1381-68(4-EAM-4597)

U.S. NAVAL SURFACE SHIPS

CONSTRUCTION COST MODEL

PREPARED BY: Gibbs & Cox, Inc.
Arlington, Virginia

CONTRACT NO. N00024-91-C-2801
FOR: Naval Center for Cost Analysis

June 1994

108-82

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CONSTRUCTION COST MODEL

BY:
ERIC MIDBOE
LYNDA KELLY
STEVEN CEREGHINO

APPROVED:

R J Scott for
W. W. Rogalski, Jr.
Vice President

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REFERENCES

(1) Gibbs & Cox, Inc. Report No. 1021(4-EAM-6000) "Revised Destroyer/Cruiser Construction Cost Model," August 1988

(2) Gibbs & Cox, Inc. Report No. 1021(4-EAM-6026) "U.S. Naval Vessels (Auxiliary & Amphibious Ships) Construction Cost Model," September 1988

(3) Gibbs & Cox, Inc. Report No. 1381-22(4-EAM-1195), "U.S. Naval Vessels (Surface Combatant) Detail Design Cost Estimating Model," June 1991

(4) Gibbs & Cox, Inc. Report No. 1381-22(4-EAM-2575) "U.S. Naval Auxiliary, Amphibious, MSC and Minehunting Type Vessels Detail Design Cost Estimating Model," July 1992

(5) Naval Center for Cost Analysis, "Inflation and Outlay Profile Factors," February 1992

(6) Janes' Fighting Ships, 1992 - 93

(7) "Naval Vessel Register," Document No. S0300-A4-MAN-A20/(c)(u), 1 July 1992

(8) NAVSEA 017 Data Sheet, "BIW FFG Program-Manhours at Completion," August 1992

(9) NAVSEA 017 Data Sheet, "FFG 7 Class Todd LA," 15 May 1987

(10) Naval Center for Cost Analysis Ships Division, "Ship Construction Cost and Technical Data Base," 12 February 1993

(11) NAVSEA 017 Data Sheet, "FFG 7 Class Todd Seattle," 15 May 1987

(12) NAVSEA 017 Data Sheet, "Cost Estimating and Analysis (DD 963)," 22 February 1980

(13) ISI CPR for CG 47, CDRL A072 Report No. X37876-R1 Issue No. 067, 27 August 1984

(14) BIW CPR for CG 51, CDRL A072, Report Period April 4, 1988 through July 3, 1988, 25 July 1988

(15) CG 51 Return Cost Data, Provided as Enclosure to Letter from BIW to Gibbs & Cox, Inc., Number WP0379q98, Subcontract 11021-2, "Parametric Shipbuilding Construction Cost Model," 18 December, 1987

REFERENCES
(continued)

(16) Department of the Navy, "CG 51 Schedule 'A' Government Furnished Equipment," 31 July 1985

(17) BIW CPR for DDG 51, 27 January 1992

(18) ISI CPR for DDG 52, CDRL A272 Issue No. 059, 21 August 1992

(19) Lockheed CPR for LSD 41, CDRL B012, 4 August 1985

(20) NAVSEA 05 Data Sheet, SWBS Breakdown or As-Built Lightship Weight for LSD 41, Received by NCA 28 June 1993

(21) Avondale CPR for LSD 44, 31 March 1989

(22) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for LSD 44, Received by NCA 28 June 1993

(23) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for AD 41, Received by NCA 28 June 1993

(24) ISI CPR for LHD 1, CDRL A003 Issue No. 100, 18 March 1991

(25) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for LHD 1, Received by NCA 28 June 1993

(26) McDermott CPR for T-AGOS 19, Contract No. N00024-87-C-2087, 30 June 1992

(27) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for T-AGOS 19, Received by NCA 28 June 1993

(28) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for A0 177, Received by NCA 28 June 1993

(29) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for AFS 6, Received by NCA 28 June 1993

(30) Avondale CPR for T-AO 187, Contract No. N00024-83-C-2012, 31 December 1987

REFERENCES
(continued)

(31) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for T-AO 187, Received by NCA 28 June 1993

(32) Tampa Shipyards CPR for T-AO 191, 30 April 1987

(33) Avondale CPR for AOE 6, 12 July 1992

(34) NAVSEA 05 Data Sheet, SWBS Breakdown of As-Built Lightship Weight for AOE 6, Received by NCA 28 June 1993

(35) NAVSEA Document No. S9040-AA-IDX-010/SWBS 5D, "Expanded Ship Work Breakdown Structure for all Ships and Ship/Combat Systems," 13 February 1985

(36) Avondale CPR for T-AGS 45, Contract No. N00024-90-C-2307, 30 June 1990

(37) Avondale CPR for LCAC 34, Contract No. N00024-89-C-2110 CDRL A075, 30 June 1992

(38) Intermarine CPR for MHC 51, 31 December 1992

(39) Avondale CPR for MHC 53, Contract No. N00024-89-C-2162, CDRL A196, 31 December 1992

(40) Peterson Builders CPR for MCM 1, Contract No. N00024-82-C-2121, CDRL A199, 28 February 1988

(41) Marinette Marine CPR, Contract No. N00024-83-C-2142, 9 November 1988

(42) "Some Basic Statistics for Cost Estimating", statistical excerpt provided by NCA August 1993.

(43) Gibbs & Cox, Inc. Report No. 19301-(4-0218), "U.S. Naval Vessels (Auxiliary and Amphibious Ships) Construction Cost Model," March 1983.

(44) Gibbs & Cox, Inc. Report No. 19141(4-6877), "U.S. Naval Vessels (Destroyer Type)," August 1981.

1.0 INTRODUCTION

The objective of this study is to revise previous lead ship construction cost models developed for the Navy Center for Cost Analysis (NCA) in order to incorporate new cost data, enhance the use of shipyard cost performance report (CPR) data, enhance the statistical analysis of the data, and develop a PC-based data base and model. In addition, this study combines the information previously contained in two separate cost models, the surface combatant construction cost model and the auxiliary and amphibious ship construction cost model [References (1) and (2)], into a single surface ship construction cost model, while still maintaining the ability to differentiate between ship types.

The primary use of this construction cost model is to develop cost estimates for shipyard construction costs of U.S. Naval surface ships. The current model is based upon the approach used in previous models, where cost estimating relationships (CER's) for shipyard related labor manhours and material dollars are developed using general ship's characteristics (e.g., weight) as the independent variable. The CER's are categorized by the ship work breakdown structure (SWBS) group. A lead ship construction cost is derived by estimating the individual SWBS groups costs, using the appropriate CER's, and then summing these costs to develop a total shipyard construction cost.

The model estimates shipyard costs, including the shipyard engineering/integration costs, which includes detail design, as well as the construction costs and other shipyard services. It does not include the acquisition of government furnished equipment (GFE) with respect to command, control, communications, weapons systems, or hull, mechanical or electrical systems, or additional costs such as training, integrated logistics support, or Navy program costs.

The model is designed to use information that is available at the end of the feasibility or conceptual stage of design, including such items as the three-digit SWBS weight breakdown, shaft horsepower, electric generation capacity (kilowatts) or anticipated construction time in the shipyard.

The previous cost models [References (1) and (2)] used a two-digit SWBS breakdown developed to identify 22 major cost groups. Shipyard estimators used in-house shipyard return and estimated cost data to assign costs to these 22 cost groups from which the CER's were developed. This model relies primarily on CPR data, which are not presented in a manner that allows a 22 cost group breakdown. As such, this model presents the data by the one digit SWBS groups that are shown in Table 1-1.

TABLE 1-1

ONE-DIGIT SWBS GROUPS

SWBS Group	Title
100	Hull Structure
200	Propulsion Plant
300	Electric Plant
400	Command and Surveillance
500	Auxiliary Systems
600	Outfit and Furnishings
700	Armament
800	Integration/Engineering
900	Ship Assembly and Support Services

The value of the SWBS system is that it is a system familiar to both the U.S. Navy and the shipbuilding industry. It is an accepted standard that is used by the Navy, and it is a system for categorizing the systems that compose the ship, allowing for consistent accounting of weight, cost and ship's system information.

The major limitation regarding the use of SWBS is that shipyards use their own in-house accounting systems for tracking expenditures. This can be by SWBS, construction trade, module, or other method. In reporting these costs in a CPR, either the costs are presented using the in-house method, or costs are transcribed into SWBS and reported by SWBS. Either way, this introduces problems in accurately converting costs into a SWBS format. This, in turn, results in possible inconsistencies in the data, and hence in the resultant CER's. To the extent possible, specific instances of uncertainty are highlighted in the discussion of the data base.

This model, and its corresponding PC-based version, provide cost data and CER's for major ship types. These include surface combatants, amphibious ships, auxiliary ships, and other ships (for which data was available). The basic approach to the model is presented in Chapter 2.

The data are presented in Chapter 3 by ship type and includes basic ship information; and weight, labor manhour, and material cost data broken down by SWBS, along with an analysis of the data.

The CER's are presented in Chapter 4 by ship type at the one-digit SWBS group level, as well as by summary groupings representing construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700, 900) and total contract costs (SWBS Groups 100-900). CER's are presented for both labor manhours and material dollars, along with the corresponding regression analysis and supporting narrative.

The estimating method is presented in Chapter 5 and is consistent among the ship types. A procedure is presented that provides a step by step description of the method, work sheets for manual estimating, and a sample estimate. In addition, guidance is provided for using the PC version of the model in Appendix (A).

Chapter 6 provides the conclusion and recommendations derived from this work. This is followed by supporting information in the appendices, including data, additional plots not used in the report and descriptive SWBS information.

2.0 APPROACH TO MODEL DEVELOPMENT

2.1 Previous Models

This model is built upon two sets of previous construction cost estimating models developed for NCA:

- Revised Destroyer/Cruiser Construction Cost Model, August 1988 [Reference (1)]

- U.S. Naval Vessels (Auxiliary and Amphibious Ships) Construction Cost Model, September 1988 [Reference (2)]

In these models, data provided by shipyards for lead ship's costs in lead yards and lead ship's costs in follow yards were used to developed CER's. Basic ships' characteristics, such as weight, shaft horsepower, or complement, were used as the independent variables. The CER's were categorized by 22 cost groups based on a two digit SWBS breakdown developed for the model. This two digit breakdown is provided in Appendix (B), along with the assignment of three digit SWBS groups to the two digit breakdown.

CER's in the original construction cost models were developed to estimate labor manhours and material dollars for shipyard activities. This included shipyard construction activities, SWBS Groups 100-700, the non-engineering portion of Group 800 costs, and SWBS Group 900 shipyard assembly and support services. It did not include the SWBS Group 800 detail design and engineering costs or Government Furnished Equipment (GFE) costs.

Detail design and engineering costs were estimated using the following models developed for NCA:

- U.S. Naval Vessels Detail Design Cost Estimating Model, June 1991 [Reference (3)]

- U.S. Naval Auxiliary, Amphibious, MSC and Minehunting Type Vessels Detail Design Cost Estimating Model, July 1992 [Reference (4)]

In these models, shipyard engineering costs were derived from shipyard and design agents's return costs or estimated cost data. In addition, shipyard CPR data was used. These data were used to develop CER's for total shipyard detail design and engineering labor manhours as a function of shipyard production labor manhours (SWBS Groups 100-700 and 900). Material costs were derived as a function of the engineering labor dollars. Single and multiple variable, linear and non-linear CER's were investigated using regression analysis, as explained in the latter part of Section 2.2.

