measuring the vertical force on each shaft bearing. Also called the bearing method, the shaft weighing method, and the method of measured bearing reactions.

line bearing - journal bearing supporting a line shaft section, located between the engine and the stern tube.

propeller bearing - the shaft bearing immediately forward of the propeller.

propulsion shafting - shafts used to transmit paver from the main engine to the propeller, including the tail shaft.

shaft centerline - an axial centerline through the shaft centers at the supporting positions. The bearing centerlines are above the shaft centerline by 1/2 the bearing clearance.

stern tube bearing - the bearings which are enclosed within the stern tube and support the tail shaft.

tail shaft - the section of propulsion shafting which mounts the propeller. Same as the propeller shaft.

5. Apparatus

5.1 Optical alignment telescope with right angle eyepiece and built in optical micrometers for measuring displacements from the line-of-sight along two orthogonal axes (two-plane micrometer). Maximum tolerances for the telescope are one part in 200,000 for measurements along the line-of-sight and 0.5 seconds (0.000139 deg) of arc for measurements at right angles to the line-of-sight.

5.2 Bracket for mounting and adjusting the position of the telescope cm the face of the shaft flange.

5.3 Open optical alignment targets with cross hairs mounted within adjustable target holders.

5 . 4 Hydraulic jack and pressure gauge combination, calibrated to ±2% of full-scale, capable of- raising the Shafting completely off each individual bearing.

5.5 Dial gauges for measuring shafting displacements in the hydraulic jacking procedure, accurate to ±0.0005 in. (±0.0127m), with mounting fixture to hold the gauge firmly.

5.6 Laser beam as an alternate to optical alignment telescope.

5.7 Strain gauges for deriving bearing loads from shaft strain measurements; alternate procedure to the use of hydraulic jack and pressure gauges.

5.8 Hydraulic jack and load cell as an alternate to hydraulic jack and pressure gauge combination.

6. Alignment Requirements' and Supporting Data

6.1 The shaft installation design and the alignment specifications are developed to meet certain objectives with respect to bearing loads, shaft stresses, and vibration response. These objectives are outlined in Annex Al. After the shafting design has been developed, engineering calculations are made to establish the design bearing positions relative to a reference centerline. Calculations are also made as required for the determination of the actual position of the bearings during the alignment operation. The design bearing positions and the alignment calculations may be compiled in a document of propulsion shafting installation data. The document should also include alignment data, such as that suggested in Tables Xl, X4 and X5 of the Appendix, which would be useful for any realignment of the shafting in service.

6.2 Calculations for Alignment

6.2.1 The calculations required for the installation and alignment procedure are outlined in the following sub-sections.

6.2.2 Bearing Load Calculation. An analysis of the shafting as a beam on multiple supports.

Input - Shafting design information.

Determinations - Bearing positions and slope of bearing journals for selected bearing reactions, as shown in Table Xl.

6.2.3 Influence Number Calculation. A supplementary analysis to that of 6.2.2.

Input- Shafting design information.

Determination - The change in each bearing reaction for a given change in the position of one bearing. Done for each bearing of the system and used to correct the bearing positions, see 12.4

6.2.4 Gap-Drop Calculation. A calculation of the deflection of each - shaft section, uncoupled, as a simple beam on two supports.

Input - Shafting design information, plus the location of supports, see 11.1.2.

Determination - Design values of gap and drop at each coupling connection, which are used to align the shafting and engine, see 11.6.

6.2.5 Hydraulic Jacking Calculations. Analysis of hydraulic force versus deflection readings.

Input - Hydraulic pressure, or load cell readings, and deflection readings from 12.2.

Determination - Bearing reaction forces for comparison with design requirements of Table Xl.

6.2.6 Strain Gage Analysis. An analysis of strain measurements on the shaft surface to determine the corresponding bearing reactions.

Input - Strain gage data from 12.3.

Determination - Bearing reaction forces for comparison with design requirements of Table XI.

Procedure of Operations

7. Establish Initial Shaft Centerline

7.1 Position the Main Engine

7.1.1 Land the main diesel engine on the structural foundation members using either jacking screws or temporary alignment blocks for support, but without permanent chocking. Position the engine in the horizontal plane at its proper position relative to the structural foundation.

7.1.2 Position the engine crankshaft in a longitudinal location within the engine bedplate to satisfy the design clearances of the main thrust bearing and hold this position mechanically until all shafting is coupled in 11.7.

7.2 Establish Preliminary Engine Alignment Data

7.2.I Center an optical alignment telescope on the engine flange. Confirm the centered telescope position by the procedure given in Annex A2. Center optical targest at the forward end, the midpoint, and the aft end of the stern tube.

7.2.2 An alternate procedure would be to center the optical telescope, mounted at the aft end of the stern tube, on the forward and aft targets in the stern tube and take a line of sjght to a centered target on the face of the engine flange.

7.2.3 The position of the three targets relative *to* the line-of-sight from the centered telescope should be measured with the engine flange in the 0° and 180° positions. Record the target positions in Table X2. Make a preliminary assessment of whether or not the stern tube and main engine are aligned within the limits of normal alignment adjustments.

7.3 Monitor Hull Distortion

7.3.1 The machinist may use the centered alignment telescope and the stern tube targets *to* periodically repeat the readings of 7.2.3 while the welding and machinery installation are being completed. A history of consistent readings will indicate that hull distortion has leveled off.

7.3.2 Proceed to stern tube boring (Section 9) when hull welding and installation of heavy components have been completed to the criteria established by the engineering department.

NOTE 1 - Readings taken with the optical alignment telescope will be definitely effected by distortion of the ship hull due to temperature of the air, solar radiation, and weight loading. For comparable readings, the telescope should be used at the same time of the day, preferably at night, and under similar ship conditions.

NOTE 2 - In this procedure, and in following sections, a line-of-sight established by a laser beam may be used in lieu of an optical alignment telescope.

8. Machine Shaft to Final Length Dimension

8.1 Measure the distance between the engine flange and the aft face of the stern tube.

8.2 One section of the line shafting may serve as a make-up section with excess thickness at one flange face. From the overall length measurement of 8.1, and the finished lengths of the other sections, determine the required length of the make-up section. Determine the amount of material to be machined from the face of the over-size flange, with tolerances.

8.3 Finish machine the flange face of the make-up section to give the required length. Confirm the shaft length by measurement.

9. Bore the Stern Tube for Bearing Shells

9.1 Position the Boring Bar for the Aft Bearing

9.1.1 Mount the boring bar in the aft bearing position. Using the optical alignment telescope centered on the engine flange, as in 7.2.1, establish the line-of-sight which is the reference centerline. Adjust the position of the boring bar to bring its target cross-hairs to the design positions, relative to the reference centerline, given in Table XI, see Note 3. The bore design position given in Table XI may be based either on a bearing parallel to the reference centerline, or on a bearing sloped in relation to the reference centerline.

9.1.2 Measure the position of the boring bar centerline relative to the rough bore of the stern tube. The machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the shell.

9.1.3 If the boring bar position is too far off-center to give a complete peripheral fit, it will be necessary to reposition the bar to a new reference centerline and reposition the main engine accordingly. The main engine position has to permit use of alignment chocks with adequate thickness. Re-establish the boring bar position as in 9.1.1 and recheck the stern tube bore position as in 9.1.2.

9.1.4 In the procedures of 9.1.1 to 9.1.3, the optical telescope may be alternately positioned at the aft end of the stern tube with a line-of-sight perpendicular to, and centered on, a target on the engine flange.

9.1.5 If a forward stem tube bearing is not provided, proceed to 9.3.

9.2 Verify the Position to be Taken by the Forward Bearing

9.2.1 Use the design position for the forward stern tube bearing, given in Table XI., as the position to be used for the boring bar at the forward end of the stern tube, relative to the line-of-sight from the engine flange established in 9.1.1.

9.2.2 Center two optical targets at the forward and aft ends of the stem tube forward bearing position. Record the cross-hair positions for the targets, relative to the line of sight, in Table X2.

9.2.3 Using the reference line-of-sight from the engine flange of 9.1.1, and the design position of 9.2.1, and the actual stern tube center position of 9.2.2, the machinist will confirm that the boring for the bearing shell will provide a complete peripheral fit for the forward bearing.

9.2.4 If a complete fit will not be provided, reposition the reference line-of-sight by repositioning the engine and repeat steps 9.1.1 to 9.1.3 and 9.2.1 to 9.2.3.

9.3 Bore the Stern Tube for the Aft Bearing

9.3.1 Position the complete boring machine at the stem tube ready for boring. The boring bar has been set in 9.1.1 at the design position given in Table X1 relative to the reference centerline, see Note 3.

NOTE 3 - The reference centerline represents the center of the shaft at the bearing locations. The optical telescope centered on the gear shaft flange is located on the reference centerline. The design position for the boring bar centerline would be located above the reference centerline by 1/2 the diametral clearance of the bearing to be installed at that location. The design position for the bearing bore, as given in Table XI , may be farther displaced from the reference centerline by an amount selected to achieve a. design "fair curve" al alignment.

9.3.2 Bore for the aft stern tube bearing according to the applicable shipyard drawings. Do not move the boring bar in anyway during the boring process by readjustment of any supporting device for either the boring bar or the boring machine. While boring, the machinist should check the location of the boring bar relative to the design position, using a telescope aligned to the reference centerline, to insure that the proper boring line is being maintained, especially before the final finish cut.

9.3.3 Measure the finish bore for the aft bearing. The measurements are to be taken at 4 to 6 in. intervals along the bearing bore within the stern tube on diameters at 0°, 45”, 90° and 135° from vertical. If possible, take measurements in the early morning or evening when temperature conditions are more stable. Record time, temperature, and measurements of the machined bore in Table X4. Also record the location and type of any other work executed on the stern tube after the bore machining.

9.4 Bore the Stern Tube for the Forward Bearing

9.4.1 Establish the reference centerline of 9.1.1 at the forward bearing location.

9.4.2 Although the bore is shorter than the aft bearing bore, the boring procedure duplicates that of steps 9.3.1 to 9.3.3.

NOTE 4 - The measurements of the aft stern tube bores, and the bearing outer diameters, Table X4, should be completed by the same machinist. Similarly, the measurements for the forward bearing fit should be completed by the same machinist.

10. <u>Install the Stern Tube Bearings</u>

10.1 The machinery foremen and engineering personnel will establish the machined dimension, with tolerances, for the outer diameter of the stern tube bearing shells. The dimension values will be based on the measured bore dimensions of 9.3.3 and 9.4.2, plus an allowance to give the design interference fit, and plus an allowance for the difference between metal temperatures in the hull and in the machine shop.

10.2 Record the required dimensions for the stern tube bearings in Table X4.

10.3 Machine the bearing shell outer diameters to the required dimensions of Table X4.

10.4 After finish machining, measure the bearing outer diameters at 4 to 6 inch intervals along the bearing length, on diameters at 0°, 45°, 90° and 135° from the vertical. To confirm concentricity, measure the bearing radial wall thickness at the forward and aft ends of each bearing and record in Table X4.

10.5 Record machined dimensions and ambient temperature in Table X4. Determine the interference fit at each interval, at the ship hull temperature conditions, and record in Table X4.

10.6 Install the stern tube bearings with a drive fit. Complete the installation conditions listed in Table X4 for the aft and forward bearings, before and after the bearing installation. Record the hydraulic force required to drive each bearing.

10.7 Center a telescope on the engine flange as in 7.2.1 and Annex A2. Mount optical targets in the bore of the aft stern tube bearing, at the aft and forward ends, centered in the bore.

10.8 Reposition the engine, if necessary, to bring the forward and aft target centers in the aft bearing bore to the design position of Table XI. This line-of-sight, from the centered telescope to the finished bore of the installed aft bearing, becomes the final reference centerline.

10.9 Mount optical targets in the bore of the foward stern tube bearing, if fitted, and measure the bearing position in relation to the new reference centerline of 10.8. Record target positions in Table XI.

10.10 Using the reference centerline of 10.8, establish the horizontal and vertical planes of the centerline and record the centerline position by permanent markings on the aft peak bulkhead on both sides of the shaft seal housing. Provide a temporary reference bracket, welded to the bulkhead in the vertical plane, to permit micrometer measurements to the top surface of the shaft. Establish the position of the reference surface above the reference centerline of 10.8 and record in Table XI.

11. Align the Main Engine and the Line Shaft Bearings

11.1 Preparation for Alignment

11.1.1 The preceding sections have established a final reference centerline from the installed position of the aft stern tube bearing to the center of the engine flange, and normal to that flange. This section outlines the procedures for positioning the line bearings at their design positions, vertically and horizontally, relative to the reference centerline. For some ships, the design position of the shaft at the bearings may be on the reference centerline. For higher power ships with machinery aft, the design position of the shaft at all the bearings may be displaced from the reference centerline along a fair-curve or "rational alignment", which establishes acceptable bearing loads. Positioning the line shaft bearings may be accomplished either by optical methods or by the gap-drop method described in 11.5 and 11.6 respectively. The gap-drop method is not readily adaptable to shafting with internal piping for controllable pitch propeller systems.

11.1.2 If the gap-drop method is to be used, engineering personnel should examine the structural details and arrangement of piping and auxiliary machinery beneath the line of shafting and select locations for temporary shaft supports which will provide two points of support for each section of shafting. After the temporary supports have been installed, engineering personnel will verify the longitudinal position of the center of each temporary support and each bearing from a known frame station and record the locations in Table X5. These positions become the design positions for the gap-drop calculation.

11.2 Alignment of the Main Engine.

11:2.1 The main diesel engine-is originally aligned during assembly in the manufacturer's workshop. Measurements are made to record the alignment of the engine bedplate; the gap between webs of the crankshaft is determined; and clearances at the crankshaft bearings are established.

11.2.2 The engine bedplate and crankshaft are originally positioned in relation to the engine foundation structure, see 7.1.1, and supported either by jackscrews or temporary chocks. Some shipyards may elect to install the engine as a complete assembly, and the alignment procedure is similar. After the stern tube bearings have been installed, the engine may be repositioned to the final reference centerline, see 10.8. After the shafting has been installed, the engine crankshaft, or thrust shaft, may be aligned to the line shaft. This is done traditionally by gap-drop measurements at the engine flange. Final engine alignment adjustments are made after the engine is completely assembled, the line shaft is installed, and the ship is in the water.

11.2.3 The internal alignment of the engine bedplate is done in the assembly shop, and duplicated on shipboard, by either establishing offset measurements from a tight piano wire, or by optical sights on targets, or by laser beam on targets. Checks for out-of-plane deflections of the bedplate may also be made by straight edge and spirit level.

The alignment of the crankshaft is checked by measuring the gap between the crankshaft webs at each cylinder with the crank up, and with the crank to either side of the down position. Clearances at the crank shaft bearings are also checked. Deviations in these measurements which exceed the manufacutrer's tolerances will be corrected by either scraping the bearings or adjusting the bedplate chocks.

11.2.4 The relative alignment between the engine crankshaft, or thrust shaft, and the ship line shaft is established by the required gap-drop measurements at the engine flange. With the required gap-drop measurements, the line shaft will impose acceptable shear load and bending moment on the crankshaft after being coupled. The gap-drop values will include- an allowance for thermal expansion, settling of the engine, and hull deflection as the manufacturer may consider appropriate. [f the engine chocking must be changed to establish the required gap-drop values, the internal alignment of the engine must be re-established as in 11.2.3. If the line shaft bearings are aligned by optical methods, it would still be appropriate to use gap-drop values to align the engine/line shaft coupling.

11.2.5 The description of engine alignment is included to correlate those procedures with the line shaft alignment procedure. The engine. manufacturer's requirements and instructions give more specific details and take precedence in every case.

11.3 Installation of Shafting

11.3.1 Install the tail shaft and outboard shaft seal. Place the inboard shaft seal around the shaft but do not bolt the seal to the bulkhead. Mount the propeller. At this time the line bearing foundations and the temporary supports would be in place. Place the line shafting and line bearings in position. In the usual construction sequence, the ship would be launched after these installations have been completed.

11.3.2 With the line shafting and line bearings in place, position the shafting roughly to the reference centerline by use of jacking screw's in the bearing base flanges and by wedges or chocks under temporary supports.

11.3.3 The uncoupled tail shaft becomes a special case because the forward end may tip upwards if the propeller is mounted. If a forward hearing is not provided a temporary support is used to hold (downward force) the tail shaft centerline at the design position, given in Table XI at the plane of the aft peak bulkhead, relative to the reference centerline as established in 10.10. If a forward bearing is provided, a temporary support may be required to seat (downward force) the shaft journal in the forward bearing. If the propeller is not mounted, and there is no forward bearing, a temporary support is used to hold, (upward force] the forward end of the tail shaft at the design position given in Table XI.

11.4 Bearing Surface Contacts

11.4.1 If a forward stern tube bearing is not provided, the bearing contact over the length of the aft stern tube bearing may be checked physically by the following optional procedure before the shafting is coupled. The forward end of the tail shaft is raised and lowered, the jacking force versus the shaft vertical position is recorded, and the total range of physical angularity between the shaft journal and the aft bearing surface is thereby determined. The force will rapidly change when the surface of the journal contacts the forward edge of the bearing surface, top or bottom. The shaft may then be set in the position of design angularity, given in Table XI, within the measured total range of angularity. The corresponding shaft centerline position, vertically and horizontally, at the plane of the aft peak bulkhead may then be recorded in Table XI.

11.4.2 Either the optical method or the gap-drop method of alignment will position the line bearings at the design vertical and horizontal positions to provide the design load reactions. However, the methods do not insure that there is not a skew angle between the bearing and shaft centerlines which would reduce the load capacity of the bearings.

11.4.3 Remove caps of line bearings, wherever possible, for measurement of clearances between the shaft journals and bearing surfaces in a horizontal plane. Maintain equal clearances during the following alignment operations. Also use feeler gauges to check vertical clearances between the shaft journal and the bearing surface at the forward and aft ends of each line bearing to insure that there is contact over the length of the bearing.

11.5 Optical Alignment of Line Bearings

11.5.1 If the line bearings are to be installed before the shafting, they may be positioned optically at their design positions from the reference center-line established in 10.8.

11.5.2 If the line bearings are installed integral with the shafting, it will be necessary to establish an offset line-of-sight parallel to the reference centerline, and in the same vertical plane. Using targets mounted on the shaft, adjacent to the bearings, the bearings can be positioned at their design positions relative to the established line-of-sight. The targets must be accurately centered and vertical in order to achieve accurate horizontal alignment; alternately a line-of-sight may be established in the horizontal plane of the reference centerline to position the bearings in the horizontal direction.

11.6 Gap-Drop Alignment

11.6.1 The gap-drop method uses the uncoupled sections of shafting as alignment gauges to locate the line bearings at the design displacements from the reference centerline. An engineering calculation is performed to determine the gap and drop values that would exist between each set of flanges when the bearings are at their design position from the reference centerline. The calculation includes the effect of the deflection, or "droop", of each section of shafting under its own weight and supported at the two specified points of 11.1.2. The calculated gap and drop values are prepared by the Engineering Department and presented in Table X5. The values apply only under the conditions stated: bearings and temporary supports in the positions given by Table X5, propeller eilther mounted or not mounted, and ship either waterborne or on dry dock.

11.6.2 Maintain the longitudinal posi tion of the bearings and temporary supports established in 11.1.2 within a to lerance of ±0.5 inches (12.7mm) during the alignment operation.

11.6.3 Move line bearings and temporary supports vertically and transversely, either by jacking screws or by wedges, to achieve the gap and drop measurements specified in Table X5 within ±0.001 in. (±0.0254 mm). When measuring the gap and drop at a coupling, push the mating flanges together to make the gap and drop measurements more accurate.

11.6.4 Record in Table X5 the final gap and drop measurements taken when the bearings and temporary supports are in the positons given in Table X5. indicate in the table whether or not the propeller was mounted and whether or not the ship was waterborne. The Engineering Department will signify acceptance of the gap and drop measurements of Table X5, if they are suitable for proceeding to bearing and engine chocking.

11.6.5 The gap-drop method of alignment will give the best results with the hull waterborne and the propeller mounted. The procedure can also be performed without the propeller in place, however, there will be some loss in accuracy because the propeller is a major weight item. The procedure will give least reliable results if the ship is in a dry dock because the hull deflection may differ radically from a normal waterborne deflection line. The design gap-drop values must be calculated for the conditions that will exist at the time of measurement.

11.7 Coupling of the Shafting

11.7.1 All of the shaft coupling connections either flanged, muff-coupling, or hydraulic sleeve type must be made-up complete before the following alignment checks can be performed. The mechanical stops on the longitudinal position of the engine crankshaft should be removed, see 7.1.2.

11.7.2 The forward stern tube seals may be mounted on the bulkhead.

11.7.3 The ship should be waterborne and the propeller in place.

11.8 Chocking of the Main Engine and the Line Bearings.

11.8.1 The shipyard may elect to chock the main engine and the line bearings after these bearings have been positioned by the procedures of 11.4, 11.5 and 11.6. If the above procedures have been completed successfully, the final measurement of bearing reactions will usually result in only a minor readjustment of the line bearings. Performing the chocking after the measurement of the bearing reactions may result in schedule delays for the machinery installation.

11.8.2 Make an inspection of the engine position relative to the foundation supports and structural clearances. Request the approval of engineering and the engine manufacturer's representative to proceed with fitting of chocks under the main engine.

11.8.3 Fit final chocks as specified by the engine manufacturer between the engine bedplate and the ship structural foundation. Fit side chocks as specified by the engine manufacturer with allowance for expansion.

11.8.4 Drill and fit engine foundation bolts and back-off jacking screws. Foundation bolts to be tightened to torque limit set by engine manufacturer. Re-check the crank throw gap measurements during the chocking and bolting procedure, see 11.2.3.

11.8.5 Measure the vertical distance between the line bearing base flange and the bearing foundation surface for each line bearing at the locations where chocks are to be fitted. Machine chocks to fit each location. Check each chock for contact on both surfaces and refit if the contact is less than 80%.

12. <u>Measurement of Bearing Reactions</u>

12.1 Conditions for Measurement

12.1.1 After the journal bearings of the shafting system have been positioned by either the optical or gap-drop methods described in 11.5 and .11.6, the bearing reactions should be actually measured. The measurements may be accomplished by either the hydraulic jacking method (shaft weighing) or by the strain gage method . Some shipyards use one method as the principal procedure and use the alternate method on occasion to check critical bearings.

The measurements should be made with the ship waterborne and the propeller in place. The ideal conditions for measurement would be with ballast hull loading; actually the measurements usually have to be made at a lighter displacement during outfitting.

12.1.2 Any support connections for the main engine should be coupled and properly adjusted.

12.2 Hydraulic Jacking of Bearings

12.2.1 Engineering will select the location at which the hydraulic jack will be applied for measuring each line bearing reaction by the hydraulic jacking method. Measure the axial distance from the jack location to the corresponding bearing and record these data in Table x6. The jack is to be supported on solid steel structure which carries the jack load to a frame or longitudinal member; wooden blocks or posts are not adequate. Assign numbers to each jack position and to the corresponding bearing. The stem tube bearing reactions cannot be conveniently measured by jacking.

12.2.2 Engineering personnel shall conduct the hydraulic jacking procedure at each available line bearing. All bearings should be done in the same time period shortly before or after dock trials when the bearing and engine temperatures are close to actual service conditions. A decision to forego jacking for a particular bearing reaction is the responsibility of the engineering department. A second set of jacking measurements may be taken after sea trial and also under different conditions of vessel loading.

12.2.3 At each bearing, progressive sets of readings (either hydraulic pressure or hydraulic force versus shaft displacement) are taken as the shaft is raised and lowered by the. hydraulic jack. A mean line, plotted through the data reflecting elastic deflection, will indicate the jack reaction pressure at zero displacement. Record the ambient temperature and the engine lube oil temperature. A variation in the procedure is to roll out the bearing and measure the jacking force required to restore the shaft to its operating position.

12.2.4 An alternate method for measuring bearing reactions is to use a load cel to measure the reaction force on the hydraulic jack. This method eliminates the hysteresis effect in the hydraulic fluid pressure. Also it may be conveniently used to measure a bearing reaction plus the simultaneous change in the reactions on adjacent line bearings.

12.2.5 The engineering department will convert the hydraulic force figure of 12.2.3 - 12.2.4 for each bearing to a bearing reaction force by calculating a correction for the axial displacement of the jack from the bearing center plane. Record the corrected bearing reactions in Tables x6 and XI.

12.3 Load Determination by Alternate Strain Gage Technique

12.3.1 An alternate to the hydraulic jacking procedure is the use of strain gages mounted on the surface of the shaft at selected stations to determine shaft strains. By calculation procedures, the strains are converted to bending moments which lead to the determination of the line bearing reactions. Strain measurements are made with the shaft in several rotational positions, correlated with the position of the engine aft crank webs.

12.3.2 The data needed for this method are the weight of the shafting components including the propeller, the shaft diameter at all sections, and the longitudinal position of the bearings.

12.3.3 The application of the strain gages, the strain readings, and the determination of the line bearing reactions are accomplished by the engineering department. The bearing reactions are tabulated in Table XI.

12.3.4 The particular advantage of the strain gage method is that once the strain gages have been applied to the shaft, a complete set of strain readings may be taken in a short period of time. This makes it possible to take a complete set of readings at different hull loading conditions if the sailing schedule permits stopping the main engine for a short period. Another advantage is that the method gives the horizontal reactions on each line bearing in addition to the vertical reactions.

12.4 Corrections to Bearing Positions

12.4.1 The measured bearing reactions of either section 12.2 or 12.3 are compared with the design bearing loads of Table XI. If the compliance with the design load is not acceptable to the engineering department a change in the vertical posit ion of the line bearing will be recommended. By the calculated values of influence numbers, see section 6.2.3, the amount of change in the vertical position of the bearings to correct the loadings can be quickly determined. Recommended changes should generally be in multiples of 0.005 inches (.0.127 mm). If changes are not recommended in cases of marginal compliance, the fact should be noted in Table XI.

12.4.2 If significant changes are made in the chocks to correct the vertical position of the bearings, the engineering department will require another measurement of the bearing reactions to confirm the proper bearing positions, either by hydraulic jacking or by the strain gage method. If no changes are required, the alignment procedure is complete. The final measured bearing reactions should be recorded in Table XI.

13. Documentation

13.1 The record of the shaft installation alignment should be assembled in a "Propulsion Shafting Installation Data" document. The purpose of the document is to describe the results of the shafting alignment and to provide enough information so that the shafting may be readily re-aligned in the future. The document should include at least the following information:

Design bearing positions and reactions, plus the final measured positons and reactions, as suggested by Table Xl.

Angle of the tailshaft in the aft stern tube bearing as given in Table Xl.

Force fit requirements for the stern tube bearings, similar to that of Table X4.

The calculations for alignment, particularly the influence number and the gap-drop values, see 6.3.

13.2 The tables of the Appendix present typical data tabulations for the purpose of illustrating the alignment process. Some sections will not be applicable for the selected method of alignment. Also the data format may have to be adjusted to suit the shaft arrangement, special features of a ship design, and practices of individual shipyards.

To reduce the number of tables, they have been designed to be used by either engineers or machinists on different occasions. The user must define the location and conditions by checking the appropriate box in the heading format.

September 9, 1980

Annex Al

Objectives of the Shafting Alignment Design

A1.1 The design positions of the line bearings are calculated to produce reactions at the engine flange which are acceptable to the diesel engine manufacturer. The deflection characteristics of the engine crankshaft are the responsibility of the engine manufacturer, therefore the manufacturer must specify the allowable alignment conditions at the engine flange. The most exact specification would be the allowable shear force and bending moment imposed on the engine flange when coupled to the line shaft, with the aft crank in a given position. The specified condition has to be translated into design positions for the line shaft bearings and corresponding gap and drop values for the engine flange coupling. As an alternative specification, the engine manufacturer may give gap and drop values at the engine flange, presuming the line shaft stiffness corresponds to the rules of the regulatory bodies.

A1.2 The spacing of the line shaft bearings shall be set to maintain the bearing reactions within the manufacturer's limits. Typical maximum unit loads are 50 psi for line bearings and 100 psi for stern tube bearings. Minimum load to be at least 202 of sum of adjacent shaft span weights.

A1.3 The spacing of the line shaft bearings shall be set with consideration of the lateral modes of shaft vibration. The longitudinal position of the first bearing forward of the propeller bearing will have a major influence on the lateral critical. The engine manufacturer's alignment requirements will influence the position selected for the first line bearing, see A1.1. Within these constraints, the use of a minimum number of bearings should be favored.

A1.4 The design alignment of the shafting should be optimized to give acceptable bearing loads under the normal service conditions of hull deflection. This is particularly significant for ships with short shafting and subject to operation under very different draft conditions.

A1.5 The design alignment should consider all steady forces acting on the shafting system including deadweight loads, propeller buoyancy, and the off-center thrust of the propeller. The resolution of forces and bearing reactions should be made in the vertical and horizontal planes.

A1.6 Positioning the shafting system bearings on a common center line, or line-of-sight, offers the most simple installation procedure. A centerline alignment, however, may not be satisfactory for high power ships with short shaft lines. The bearings must be displaced, or offset, from a reference centerline along a fair curve of alignment to obtain the desired bearing loads and to give proper bearing contacts, particularly at the propeller bearing.

A1.7 The propeller bearing reaction is usually assumed to be located at 0.33 to O.5 x shaft diameter, from the aft end of the bearing, in the case of oil-lubricated bearings. The contact angle between the shaft line and the bearing should not exceed 0.3 x 10-3 radians, as a typical value for bearings with an L/D = 2, in order to maintain a load-bearing oil film. The angle of contact should be checked for the possible range of hull deflections to insure that the angle does not become negative, indicating contact at the forward end of the bearing. To achieve the desired angle of contact it may be necessary either to lower the design position of the bearings forward of the propeller bearing, or to position the propeller bearing with a fixed slope relative to the reference centerline. To ensure a satisfactory oil film, the diametral clearance should be .0013 - .0017 x shaft diameter.

A1.8 The strength of the shafting shall comply with the rules of the Regulatory Bodies. Bending and torsional stresses shall be carefully considered at local areas of stress concentration.

A1.9 The alignment of the shafting is made with the shaft at rest. The oil film thickness under operating condition should be included in the calculation of the cold alignment offsets. Also the weardcwn of the propeller bearing in service should be included in the calculation of the fair curve of alignment.