GFE costs were derived separately using other models available to NCA.

A total construction cost estimate for a ship was derived by first estimating the appropriate individual cost group CER's based on the ship type and selected ship characteristics. These CER's were then summed by SWBS group. Production manhours were estimated by summing the manhours for SWBS Groups 100-700 and 900. The SWBS Group 800 Engineering labor manhours and material dollars were derived using the production manhours estimate and the appropriate engineering CER's. The total labor cost in dollars was derived by summing all the manhours and multiplying by a labor rate developed by NCA. Material dollars were derived by escalating the material costs using escalation factors provided by NCA [Reference (5)]. A total shipyard cost estimate was developed by summing the total SWBS Groups 100-900 labor and material dollars and adding GFE costs derived separately.

2.2 Model Approach

Many of the attributes of the previous models have been carried over into the current model. The major difference is that the current model relies more heavily on shipyard CPR data instead of independently derived shipyard return cost data or estimated cost data. The model is a collection of CER's that estimate labor manhours and material dollars as a function of ship's characteristics, such as lightship weight, shaft horsepower, and total accommodations. Due to limitations of the data base, CER's are developed for manhours only to the one digit SWBS breakdown shown in Table 1-1 and for total material dollars. Included in these CER's are all shipyard related construction costs (SWBS Groups 100-700), engineering and integration costs (SWBS Group 800) and shipyard assembly and support service costs (SWBS Group 900).

Summary CER's are also provided in the model. These estimate labor manhours for shipyard construction costs (SWBS Groups 100-700), shipyard production costs (SWBS Groups 100-700 and 900) and total costs (SWBS Groups 100-900).

The model combines the various data bases into a single data base. This single data base in segmented into the following four general ship types:

- Surface Combatants
- Amphibious Ships
- Auxiliary Ships
- Other Ships (LCAC, MCM, MHC)

These ship types and data are discussed in detail in Section 3.0. CPR data provided by NCA is primarily used to develop the data base. The CPR data have the advantage of representing actual government costs for the shipbuilding contract. The CPR data also allow a wide variety of ships, from various yards, to be included in the data base. Since the shipyards report costs in a variety of ways, such as by SWBS, construction trade, or zone, it is not possible to segment the data into the 22 cost groups used in previous models.

As with the previous models, data from the lead ship in the lead yard and the lead ship in the follow yard are used in this model. This is considered appropriate for the production costs of the ship, since in both the lead and follow yards, these costs are representative of a lead ship cost. It is not considered appropriate for SWBS Group 800 costs, since a large element of SWBS Group 800 are non-recurring costs, such as engineering and detail design. For Group 800, only the lead ship in a lead yard cost data is considered.

The CPR data were analyzed to determine the contract type, method of shipyard cost reporting, the base year for dollar escalation, the constituent elements of the data, the completeness of the data for modeling purposes, any peculiarities within the data set, and any data not provided. The data were then assigned to the appropriate SWBS groups. The data were evaluated for reasonableness by comparison with other ships in the data set and any outliers were identified for further assessment. Outliers were assessed first to determine the correctness of the SWBS assignment, and then to identify any potential problems, either resulting from production requirements, or from multipliers (such as escalation factors) used to adjust the data. Inappropriate or incomplete data were not used in developing CER's. These data are identified in the data base and rationale for their deletion from the CER's is provided.

Single and multiple variable, linear and non-linear CER's were investigated using regression analysis. The resulting preferred CER's are principally single variable, linear relationships. Analyses of relationships that were deemed non-contributory to the model are provided for information in Appendix (C). For the preferred CER's, a number of different independent variables are used based on best engineering judgment regarding their potential for being an indicator of shipyard expenditure. In addition, CER's are provided for each SWBS Group as a function of SWBS Group weight to allow development of an estimate using a ship weight breakdown. A statistical analysis of each CER is also provided which identifies the following statistical information:

- **R^2 (correlation coefficient)^2**

  This measures goodness of fit of the CER. R^2 ranges from 0 to 1. If all the observations fall on the regression line, R^2 is equal to 1.

- **T statistic**

  This measures the significance of the regression coefficient. The T statistic is calculated as the ratio of the coefficient of the independent variable to the standard error of that same coefficient.

- **F statistic**

  This measures the overall significance of the regression equation, and is calculated using R^2, the number of independent variables, and the number of observations using the following formula:

  $$F = \frac{R^2/k}{(1-R^2)/(n-k-1)}$$

  where k = number of independent variables

  n = number of observations

  n-k-1 = degrees of freedom

  Although multiple variable CER's were investigated, most CER's in the model are single variable, so the significance level of T and F are the same.

- **CV (coefficient of variation)**

  CV is the statistic which allows the use of the standard error of the estimate to compare different regression lines. It is actually a relative standard error of the estimate since it becomes a dimensionless quantity. CV is calculated as the ratio of the standard error of the estimate to the mean ($\bar{y}$.) A small CV indicates the model is a good predictor.

The CER's are presented in both graphical and computational forms. The data used to derive the CER are also presented both graphically and in a tabular format. In addition, notes are provided that highlight issues relating to the data or the CER.

CER's are provided for labor manhours and material dollars, in FY 93 dollars. Labor manhour rates and inflation factors will be provided by NCA based on in-house data.

The model provides work sheets for use in estimating shipyard engineering and construction costs. In addition, the PC version of the model integrates the data base, the CER's and the estimating function into an interactive model for estimating purposes. The PC version of the model is provided on floppy disk using Lotus 1-2-3 Release 3.1. A user guide for the PC model is provided in Appendix (A).

3.0 DATA BASE

The data base for this model consists of two main elements: ship's characteristics data and ship's cost data. The ship's characteristics data represent the potential independent variables that can be used to develop CER's and to evaluate the relationship between different ships. The data consist of a combination of physical characteristics, mission characteristics and shipyard construction information. The ship's cost data consist of the labor and material costs incurred by a shipyard to design and construct the ship. For the purposes of this model, data consist of labor manhours and material dollars in FY 93 dollars.

The ship's characteristics data presented in this report consist of both descriptive narrative and tabular information. The narrative data is excerpted from Janes Fighting Ships [Reference (6)]. The primary source of physical characteristics information is the Naval Vessel Register [Reference (7)], which is a Navy approved document. This was used in order to be consistent with other modeling activities ongoing at NCA.

The ship's characteristics data base is relatively comprehensive in order to provide reference information on the individual characteristics of the lead ships. This is useful for categorizing the ships into common groups, and for assessing similarities between future ships being estimated and ships currently within the data base.

The ships data are grouped by general mission type. Four categories of ship type are presented. These ship types, along with the ship classes included in the data base, are the following:

Surface Combatants:	FFG 7, DD 963, CG 47, DDG 51, DD 931(1), DDG 2(1), CG 16(1), CG 26(1)
Amphibious Ships:	LST 1182, LSD 41, AD 41(2), LHD 1
Auxiliary Ships:	TAGOS 19, AO 180(3), AFS 6(3), AOR 7(3), TAO 187, AOE 6, TAGS 45
Other Ships:	LCAC 34, MHC 51, MCM 1

Within each group there is an individual section on each ship class, providing a narrative description of its mission, construction history and key mission systems. This is followed by tables providing general lead ship's physical characteristics and key hull, electrical and mechanical systems information. This is then followed by contract and cost information, as available, for the lead ship in the lead yard, and lead ships in follow yards. The detailed ship data is provided to allow the user to compare existing ship characteristics for ships in the database to the proposed ship under consideration. This will assist the user in determining the adequacy of individual CER's and in identifying potential outliers.

The database also includes two ships, the AFS 6 and AO 180, that are follow ships in a yard. These ships were part of the Auxiliary and Amphibious Construction Cost Model [Reference (2)]. Their return costs were adjusted by NASSCO cost estimators to reflect lead

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(1)These ships were part of the Revised Destroyer/Cruiser Construction Cost Model. While they are adequate for the purposes of this model, they are not representative of current technology, and, therefore, detailed descriptions and comparative data are not provided for them in this model.

(2)Cost data for the AD 41 was adjusted by NASSCO cost estimators to represent a lead ship in a follow yard. Although the AD 41 is an auxiliary ship, it has historically been included in the amphibious ship portion of the model. The AD 41 is a more complex ship than is typical of other auxiliary ships in the model, and its construction requirements are more like amphibious ships than auxiliary ships. See Section 3.2.3 for details.

(3)Cost data for the AO 180, AFS 6 and AOR 7 were adjusted by NASSCO cost estimators to represent lead ships. See Sections 3.3.2 through 3.3.4 for details.

ship construction costs. As such, they are considered representative of lead ship costs for the purposes of this model.

Included in the data base are four ships that were commissioned prior to the 1970's: DD 931, DDG 2, CG 16 and CG 26. These ships were part of the Revised Destroyer/Cruiser Construction Cost Model. While these ships are adequate for the purposes of this model they are not representative of current technology (for example, they have steam turbines). As such, detailed descriptions and comparative data are not provided for these four ships in this model; however, a summary of their weight, labor and material cost data is provided in Appendix (D).

The cost data consist primarily of labor manhours and material dollars derived from CPR reports. The data used represent the "estimate at completion" for the most recent CPR available. Labor manhours are used to avoid variations that would occur due to different labor rates at different yards, as well as inaccuracies caused by escalating then year dollars into FY 93 or future year dollars. Material dollars are presented and escalated to FY 93 dollars using inflation factors provided by NCA [Reference (5)]. No G&A or fee is added to the material dollars.

Where CPR data are not available, other data sources, including NAVSEA 017 reports and previous cost models, are used. These data sources are identified in the subsection and the value of the data is assessed. The cost data used are derived from return costs incurred by the shipyard. Unlike previous models, no bottom up construction cost estimates are provided in the data base or used in the model.

To the extent possible, lightship weight, labor manhours and material dollars are broken down by the one digit SWBS breakdown shown in Table 1-1. Since CPR data are presented in a variety of formats such as by total cost, SWBS breakdown, construction module, or construction trade, it was not always possible to divide the costs into SWBS groups. In a number of cases, such as for the FFG 7 and DDG 51 Classes, CPR costs have been assigned a SWBS breakdown based on analysis of the CPR cost breakdown, assessment of historical data from the same yard, and best engineering judgment. This was considered necessary in order to provide essential data to specific CER's to calibrate them to recent cost trends. The assessments performed are discussed in the appropriate data sections and these data points are highlighted in the notes supporting the CER's.

All the data were assessed for reasonableness by comparison with other ships in its category. These comparisons are shown graphically in Appendix (E). Outliers or data that appeared inaccurate were noted and further assessments were performed. In these additional assessments, each piece of data was evaluated to determine if it was complete, if it had been properly assigned to a SWBS group, if there was a technical or programmatic reason for its value, or if, in the case of material dollars, it had been escalated correctly. These analyses are discussed in the individual data sets. Overall, most of the initial outliers were able to be corrected, or a reasonable explanation for their difference was determined that allowed the outlier to be deleted from the CER. The only major exception is the DDG 51. In this case, the CPR data were too general and the technical and programmatic issues too broad to identify specific cost drivers. Nevertheless, data for the DDG 51 data were used in the model since the DDG 51 is a key lead ship data point. However, comparisons with the DDG 52 (lead ship at follow yard) and analysis of the DDG 53 (second ship at lead yard), indicate that the DDG 51 costs are unusually high.