September 9, 1980

Annex A2

Centering an Optical Alignment Telescope

A2.1 Mount an optical alignment telescope on the engine flange. Confirm the centered telescope position using the follwing steps:

A2.2 Place optical targets at the forward and aft ends of the stern tube such that the two target cross-hair positions can be measured using the built-in optical micrometers of the telescope. Note that the targets need not be centered within the stern tube.

A2.3 Take telescope readings in the horizontal and vertical directions for both targets.

A2.4 Rotate the engine flange 180°. If the target cross-hair positions are within the telescope field after the flange rotation, take telescope readings in the horizontal and vertical directions for both targets and continue to A2.5. If the target cross-hair positions are not within the telescope field after the flange rotation, adjust the position of the targets, or the telescope, or both, without changing the longitudinal locations of the targets, such that the target cross-hair positions can be measured before and after a 180° engine flange rotation. If the target or telescope positions are changed, return to A2.3.

A2.5 Compare the readings of A2.3 and A2.4. For each target the horizontal readings at zero rotation must be identical (within telescope accuracy) to the horizontal readings of the same target at 180° rotation. Similarly, for each target, the vertical readings must be identical (within telescope accuracy) at each rotated position. The telescope is centered only if these readings are equivalent for both targets. If the readings are not equivalent, adjust the telescope position and return to A2.3. Note that the readings for the two different targets need not be equivalent.

APPENDICES

XI Design Alignment Requirements and Installation Results

X2 Alignment Readings

X3 (not applicable)

X4 Stern Tube Bearing Fit

X5 Gap-Drop Alignment

x6 Hydraulic Jacking of Bearings

TABLE XI

DESIGN ALIGNMENT REQUIREMENTS
AND INSTALLATION RESULTS

HULL NO.______ DATE______________

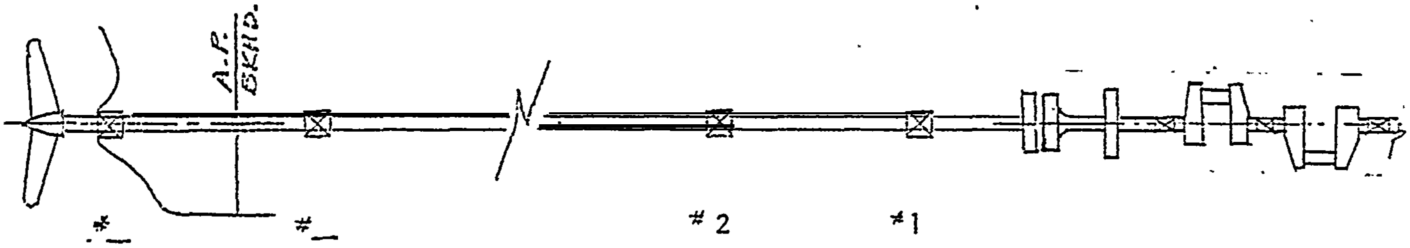
PROCEDURE		Ref. Sec. of Std.
DESIGN BEARING REACTIONS AND BEARING POSITIONS	☐	6.2.2
MEASURED BEARING REACTIONS	☐	12.2.5/12.3.3

CONDITIONS

MAIN ENGINE OPERATING CONDITION - COLD ☐ OIL TEMP_____°F
- HOT ☐ 01 L TEMP_____°F

ENGINE CRANK POSITION ______________________

SHIP HULL CONDITION LIGHT SHIP ☐ DRAFT FWD__ AFT__
LOADED ☐ DRAFT FWD__ AFT



BRG. No.	DESIGN SHAFT POS. FROM REF. CL: VERTICAL inches	HORIZ. inches	MEASURED FINAL SHAFT POSITION FROM REF. CL* VERTICAL inches	HORIZ. inches	DESIGN BEARING REACTION pounds	FINAL MEASURED REACTION pounds
3						
4						
5						
6						

.L.. POSITION A.P. BKHD.					(See 10.10 and 11.3.3)	
	VERTICAL inches	radians	VERTICAL inches	ANGULAR radians	ENGINE FLANGE DESIGN	FORCE-lbs MEASURED
ENGINE FLANGE +	-	4				

PROPELLER BEARING DESIGN CONTACT ANGLE______________________________radians

MEASURED LIMITS OF CONTACT ANGLE AT A.P. BULKHEAD (See 11.4.1):

UP POSITION, MEASURED FROM REF. CENTERLINE________ inches

DOWN POSITION, MEASURED FROM REF. CENTERLINE_______ inches'

CALC. POSITICN REL. TO REF. CL TO GIVE DESIGN ANGLE______ inches above
inches below

*Positive values indicate position above, or to star board reference centerline.

ENGINEER DEPT.

TABLE X2 ALIGNMENT READINGS

HULL NO. ______ DATE ______

STERN TUBE AFT BEARING ☐ or FORWARD BEARING

OPERATION		Ref. Sec. of Std.
INITIAL LINE-OF-SIGHT	☐	7.2.4/7.3.1
BORING BAR POSITION - AFT BRG . BORE	☐	9.1.2
STERN TUBE CENTER POSITION - FWD BRG . BORE	☐	9.2.3
FINAL BORING BAR POSITION - FWD BRG. BORE	☐	9.4.2
INSTALLED BEARING POSITION - FWD BRG.	☐	10.9

CONDITIONS

SIGHTING: FROM GEAR FLANGE TO STERN TUBE ☐
FROM STERN TUBE TO GEAR ☐

INSTRUMENT: CENTERED OPTICAL TELESCOPE ☐
LASER BEAM ☐

WEATHER: CLOUDY______ FAIR______ AIR TEMP. ______°F

INCOMPLETE HULL STRUCTURE, AFT______

OPTICAL ALIGNMENT READINGS

TARGET POSITION	DISTANCE OF TARGET TO SCOPE	TELESCOPE READINGS* INITIAL SHAFT ROTATION VERTICAL	HORIZ.	SHAFT ROTATED 180° VERTICAL	HORIZ.
AFT					
FORWARD					
CENTER					

TIME OF DAY______

AFT					
FORWARD					
CENTER					

TIME OF DAY______

AFT					
FORWARD					
CENTER					

TIME OF DAY______

Positive readings indicate target cross hairs are above, or to starboard, of telescope line-of-sight.

MACHINIST DEPT.

TABLE X4 STERN TUBE BEARING FIT

HULL NO. ______ DATE ____________

STERN TUBE AFT BEARING ☐ or FORWARD BEARING ☐

OPERATION		Ref. Section of Std.
STERN TUBE BORE MEASUREMENT	☐	9.3.3 /9.4.2
REQUIRED BEARING SHELL O.D.	☐	10.2
FINISHED SHELL O.D. MEASUREMENT	☐	10.4 .
BEARING INSTALLATION	☐	10.6

CONDITIONS

STERN TUBE METAL TEMP. ______°F AIR TEMP °F

BEARING SHELL METAL TEMP. °F AIR TEMP °F

BORE I.D. AND SHELL O.D. MEASUREMENTS

DISTANCE FROM AFT END OF BORE OR SHELL	DIAMETERS, AT ANGLES FROM VERTICAL, LOOKING FORWARD: 0°	45°	90°	135°	INTERFERENCE, BRG. SHELL O.D. MINUS BORE I.D.
Lo @ O inches					
L1 @ inches					
L_2 @ inches					
L3 @ inches					i
L4 @ imches				i	
L_5 e inches					
L6 @ inches					
L_7 @ inches					
L8 @ inches					
L9 @ _ inches				.	
L 10 inches					

BEARING CONCENTRICITY

RADIAL WALL THICKNESS (shell plus babbitt) ANGULAR POSITIONS, LOOKING FORWARD

AFT END ________

FORWARD END ______ ________________________________

BEARING INSTALLATION

HYDRAULIC FORCE REQUIRED TO DRIVE BEARING: ________TONS

________% APPROX.

MACHINIST ________________________ DEPT. ____________________

ENGINEER DEPT.

TABLE X5 | GAP - DROP ALIGNMENT | Direct Diesel Drive/Inboard Shaft

HULL NO. ________ DATE ____________

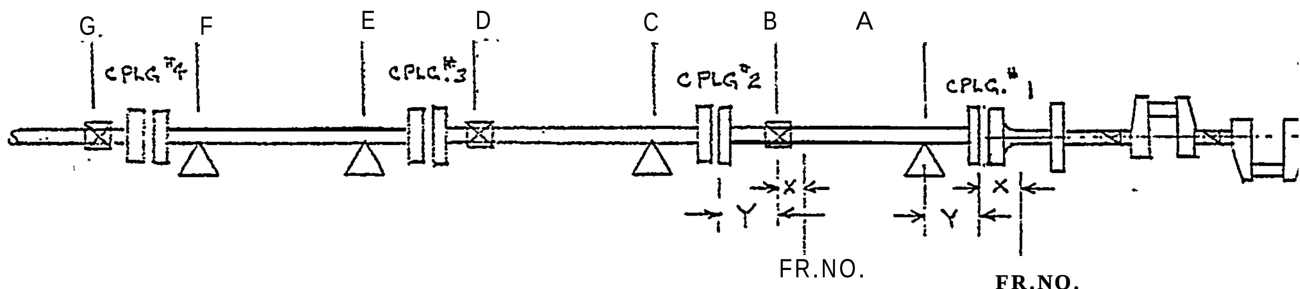
OPERATION	Ref. Sec. of Std.
LOCATION OF SHAFT SUPPORTS ☐	11.1.2
GAP - DROP DESIGN VALUES ☐	11.6.1
GAP - DROP MEASUREMENTS ☐	11.6.4

CONDITIONS

SHIP CONDITION: BUILDING WAY DRY DOCK WATERBORNE ☐

PROPELLER MOUNTED OFF

SUPPORT POSITIONS	A	B	C	D	E	F	G	H	I	J
TYPE (Temp. or Brg.)										
FRAME NO.										
DIST. AFT OF FRAME-X										
CPLG. NO.										
DIST. FROM CPLG. -Y										



COUPLING GAPS AND DROPS*

CPLG. NO. ________ CPLG. NO ________ CPLG, NO, ________

L

CPLG. NO. ________ CPLG. NO. ________ C~LG, NO, ________

o

*:A positive drop indicates fwd. f ange is above, or to stbd., of after flange.

ENGINEER ____________________ DEPT. ________________

MACHINIST ____________________ DEPT. ________________

TABLE X6 HYDRAULIC JACKING OF BEARINGS

HULL NO._____ DATE____________

CONDITIONS

Ref. Section 12.2 of Std.

MAIN ENGINE OPERATING CONDITION - COLD ☐ OIL TEMP. °F
- HOT ☐ OIL TEMP. _____° F

ENGINE CRANK POSITION ____________________

SHIP HULL CONDITION - LIGHT SHIP DRAFT FWD , AFT
- LOADED ☐ DRAFT FWD AFT

FORCE MEASUREMENT BY HYD. PRESSURE BY LOAD CELL ☐

BEARING NO._____ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:
HYD. PRESS.
LOAD CELL RDG.
DIAL GAUGE RDG.

JACKING DOWN:
HYD. PRESS.
LOAD CELL RDG.
DIAL GAUGE RDG.

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT________
CONVERSION FACTOR FOR PRESSURE TO FORCE________
JACK LOAD________POUNDS
CORRECTION FACTOR FOR JACK POSITION________

BEARING REACTION________POUNDS

BEARING NO._____ JACK C.L. FROM END OF BRG. SHELL: FWD______INCHES
AFT______INCHES

JACKING UP:
HYD. PRESS.
LOAD CELL RDG.
DIAL GAUGE RDG

JACKING DOWN:
HYD. PRESS.
LOAD CELL RDG.
DIAL GAUGE RDG.

MEAN PLOTTED PRESS (OR LOAD CELL RDG) AT ZERO DISPL. OF SHAFT
CONVERSION FACTOR FOR PRESSURE TO FORCE
JACK LOAD________POUNDS
CORRECTION FACTOR FOR JACK POSITION

BEARING REACTION POUNDS

ENGINEER DEPT.

ASTM Designation: F

STANDARD SPECIFICATION FOR COMMERCIAL STEEL HYDROPNEUMATIC POTABLE WATER TANKS [1]

1. Scope

1.1 This standard specification covers steel hydropneumatic potable water tanks in the capacity range 200 gallons to 600 gallons, for vertical installation. Two types are provided, for operating pressures up to 100 PSI and 150 PSI respectively.

NOTE 1: The values stated in U.S. Customary Units are to be regarded as standard.

2. Applicable Documents

2.1 ASTM Standards

A105 Standard Specification for Forgings, Carbon Steel, for Piping Components.[2]

A106 Specification for Seamless Carbon Steel Pipe for High Temperature Service.[2]

A285 Standard Specification for Pressure Vessel Plates, Carbon Steel, Low-and-Intermediate-Tensile Strength.[3]

A515 Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-and-Higher-Temperature Service.[3]

[1] This standard specification is under the jurisdiction of ASTM Committee on

[2] Annual Book of ASTM Standards, Part 1

[3] Annual Book of ASTM Standards, Part 4

A663 Merchant Quality Hot-Rolled Carbon Steel Bars subject to Mechanical Property Requirements.[4]

A675 Special Quality Hot-Rolled Carbon Steel Bars Subject to Mechanical Property Requirements.[4]

2.2 ANSI Standards

B16.5 Steel Pipe Flanges and Flanged Fittings 150, 300, 400, 600, 900, 1500 and 2500 lb.[3]

2.3 Other Standards

ASME Section VIII Div. I Boiler and Pressure Vessel Code.[5]

The Code of Federal Regulations 46 CFR. Part 54

American Bureau of Shipping Rules for Building and Classing Steel Vessels 1979. Group 11 Unfired Pressure Vessels.[7]

[4]Annual Book of ASTM Standards, Part 5

[5]Available from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, New York 10017

[6]Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

[7]Available from American Bureau of Shipping, 65 Broadway, New York, New York 10006

3. Classification

Type I 100 PSI maximum allowable working pressure

Type II 150 PSI maximum allowable working pressure

4. Ordering Information

4.1 Orders for tanks to this specification shall include the following information:

4.1.1 Quantity

4.1.2 Inside diameter (in.)

4.1.3 Capacity (gal.)

4.1.4 Type (Type I or Type II)

4.1.5 Orientation and size of all service connections, nozzles, vents and drains.

4.1.6 Critical dimensions for supports and sway braces, or attachments for sway braces, as required.

4.1.7 Size and location of manhole or threaded and plugged-inspection holes.

4.1.8 Required internal and external finishes.

4.1.9 ASTM designation and date of issue.

5. Manufacture and Materials

5.1 Tanks shall be of all-welded construction, (see Fig. 1).

5.1.1 Shells shall be made from carbon steel plate to ASTM AS15 Grade 70 and of thicknesses specified in Table 1. More than one course may be used where necessary for longer tanks.

5.1.2 Service connections 2 inches and below are to be 3000 lb. steel couplings ASTM A-105 and service connections above

2 inches are to be flanged ASTM-A-106 GR A seamless extra strong pipe nozzle and 150 lb or 300 lb ANSI B16.5 SH flange, ASTM-A-105.