Escalation of material costs was a source of potential error in the data base. Each contract type used a different method for reporting dollars in a CPR. In a fixed price contract, such as the DDG 51 construction contract, actual costs were de-escalated and reported in base year dollars. To escalate the costs to FY 93 dollars, reported costs had to be escalated from the contract base year. In a cost plus type contract, costs are reported in current year dollars based on the date of the CPR. Accumulated costs are escalated to correspond with the date of the CPR. To escalate these costs to FY 93 dollars, the reported costs had to be escalated from the date of the CPR. Care was taken to ensure that the data were escalated properly, and the specific method of escalation is discussed in each data set.

Another potential source of error with regard to material dollars is that GFE would vary between lead and follow ships. A good example is the CG 47 Class, where the CG 51's (lead ship at follow yard) material costs are substantially less than the CG 47. This is caused primarily by the fact that systems, such as the LM 2500 gas turbines, were purchased by separate contract for the follow ships and provided to the yard as GFE. To avoid this lead ship/follow ship problem, only lead ship material costs at the lead yard are considered in developing material cost CER's.

A further source of error for material dollars was the problem that older data required escalation over a longer number of years. This may explain why older data for similar ships are in excess of more current data. Examples of these are the CG 47 versus DDG 51 material costs or the DD 963 versus CG 47 material costs.

Since the CPR data often report material costs as a single item, it is not possible to determine the actual source of differences between material cost data points. Because of this data limitation, and uncertainty of the data, only total material costs (FY 93 dollars) are used to develop material cost CER's in this model.

Overall, the data base is rather broad and comprehensive. The major recent lead ships in each ship type are contained in the data base. In addition, the data base contains examples of different hull forms (e.g., monohull and SWATH), hull materials (e.g., steel, aluminum, GRP and wood), propulsion systems (e.g., steam, diesel, diesel electric, and gas turbine) and mission systems (in particular, AEGIS and non-AEGIS combatants). The major limitation of the data base is the lack of detailed SWBS breakdown to perform system level cost analyses, or detailed comparisons between different ships. As such, the corresponding CER's developed using this data base are at a one digit SWBS level, or total construction, production or contract value.

3.1 Surface Combatant Data

3.1.1 FFG 7 Class Guided Missile Frigate

The lead ship of the FFG 7 Class guided missile frigates was authorized in FY 1973 and commissioned in 1977. The class consists of 51 ships; the last of which, FFG 61, was commissioned in 1989. In addition, the Spanish Navy has built four ships of the class, the Australian Navy six, and the Taiwan Navy is currently building six. General characteristics of the FFG 7 are shown in Table 3-1.

TABLE 3-1

GENERAL CHARACTERISTICS OF FFG 7

LENGTH	Overall (ft)	445.0
	At Waterline (ft)	408.0
BEAM	Extreme (ft)	47.0
	At Waterline (ft)	47.0
DRAFT	Maximum Navigational (ft)	25.0
	Limiting (ft)	16.0
MATERIAL	Hull	Steel
	Superstructure	Aluminum
DISPLACEMENT	Light Ship (LT)	2,667
	Full Load (LT)	3,624
TOTAL ACCOMMODATIONS		215
SHAFT HORSEPOWER (SHP)		40,000
ENGINES	Number	2
	Type	Gas Turbine
NUMBER OF SCREWS		1
MAIN REDUCTION GEARS	Type	Double Reduction-
MAIN GENERATORS	Number	4
	Type	Diesel
	Total KW	4,000

The FFG 7 Class ships were designed as multipurpose ASW and AAW ships. The FFG 7 is powered by two LM 2500 gas turbines with a single shaft and controllable pitch propellers. It has two retractable auxiliary propulsion units to provide a take-home capability for a crippled ship. The ship service generators are diesel powered. The ship has an aluminum deckhouse, and a steel hull structure. It also has the AN/SQS-56 hull mounted sonar and AN/SQR-19 TACTAS towed array passive sonar system for underwater surveillance and communication, a variety of armament systems, including a Mk 13/4 guided missile launcher, Mk 75/76 mm gun, CIWS, and two Mk 32/5 surface vessel torpedo tubes. Countermeasure devices include two Mk 36/5 Super Rapid Blooming Offboard Chaff systems, one AN/SLQ-25 NIXIE torpedo countermeasure system, and AN/SLQ-32(V)2 ECM system. Later ships incorporated hangars for two LAMPS 2 helicopters.

There were four flights of the FFG 7 Class. Flight I included FFG 8-18, Flight II FFG 19-35, Flight III FFG 36-49, and Flight IV FFG 50-61. In addition, modified FFG's have been built for the Australian, Spanish and Taiwanese navies.

Gibbs & Cox, Inc. developed the detail design of the FFG 7, and the lead ship was built at BIW. Follow ship designs were also developed by Gibbs & Cox, Inc. Follow U.S. ships were built at BIW and Todd Shipyards Corporation in Los Angeles and Seattle.

FFG 7 Data

Contract data for the FFG 7 are listed in Table 3-2.

TABLE 3-2

CONTRACT DATA FOR FFG 7

Ship Type: FFG 7 Class Guided Missile Frigate	**Contract Type:** N\A
Shipyard: BIW	**Contract No./Base Yr:** BY 73
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 10/73
Cost Data Source: NAVSEA 017 data sheet: "BIW FFG Program Manhours at Completion"/Rev C/D CCM	**Start Construction:** 6/12/75
Date of Cost Source: 8/92 and 8/81	**Delivery:** 12/17/77
% Complete at Report: 100	**Months to Construct:** 30.1

Cost data for FFG 7 were obtained from a NAVSEA 017 data sheet [Reference (8)] and consisted of production manhours and total manhours. Total material cost data were taken from the Revised Destroyer/Cruiser Construction Cost Model [Reference (1)]. No SWBS breakdown for labor manhours was available. However, previous models developed for NCA using BIW return costs have demonstrated high consistency in the percent breakdown of lead ship SWBS Group 100-700 construction costs. Historically, construction costs (Group 100-700) for the FFG 7 are 45 percent of total ship costs (Group 100-900). Applying this percentage to the total ship labor cost of 3550 kmhrs for FFG 7 provided by NAVSEA 017, gives 1611 kmhrs for construction costs (Groups 100-700). A further breakdown of construction costs was obtained by using the percentage breakdown for lead ship construction costs from the BIW return costs, as illustrated in Table 3-3. A comparison of the SWBS Groups 100-700 breakdown for a variety of BIW data shows that the variation within any individual SWBS group is less than 2 percent.

TABLE 3-3

SWBS BREAKDOWN OF LABOR MANHOURS FOR FFG 7

SWBS	% Breakdown (% of 100-700 Mhrs)	Labor KMHRS Based on % Breakdown
100	26	419
200	6	99
300	13	202
400	6	96
500	23	376
600	24	391
700	2	28
TOTAL 100-700	100	1611 = 45.3% of 3550 kmhrs

(Note: Percentage figures are rounded off to nearest integer.)

An historical comparison of SWBS Group 900 costs at BIW shows that SWBS Group 900 costs were 60 percent of SWBS Groups 100-700. For the FFG 7, this equates to a SWBS Group 900 cost of 966 manhours.

For the FFG 7, SWBS Group 800 costs are a combination of shipyard costs and detail design agent costs. The shipyard costs are the difference between the total shipyard costs of 3550 kmhrs and the shipyard production costs (SWBS Groups 100-700, 900) of 2577 kmhrs, resulting in a shipyard portion of SWBS Group 800 of 973 kmhrs. The detail design agent costs are 2168, per Reference (3). This results in a total SWBS Group 800 cost of 3141 kmhrs.

Total material costs for FFG 7, as per Reference (1), were $31.6M (FY 77). When escalated to FY 93 using Reference (5), the material costs are $81.2M.

A summary of weight and cost data for FFG 7 is provided in Table 3-4.

TABLE 3-4

FFG 7 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	1,235	419	
200	267	99	
300	195	202	
400	116	96	
500	447	376	
600	314	391	
700	93	28	
800[1]		3141	
900		966	
TOTAL	2,667	5718	81.2

Note: [1] Includes Detail Design.

FFG 9 Data

The FFG 9 is the third ship in the FFG 7 Class. It is the first ship of the class built by Todd Shipyards in Los Angeles. Contract data for this ship are listed in Tables 3-5.

TABLE 3-5

CONTRACT DATA FOR FFG 9

Ship Type: FFG 7 Class Guided Missile Frigate	**Contract Type:** N/A
Shipyard: Todd LA	**Contract No./Base Yr:** BY 75
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 02/27/76
Cost Data Source: NAVSEA 017 Data Sheet: "FFG 7 Class Todd LA"	**Start Construction:** 7/13/77
Date of Cost Source: 05/15/87	**Delivery:** 2/28/80
% Complete at Report: 100	**Months to Construct:** 31.5

Cost data for the FFG 9 were extracted from a NAVSEA 017 data sheet [Reference (9)] and consisted of total manhours and total material costs. A SWBS breakdown of labor costs was estimated based on the percentage breakdown developed in concert with NCA as shown in Reference (10). This breakdown represents the percentage allocations for each SWBS group as found in CPR data for other frigates of this class built by Todd LA.

Material costs for FFG 9 were $21.5M in base year 1975 dollars. This escalates to $69.0M in FY 93 dollars.

Weight and cost data for FFG 9 are summarized in Table 3-6. Note that the lead ship weight breakdown was used for this ship.

TABLE 3-6

FFG 9 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)[1]	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	1,235	460	
200	267	141	
300	195	177	
400	116	141	
500	447	460	
600	314	353	
700	93	35	
800		558	
900		775	
TOTAL	2,667	3,100	69.0

Note: (1) Lightship weight for FFG 7 was used.

FFG 10 Data

FFG 10, the fourth ship in the FFG 7 Class, was built by Todd Shipyards in Seattle. Contract data for this ship are given in Table 3-7.

TABLE 3-7

CONTRACT DATA FOR FFG 10

Ship Type: FFG 7 Class Guided Missile Frigate	**Contract Type:** N/A
Shipyard: Todd Seattle	**Contract No./Base Yr:** BY 75
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 02/27/76
Cost Data Source: NAVSEA 017 Data Sheet: "FFG 7 Class Todd Seattle"	**Start Construction:** 04/29/77
Date of Cost Source: 05/15/87	**Delivery:** 5/15/80
% Complete at Report: 100	**Months to Construct:** 36.5

Cost data for the FFG 10 were extracted from a NAVSEA 017 data sheet [Reference (11)] and consisted of total manhours and total material costs. A SWBS breakdown of labor costs was estimated based on the percentage breakdown provided, developed in concert with NCA, as shown in Reference (10). This breakdown represents the percentage allocations for each SWBS group as found in CPR data for other frigates of this class built by Todd in Seattle.

Material costs for FFG 10 were $20.9M in base year 1975 dollars, which escalates to $67.1M in FY 93 dollars.