5.1.3 Heads shall be of seamless construction, and made from carbon steel plate to ASTM A515 Grade 70. Thickness shall be as specified in Table 1. The form shall be ASTM ellipsoidal (2:1 ellipse), with 2 in. long integral skirts.

5.1.4 Welding

5.1.4.1 Longitudinal weld seams in the shell shall be as shown in Fig. 2. Where two or more courses are used, longitudinal welds in adjacent courses shall be staggered by not less than five times the shell plate thickness.

5.1.4.2 Circumferential welds between courses shall be as shown in Fig. 3.

5.1.4.3 Circumferential welds between heads and shell shall be as shown in Fig. 4.

5.1.4.4 For galvanized tanks, all welds shall be “brushed blasted”. “Bright blasted” finish is not acceptable.

5.1.5 Shell and Head Openings

5.1.5.1 No opening in the shell shall be closer than ½ in. from any longitudinal or circumferential weld seam in the tank plating.

5.1.5.2 All openings in the shell or head shall be normal to the plating.

5.1.5.3 30 in. and 36 in. inside diameter tanks shall have two threaded pipe plug inspection openings, one located near to each end of the shell. ASTM A105 3000 lb. threaded full-or-half-couplings and square or hex headed plugs shall be used. Openings to be not less than 2 in. nominal pipe size.

5.1.5.4 48 in. inside diameter tanks shall be provided with one elliptical or obround 11 in. by 15 in. minimum ASME boiler-type manhole with manhole ring not less than 3/4 in. in thickness. This ring shall be of ASTM A663 Grade 55 or A675 Grade 55 steel. Covers shall be of ASTM A285 C steel. A flanged and bolted manhole cover may be used in lieu of a boiler type manhole.

5.1.5.5 Where tanks are required to be internally galvanized, provision shall be made for filling, venting, flushing and draining. Special openings will be necessary except where suitably located nozzles, service connections or clean-out openings already exist, and are both of adequate size and flush with the inside of the tank.

Size and location of any special openings for galvanizing purposes shall be agreed between the manufacturer and the purchaser. 3000 lb. 2 in. nominal size threaded full-or-half-couplings to ASTM A105, installed flush with the inside of the tank and welded as shown in Fig. 6, which are suitable for tanks covered by this standard. (Note: For small tanks, it may be only necessary to provide one opening in each head, shell openings not being required.)

5.1.5.6 Service connections shall be provided, sizes and locations being as specified by the purchaser. Details shall be as shown in Figs. 5 thru 8. For flanged, nozzles, 150 lb. ANSI B16.5 slip-on flat face welding flanges shall be fitted, as shown in Fig. 9.

5.1.5.7 Where flanged nozzles are specified by the purchaser, ANSI B16.5 300 lb. blind flanges shall be provided together with suitable gaskets and attaching hardware, for protection during shipping and storing.

5.1.6 Reinforcing plates where required, shall be made from carbon steel plate to ASTM A515 Grade 70.

5.1.7 Non-metallic, no-fusing backing bars may be used in lieu of metal backing bars shown in Fig. 4.

5.2 Finish

5.2.1 Tanks shall be finished externally and internally with anti-corrosion finish specified by the purchaser. Where galvanized finish is specified, the following requirements-shall be complied with:

5.2.1.1 Tanks, complete with all welded features including support and sway brace components as applicable, shall be hot-dip galvanized on all external and internal surfaces.

5.2.1.2 The thickness of the galvanized coating shall be as specified by the purchaser.

5.2.1.3 Threaded and tapped connections shall be protected during galvanizing.

5.2.1.4 Refer to paragraph 5.1.4.4 for special sand-blasting requirement.

6. Testing

6.1 Completed tanks are to be hydrostatically tested to 1.5 times the maximum designed working pressure.

6.2 9 in. by 12 in. test plates shall be provided for each individual tank, as required by CFR 57.06.2(c).

6.3 X-ray, impact testing and stress relieving are not required.

7. Workmanship, Finish and Appearance

7.1 All parts manufactured to this specification shall have a workmanlike finish, free of scale, weld spatter, burrs, sharp edges, cracks, or other defects affecting serviceability or appearance.

7.2 Paint or coating if any, to be specified by the purchaser, see Paragraph 5.2.

8. Markings

Tanks shall be stamped with regulatory body markings in accordance with ASME Section VIII, Div. 1. UG 115 through UG. 119 as applicable and shipyard identification number, and shall bear a tag or be plainly marked with the following:

ASTM designation number
Name or trademark of manufacturer and
Purchase order number.

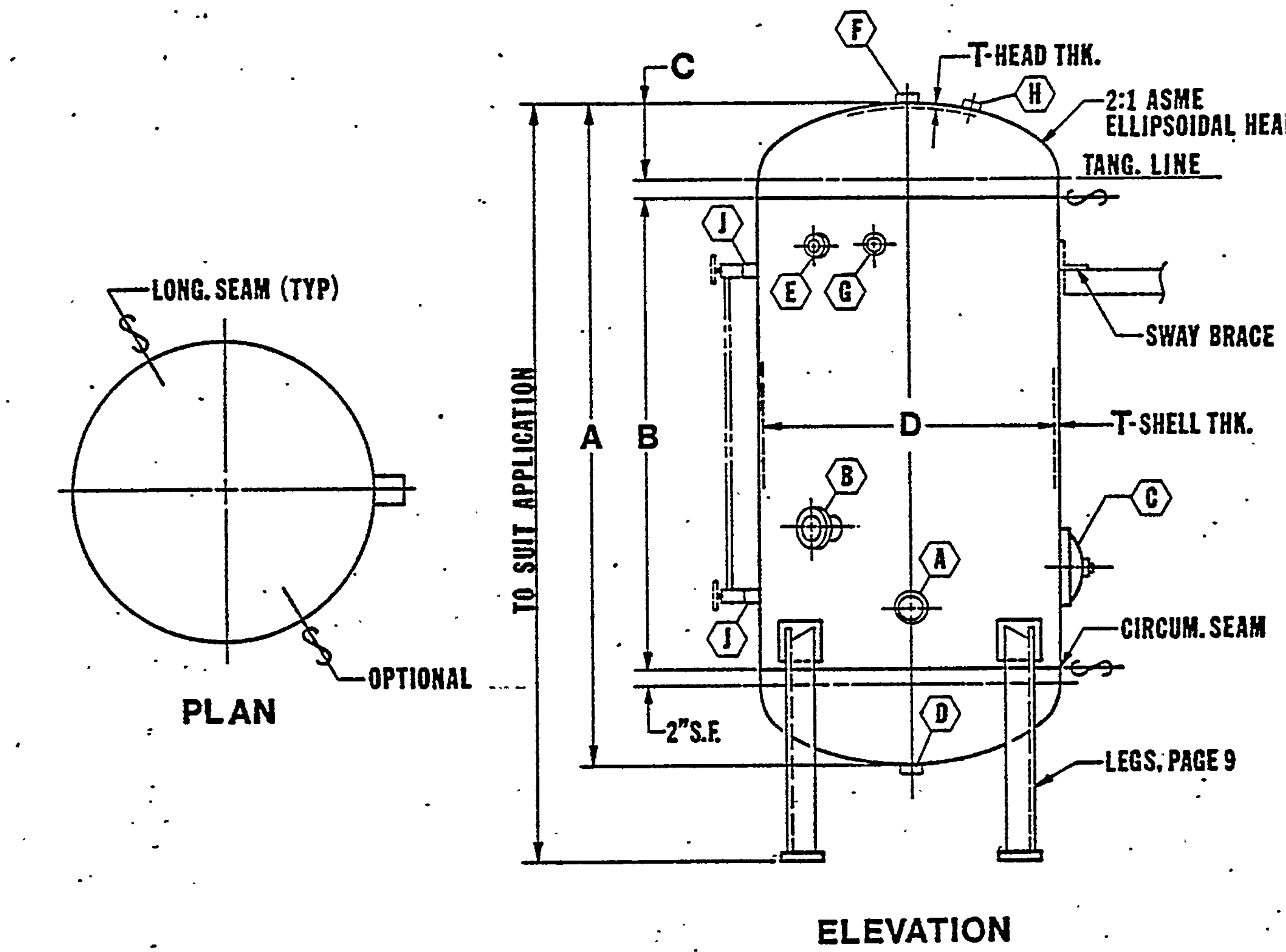


FIG. 1
Hydro-pneumatic Potable Water Tank

TABLE 1. Steel Hydro–Pneumatic Potable Water Tank Design Data and Dimensions See FIG.1

Capacity Galls	A in.	B in.	150 psi C in.	D in.	100 psi Type I Trs[A] in.	100 psi Type I Trh[B] in.	100 psi Type I Shell Thk in.	100 psi Type I Head Thk in.	Legs	150 psi Type II Trs[A] in.	150 psi Type II Trh[B] in.	150 psi Type II Shell Thk in.	150 psi Type II Head Thk in.	Legs	100 psi C in.
200 (1)	71.125	51.500	7.8125	30	.123	.107	3/16	3/16	3x3x3/8 L	.185	.161	5/16	5/16	3x3x3/8 L	7.6872
200 (2)	52.125	29.500	9.3125	36	.148	.129	3/16	3/16	3x3x3/8 L	.222	.193	5/16	5/16	3x3x3/8 L	9.1875
250(1)	87.375	67.750	7.8125	30	.123	.107	3/16	3/16	3x3x3/8 L	.185	.161	5/16	5/16	3x3x3/8 L	7.6875
250(2)	63.375	40.750	9.3125	36	.148	.129	3/16	3/16	3x3x3/8 L	.222	.193	5/16	5/16	3x3x3/8 L	9.1875
300(1)	103.750	84.125	7.8125	30	.123	.107	3/16	3/16	3x3x3/8 L	.185	.161	5/16	5/16	3x3x3/8 L	7.6875
300(2)	74.750	52.125	9.3125	36	.148	.129	3/16	3/16	3x3x3/8 L	.222	.193	5/16	5/16	3x3x3/8 L	9.1875
350	86.125	63.500	9.3125	36	.148	.129	3/16	3/16	3x3x3/8 L	.222	.193	5/16	5/16	4x4x3/8 L	9.1875
400	59.875	31.125	12.3750	48	.196	.172	5/16	5/16	4x4x5/16 L	.296	.257	3/8	3/8	4x4x3/8 L	12.3125
500	72.625	43.875	12.3750	48	.196	.172	5/16	5/16	4x4x5/16 L	.296	.257	3/8	3/8	4x4x3/8 L	12.3125
600	85.375	56.625	12.3750	48	.196	.172	5/16	5/16	4x4x5/16 L	.296	.257	3/8	3/8	4x4x3/8 L	12.3125

1 in = 25.4 mm

[A] Trs = Calculated minimum required shell thickness.

[B] Trh = Calculated minimum required head thickness.

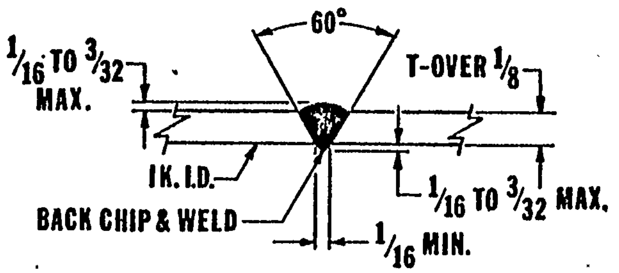


FIG. 2
Longitudinal Seam

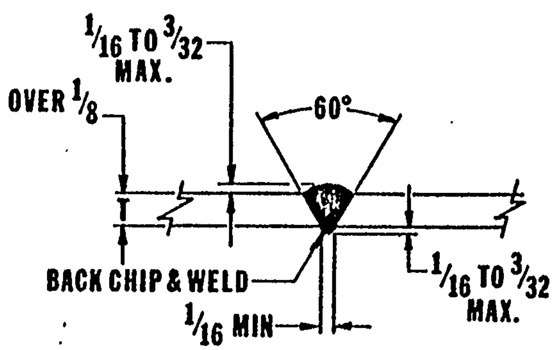


FIG. 3
Circumferential Seam

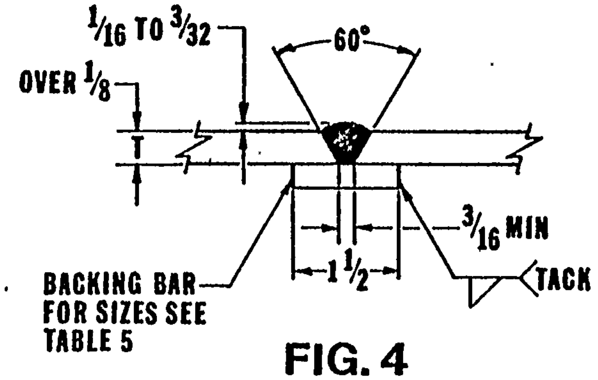


FIG. 4
Circumferential Seam

TABLE 2 100 psi, Type I . . . Permissible Weld Details & Reinf. Elem. or Dblr. Dim's.																								
N.P.S. Nozzles Extra Strong Pipe																								
Capacity Galls	2 1/2				3				4				5				6				8			
	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.
	O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.	
200 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	8 7/8	6 7/8	3/16	8	10 7/8	8 7/8	3/16	8
200 (2)	—	—	—	5	—	—	—	5	—	—	—	5	7 13/16	5 13/16	3/16	7	8 7/8	6 7/8	3/16	7	10 7/8	8 7/8	3/16	7
	5 1/8	3 1/8	3/16	8	5 3/4	3 3/4	3/16	8	6 3/4	4 3/4	3/16	8	8 13/16	5 13/16	3/16	8	9 7/8	6 7/8	1/4	8	12 7/8	8 7/8	1/4	8
250 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	8 7/8	6 7/8	3/16	8	10 7/8	8 7/8	3/16	8
250 (2)	—	—	—	5	—	—	—	5	—	—	—	5	7 13/16	5 13/16	3/16	7	8 7/8	6 7/8	3/16	7	10 7/8	8 7/8	3/16	7
	5 1/8	3 1/8	3/16	8	5 3/4	3 3/4	3/16	8	6 3/4	4 3/4	3/16	6	8 13/16	5 13/16	3/16	8	9 7/8	6 7/8	1/4	8	12 7/8	8 7/8	1/4	8
300 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	8 7/8	6 7/8	3/16	8	10 7/8	8 7/8	3/16	8
300 (2)	—	—	—	5	—	—	—	5	—	—	—	5	7 13/16	5 13/16	3/16	7	8 7/8	6 7/8	3/16	7	10 7/8	8 7/8	3/16	7
	5 1/8	3 1/8	3/16	8	5 3/4	3 3/4	3/16	8	6 3/4	4 3/4	3/16	6	8 13/16	5 13/16	3/16	8	9 7/8	6 7/8	1/4	8	12 7/8	8 7/8	1/4	8
350	—	—	—	5	—	—	—	5	—	—	—	5	7 13/16	5 13/16	3/16	7	8 7/8	6 7/8	3/16	7	10 7/8	8 7/8	3/16	7
	5 1/8	3 1/8	3/16	8	5 3/4	3 3/4	3/16	8	6 3/4	4 3/4	3/16	6	8 13/16	5 13/16	3/16	8	9 7/8	6 7/8	1/4	6	12 7/8	8 7/8	1/4	8
400	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	10 7/8	8 7/8	5/16	8
500	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	10 7/8	8 7/8	5/16	8
600	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	10 7/8	8 7/8	5/16	8