Weight and cost data for FFG 10 are summarized in Table 3-8. Note that the lead ship weight breakdown was used for this ship.

TABLE 3-8

FFG 10 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)[1]	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	1,235	539	
200	267	124	
300	195	207	
400	116	249	
500	447	601	
600	314	331	
700	93	21	
800		601	
900		668	
TOTAL	2,667	3,341	67.1

Note: [1] Lightship weight for FFG 7 was used.

3.1.2 DD 963 Class Destroyers

The lead ship of the DD 963 Class destroyers was authorized in FY 1970 and commissioned in 1975. The class consists of 31 ships; the last of which, DD 997, was commissioned in 1983. To date there have been no foreign sales of DD 963 class ships, although four ships of the class (DD 993-996) were originally designed for the Iranian Government. In 1979 the Navy took over the contracts for these ships, which were then built as general warfare ships and became the U.S. Navy DDG 993 Class Guided Missile Destroyers. General characteristics of the DD 963 are shown in Table 3-9.

TABLE 3-9

GENERAL CHARACTERISTICS OF DD 963

LENGTH	Overall (ft)	563.0
	At Waterline (ft)	529.0
BEAM	Extreme (ft)	55.0
	At Waterline (ft)	55.0
DRAFT	Maximum Navigational (ft)	32.0
	Limiting (ft)	23.0
MATERIAL	Hull	Steel
	Superstructure	Aluminum
DISPLACEMENT	Light Ship (LT)	5827
	Full Load (LT)	8928
TOTAL ACCOMMODATIONS		353
SHAFT HORSEPOWER (SHP)		80,000
ENGINES	Number	4
	Type	Gas Turbine
NUMBER OF SCREWS		2
MAIN REDUCTION GEARS	Manufacturer	Westinghouse
	Type	Double Reduction-Locked Train
MAIN GENERATORS	Number	3
	Type	Gas Turbine
	Total KW	6,000

The DD 963 Class ships were the first large U.S. warships to employ gas turbine propulsion and advanced self-noise reduction features. The DD 963 is powered by four LM 2500 gas turbines with two shafts and controllable pitch propellers. The modular concept was used to facilitate construction and block modernization. There is a high level of automation and kevlar internal armor in all vital spaces. Ship service generators are gas turbine powered. The ships have an aluminum deckhouse, a steel hull structure, and a hangar for two LAMPS I or LAMPS III helicopters. They also have the AN/SQS-53B bow-mounted sonar for active search and attack and AN/SQR-19 TACTAS passive towed array sonar system for underwater surveillance. The ship is outfitted with several armament systems, including Sea Sparrow, two HARPOON quad launchers, two Mk 32 surface vessel triple torpedo tubes, one ASROC 8-tube launcher and a 5" 54 caliber MK 45 gun. CIWS was added for later ships of the class. Countermeasure devices include two Mk 36 chaff systems, one AN/SLQ-25 NIXIE torpedo decoy, and one AN/SLQ-32(V)2 ECM system.

Ingalls Shipbuilding developed the design of the DD 963 and constructed all ships of the class. Contract data for the DD 963 are provided in Table 3-10.

TABLE 3-10

CONTRACT DATA FOR DD 963

Ship Type: DD 963 Class Destroyer	**Contract Type:** Tot. Pkg. Proc.
Shipyard: Ingalls	**Contract No./Base Yr:** BY 70
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 06/23/70
Cost Data Source: NAVSEA 017 Data Sheet: "Cost Estimating and Analysis (DD 963)"[1]	**Start Construction:** 06/05/72
Date of Cost Source: 02/22/80	**Delivery:** 08/12/75
% Complete at Report: 100	**Months to Construct:** 38.2

Note: [1] Cost source is assumed to represent a summary of CPR data for DD 963.

No CPR data were available for DD 963. Instead, the labor and material cost data for DD 963 are from a NAVSEA 017 data sheet for cost estimating and analysis [Reference (12)]. The data sheet was considered to represent a summary of CPR data for DD 963 compiled by NAVSEA 017 for cost estimating purposes. The production labor (SWBS 100-700 and 900) breakdown for DD 963 is consistent with other lead ship surface combatants. However, the Group 800 costs noted in the data sheet do not appear to include detail design and engineering. Because of this, DD 963 was excluded in the development of CERs for Group 800 labor and Groups 100-900 labor.

Total material cost for DD 963, as noted in the NAVSEA 017 data sheet, was $72.4M. This data sheet provides a one-digit SWBS breakdown of material costs as well as summaries for construction and production costs. Table 3-11 provides a percentage breakdown of material costs by SWBS as identified in the data sheet. Given the lack of detail, it is not possible to identify the material within each group, especially given the large percentage of miscellaneous costs, which may include subcontractor costs.

TABLE 3-11

PERCENTAGE BREAKDOWN OF MATERIAL COSTS BY SWBS

SWBS GROUP	% MATERIAL COST
100	9
200	16
300	7
400	8
500	9
600	9
700	1
800	<1
900	2
Misc. Data	37
TOTAL	**100**

Escalation of material dollars from the base year 1970 results in FY 93 material costs of $392.2M. Since this cost is unexplainably high compared to the other ships in the class, the DD 963 material cost was excluded from the material cost CER. One possible explanation is that, due to the fact that the DD 963 Class acquisition was a total package procurement, the lead ship material cost value may also include some follow ship cost.

Weight and cost data for DD 963 are given in Table 3-12. The lightship weight data for DD 963 were from an as-built weight report dated April 30, 1975.

TABLE 3-12

DD 963 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	3,105	1,105	
200	760	261	
300	285	587	
400	354	208	
500	718	706	
600	454	462	
700	151	70	
800		268	
900		1,586	
TOTAL	**5828**	**5253**	**N/A**

3.1.3 CG 47 Class Guided Missile Cruisers

The lead ship of the CG 47 Class guided missile cruisers was authorized in FY 1977 and commissioned in 1983. The class consists of 27 ships; the last of which CG 73 was commissioned in 1993. To date, there have been no foreign sales of CG 47 Class ships and none are expected. The general characteristics of CG 47 are shown in Table 3-13.

TABLE 3-13

GENERAL CHARACTERISTICS OF CG 47

LENGTH	Overall (ft)	567.0
	At Waterline (ft)	529.0
BEAM	Extreme (ft)	55.0
	At Waterline (ft)	55.0
DRAFT	Maximum Navigational (ft)	33.0
	Limiting (ft)	23.0
MATERIAL	Hull	Steel
	Superstructure	Aluminum

DISPLACEMENT	Light Ship (LT)	6,587
	Full Load (LT)	9,962
TOTAL ACCOMMODATIONS		374
SHAFT HORSEPOWER (SHP)		80,000
ENGINES	Number	4
	Type	Gas Turbine
NUMBER OF SCREWS		2
MAIN REDUCTION GEARS	Manufacturer	Westinghouse
	Type	Double Reduction-Locked Train
MAIN GENERATORS	Number	3
	Type	Gas Turbine
	Total KW	7,500

The CG 47 Class is the first class of AEGIS surface combatants and is a modification of the DD 963 Class destroyers. The ship is powered by four LM 2500 gas turbines with two shafts. The three ships service generators are gas turbine powered. It has an aluminum deckhouse and steel hull. It has the AN/SQS-53 A/B bow-mounted sonar and AN/SQR-19 TACTAS towed array passive sonar system for underwater surveillance and communication. Although the same basic DD 963 hull and propulsion plant were used, the following changes were made:

- The superstructure was redesigned to accommodate AEGIS
- The helicopter hangar was modified to add the after AEGIS deckhouse atop the hangar
- The stacks and masts were modified
- CIC was modified

- Fragmentation protection and fire insulation were added to the superstructure
- Improvements were made to enhance stability
- Ship service generators were upgraded
- The 400 Hz system was upgraded
- The air conditioning plant was enhanced
- Underwater shafting was modified
- New gas turbine clutches were added
- Gas turbine uptakes were redesigned
- Two Mk 26 missiles launchers were added
- The sewage system was modified
- Outfit and furnishings as well as general arrangements were modified to account for increased modifications.

Ingalls Shipbuilding Corporation (ISI) developed the detail design of the CG 47 and also built the lead ship. Follow ships were designed at ISI and built at both ISI and BIW.

CG 47 Data

Contract data for the CG 47 are provided in Table 3-14.

TABLE 3-14

CONTRACT DATA FOR CG 47

Ship Type: CG 47 Class Guided Missile Cruiser	**Contract Type:** CPFF
Shipyard: Ingalls	**Contract No./Base Yr:** 78-C-2316
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 09/22/78
Cost Data Source: CPR CDRL A072, Issue 067	**Start Construction:** 07/25/79
Date of Cost Source: 08/27/84	**Delivery:** 12/13/82
% Complete at Report: 100	**Months to Construct:** 40.6

Cost data for CG 47 are from a 1984 CPR prepared by Ingalls [Reference (13)]. The CPR provided a SWBS breakdown of labor manhours, which are summarized in Table 3-15. Added to the return costs for SWBS Group 800 is an additional 3871 manhours that represents the additional engineering and other nonrecurring costs that would have been required if the CG 47 were a complete new ship design as opposed to a modification to the DD 963 Class ships. These additional manhours were estimated as part of the detail design cost model [Reference (3)] and have been carried over to this model. Although presented in the data and on the CER plot as an estimated point, the modified CG 47 SWBS Group 800 costs were not used in developing the CER for SWBS Group 800.

The CG 47 was awarded as a CPFF contract. In a CPFF contract, material costs are reported in the CPR as current dollars for the date of the report. Since the report is from 1984, the total material cost of $187.2M was escalated 9 years to a FY 93 value of $252.4M. A summary of material and cost data for CG 47 is provided in Table 3-15.

TABLE 3-15

CG 47 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	3,333	791	
200	665	181	
300	379	757	
400	381	207	
500	884	849	
600	590	751	
700	355	72	
800(1)		8,431	
900		1,702	
TOTAL	**6,587**	**13,741**	**252.4**

Note: (1) SWBS Group 800 cost includes an estimated 3871 additional kmhrs to account for engineering and other nonrecurring costs required if CG 47 were a new ship instead of a modification to the DD 963 Class.

CG 51 Data

CG 51 was the first ship of the CG 47 Class built by BIW. Contract data for this ship are given in Table 3-16.

TABLE 3-16

CONTRACT DATA FOR CG 51

Ship Type: CG 47 Class Guided Missile Cruiser	**Contract Type:** CPAF
Shipyard: BIW	**Contract No./Base Yr:** 82-C-2001
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 05/20/82
Cost Data Source: BIW CPR, CDRL A072	**Start Construction:** 11/03/83
Date of Cost Source: 07/25/88	**Delivery:** 06/22/87
% Complete at Report: 100	**Months to Construct:** 43.6

Cost data for the CG 51 are from a 1988 CPR prepared by BIW [Reference (14)]. The CPR provided total manhours(SWBS 100-900), SWBS Groups 800 manhours, and total material costs. Production (SWBS 100-700 and 900) costs were determined by subtracting the SWBS Group 800 manhours (4017 kmhrs) from the total manhours, resulting in 5897 kmhrs. Then, previous BIW data on the CG 51 (Reference 15) were assessed and it was determined that SWBS Group 900 was 45 percent of the production manhours, or 2664 kmhrs. The remaining 3233 kmhrs were assigned to SWBS Groups 100-700 (construction) using historical percentages of the total SWBS Groups 100-700 for ships at BIW. Table 3-17 provides the percentages used and the manhours assigned for SWBS Groups 100-700.

TABLE 3-17

SWBS BREAKDOWN OF CONSTRUCTION COSTS FOR CG 51

SWBS	% Breakdown (% of 100-700 Mhrs)	Labor KMHRS Based on % Breakdown
100	27	873
200	4	120
300	13	426
400	10	324
500	21	686
600	23	734
700	2	70
TOTAL 100-700	100	3233

Material costs for CG 51 were listed in the CPR as $61.0M at the time of the report. This number is very low due to the significant amount of GFE provided for the ship. Because of this, CG 51 is not included in the development of the material cost CER for surface combatants. A list of some of the major items of GFE provided for CG 51, as taken from Reference (16), is given in Table 3-18.

TABLE 3-18

CG 51 GFE - MAJOR ITEMS

SWBS GROUP	GFE
100	Sonar Dome and Window
200	LM 2500 Propulsion Gas Turbine Engines
300	Gas Turbine Generators
400	Unitized Foundation 172-1G (ADG Computer)
	Ship Control System
	U.F. 172-8 (AN/SPY-1A Computer)
	AN/SQS-53A Sonar System & Power Supply
	U.F. 172-13 (Weapon Control Computer)
500	Air Conditioning Plant/Fan Coil Assemblies
	Refrigeration Plants
600	Impressed Current System
	Hangar Doors
700	Strikedown Elevators

A summary of weight and cost data for CG 51 is given in Table 3-19.

TABLE 3-19
CG 51 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	3,442	873	
200	670	120	
300	376	426	
400	396	324	
500	932	686	
600	582	734	
700	346	70	
800		4017	
900		2664	
TOTAL	6,744	9914	73.1

3.1.4 DDG 51 Class Guided Missile Destroyers

The lead ship of the DDG 51 Class guided missile destroyers was authorized in FY 1985 and commissioned in 1991. The class is currently proposed to consist of 41 ships, of which 17 are currently under contract. No foreign sales of the DDG 51 Class are currently envisioned, although the Japanese are designing and building a similar, but slightly larger version. The general characteristics of the DDG 51 are shown in Table 3-20.

TABLE 3-20

GENERAL CHARACTERISTICS OF DDG 51

LENGTH	Overall (ft)	504.0
	At Waterline (ft)	466.0
BEAM	Extreme (ft)	66.0
	At Waterline (ft)	59.0
DRAFT	Maximum Navigational (ft)	32.0
	Limiting (ft)	22.0

MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	6,597
	Full Load (LT)	8,344
TOTAL ACCOMMODATIONS		341
SHAFT HORSEPOWER (SHP)		92,000
ENGINES	Number	4
	Manufacturer	GE
	Type	Gas Turbine
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	Double Reduction-
MAIN GENERATORS	Number	4
	Type	Gas Turbine
	KW	7,500

The DDG 51 is the second generation of AEGIS surface combatant ships and represents the first new full ship design of an AEGIS surface combatant. The ship is powered by four LM 2500 gas turbines with two shafts and controllable pitch propellers. The three ships service generators are gas turbine powered. It has landing facilities for LAMP III helicopters, but no hangars. The DDG 51 contains the Mk 41 Mod 2 Vertical Launch System (VLS), consisting of a 29 missile cell launch module forward and a 61 cell module aft. Other weapon systems include twin HARPOON launchers, two CIWS, one 5"/54 caliber gun and two Mk 32 surface vessel torpedo tubes. The ship also has the AN/SQS-53C bow mounted sonar system and AN/SQR-19 TACTAS towed array passive sonar system for underwater surveillance.

The DDG 51 contains a number of survivability features, including all steel construction (aluminum mast), partial collective protection system, shock hardening, improved nuclear blast resistance, EMP protection, fragmentation protection and separation and redundancy of vital equipment.

Gibbs & Cox, Inc. and BIW developed the detail design of the DDG 51, and the lead ship was built at BIW. Follow ships are being built at BIW and ISI.

DDG 51 Data

Contract data for the DDG 51 are provided in Table 3-21.

TABLE 3-21

CONTRACT DATA FOR DDG 51

Ship Type: DDG 51 Class Guided Missile Destroyer	**Contract Type:** FPIF
Shipyard: BIW	**Contract No./Base Yr:** 85-C-2144
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 04/02/85
Cost Data Source: CPR	**Start Construction:** 09/06/87
Date of Cost Source: 01/27/92	**Delivery:** 04/21/91
% Complete at Report: 100	**Months to Construct:** 43.5

Cost data for DDG 51 were extracted from a 1992 CPR prepared by BIW [Reference (17)]. The CPR provided a labor breakdown by technical trades and total material costs. A SWBS breakdown of the labor costs for Groups 100-700, 800 and 900 was developed by assigning manhours from the various technical trades to these SWBS groups. A breakdown of the SWBS Groups 100 to 700 was derived by applying the percentages noted in Figure 3-2 to the SWBS Groups 100-700 manhours. In addition, 3709 kmhrs were added to SWBS Group 800 to account for the detail design effort performed by Gibbs & Cox, Inc. (This is presented as a separate line item in the CPR.) The resulting breakdown indicates that DDG 51 is high in most of the individual SWBS groups. Because of the lack of detail in the data and the broad number of technical and programmatic issues relating to the construction of the ship, it is not possible to isolate individual cost drivers accounting for the high labor costs. In addition, since the CG 47 was a modification of the DD 963, the DDG 51 represents the first new full ship design of an AEGIS surface combatant. As such, there are no other lead ship benchmarks to compare the DDG 51 against. A comparison can be made with the DDG 52 at Ingalls or an estimate of what lead ship labor costs would be if the second ship at BIW (the DDG 53) was estimated as a lead ship. (This was estimated by multiplying the DDG 53 by a 1.07 factor to account for learning.) In the case of DDG 52, the production labor costs appear consistent with previous similar ships. The DDG 53 T-1 (DDG 53 costs "backed up" the learning curve to represent lead ship costs) was low compared to other ships. A comparison of labor costs between DDG 51, DDG 52 and DDG 53 T-1 is as follows:

SWBS Group	DDG 51	DDG 52	DDG 53 T-1
100-700	6581	4237	3215
100-700 & 900	7725	5960	5240

The consistency of DDG 52 with other lead ships tends to suggest that the DDG 51 is an outlier; however, given the DDG 51's uniqueness as a data point, it is used in the development of CER's.

Material costs for DDG 51, as per Reference (17), were $153.3M. When escalated to FY 93 dollars, this amount becomes $199.8M, which is consistent with other lead ship surface combatants.

Table 3-22 provides a summary of weight and cost data for DDG 51.

TABLE 3-22

DDG 51 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	3,124	1,710	
200	804	404	
300	374	825	
400	400	392	
500	961	1,537	
600	617	1,598	
700	317	115	
800		8,122	
900		1,144	
TOTAL	**6,597**	**15,847**	**199.8**

Note: (1) SWBS Group 800 labor cost includes detail design.

DDG 52 Data

DDG 52 is the second ship in the ARLEIGH BURKE Class of guided missile destroyers. The ship was awarded in 1987 and is the lead ship built by Ingalls Shipbuilding. Contract data for DDG 52 are shown in Table 3-23.

TABLE 3-23

CONTRACT DATA FOR DDG 52

Ship Type: DDG 52 Class Guided Missile Destroyer	**Contract Type:** FPIF
Shipyard: Ingalls	**Contract No./Base Yr:** 87-C-2256
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 05/26/87
Cost Data Source: CPR	**Start Construction:** 05/11/89
Date of Cost Source: 08/21/92	**Delivery:** 10/19/92
% Complete at Report: 87.9	**Months to Construct:** 41.3

Cost data for DDG 52 were from a 1992 CPR [Reference (18)] and consisted of total manhours and total material costs. A SWBS breakdown of the labor costs for SWBS Groups 100-700, 800 and 900 was first developed by assigning manhours from the CPR line items to individual SWBS groups. A breakdown for the individual SWBS Groups 100 through 700 was then developed using the percentage breakdown of these costs for the CG 47 Class at Ingalls [Reference (1)]. This breakdown and the manhours applied to the DDG 52 are shown in Table 3-24.

TABLE 3-24

SWBS BREAKDOWN OF LABOR MANHOURS FOR DDG 52

SWBS	% Breakdown (% of Groups 100-700 Manhours)	Labor KMHRS based on % Breakdown
100	22	928
200	5	213
300	21	889
400	6	243

SWBS	% Breakdown (% of Groups 100-700 Manhours)	Labor KMHRS based on % Breakdown
500	23	997
600	21	882
700	2	85
TOTAL 100-700	**100**	**4237**

Note: Percentage figures are rounded off to nearest integer.

The resulting breakdown is consistent with other lead ship/follow yard surface combatants (i.e., FFG 7 and FFG 9).

Material costs for DDG 52 are presented as a single line item in the CPR [Reference (18)]. The material costs presented were $118.4M in FY 87 dollars. When escalated to FY 93 dollars, this amount becomes $146.2M.

Table 3-25 provides a summary of weight and cost data for DDG 52.

TABLE 3-25

DDG 52 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)[1]	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	3,124	928	
200	804	213	
300	374	889	
400	400	243	
500	961	997	
600	617	882	
700	317	85	
800		803	
900		1,723	
TOTAL	**6,597**	**6,763**	**146.2**

Note: [1] Lightship weight for DDG 51 was used.

3.2 Amphibious Ships Data

3.2.1 LST 1182 Class Tank Landing Ships

The LST 1182 is a member of the "NEWPORT" Class tank landing ships, of which LST 1179 was the lead ship. The LST 1182 is the lead ship for the follow yard, National Steel & Shipbuilding Co. (NASSCO). The first three were built at Philadelphia Naval Shipyard and the remaining at NASSCO. This class is the first class to use an over-the-bow ramp for unloading tanks and other heavy vehicles. The LST 1182 was commissioned in November 1969. General characteristics of LST 1182 are shown in Table 3-26.

TABLE 3-26

GENERAL CHARACTERISTICS OF LST 1179 CLASS

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	522.0
	At Waterline (ft)	500.0
BEAM	Extreme (ft)	70.0
	At Waterline (ft)	70.0
DRAFT	Maximum Navigational (ft)	19.0
	Limiting (ft)	19.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	4,468
	Full Load (LT)	8,677
TOTAL ACCOMMODATIONS		650
SHAFT HORSEPOWER (SHP)		16,000
ENGINES	Number	6
	Manufacturer	American Locomotive Co.
	Type	Diesel
MAIN REDUCTION GEARS	Manufacturer	General Electric
	Type	Single Reduction
MAIN GENERATORS	Number	3
	Type	Diesel
	KW	2,250

The LST 1179 Class ships are designed to operate with 20 knot amphibious squadrons to transport tanks, other heavy vehicles, engineering equipment, and supplies which cannot be readily landed by helicopters or landing craft. The LST 1182 is powered by six ALCO diesels, which drive two shafts with controllable pitch propellers. The ship is constructed entirely of steel and is equipped with a helicopter platform. Armament for the LST 1182 consists of four Mk 33 3-inch guns as well as one CIWS. Contract data for the LST 1182 are provided in Table 3-27.