1 in.= 25.4 mm

TABLE 3, 150 psi Type II . . . **Permissible Weld Details & Reinf. Elem. or Dblr. Dim's.**

N.P.S. Nozzles Extra Strong Pipe

Capacity Galls	2 1/2				3				4				5				6				8			
	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.
	O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.	
200 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6
200 (2)	—	—	—	5				5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	8 7/8	6 7/8	5/16	8	11 7/8	8 7/8	5/16	8
250 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6
250 (2)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	8 7/8	6 7/8	5/16	8	11 7/8	8 7/8	5/16	8
300 (1)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6
300 (2)	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	8 7/8	6 7/8	5/16	8	11 7/8	8 7/8	5/16	8
350	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5	—	—	—	5
	—	—	—	6	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	—	—	—	6	8 7/8	6 7/8	5/16	8	11 7/8	8 7/8	5/16	8
400	—	—	—	5	—	—	—	5	—	—	—	5	8 13/16	5 13/16	3/8	7	—	—	—	5	11 7/8	8 7/8	3/8	7
	5 1/8	3 1/8	3/8	8	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	8	6 7/8	3/8	8	13 7/8	8 7/8	3/8	8
500	—	—	—	5	—	—	—	5	—	—	—	5	8 13/16	5 13/16	3/8	7	—	—	—	5	11 7/8	8 7/8	3/8	7
	5 1/8	3 1/8	3/8	8	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	8	6 7/8	3/8	8	13 7/8	8 7/8	3/8	8
600	—	—	—	5	—	—	—	5	—	—	—	5	8 13/16	5 13/16	3/8	7	—	—	—	5	11 7/8	8 7/8	3/8	7
	5 1/8	3 1/8	3/8	8	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	5/16	8	7 13/16	5 13/16	3/8	8	/8	6 7/8	3/8	8	1 7/8	8 7/8	3/8	8

1 in.= 25.4 mm

TABLE 4 — Service Connection	
A	Inlet
B	Outlet
C	Inspection Openings or Manhole
D	Drain
E	Pressure Gage
F	Relief Valve
G	Pressure Switch
H	Air Charge Vent
J	Gage GLass Connection

TABLE 5 — Backing Bar Details

Vessel Material	Vessel Shell Thickness	Backing Bar	
		Material	Size
Steel ASTM-A-515 GR-70	$3/16$ or Less	ABS Steel	$1\frac{1}{2} \times \frac{1}{8}$ FB
	over $3/16$	ABS Steel	$1\frac{1}{2} \times \frac{3}{8}$ FB

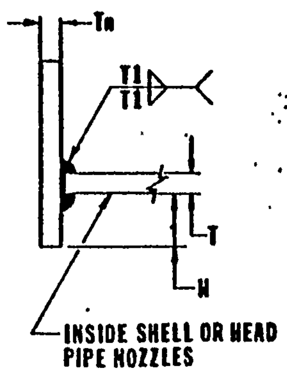


FIG. 5

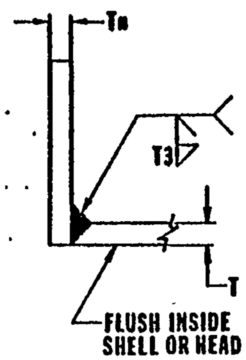


FIG. 6

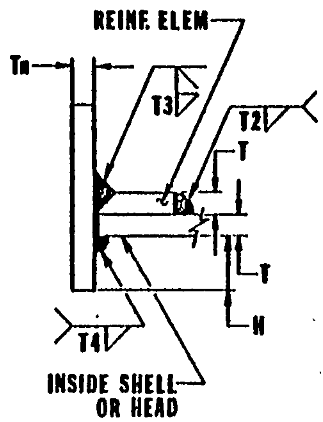


FIG. 7

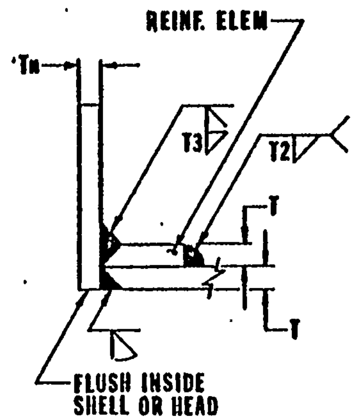


FIG. 8

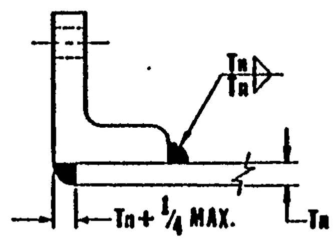


FIG. 9

Cplg Size ips	Cplg Wall Thickness Tn	TABLE 6 — Weld Sizes for Steel Coupling Nozzles			
		T = Head or Shell Thickness			
		3/16		1/4 and Above	
		T1	T3	T1	T3
1/4	.160	5/32	5/32	5/32	5/32
3/8	.155	5/32	5/32	5/32	5/32
1/2	.198	3/16	3/16	7/32	7/32
3/4	.218	3/16	3/16	7/32	7/32
1	.210	3/16	3/16	7/32	7/32
1 1/4	.288	3/16	3/16	1/4	1/4
1 1/2	.293	3/16	3/16	1/4	1/4
2	.297	3/16	3/16	1/4	1/4

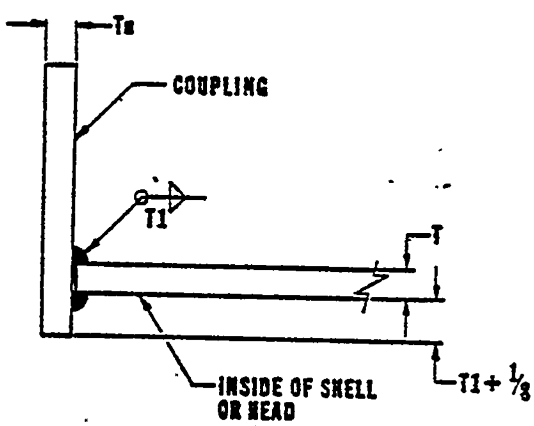


FIG. 10
Coupling Nozzle

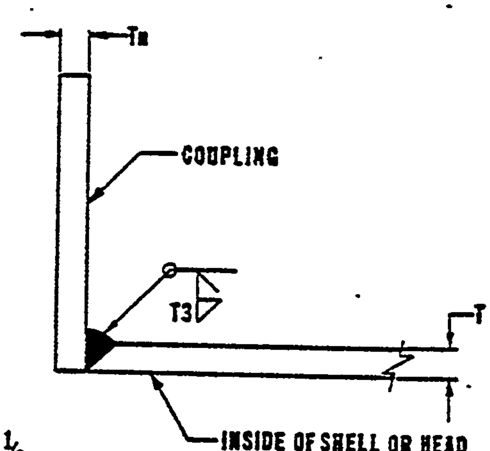


FIG. 11
Coupling Nozzle

TABLE 7—100 psi & 150 psi **Extra Strong Nozzle Weld Dimensions**

NPS Nozzle Size

Shell or Head T	2 1/2 Tn = .276					3 Tn = .300					4 Tn = .337					5 Tn = .375					6 Tn = .432					8 Tn = .500				
	T1	T2	T3	T4	H	T1	T2	T3	T4	H	T1	T2	T3	T4	H	T1	T2	T3	T4	H	T1	T2	T3	T4	H	T1	T2	T3	T4	H
3/16	3/16	3/16	3/16	3/16		3/16	3/16	3/16	3/16		3/16	3/16	3/16	3/16	1/2	3/16	3/16	3/16	3/16	1/2	3/16	3/16	3/16	3/16	1/2	3/16	3/16	3/16	3/16	1/2
5/16	5/16	1/4	5/16	5/16	13/16	5/16	1/4	5/16	5/16	13/16	5/16	1/4	5/16	5/16	13/16	5/16	1/4	5/16	5/16	13/16	5/16	1/4	5/16	5/16	13/16	5/16	1/4	5/16	5/16	13/16
3/8	5/16	1/4	5/16	5/16	15/16	3/8	5/16	3/8	3/8	15/16	3/8	5/16	3/8	3/8	15/16	3/8	5/16	3/8	3/8	15/16	3/8	5/16	3/8	3/8	15/16	3/8	5/16	3/8	3/8	15/16

SAMPLE CALCULATION

<u>SHELL THICKNESS</u> 600 Cu. Ft. Tank 150 PSI

$$Trs = \frac{150 \times 24}{(.7 \times 17{,}500) - (0.2 \times 150)} = .296$$

<u>HEAD THICKNESS</u>

$$Trh = \frac{150 \times 48}{(2x.8x17{,}500)-(0.2x150)} = .257$$

<u>6" NOZZLE REINFORCEMENT</u>

Shell thickness = .375

$\therefore$ t = .375

Using 6 in. ex. strong pipe for nozzle $\therefore$ d = 5.761

tr = .296 (actual calculated thickness)
tn = .432
A = area removed
F = 1.00 corr. factor (for 90° Pen-UG-37)
E = 1.00
fr = 12.0/17.5 (for A_2 & A_3) (Sn/Sv)

fr = 12.0/17.5 (for A_{41} & A_{43}without reinforcing element

fr = (lesser of Sn or Sp)/Sv (for A_{41} with reinforcing element) 12.0/17.5

fr = Sp/Sv (for A_{42} with reinforcing element)

fr = Sn/Sv (for A_{43} with reinforcing element)

Sp = allowable stress in reinforcing element PSI

Sv = allowable stress in vessel shell

Sn = allowable stress in nozzle = 12,000

Sv = allowable stress in tank = 17,500

Sp = allowable stress in reinforcing plate = 17,500

TOTAL CROSS SECTIONAL AREA OF REINFORCEMENT REQUIRED

A= d x tr x F

= 5.761 x .296 x 1 = 1.7052

te = Thickness or height of rein. elem. inches

2.5t =

2.5 tn + te =

$A_1+A_2+A_3+A_4 < A$ Diff must be supplied by reinforcing element - A_5

A_1 = (Et-Ftr) d

=[(1 x .375)] - [1x.296] 5.761

= (.079) x 5.761 = .4551 (Greater)

OR IF GREATER

[(1.079)x(tn+t)2]

= .079 x (.432+.375)2

= .079 x 1.614 = .1275

$\therefore$ Al = .4551

A_2= SMALLER OF FOLLOWING:

=(tn-trn) 5tfr where fr = $\frac{Sn}{Sv}$ = $\frac{12000}{17500}$ = .6857

THEREFORE fr = .6857 USED

= (.432 - .0454) 5 x .375 x .6857

= .4970

OR (.432 - .0454) 5 x .432 x .6857

= .5725

$\therefore$ A_2 = .4970 (SMALLER)

trn = $\frac{PRn}{SE-0.6P}$

= $\frac{150 \times 2.8805}{(9600x1)-(.06x150)}$ =.0454

Rn = INSIDE RADIUS OF THE NOZZLE UNDER CONSIDERATION

= $\frac{5.671}{2}$ = 2.8805

A_3 = (tn-c) h x 2 fr

$\therefore$ (.432 - 0) .9375 x 2 x .6857

A_3 = .5554

h=smaller of 2.5t or 2.5tn = 2.5 x .375 or 2.5 x .432

h = .9375 (SMALLER)

A_{41} = AREA OF WELDS

$2 \times 0.5 \times (0.375)^2 \times (0.686)$

$= 1 \times 0.1406 \times 0.686$

$= .09645$ WELD AREA WITH NO REINFORCEMENT

SIZE OF WELD REQUIRED (UW - 16(e)

FIG UW-16-1 (m)

INNER (REINFORCING ELEMENT) FILLET WELD

tw = 0.7t min
= 0.7 x .375
= 0.263 (min throat req'd)

tw = 0.7 x weld size
= 0.7 x .375
= 0.263

$\therefore$ 3/8" weld req'd

$A_1+A_2+A_3+A_{41}$

$= .4551 + .4970 + .9375 + .9375 + .09645 = 1.986$

$1.986 \geq 1.7052$

NO REINFORCEMENT REQUIRED FOR NOZZLE PENETRATING TANK. SEE FIG. 5

FOR FLUSH TYPE PENETRATION

$A_1+A_2+A_{41} = 1.7052$

.4551 + .4970 + 09645

1.04855<1.7052

REINFORCEMENT REQUIRED (A_5)

1.7052 - 1.0485 = 0.6567

[10-3/8 - 6-7/8-(2 x .432)] .375 x.6857

3½ - .864

2.636 x .375 x .6857 =.6778

.6778 > .6567

REINFORCING ELEMENT REQUIRED

10.875 OD
6.875 ID
0.375 THICK

RATIONALE

TITLE : Standard Specification for Commercial Steel Hydro-Pneumatic Potable Water Tank

OBJECTIVE:

1. To design series of hydro-pneumatic potable water tanks for 100 psi and 150 psi service.
2. To establish a series of nozzles and re-inforcing elements, for each shell thickness of receivers.
3. To establish welding details and dimensions for receivers, nozzles and manholes.

REFERENCES:

1. ASTM Ales
2. ASTM A106
3. ASTM A285
4. ASTM A515
5. ASTM A663
6. ASTM A675
7. ANSI B16-5
8. ASME Section VIII Div. I
9. 46 CFR 54-01-1
10. ABS Rules 1977

CALCULATIONS: Shell Plating thickness was arrived at by the following calculation per ASME U6-27(C).

$t = \frac{PR}{SE-0.6P}$ with symbols defined as below

t = minimum required thickness of shell plates exclusive of corrosion allowance (see UG-25) inches.

P = design pressure, pounds per square inch (see UG-21) .

R = inside radius of the shell course under consideration, before corrosion allowance is added.

s = maximum allowable stress value, pounds per square inch (see applicable table of stress values in Subsection C) .

E = joint efficiency for, or the efficiency of, appropriate joint in cylindrical shell (US-12 for welded vessels).

Ellipsoidal Heads - Thickness was arrived at by the following calculations per UG-32(d).

$t = \frac{PD}{2SE-0.2P}$ with symbols defined as below

t = minimum required thickness of head after forming, exclusive of corrosion allowance, inches.

RATIONALE

CALCULATIONS: Continued

<u>Ellipsoidal Heads</u> (Continued)

P = design pressure, pounds per square inch (see UG-21).

D = inside diameter of the head skirt.

S = maximum allowable stress value as given in Subsection C pounds per square inch.

E = lowest efficiency of any joint in the head (UW-12 for welded vessels).

Total cross sectional area of Reinforcement.

A = d x tr x F with symbols defined as below

d = the diameter in the given plane of the finished opening in its corroded condition inches.

F = a correction factor which compensates for the variation in pressure stresses on different planes with respect to the axis of a vessel. A value of 1.00 shall be used.

tr = the required thickness of a seamless shell or head computed by the rules of this division for the designated pressure, inches.

If $A_1+A_2+A_3+A_4$ A opening is adequately reinforced.

If $A_1+A_2+A_3+A_4$ A the difference must be supplied by reinforcing element.

Where A_1 = (E, t-Ftr)d / (E,t-Etr) (tn+t)2 — larger value is are of shell available for reinforcement.

A_2 = (tn-trn)5t fr / (tn-trn)5tn fr — smaller value is area of nozzle wall available for reinforcement

A_3 = (tn-c)2h fr

A_4 = area of welds x fr

A_5 = (Dp-d-2tn)te x f_r = area of reinforcing element

RATIONALE

CALCULATIONS: Continued

If $A_1+A_2+A_3+A_4+A_5$ A opening is adequately reinforced.

A_1 = area in excess thickness in the vessel wall available for reinforcement, square inches.

A_2 = area in excess thickness in the nozzle wall available for reinforcement, square inches.

A_3 = area available for reinforcement when the nozzle wall extends inside the vessel wall square inches.

A_4 = cross-sectional area of welds available for reinforcement, square inches.

A_5 = cross-sectional area of material added as reinforcement, square inches.

A_{41} = outward nozzle weld = $(\text{leg dim})^2$ x fr

A_{42} = outer plate weld = $(\text{leg dimension})^2$ x fr

A_{43} = inward nozzle weld = $(\text{leg dimension})^2$ x fr

C = corrosion allowance, inches.

Dp = outside diameter of reinforcing element, inches.

d = diameter in the plane under consideration of the finished opening in its corroded condition, inches.

E = L (see definition for tr and Trn).

E_1 = 1 when an opening is in the solid plate or when the opening passes through a circumferential joint in shell or cone.

F = a correction factor which compensates for the variation in pressure stresses on different planes with respect to the axis of a vessel - value of 1.00 shall be used.

h = horizontal nozzle projects beyond the inner or outer surface of the vessel wall, for reinforcement calculations the dimensions shall not exceed the smaller of 2.5t or 2.5tn without a reinforcing element and the smaller of 2.5t or 2.5tn + tc with a reinforcing element or integral compensation.

RATIONALE

CALCULATIONS : Continued

p = design pressure, pounds per square inch.

R = inside radius of the shell course under consideration.

Rn = inside radius of the nozzle under consideration before corrosion.

S = allowable stress value as given in the applicable part of Subsection C, pounds per square inch - except vessels designed under UW-12(C) and Column (c) of Table UW 12 must have the applicable stress value multiplied by 0.8.

Sp = allowable stress in reinforcing element psi.

fr = strength reduction factor, not greater than 1.

fr = Sn/Sv for A_2 and A_3

fr = Sn/Sv for A_{41} and A_{42} without reinforcing element

fr = (Lesser of Sn or Sp)/Sv for A_{41} with reinforcing element

fr = SP/Sv for A_{42} with reinforcing element

fr = Sp/Sv for A_{43} with reinforcing element

t = nominal thickness of the vessel wall, less corrosion allowance, inches.

tr = required thickness of a seamless shell or head as defined in UG-37, inches.

tn = nominal thickness of nozzle wall, less corrosion allowance, inches.

trn = required thickness of a seamless nozzle wall, inches.

tc = weld dimension

te = thickness or height of reinforcing element, inches

RATIONALE

CALCULATIONS : Continued

Weld Size Selection

$T_1 = .7 \times T$ min.

$T_2 = 1/2 \times T$ min.

$T_3 = .7 \times T$ min.

$T_4 = .7 \times T$ min.

CONCLUSION:

1. Range of 100 psi and 150 pressure vessels has been established based on capacities presently being used by many shipbuilders throughout the country.

2. Series of nozzles, reinforcing elements and welding details have been established.

3. This standard should provide information that will enable a designer to select a tank and appropriate nozzles that will suit his arrangement at an early stage of development.

ASTM Designation: F

Standard Specification for

COMMERCIAL STEEL AIR RECEIVERS

1. Scope

1.1 This scope covers steel air receivers with a capacity range of 2.5 cubic feet to 200 cubic feet and pressures of 150 PSI and 450 PSI.

1.2 This scope covers horizontal and vertical air receivers.

Note 1: The value stated in U.S. customary units are to be regarded as standard.

2. Applicable Documents

2.1 ASTM Standards

A106 Specification for Seamless Carbon Steel Pipe for High Temperature Service[2]

A-285 Standard Specification for Pressure Vessel Plates, Carbon Steel, Low and Intermediate-Tensile Strength[3]

A515 Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-and-Higher-Temperature Service[3]

A306 Steel Bars and Bar Size Shapes, Carbon Hot Rolled[7]

2.2 ANSI Standards

B16.5 Steel Pipe Flanges and Flanged Fittings, 150, 300, 400, 600, 900, 1500 and 2500 lb.[4]

[1]This specification is under the jurisdiction of ASTM Committee o

[2]Annual Book of ASTM Standards, Part 1, available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

[3]Annual Book of ASTM Standards, Part 4, available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

[4]Available from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th. Street, New York, New York 10017

[5]Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

[6]Available from American Bureau of Shipping, 65 Broadway, New York, New York 10006

[7]Annual Book of ASTM Standards, Part16, available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

2.3 Other Standards

ASME Section VIII Div. 1 Boiler and Pressure Vessel Code[4]

The Code of Federal Regulations 46 CFR.54[5]

American Bureau of Shipping Rules for Building and Classing Steel Vessels 1979. Group II unfired pressure vessels[6]

3. Classification

3.1 Type and Class

3.1.1 Type I Horizontal Air Receiver Fig. 1

3.1.2 Type II Vertical Air Receiver Fig. 2

3.1.3 *Class I* 150 PSI Air Receiver

3.1.4 Class II 450 PSI Air Receiver

4. Ordering Information

4.1 Orders for pressure vessels under this specification shall include the following information.

4.1.1 Quantity

4.1.2 Size

4.1.3 Class (Class I or Class II)

4.1.4 Type (Type I or Type II)

4.1.5 Orientation, size of nozzles

4.1.6 Support Details, for Type II

4.1.7 Manhole size or threaded inspection hole

4.1.8 Paint or coating (if required, to be specified by purchaser)

4.1.9 ASTM designation and date of issue

5. Manufacture

5.1 All heads to be 2:1 A.S.M.E. Code Elliptical Dished head with 2" straight flange, If head is thicker than shell, or shell thicker than head, the head or shell is to be beveled per Figure 4 and Figure 5, heads to be seamless.

5.1.1 The shell plate thickness of pressure vessels to be in accordance with A.S.M.E. UG-27 (c).

5.1.2 To ensure *a* finished head is not less than the minimum thickness required, manufacturer should use a thicker plate to take care of possible thinning during the process of forming.

5.1.3 Manholes are to be 11 inches x 15 inches minimum, boiler type ASME Code, with manhole ring of 3/4 inch minimum thickness. *This* ring shall be of ASTM A-663 Grade 55 *or* ASTM A 675 Grade 55 steel. Covers shall be of ASTM A285 C steel. The gasket to have a minimum face width of 11/16 in, as required by ASME Code.

5.1.4 Openings shall not be placed closer than 1/2 inch to the edge of a weld in a main joint (circumferential and longitudinal seams).

5.1.5 Nozzles for drains shall not extend into the vessel interior beyond 1/4 inch above the lowest point in vessel.

5.1.6 For permissible weld detail for nozzles, heads and shell, see Tables 1, 2, 3, 6, 7, and 8, pressure vessels with two or more courses shall have the centers of the welded longitudinal joints of adjacent courses staggered by a distance of at least five times the plate thickness per ASME VW-9(d). Non-metalic, non-fusing backing strips may be used in lieu of metal backing bars shown in Fig. 5.

5.1.7 Pressure vessels 36 inches in diameter or less to have two (2) threaded pipe plug inspection openings of not less than 2 inches nominal pipe size. Inspection openings are to be located near each head or in each head.

5.1.8 Pressure vessels over 36 inches in diameter are to have one (1) manhole.

5.1.9 Bolt holes on pads and nozzle flanges to straddle normal centerline.

6. Test

6.1 Tanks are to be subjected to a hydrostatic test pressure 1.5 times the maximum design pressure unless otherwise specified.

6.2 Two 9" x 12" test plates are to be provided as required by 46 CFR 57-06 (c) .

6.3 X-ray, impact test and stress-relieving not required.

7. Workmanship, Finish and Appearance

7.1 All parts manufactured to this specification shall have a workmanlike finish, free of scale, weld spatter, burrs, sharp edges, cracks or other defects affecting serviceability or appearance.

7.2 Paint or coating, if any, shall be specified by purchaser.

8. Markings

8.1 Tanks are to be stamped or a welded on stamped label with regulatory body markings in accordance with ASME Section VIII, Div. 1, UG 115 through UG 119 as applicable and shipyard identification number and shall bear a tag or be plainly marked with the following, ASTM designation number, name or trademark of manufacturer and purchase order number.

9. Material

9.1 Shell course and heads to be manufactured from steel ASTM A-515-GR 70 (or ASTM-A-285 up to 3/16 thickness), maximum allowable stress of 17,500 PSI at 650°F.

9.1.1 Service connections 2 inches-and below are to be 3000 lb. steel couplings ASTM-A-105 and service connections above 2 inches are to be flanged ASTM-A-106 GR.A seamless extra strong pipe nozzle and 150 lb. or 300 lb. ANSI B16.5 SH Flange, ASTM-A-105.