TABLE 3-27

CONTRACT DATA FOR LST 1182

Ship Type: Newport Class Tank Landing Ship	**Contract Type:** N/A
Shipyard: National Steel & Shipbuilding Co.	**Contract No./Base Yr: N/A**
Cost Data Type: Lead Ship/Follow Yard	**Contract Award:** 07/66
Cost Data Source: Aux. & Amphib. CCM(1)	**Start Construction:** 12/16/67
Date of Cost Source: 09/01/88	**Delivery:** 11/22/69
% Complete at Report: 100	**Months to Construct:** 23.2

Note:(1) Internal accounting reports adjusted by NASSCO.

Cost data for the LST 1182 were from the Auxiliary and Amphibious Ships Construction Cost Model [Reference (2)]. The cost data represent data from internal accounting reports adjusted by NASSCO. This model provided weight data and labor and material costs in both a SWBS breakdown and a 22 cost group breakdown. SWBS Groups 100 to 700 labor costs were derived from the data base presented in the model for the LST 1182. The SWBS Group 800 labor costs were estimated as 2,000 kmhrs, and SWBS Group 900 labor costs were estimated as 750 kmhrs, using the constants presented in the model for these groups. (The raw SWBS Group 800 and 900 data for the LST 1182 are not in the report.)

Material costs were reported as \$25.9M in 1980 dollars in the model [Reference (2)]. This amount was escalated over 13 years to a FY 93 value of \$49.9M.

The weight and cost data for LST 1182 are provided in Table 3-28.

TABLE 3-28

LST 1182 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	2,707	455	
200	348	103	
300	136	57	
400	77	45	
500	750	415	
600	379	147	
700	71	7	
800		2,000 (Est)	
900		750 (Est)	
TOTAL	4,468	3,979	49.9

3.2.2 LSD 41 Class Dock Landing Ships

The lead ship of the WHIDBEY ISLAND Class, LSD 41, was built by Lockheed Shipbuilding and Construction Company and was commissioned in May 1985. The class consists of 13 ships, LSD 41 through LSD 53. The LSD program was transferred to Avondale Shipyard beginning with the LSD 44. Avondale has been responsible for all subsequent design and construction activities for the program. The general characteristics of the LSD 41 are shown in Table 3-29.

TABLE 3-29

GENERAL CHARACTERISTICS OF LSD 41

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	610.0
	At Waterline (ft)	580.0
BEAM	Extreme (ft)	84.0
	At Waterline (ft)	84.0
DRAFT	Maximum Navigational (ft)	21.0
	Limiting (ft)	21.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	11,165
	Full Load (LT)	16,469
TOTAL ACCOMMODATIONS		852
SHAFT HORSEPOWER (SHP)		33,000
ENGINES	Number	4
	Manufacturer	
	Type	Diesel
MAIN REDUCTION GEARS	Manufacturer	Philadelphia Gear Co.
	Type	
MAIN GENERATORS	Number	4
	Type	Diesel
	KW	5,200

The ships of the WHIDBEY ISLAND Class, principally carry cargo and landing craft and are equipped with a removable helicopter platform above the docking well. The ships of this class are based on the ANCHORAGE Class (LSD 36 - LSD 40) design, but have a slightly larger docking well suitable for air cushion assault landing craft (LCAC). The WHIDBEY ISLAND Class has a capacity of 5000 cubic feet for marine cargo and 12,500 square feet for vehicles. It is also equipped with one 60 ton and one 20 ton crane.

The LSD 41 carries a complement of 340 troops including 21 officers. The ship is outfitted with SATCOM SAR-1 and WSC-3 (UHF) communications systems, and a variety of air, surface and navigation radars. Its armament systems include two Vulcan Phalanx Mk 15 and two Mk 67 20 mm 8-12.7 mm MG guns. Countermeasures include four SRBOC 6 Mk 36 decoy launchers and an ESM:SLQ32 intercept system. Power for the ship is provided by four Colt-Pielstick Type 16 PC25-V400 diesels with two controllable pitch propellers.

Beginning with LSD 49, five cargo variants of the LSD 41 Class ships are planned for construction. There is approximately 90% commonality between the original design and the cargo variants, which are designed to increase cargo carrying capacity.

LSD 41 Data

Contract data for the LSD 41 are provided in Table 3-30.

TABLE 3-30

CONTRACT DATA FOR LSD 41

Ship Type: LSD 41 Class Dock Landing Ship	**Contract Type:** CPFF w/ ceiling
Shipyard: Lockheed	**Contract No./Base Yr:** 80-C-2080
Cost Data Type: Return Cost, Lead Ship, Lead Yard	**Contract Award:** 02/09/81
Cost Data Source: CPR	**Start Construction:** 04/06/81
Date of Cost Source: 08/04/85	**Delivery:** 01/08/85
% Complete at Report: 100	**Months to Construct:** 45.1

Cost data for the LSD 41 were from a 1985 CPR [Reference (19)] prepared by Lockheed. The data included a SWBS breakdown of labor manhours and total material costs. Production costs (SWBS Groups 100-700 and 900) for the LSD 41 were 4348 kmhrs and engineering costs were 2020 kmhrs. Construction costs (SWBS Groups 100-700) were 3080 kmhrs.

The material costs listed in the CPR for LSD 41 were $164M. As with most CPFF contracts, material costs are reported in current year dollars in the CPR. In this case, determining the equivalent material costs in FY 93 dollars required escalating the reported material costs from the date of the report instead of from the ship's contract base year. Since the CPR was from 1985, the $164M was escalated over eight years to a FY 93 value of $214M. Weight data for the LSD 41 were provided in SWBS breakdown by NAVSEA 05 [Reference (20)].

A summary of weight and cost data for LSD 41 is provided in Table 3-31.

TABLE 3-31

LSD 41 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	6,627	1,215	
200	985	239	
300	435	310	
400	141	126	
500	1,796	897	
600	1,134	288	
700	47	5	
800		2,020	
900		1,268	
TOTAL	11,165	6,368	214.4

LSD 44 Data

LSD 44 was the first ship of the class built by Avondale Shipyards. Contract data for LSD 44 is shown in Table 3-32.

TABLE 3-32

CONTRACT DATA FOR LSD 44

Ship Type: LSD 41 Class Dock Landing Ship	**Contract Type:** FPI
Shipyard: Avondale	**Contract No./Base Yr:** 84-C-2027
Cost Data Type: Return Cost, Lead Ship, Follow Yard	**Contract Award:** 11/21/83
Cost Data Source: CPR + NCA Report	**Start Construction:** 11/18/85
Date of Cost Source: 03/31/89	**Delivery:** 02/24/89
% Complete at Report: 100	**Months to Construct:** 39.2

Labor and material cost data for the LSD 44 were from a 1989 CPR prepared by Avondale Shipyards [Reference (21)]. The data consisted of total material costs and total labor manhours, which were also broken down by zone. Since this could not be translated into a SWBS breakdown, the estimated breakdown provided in Reference (10) was used. This breakdown compared very well with other lead ship/follow yard labor cost data. Construction costs (SWBS Groups 100-700) were 3519 kmhrs, production costs (SWBS Groups 100-700 and 900) were 4376 kmhrs and engineering/integration costs (SWBS Group 800) were 2097 kmhrs.

Material costs listed in the CPR for LSD 44 were $69.0M. Since the LSD 44 was negotiated as a Fixed Price Incentive Contract, the material costs were reported in the CPR in base year dollars. When escalated from 1984 base year dollars to FY 93 dollars, this amount becomes $93.1M.

The weight breakdown for LSD 44 is based on the lightship weight data provided by NAVSEA 05 [Reference (22)] for the lead ship, LSD 41.

Table 3-33 provides a summary of weight and cost data for the LSD 44.

TABLE 3-33

LSD 44 WEIGHT AND COST DATA SUMMARY

SWBS	Weight[1] (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	6,627	1,282	
200	985	287	
300	435	374	
400	141	155	
500	1,796	1,049	
600	1,134	366	
700	47	6	
800		2,097	
900		857	
TOTAL	11,165	6,473	93.1

Note: [1] Lightship weight for LSD 41 was used.

3.2.3 AD 37 Class Destroyer Tenders

The AD 37 Class is the first class of destroyer tenders built after World War II. The AD 41 is the lead ship of the AD 37 Class built in the follow yard, National Steel & Shipbuilding Co. (NASSCO). The first two ships (AD 37, AD 38) were built at Puget Sound Naval Shipyard. All subsequent ships were built at NASSCO.

The AD 41 was commissioned in May 1980. The general characteristics of AD 41 are in Table 3-34.

Although the AD 41 is an auxiliary ship, it has historically been included in the amphibious ship portion of the model. The AD 41 is a more complex ship than is typical of the other auxiliary ships in the model, and its construction requirements are more like amphibious ships than the auxiliary ships. This is borne out by a comparison of the AD 41's labor costs to other ships within the amphibious and auxiliary categories.

The AD 41 power plant consists of two Combustion Engineering boilers and one DeLaval turbine which drives a single fixed pitch propeller. The hull and superstructure are all steel construction. The capabilities of the AD 41 include two 30-ton cranes, a helicopter platform, and facilities for servicing nuclear power plants.

TABLE 3-34

GENERAL CHARACTERISTICS OF AD 41

LEAD SHIP CHARACTERISTICS			
LENGTH	Overall (ft)	642.0	
	At Waterline (ft)	620.0	
BEAM	Extreme (ft)	85.0	
	At Waterline (ft)	67.0	
DRAFT	Maximum Navigational (ft)	22.5	
	Limiting (ft)	27	
MATERIAL	Hull	Steel	
	Superstructure	Steel	
DISPLACEMENT	Light Ship (LT)	13,312	
	Full Load (LT)	20,423	
TOTAL ACCOMMODATIONS		1,681	
SHAFT HORSEPOWER (SHP)		20,000	
ENGINES	Number	1	
	Manufacturer	Delaval	
	Type	Steam Turbine	
MAIN REDUCTION GEARS	Manufacturer	Delaval	
	Type	Double	
MAIN GENERATORS	Number	4	1
	Type	Steam Turbine	Diesel
	KW	10,000	1,000

Contract data for the AD 41 are provided in Table 3-35.

TABLE 3-35

CONTRACT DATA FOR AD 41

Ship Type: Destroyer Tender	**Contract Type:** FPI
Shipyard: National Steel & Shipbuilding Co.	**Contract No./Base Yr:** N/A
Cost Data Type: Estimated to be Lead Ship/ Follow Yard[1]	**Contract Award:** 12/75
Cost Data Source: Auxiliary & Amphibious CCM	**Start Construction:** 01/10/77
Date of Cost Source: 09/01/88	**Delivery:** 05/31/80
% Complete at Report: 100	**Months to Construct:** 40.6

Note: [1] Cost data for the AD 41 was adjusted by NASSCO cost estimators to represent a lead ship in a follow yard.