9.1.2 Manhole ring *to* be steel SA 306, GR55 maximum allowable stress 13,700 PSI at 650°.

This Standard Contains the Following

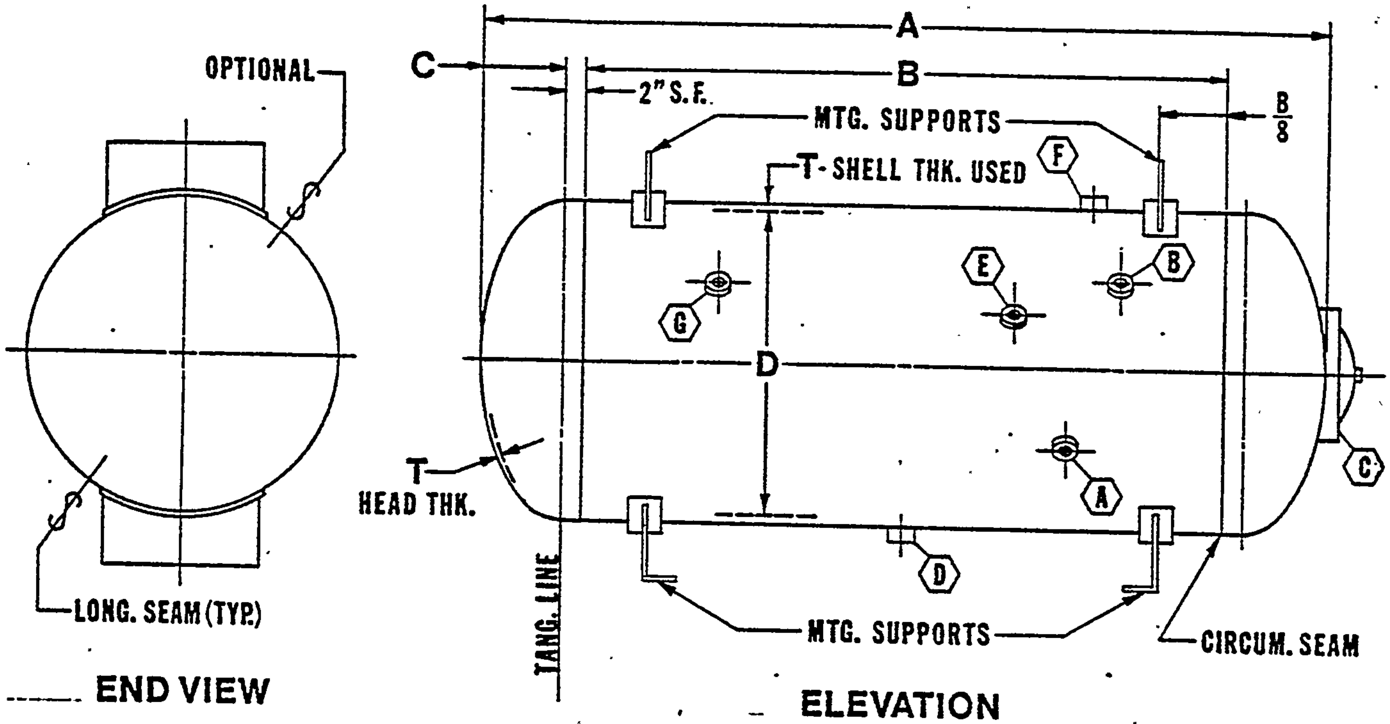


FIG. 1
Horizontal Type 1 Air Receiver

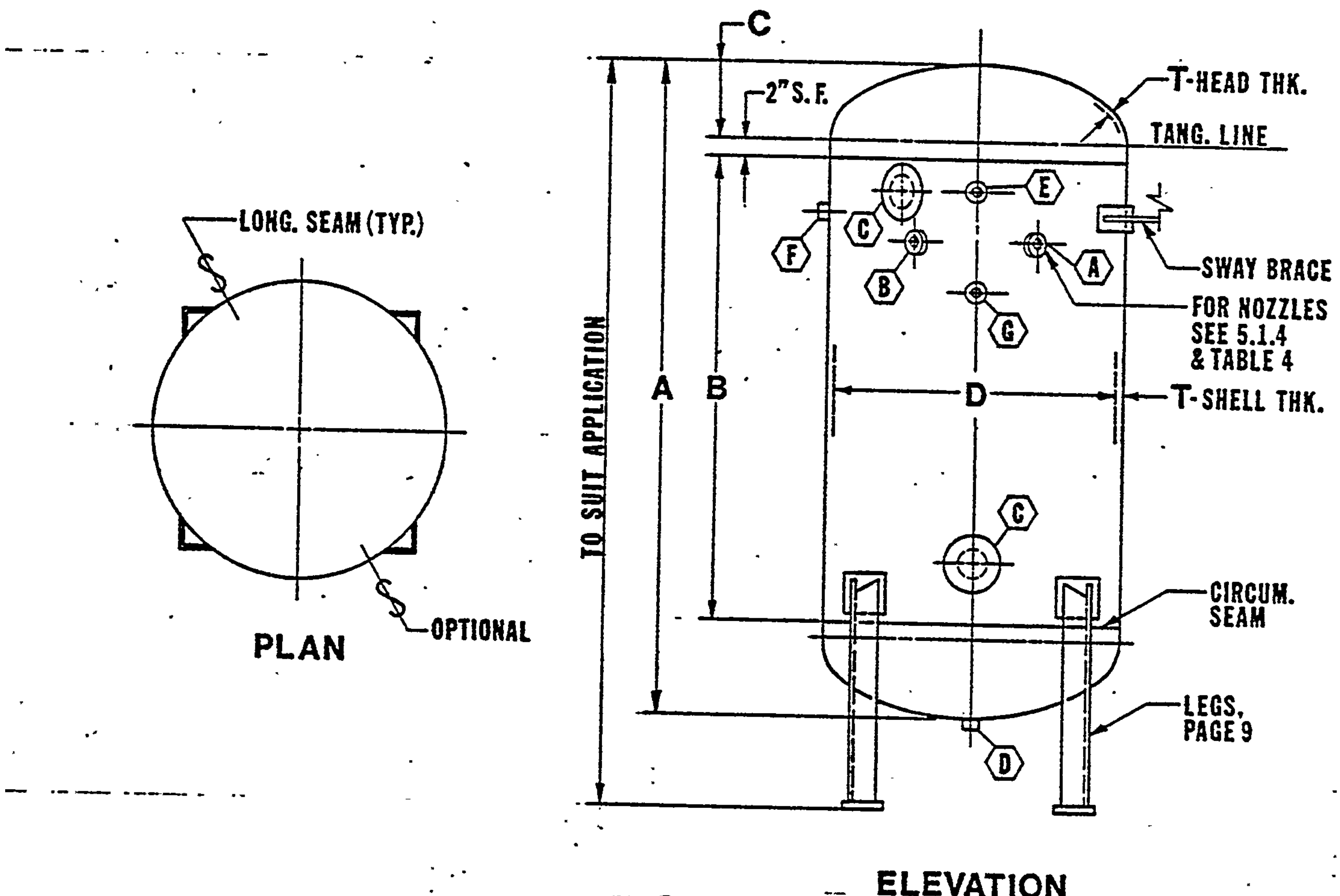


FIG. 2
Vertical Type 2 Air Receiver

TABLE 1. Steel Air Receivers Design Data and Dimensions, See FIG.1 & FIG.2

Capacity cu.ft.	A in.	B in.	D in.	150 psi Class I: C in.	Trs[B] in	Trh[B] in	Shell Thk in	Head Thk in	Legs Vertical Vessel Only	450 psi Class II: Trs[A] in	Trh[B] in	Shell Thk in	Head Thk in	C in.	Legs Vertical Vessel Only
2-5	30.875	19.500	14	3.6250	.086	.075	1/8	1/8	2 x 2 x 1/4 L	.263	.226	5/16	1/4	3.7500	2 x 2 x 3/8 L
5	37.500	24.000	18	4.6250	.111	.097	1/8	1/8	2 x 2 x 1/4 L	.338	.290	3/8	5/16	4.8125	2 x 2 x 3/8 L
10	49.750	34.250	22	5.6875	.136	.118	3/16	3/16	2 x 2 x 1/4 L	.414	.355	7/16	3/8	5.8750	2 x 2 x 3/8 L
20	61.500	42.875	28	7.1875	.173	.150	3/16	3/16	2 1/2 x 2 1/2 x 1/4 L	.526	.451	9/16	1/2	7.5000	2 1/2 x 2 1/2 x 3/8 L
50	91.750	69.000	36	9.2500	.222	.193	1/4	1/4	4 x 4 x 1/4 L	.677	.580	11/16	5/8	9.6250	4 x 4 x 3/8 L
70(1)	76.125	46.875	48	12.3125	.296	.257	5/16	5/16	4 x 4 x 3/8 L	.902	.774	15/16	13/16	12.8125	4 x 4 x 3/8 L
70(2)	95.375	69.375	42	10.8125	.259	.225	5/16	5/16	4 x 4 x 3/8 L	.790	.677	13/16	11/16	10.6875	4 x 4 x 3/8 L
100(1)	85.500	53.500	54	13.8750	.333	.290	3/8	3/8	5 x 5 x 3/8 L	1.015	.871	1 1/16	7/8	14.3750	4 x 4 x 3/8 L
100(2)	98.125	67.375	50	12.8125	.308	.268	5/16	5/16	5 x 5 x 3/8 L	.939	.806	1	13/16	13.3125	5 x 5 x 3/8 L
150	103.000	67.750	60	15.3750	.370	.322	3/8	3/8	5 x 5 x 3/8 L	1.126	.967	1 5/16	1	16.0000	6 x 6 x 3/8 L
200	113.250	75.000	66	17.0000	.407	.472	5/8	1/2	5 x 5 x 3/8 L	1.241	1.108	1 1/4	1 1/8	17.6250	6 x 6 x 1/2 L

1 in = 25.4 mm

[A] Trs = Calculated minimum required shell thickness.

[B] Trh = Calculated minimum required head thickness.

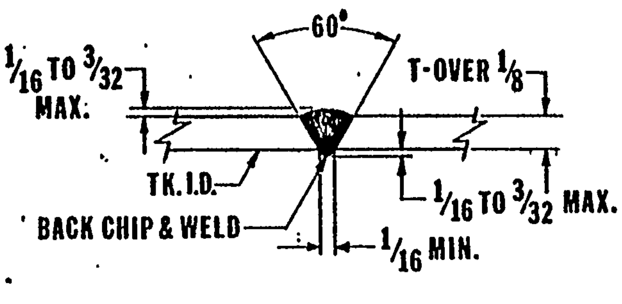


FIG. 3
Longitudinal Seam

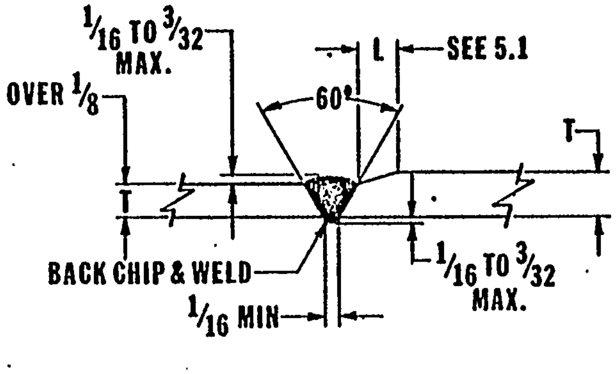


FIG. 4
Circumferential Seam

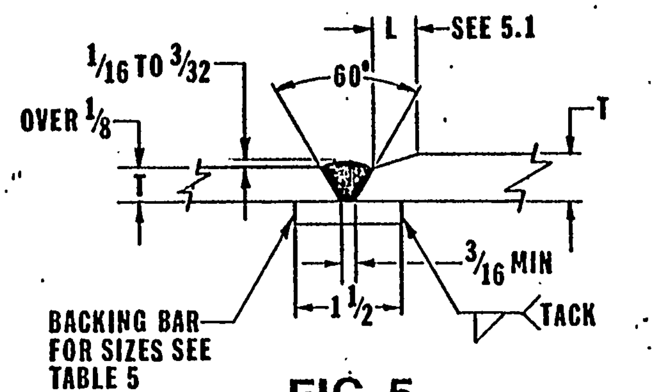


FIG. 5
Circumferential Seal

TABLE 2 - 150 psi Class I Pressure Vessel... Permissible Weld Details & Reinf. Elem. or Dblr. Dim's.

N.P.S. Nozzles Extra Strong Pipe

Capacity Cu. Ft.	2 1/2				3				4				5				6				8			
	Dblr. in.			Weld	Dblr. in.			Weld	Dblr. in.			Weld	Dblr. in.			Weld	Dblr. in.			Weld	Dblr. in.			Weld
	O.D.	I.D.	Thk.	Fig.	O.D.	I.D.	Thk.	Fig.	O.D.	I.D.	Thk.	Fig.	O.D.	I.D.	Thk.	Fig.	O.D.	I.D.	Thk.	Fig.	O.D.	I.D.	Thk.	Fig.
2–5	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6	—	—	—	6
	—	—	—	7	—	—	—	7	6 3/4	4 3/4	1/8	9	7 13/16	5 13/16	1/8	9	8 7/8	6 7/8	1/8	9	10 7/8	8 7/8	1/4	9
5	—	—	—	6	5 3/4	3 3/4	1/4	8	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	1/4	8	8 7/8	6 7/8	1/4	8	11 7/8	8 7/8	1/4	8
	5 1/8	3 1/8	1/4	9	5 3/4	3 3/4	1/4	9	6 3/4	4 3/4	1/4	9	7 13/16	5 13/16	3/8	9	8 7/8	6 7/8	1/2	9	11 7/8	8 7/8	1/2	9
10	—	—	—	6	—	—	—	6	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	1/4	8	—	—	—	6	—	—	—	6
	—	—	—	7	5 3/4	3 3/4	1/4	9	6 3/4	4 3/4	3/8	9	7 13/16	5 13/16	1/4	9	8 7/8	6 7/8	1/4	9	11 7/8	8 7/8	1/4	9
20	—	—	—	6	5 3/4	3 3/4	1/4	8	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	3/8	8	8 7/8	6 7/8	3/8	8	11 7/8	8 7/8	3/8	8
	5 1/8	3 1/8	1/4	9	5 3/4	3 3/4	1/4	9	6 3/4	4 3/4	3/8	9	7 13/16	5 13/16	3/4	9	8 7/8	6 7/8	3/4	9	11 7/8	8 7/8	5/8	9
50	5 1/8	3 1/8	1/4	8	—	—	—	6	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	1/4	8	8 7/8	6 7/8	3/8	8	11 7/8	8 7/8	1/2	8
	5 1/8	3 1/8	3/8	9	5 3/4	3 3/4	1/4	9	6 3/4	4 3/4	1/8	9	7 13/16	5 13/16	3/4	9	8 7/8	6 7/8	3/4	9	12 7/8	8 7/8	1/2	9
70 (1)	—	—	—	6	5 3/4	3 3/4	1/4	8	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	1/2	8	9 7/8	6 7/8	1/2	8	12 7/8	8 7/8	1/2	8
	5 1/8	3 1/8	1/4	9	5 3/4	3 3/4	1/2	9	7 3/4	4 3/4	1/2	9	8 13/16	5 13/16	3/8	9	9 7/8	6 7/8	7/8	9	12 7/8	8 7/8	7/8	9
70 (2)	—	—	—	6	—	—	—	6	7 3/4	4 3/4	1/4	8	8 13/16	5 13/16	1/4	8	9 7/8	6 7/8	1/4	8	12 7/8	8 7/8	1/4	8
	5 1/8	3 1/8	1/4	9	5 3/4	3 3/4	1/4	9	7 3/4	4 3/4	1/2	9	8 13/16	5 13/16	3/8	9	9 7/8	6 7/8	1/2	9	12 7/8	8 7/8	1/2	9
100 (1)	—	—	—	6	—	—	—	6	—	—	—	6	8 13/16	5 13/16	1/4	8	9 7/8	6 7/8	1/4	8	12 7/8	8 7/8	1/2	8
	5 1/8	3 1/8	3/8	9	5 3/4	3 3/4	1/2	9	7 3/4	4 3/4	3/8	9	8 13/16	5 13/16	1/2	9	9 7/8	6 7/8	3/4	9	12 7/8	8 7/8	3/4	9
100 2	5 1/8	3 1/8	1/4	8	5 3/4	3 3/4	1/4	8	7 3/4	4 3/4	1/4	8	8 13/16	5 13/16	3/8	8	9 7/8	6 7/8	3/8	8	12 7/8	8 7/8	5/8	8
	5 1/8	3 1/8	3/8	9	5 3/4	3 3/4	1/2	9	7 3/4	4 3/4	1/2	9	8 13/16	5 13/16	3/4	9	9 7/8	6 7/8	7/8	9	13 7/8	8 7/8	5/8	9
150	5 1/8	3 1/8	1/4	8	5 3/4	3 3/4	3/8	8	7 3/4	4 3/4	1/4	8	8 13/16	5 13/16	1/2	8	9 7/8	6 7/8	5/8	8	13 7/8	8 7/8	1/2	8
	5 1/8	3 1/8	1/2	9	6 1/4	3 3/4	1/2	9	7 3/4	4 3/4	5/8	9	9 5/16	5 13/16	5/8	9	9 7/8	6 7/8	7/8	9	13 7/8	8 7/8	3/4	9
200	5 1/8	3 1/8	1/2	8	5 3/4	3 3/4	1/2	8	7 3/4	4 3/4	3/4	8	8 13/16	5 13/16	1/2	8	9 7/8	6 7/8	1	8	13 7/8	8 7/8	5/8	8
	5 1/8	3 1/8	3/4	9	6 1/4	3 3/4	5/8	9	7 3/4	4 3/4	1	9	9 5/16	5 13/16	7/8	9	10 7/8	6 7/8	1	9	13 7/8	8 7/8	1	9

1 in = 25.4 mm

TABLE 3, 450psi Class II Pressure Vessel... Permissible Weld Details & Reinf. Elem. or Dblr. Dim's.

N.P.S. Nozzles Extra Strong Pipe

Capacity Cu. Ft.	2 1/2				3				4				5				6				8			
	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.	Dblr. in.			Weld Fig.
	O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.		O.D.	I.D.	Thk.	
2–5	—	—	—	6	5 3/4	3 3/4	1/4	8	6 3/4	4 3/4	1/4	8	7 13/16	5 13/16	5/16	8	9 3/8	6 7/8	5/16	8	11 7/8	8 7/8	1/2	8
	—	—	—	7	5 3/4	3 3/4	5/16	9	7 3/4	4 3/4	5/16	9	9 13/16	5 13/16	3/8	9	10 3/8	6 7/8	1/2	9	12 7/8	8 7/8	5/8	9
5	5 1/8	3 1/8	1/4	8	5 3/4	3 3/4	3/8	8	6 3/4	4 3/4	3/8	8	8 13/16	5 13/16	3/8	8	9 7/8	6 7/8	7/16	8	12 7/8	8 7/8	1/2	8
	5 5/8	3 1/8	3/8	9	6 1/4	3 3/4	1/2	9	7 3/4	4 3/4	1/2	9	9 13/16	5 13/16	1/2	9	10 7/8	6 7/8	5/8	9	13 7/8	8 7/8	3/8	9
10	5 1/8	3 1/8	1/4	8	6 3/4	3 3/4	1/4	8	7 1/4	4 3/4	1/2	8	9 5/16	5 13/16	7/16	8	10 7/8	6 7/8	7/16	8	14 3/8	8 7/8	1/2	8
	5 5/8	3 1/8	7/16	9	6 3/4	3 3/4	1/2	9	8	4 3/4	5/8	9	9 13/16	5 13/16	5/8	9	11	6 7/8	3/4	9	14 3/8	8 7/8	3/4	9
20	5 1/8	3 1/8	1/2	8	6 3/4	3 3/4	7/16	8	8	4 3/4	9/16	8	9 13/16	5 13/16	3/4	8	11	6 7/8	11/16	8	14 3/8	8 7/8	3/4	8
	5 5/8	3 1/8	5/8	9	6 3/4	3 3/4	5/8	9	8	4 3/4	7/8	9	9 13/16	5 13/16	7/8	9	11 7/8	6 7/8	7/8	9	14 7/8	8 7/8	7/8	9
50	5 5/8	3 1/8	11/16	8	6 3/4	3 3/4	3/4	8	8	4 3/4	1	8	9 13/16	5 13/16	1	8	11 7/8	6 7/8	7/8	8	14 7/8	8 7/8	1	8
	6 1/8	3 1/8	3/4	9	6 3/4	3 3/4	1	9	8 3/4	4 3/4	1 1/8	9	9 13/16	5 13/16	1 1/4	9	11 7/8	6 7/8	1 1/8	9	14 7/8	8 7/8	1 3/8	9
70 (1)	6 1/8	3 1/8	7/8	8	6 3/4	3 3/4	1 1/8	8	8 3/4	4 3/4	1 1/8	8	10 5/16	5 13/16	1 1/4	8	12 3/8	6 7/8	1 1/4	8	14 7/8	8 7/8	1 5/8	8
	6 5/8	3 1/8	7/8	9	7 1/4	3 3/4	1 1/8	9	8 3/4	4 3/4	1 3/8	9	10 5/16	5 13/16	1 1/2	9	12 7/8	6 7/8	1 3/8	9	14 7/8	8 7/8	2	9
70 (2)	6 5/8	3 1/8	5/8	8	7 1/4	3 3/4	7/8	8	8 3/4	4 3/4	7/8	8	9 13/16	5 13/16	1 1/8	8	12 7/8	6 7/8	1	8	14 7/8	8 7/8	1 1/4	8
	6 5/8	3 1/8	3/4	9	7 1/4	3 3/4	1	9	8 3/4	4 3/4	1 1/8	9	9 13/16	5 13/16	1 1/2	9	12 7/8	6 7/8	1 1/4	9	14 7/8	8 7/8	1 1/2	9
100(1)	6 5/8	3 1/8	7/8	8	7 1/4	3 3/4	1 1/8	8	8 3/4	4 3/4	1 1/4	8	9 13/16	5 13/16	1 5/8	8	12 7/8	6 7/8	1 1/4	8	14 7/8	8 7/8	1 3/4	8
	6 5/8	3 1/8	1	9	7 1/4	3 3/4	1 1/4	9	8 3/4	4 3/4	1 1/2	9	10 13/16	5 13/16	1 1/2	9	12 7/8	6 7/8	1 1/2	9	14 7/8	8 7/8	2	9
100(2)	7 1/8	3 1/8	5/8	8	7 3/4	3 3/4	7/8	8	8 3/4	4 3/4	1 1/8	8	10 13/16	5 13/16	1 1/8	8	12 7/8	6 7/8	1 1/8	8	14 7/8	8 7/8	1 1/2	8
	7 1/8	3 1/8	3/4	9	7 3/4	3 3/4	1	9	8 3/4	4 3/4	1 1/2	9	10 13/16	5 13/16	1 3/8	9	12 7/8	6 7/8	1 3/8	9	14 7/8	8 7/8	1 3/4	9
150	7 1/8	3 1/8	1	8	7 3/4	3 3/4	1 1/4	8	8 3/4	4 3/4	1 1/2	8	10 13/16	5 13/16	1 3/4	8	12 7/8	6 7/8	1 3/4	8	14 7/8	8 7/8	2 1/2	8
	7 1/8	3 1/8	1 1/4	9	7 3/4	3 3/4	1 3/8	9	8 3/4	4 3/4	1 1/2	9	10 13/16	5 13/16	2	9	12 7/8	6 7/8	1 7/8	9	14 7/8	8 7/8	2 3/4	8
200	7 1/8	3 1/8	1	8	7 3/4	3 3/4	1 1/4	8	8 3/4	4 3/4	1 3/8	8	10 13/16	5 13/16	1 5/8	8	12 7/8	6 7/8	1 5/8	8	14 7/8	8 7/8	2 1/4	8
	7 1/8	3 1/8	1 1/8	9	7 3/4	3 3/4	1 3/8	9	8 3/4	4 3/4	1 1/2	9	10 13/16	5 13/16	1 7/8	9	12 7/8	6 7/8	1 7/8	9	14 7/8	8 7/8	2 1/2	9