Cost data for the AD 41 were from the Auxiliary and Amphibious Ships Construction Cost Model [Reference (2)]. The return cost for the AD 41 was adjusted by NASSCO cost estimators to represent a lead ship in a follow yard. The Reference (2) model provided labor and material costs in both a SWBS breakdown and a 22 cost group breakdown. Construction costs (SWBS Groups 100-700) were derived from the data base presented in the model for the AD 41. The SWBS Group 800 labor costs were estimated as 2,000 kmhrs, and SWBS Group 900 labor costs were estimated as 750 kmhrs, using the constants for these groups provided in the Reference (2) model. (The raw SWBS Group 800 and 900 data for the AD 41 were not in the Reference (2) report.) Material costs for AD 41 were reported in the model [Reference (2)] as $72.4M in 1980 dollars. This amount was escalated over 13 years to a FY 93 value of $139.7M.

Weight data for the AD 41 was provided by a NAVSEA 05 weight report [Reference (23)]. A summary of weight and cost data for the AD 41 is presented in Table 3-36.

TABLE 3-36

AD 41 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	7,333	1,280	
200	498	179	
300	453	351	
400	72	75	
500	2,157	1,640	
600	2,698	909	
700	101	18	
800		2,000* Est	
900		750* Est	
TOTAL	**13,312**	**7,202**	**139.7**

3.2.4 LHD 1 Class Amphibious Assault Ships (Multi-Purpose)

The lead ship of the WASP Class amphibious assault ships was commissioned in 1989. The class consists of five ships: the fourth of which, LHD 4, will be commissioned in 1994. The general characteristics of the LHD 1 are shown in Table 3-37.

TABLE 3-37

GENERAL CHARACTERISTICS OF LHD 1

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	844.0
	At Waterline (ft)	778.0
BEAM	Extreme (ft)	110.0
	At Waterline (ft)	106.0
DRAFT	Maximum Navigational (ft)	27.0
	Limiting (ft)	28.0
MATERIAL	Hull	Steel
	Superstructure	Steel

LEAD SHIP CHARACTERISTICS		
DISPLACEMENT	Light Ship (LT)	27,554
	Full Load (LT)	40,674
TOTAL ACCOMMODATIONS		3,150
SHAFT HORSEPOWER (SHP)		70,000
ENGINES	Number	2
	Manufacturer	Westinghouse
	Type	Steam Turbine
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	N/A
	KW	14,600

The WASP Class ships were designed as multi-purpose amphibious assault ships that combine the features of several previous amphibious ships. The LHD carries a complement of 1873 troops including 98 officers, and has a cargo capacity of 101,000 cubic feet, with an additional 20,000 square feet to accommodate vehicles. In addition, a 50-foot wide well deck accommodates up to three amphibious air-cushion vehicles (LCAC). The LHD has a HY-100 steel flight deck with two aircraft elevators and nine helicopter landing spots. The ship typically carries a mix of 30 helicopters and six to eight Harriers (AV-8B), but also has the capability to support the AH-1W Super Cobra, CH-53E Super Stallion, CH-53D Sea Stallion, U/CH-46E Sea Knight, UH-1N Twin Huey, AG-1T Sea Cobra, and SH-60B Seahawk helicopters. The LHD's bridge is two decks lower than that of an LHA, and command, control and communication spaces were moved inside the hull to avoid "cheap kill" damage. The ship is outfitted with ITAWDS and MTACCS combat data systems and a variety of air, surface, and navigation radar systems. Its armament systems include SAM, Sea Sparrow with two launchers, Vulcan Phalanx Mk 15 and 8-12.7 mm MG guns. Countermeasures include four Loral Hycor SRBOC 6-barrelled fixed Mk 36, a SLQ 25 Nixie acoustic torpedo decoy system, and an ESM/ECM SLQ 32 (V)3 combined radar warning, jammer and deception system. Power for the ship is provided by two Westinghouse geared steam turbines of 70,000 shaft horsepower.

Ingalls Shipbuilding Corporation (ISI) developed the detail design of the LHD and also built the lead ship. Follow ships are also being built by ISI.

Contract data for the LHD 1 are provided in Table 3-38.

TABLE 3-38
CONTRACT DATA FOR LHD 1

Ship Type: LHD 1 Class Amphibious Assault Ship (Multi-Purpose)	**Contract Type:** N/A
Shipyard: Ingalls	**Contract No./Base Yr:** 82-C-2260
Cost Data Type: Return Cost, Lead Ship, Lead Yard	**Contract Award:** 02/28/84
Cost Data Source: CPR	**Start Construction:** 07/09/84
Date of Cost Source: 03/18/91	**Delivery:** 05/05/89
% Complete at Report: 100	**Months to Construct:** 57.9

Cost data for the LHD 1 were provided by a 1991 CPR prepared by Ingalls [Reference (24)]. The data included a SWBS breakdown of both labor and material cost data. Total production costs (SWBS Groups 100 - 700 and 900) for the ship were 12,973 kmhrs, and integration/engineering costs (SWBS Group 800) were 6,688 kmhrs, giving a total ship effort of 19,661 kmhrs.

Material costs for the LHD 1 were given in the CPR as $428M, including escalation. After subtracting out escalation and inflating to FY 93 dollars, this amount becomes $601.4M.

Weight and cost data for the LHD 1 are summarized in Table 3-39. Weight data for the ship were provided by NAVSEA 05 [Reference (25)].

TABLE 3-39

LHD 1 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	16,614	2,773	
200	1,360	115	
300	1,082	1,777	
400	521	278	
500	4,622	2,214	
600	3,043	2,097	
700	312	85	
800		6,688	
900		3,634	
TOTAL	27,554	19,661	601.4

3.3 Auxiliary Ships Data

3.3.1 T-AGOS 19 Class SWATH Ocean Surveillance Ships

The ships of the VICTORIOUS Class, T-AGOS 19 through T-AGOS 22, are ocean surveillance ships built by McDermott Marine, Inc. The T-AGOS 19 is a follow-on to the STALWART Class (T-AGOS 1) of ocean surveillance ships and is primarily used to support the SURTASS towed array surveillance system. The T-AGOS 19 ships are a SWATH design (small waterplane area twin hull), which provides greater capability to operate in high latitudes under adverse weather conditions. The contract for the first SWATH ship, T-AGOS 19, was awarded in November 1986, and options for the next three were exercised in October 1988. These ships are outfitted with two Raytheon navigation radars, a UQQ2 SURTASS sonar and a towed array. They are diesel-electric powered and carry a complement of 34. General characteristics of this class are shown in Table 3-40.

TABLE 3-40

GENERAL CHARACTERISTICS OF T-AGOS 19

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	235.0
	At Waterline (ft)	232.0
BEAM	Extreme (ft)	94.0
	At Waterline (ft)	94.0
DRAFT	Maximum Navigational (ft)	25.0
	Limiting (ft)	25.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	2,602
	Full Load (LT)	3,384
TOTAL ACCOMMODATIONS		N/A
SHAFT HORSEPOWER (SHP)		1,600
ENGINES	Number	2
	Manufacturer	General Electric
	Type	Diesel Electric
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	4
	Type	Diesel
	KW	4,070

Contract data for the T-AGOS 19 are provided in Table 3-41.

TABLE 3-41

CONTRACT DATA FOR T-AGOS 19

Ship Type: T-AGOS 19 Class Swath Ocean Surveillance Ship	**Contract Type:** FPIF
Shipyard: McDermott MC	**Contract No./Base Yr:** 87-C-2087
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 10/31/86
Cost Data Source: CPR	**Start Construction:** 09/16/87
Date of Cost Source: 06/30/92	**Delivery:** 08/13/91
% Complete at Report: 100	**Months to Construct:** 46.9

Cost data for the T-AGOS 19 are provided by a 1992 CPR prepared by McDermott Shipyards [Reference (26)]. The CPR reported total material costs and a SWBS breakdown of labor costs. Total production costs (SWBS Groups 100-700 and 900) for the ship were 802 kmhrs and integration/engineering costs (SWBS Group 800) were 301 kmhrs. Construction costs (SWBS Groups 100-700) were 584 kmhrs.

Material costs for the T-AGOS 19 were given in the CPR as $19M including escalation. After subtracting out escalation and inflating to FY 93 dollars, this amount becomes $22.9M.

Weight and cost data for the T-AGOS 19 are summarized in Table 3-42. Weight data for the ship were provided by NAVSEA 05 [Reference (27)].

TABLE 3-42

T-AGOS 19 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	1,692	194	
200	55	14	
300	157	82	
400	65	24	
500	384	168	
600	248	101	
700	1	0	
800		301	
900		219	
TOTAL	2,602	1,103	22.9

3.3.2 AO 177 Class (Oilers)

The AO 177 is the lead ship of the "CIMARRON" Class oiler. The entire class of AO 177 oilers were built at Avondale shipyards. The AO 180 is a follow ship of the class. The AO

180 was commissioned in December 1982. The ships of the CIMARRON Class were designed to provide two complete refuelings of a fossil-fueled aircraft carrier and six to eight refuelings for accompanying destroyers. They carry approximately 120,000 barrels of petroleum products and are fitted with a helicopter platform aft.

General characteristics for the AO 177 Class oilers are provided in Table 3-43.

TABLE 3-43

GENERAL CHARACTERISTICS OF AO 177 CLASS (AO 180)

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	700.0
	At Waterline (ft)	661.0
BEAM	Extreme (ft)	88.0
	At Waterline (ft)	86.0
DRAFT	Maximum Navigational (ft)	33.0
	Limiting (ft)	35.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	8,252
	Full Load (LT)	27,276
TOTAL ACCOMMODATIONS		200
SHAFT HORSEPOWER (SHP)		24,000
ENGINES	Number	2
	Manufacturer	General Electric
	Type	Turbine Reduction
MAIN REDUCTION GEARS	Manufacturer	General Electric
	Type	Double
MAIN GENERATORS	Number	3
	Type	Turbine
	KW	7,500

Contract data for the AO 180 are provided in Table 3-44.

TABLE 3-44

CONTRACT DATA FOR AO 180

Ship Type: AO 177 Class Oiler	**Contract Type:** N/A
Shipyard: NASSCO	**Contract No./Base Yr:** N/A
Cost Data Type: Estimated Lead Ship[1]	**Contract Award:** 04/78
Cost Data Source: Auxiliary and Amphibious CCM	**Start Construction:** 12/19/79
Date of Cost Source: 09/01/88	**Delivery:** 08/27/82
% Complete at Report: 100	**Months to Construct:** 33.3

Note: [1] Return costs for AO 180 were adjusted by NASSCO cost estimators to reflect a lead ship.

Cost data for the AO 180 were extracted from the Auxiliary and Amphibious Ships Construction Cost Model [Reference (2)] and represent an estimate by NASSCO cost estimators, of what a lead ship of the class would cost. Although the AO 180 was a follow ship at Avondale, NASSCO cost estimators modified return cost data for the AO 180 in the original auxiliary ship cost model, to adjust it to equal lead ship costs. These adjusted costs are considered satisfactory for use in this model. The model provides labor and material costs in both a SWBS breakdown and a 22 cost group breakdown. SWBS Groups 100-700 labor costs were derived from the data base presented in the model for the AO 180. The SWBS Group 800 labor costs were estimated as 2,000 kmhrs, and SWBS Group 900 labor costs were estimated as 750 kmhrs, using the constants for these groups provided in the model. (The raw SWBS Group 800 and 900 data for the AO 180 are not in the Reference (2) report.)