1 in = 25.4 mm

TABLE 4 — Service Connection	
A	Inlet
B	Outlet
C	Inspection Openings or Manhole
D	Drain
E	Pressure Gage
F	Relief Valve
G	Pressure Switch

TABLE 5— Backing Bar Details

Vessel Material	Vessel Shell Thickness	Backing Bar	
		Material	Size
Steel-ASTM A-285	$3/16$ or Less	ABS Steel	$1\frac{1}{2} \times \frac{1}{8}$ FB
Steel-ASTM A-515	over $3/16$	ABS Steel	$1\frac{1}{2} \times \frac{3}{8}$ FB

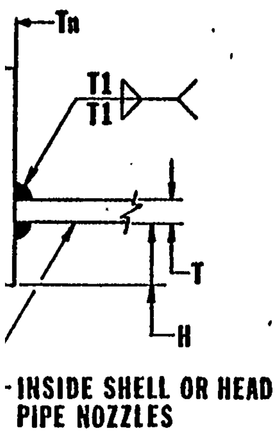


FIG.6

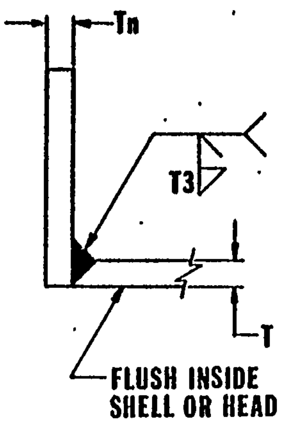


FIG.7

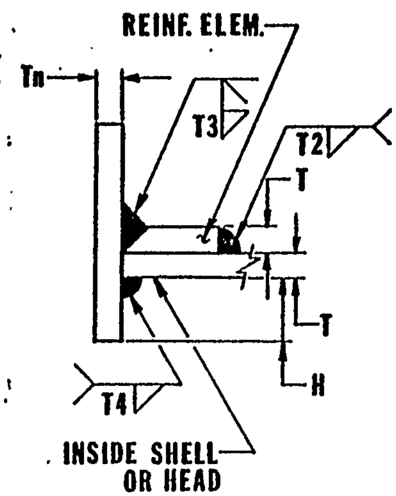


FIG.8

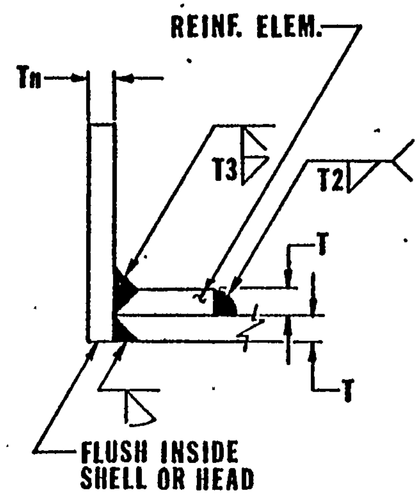


FIG.9

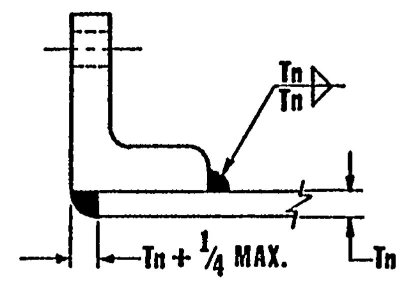


FIG.10

Cplg Size nps	Cplg Wall Thickness Tn	TABLE 6 — Weld Sizes for Steel Coupling Nozzles T = Head or Shell Thickness 3/16 T1	3/16 T3	1/4 and Above T1	1/4 and Above T3
1/4	.160	5/32	5/32	5/32	5/32
3/8	.155	5/32	5/32	5/32	5/32
1/2	.198	3/16	3/16	7/32	7/32
3/4	.218	3/16	3/16	7/32	7/32
1	.210	3/16	3/16	7/32	7/32
1 1/4	.288	3/16	3/16	1/4	1/4
1 1/2	.293	3/16	3/16	1/4	1/4
2	.297	3/16	3/16	1/4	1/4

1in=25.4mm

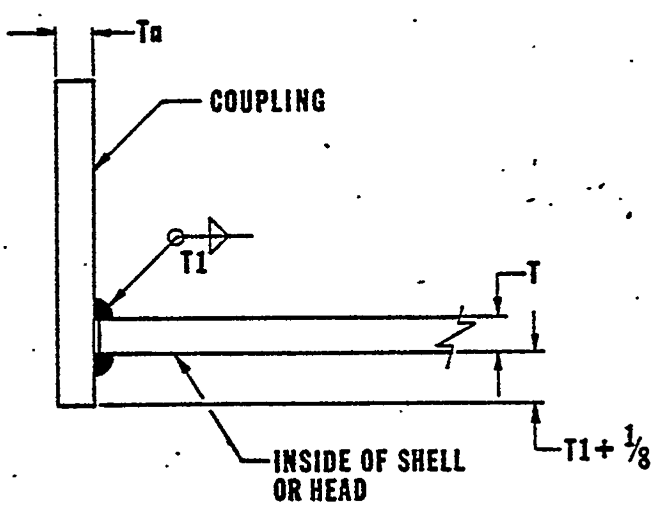


FIG. 11
Coupling Nozzle

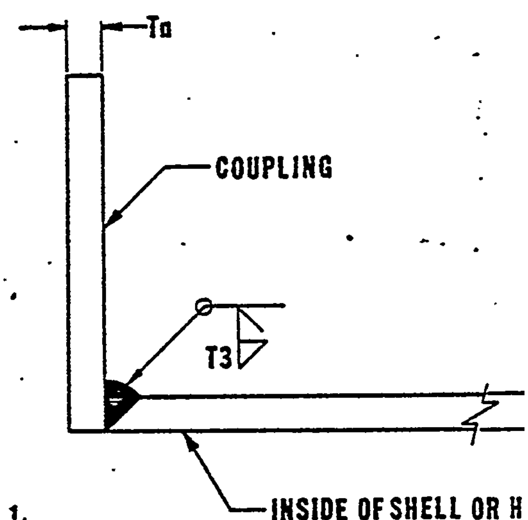


FIG. 12
Coupling Nozzle

SAMPLE CALCULATION

SHELL THICKNESS 200 CU. Ft. Pressure Vessel 450 PSI

$$Trs = \frac{450 \times 33}{(17{,}500 \times 7) - (0\text{-}6 \times 450)} = 1.2408 \text{ inches}$$

HEAD THICKNESS

$$Trh = \frac{450 \times 60}{(2 \times .8 \times 17{,}500 \times 1) - (0.2 \times 450)} = .96739 \text{ inches}$$

6" NOZZLE REINFORCEMENT

Shell Thickness 1-25 ins.

t = 1.250

Using 6 in. ex. strong pipe for nozzle d = 5.761.

tr = 1.2408 (actual calculated thickness)

tn = .432

A = Area removed

F = 1.00 Corr. Factor (for 90° Pen - UG - 37)

E = 1.00 Joint Efficiency

fr = Strength reduction factor, not greater than 1.0

fr = Sn/Sv for A_2, A_3 & A_4

$$fr = \frac{12000}{17500} = .686$$

trn = .139 (calculated below)

Total Cross Sectional Area of Reinforcement Required

A = d x t r x F
= 5.761 X 1.2408 X 1 - 7.1482

te = Thickness or height of re-elem inches

2.5t =
2.5 tn + te = 2.5 x .432 + 1.25 = 2.375

$A_1 + A_2 + A_3 + A_4 < A$ Dif. must be supplied by reinforcing element = A_5.

$A_1 = (Et - Ftr)\ d$
$= (1 \times 1.25) - (1-1.2408) \times 5.761$
$= (.0092) \times 5.761$
$A_1 = .053$

$A_2 = (tn-trn)\ \ 5tn \times fr$
$= (.432 - .13893)\ 5 \times .432 \times .686 = .434$
$A_2 = .434$

$$trn = \frac{PRn}{SE - 0.6P}$$

$$= \frac{450 \times 2.8805}{(9600 \times 1)\ \ (0.6 \times 450)} = .139$$

$$Rn = \frac{5.761}{2} = 2.8805$$

$A_3 = (tn - c)\ h \times 2 \times fr$

$(.432 - 0)\ 1.08 \times 2 \times .686 = .640$

$A_3 = .640$

$h = 2.5\ tn + te$
$= 2.5 \times .432 = 1.08 + 1.125$
$= 2.20$

A_4 = <u>Area</u> of <u>Welds</u>

$= (Leg)^2\ fr \times fr$

$= .375^2 \times .686$

$A_4 = .096$

WELD = .7 x .432
= .3024 (Use .25 which is smaller)

Using 3/8 Weld
= .7 x .375
= .2625

$A_1 + A_2 + A_3 + A_4$

$= .053 + .434 = .640 + .096 + .096 + .096 < A$

$= 1.415 < 7.1482$

REINFORCEMENT REQUIRED (A_5)

A_5= (Dp - d - 2rn) te X fr

A_5= (12.875 - 6.875 - .864) 1.625
= 5.136 x 1.625 x .686
= 5.725
1.415 + 5.725 7.148

= 7.148 = 7.148

$$\left.\begin{array}{l}\text{12.875 OD}\\ \text{6.875 I/D}\\ \text{1.625 Thick}\end{array}\right\}\ \text{REINFORCING ELEMENT}$$

REINFORCEMENT REQUIRED (A_5)

For Flush Nozzle

$A_1+A_2+A_4$

.053 + .434 + .096 + .096

= .679 < 7.1482

(A_5) = (Dp - d - 2tn) te x fr

= (12.875 - 6.875 - .864) 1.875 x .686

= 5.136 x 1.875 x .686 = 6.606

.679 + 6.06 $\geqslant$ 7.148

7.285 $\geqslant$ 7.148

Reinforcing Element Requried for Flush Type Nozzle

$$\left.\begin{array}{l}\text{12.875 OD}\\ \text{6.875 I/D}\\ \text{1.875 Thick}\end{array}\right\}\ \text{REINFORCING ELEMENT}$$

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CALL FOR PAPERS:

AUTHORS SOUGHT FOR FIRST SHIPBUILDING STANDARDS SYMPOSIUM

PHILADELPHIA, PA--A call for papers is issued for a Symposium on Shipbuilding Standards to be held at the Sheraton National Hotel, Arlington, VA, the week of 19 October 1981. The symposium will be hosted by Committee F-25 on Shipbuilding of the American Society for Testing and Materials (ASTM) in cooperation with the Society of Naval Architects and Marine Engineers (SNAME) Panel SP-6 on Standards and Specifications.

Prospective authors are asked to submit a 300 word or less abstract, title, and ASTM Paper Offer Form by 1 November 1980 explained Symposium Chairman R. J. Taylor of Exxon International, Inc. Abstracts may be sent to Kathy Greene at ASTM, 1916 Race St., Philadelphia, PA. 19103.

The symposium will cover the progress of ASTM Committee F-25 since its establishment in mid-1978.

It will also examine the benefits of the national standardization program to the shipbuilding industry. Papers will identify successes and problems encountered to date and outline requirements for new standards in the future.

A special technical publication on the symposium proceedings is anticipated by ASTM. A nonprofit organization with headquarters in Philadelphia, ASTM is a leader in the development of voluntary consensus standards for materials, products, systems, and services. ASTM standards documents are created by the more than 28,500 international members of the organization.

Invited papers for the 1981 symposium will cover:

- The role of the National Shipbuilding Research Program-development of the U.S. shipbuilding standards efforts, industry coordination through SNAME Panel SP-6, and support through research projects.
- Progress of ASTM Committee F-25--the challenges this group has discovered in attempting to consolidate existing U.S. shipbuilding standards and regulations and develop new standards in priority areas of need.

- more -

Authors are asked to submit papers on the state-of-the-art, addressing such areas as: The benefits and applications of shipbuilding standards and the future outlook for shipbuilding standards development. Included in these papers could be the short and long-term benefits to various segments of the U.S. industry. Observations from the Livingston Shipbuilding/IHI (Japan) Technology Transfer Program are also welcome.

The symposium is expected to contribute a significant and comprehensive information base to familiarize the industry with the work of Committee F-25 noted Symposium Ad Hoc Planning Committee Chairman John C. Mason of the Bath Iron Works. He added that the information exchange should serve as a guide to the future direction of the standards effort.

For further information on the program contact Mason at the Bath Iron Works, Corp., 700 Washington St., Bath, ME 04530 (207/443-3311); or Jim De Martini, ASTM Standards Development Division, 1916 Race St., Philadelphia, PA 19103 (215/299-5560). ASTM Offer Forms are available from Kathy Greene.

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