Material costs for AO 180 were reported in the model [Reference (2)] as $45.8M. This amount was escalated over 13 years to a FY 93 value of $88.5M.

Weight data for the AO 180 were provided by a NAVSEA 05 weight report [Reference (28)].

A summary of weight and cost data for the AO 180 is presented in Table 3-45.

TABLE 3-45

AO 180 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	5,572.0	628	
200	646.0	121	
300	267.0	170	
400	48.0	74	
500	1,145.0	463	
600	558.0	282	
700	16.0	3	
800		2,000 (Est)	
900		750 (Est)	
TOTAL	8,252.0	4,491	88.5

3.3.3 AFS 1 Class Combat Stores Ship

The AFS 1 is the lead ship of the "MARS" Class combat stores ships. The entire class of AFS 1 combat stores ships was built at NASSCO. The AFS 6 is a follow ship of the class which was commissioned in May 1969. The MARS Class underway replenishment ships combine the capabilities of stores ships (AF), stores-issue ships (AKS), and aviation stores ships (AVS). "M" frames have been used instead of conventional king posts and booms and are equipped with automatic tensioning devices to keep the transfer lines taut. There are five cargo holds (one is refrigerated) with 7,000-ton DWT capacity, computerized stock control and automatic propulsion controls with full bridge control capability. A helicopter hangar and platform are provided aft. The general characteristics of AFS 6 are shown in Table 3-46.

TABLE 3-46

GENERAL CHARACTERISTICS OF AFS 6

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	581.0
	At Waterline (ft)	530.0
BEAM	Extreme (ft)	79.0
	At Waterline (ft)	79.0
DRAFT	Maximum Navigational (ft)	24.0
	Limiting (ft)	28.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	9,038
	Full Load (LT)	17,079
TOTAL ACCOMMODATIONS		501
SHAFT HORSEPOWER (SHP)		22,000
ENGINES	Number	1
	Manufacturer	Westinghouse
	Type	Turbine
MAIN REDUCTION GEARS	Manufacturer	Westinghouse
	Type	Double
MAIN GENERATORS	Number	3
	Type	Steam Turbine
	KW	4,500

Contract data for the AFS 6 are provided in Table 3-47.

TABLE 3-47

CONTRACT DATA FOR AFS 6

Ship Type: MARS Class Combat Store Ship Auxiliary	**Contract Type:** N/A
Shipyard: NASSCO	**Contract No./Base Yr:** N/A
Cost Data Type: Estimated Lead Ship[(1)]	**Contract Award:** N/A
Cost Data Source: Aux CCM	**Start Construction:** ~7/67
Date of Cost Source: 09/01/88	**Delivery:** 5/24/69
% Complete at Report: 100	**Months to Construct:** 22.3

Note:[(1)] Return costs for AFS 6 were adjusted by NASSCO cost estimators to reflect a lead ship.

Cost data for the AFS 6 were extracted from the Auxiliary and Amphibious Ships Construction Cost Model [Reference (2)]. Return cost data for the AFS 6 were adjusted for G&C by NASSCO cost estimators to reflect a lead ship. These adjusted costs are considered satisfactory for use in this model. The model provides labor and material costs in both a SWBS breakdown and a 22 cost group breakdown. SWBS Groups 100-700 labor costs were derived from the data base presented in the model for the AFS 6. The SWBS Group 800 labor costs were estimated as 2,000 kmhrs and SWBS Group 900 labor costs as 750 kmhrs, using the constants provided for these groups in the model. (The raw SWBS Group 800 and 900 data for the AFS 6 are not in the report.)

Material costs for the AFS 6 were reported in the model [Reference (2)] as $38.2M. This amount was escalated over 13 years to a FY 93 value of $73.8M.

Weight data for the AFS 6 were provided by a NAVSEA 05 weight report [Reference (29)].

A summary of weight and cost data for the AFS 6 is presented in Table 3-48.

TABLE 3-48

AFS 6 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	5287	457	
200	770	112	
300	155	61	
400	78	41	
500	1428	353	
600	1234	157	
700	86	7	
800		2000	
900		750	
TOTAL	**9038**	**3938**	**73.8**

3.3.4 AOR 3 Class Replenishment Oilers

The AOR 3 is the lead ship of the WICHITA Class replenishment oilers. The first ships of this Class were built by the General Dynamics Quincy Shipyard. The only ship of the class for which data were available is the AOR 7. This ship was built by NASSCO and commissioned in October 1976.

The AOR 3 Class was designed to provide rapid replenishment at sea of petroleum and munitions with a limited capacity for provisions and fleet freight. The AOR 7 is powered by three Foster-Wheeler boilers with two General Electric turbines. Construction is all steel with an internal arrangement for vertical replenishment operations. Armament of the AOR 7 consists of Mk 29 SAM launcher and two CIWS or four 20 mm guns. Countermeasures are provided by four Mk 36 offboard chaff systems. The AOR 7 also has the facilities to house and handle two UH-46E Sea Knight helicopters.

The general characteristics of AOR 7 are listed in Table 3-49.

TABLE 3-49

GENERAL CHARACTERISTICS OF AOR 3 CLASS (AOR 7)

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	658.0
	At Waterline (ft)	640.0
BEAM	Extreme (ft)	96.0
	At Waterline (ft)	96.0
DRAFT	Maximum Navigational (ft)	35.0
	Limiting (ft)	37.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	12,744
	Full Load (LT)	40,053

LEAD SHIP CHARACTERISTICS		
TOTAL ACCOMMODATIONS		457
SHAFT HORSEPOWER (SHP)		32,000
ENGINES	Number	2
	Manufacturer	General Electric
	Type	Turbine
MAIN REDUCTION GEARS	Manufacturer	General Electric
	Type	Double
MAIN GENERATORS	Number	4
	Type	Steam Turbine
	KW	8,000

Contract data for the AOR 7 are provided in Table 3-50.

TABLE 3-50

CONTRACT DATA FOR AOR 7

Ship Type: WICHITA Class Replenishment Oilers	**Contract Type:** N/A
Shipyard: National Steel & Shipbuilding Co.	**Contract No./Base Yr:** N/A
Cost Data Type: Estimated Lead Ship[(1)]	**Contract Award:** 12/72
Cost Data Source: Aux. & Amphib. CCM	**Start Construction:** 10/6/73
Date of Cost Source: 09/01/88	**Delivery:** 10/14/76
% Complete at Report: 100	**Months to Construct:** 36.3

Note: [(1)] Return cost data for AOR 7 were adjussted by NASSCO cost estimators to relfect a lead ship.

Cost data for the AOR 7 were taken from the Auxiliary and Amphibious Ships Construction Cost Model [Reference (2)]. SWBS Groups 100-700 labor costs were derived from the data base presented in the Reference (2) model for the AOR 7. The return cost data for the AOR 7 were adjusted by NASSCO cost estimators to reflect a lead ship. The SWBS Group 800 labor costs were estimated as 2,000 kmhrs, and SWBS Group 900 labor costs were estimated as 750 kmhrs, using the constants provided for these groups in the model. (The raw SWBS Group 800 and 900 data for the AOR 7 are not in the report.)

Material costs for the AOR 7 were reported in the model [Reference (2)] as $51.5M. This amount was escalated over 13 years to a FY 93 value of $99.4M.

A summary of weight and cost data for the AFS 6 is presented in Table 3-51.

TABLE 3-51

AOR 7 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	8,183	963	
200	971	181	
300	323	144	
400	102	73	
500	2,060	717	
600	1,063	314	
700	42	5	
800		2000	
900		750	
TOTAL	12,744	5147	99.4

3.3.5 T-AO 187 Class Oiler

There are 18 ships in the HENRY J. KAISER Class of Oilers. These ships, which have a cargo capacity of 180,000 barrels of fuel oil, are equipped with both port and starboard stations for underway replenishment of fuel and stores. The ships are capable of 20 knot speeds and have a range of 6,000 miles at 18 knots. Power is provided by two Colt-Pielstick 10-PC4.2V diesels. The ships are also fitted with integrated electrical auxiliary propulsion.

With the exception of T-AO 191 and T-AO 192, all ships of the class were constructed or are planned for construction by Avondale Shipbuilding Industries. The T-AO 191 and T-AO 192 were awarded to Penn Ship. Penn Ship went out of business in 1989 while both ships were under construction. The ships were towed to the Philadelphia Navy Yard and then to Tampa Shipyards for completion. The ships required extensive refurbishing as a result of sitting idle for months prior to towing to Tampa. Recently, these ships were removed from Tampa Shipyards due to contractual disputes. It is unclear what ultimately will be done with these ships. Table 3-52 lists the general characteristics of the T-AO 187 Oiler.

TABLE 3-52

GENERAL CHARACTERISTICS OF T-AO 187

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	678.0
	At Waterline (ft)	677.0
BEAM	Extreme (ft)	97.0
	At Waterline (ft)	97.0
DRAFT	Maximum Navigational (ft)	35.0
	Limiting (ft)	N/A
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	13,923
	Full Load (LT)	47,382
TOTAL ACCOMMODATIONS		N/A
SHAFT HORSEPOWER (SHP)		30,000
ENGINES	Number	2
	Manufacturer	N/A
	Type	Diesel
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	N/A
	KW	10,000

T-AO187 Data

Contract data for the T-AO 187 are provided in Table 3-53.

TABLE 3-53

CONTRCT DATA FOR T-AO 187

Ship Type: TAO 187 Class Oiler	**Contract Type:** FPI
Shipyard: Avondale	**Contract No./Base Yr:** N/A
Cost Data Type: Return Cost, Lead Ship, Lead Yard	**Contract Award:** 11/82
Cost Data Source: CPR	**Start Construction:** 04/11/84
Date of Cost Source: 12/31/87	**Delivery:** 12/19/86
% Complete at Report: 100	**Months to Construct:** 31.3

Cost data for the T-AO 187 were extracted from a 1987 CPR prepared by Avondale [Reference (30)]. The data included a SWBS breakdown of both labor and material cost data. Total production costs (SWBS Groups 100-700 and 900) for the ship were 2,277 kmhrs, and integration/engineering costs (SWBS Group 800) were 983 kmhrs, giving a total ship effort of 3,260 kmhrs. Construction costs (SWBS Group 100-700) were 1,875 kmhrs.

Material costs for the T-AO 187 were given in the CPR as $74.7M, including escalation. After subtracting out escalation and inflating to FY 93 dollars, this amount becomes $102.9M.

Weight and cost data for the T-AO 187 are summarized in Table 3-54. Weight data for the ship were provided by NAVSEA 05 [Reference (31)].

TABLE 3-54

T-AO 187 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	9365	781	
200	1122	89	
300	405	94	
400	105	49	
500	1764	492	
600	1142	368	
700	20	2	
800		983	
900		402	
TOTAL	13,923	3,260	102.9

T-AO 191 Data

The T-AO 191 was originally awarded to PENN Ship. As noted, PENN Ship went out of business in 1989. The partially completed ship was towed to Tampa Shipyards for completion. The following cost data is from Tampa Shipyards and apparently represents their effort to complete the construction. Since the data does not reflect a total lead ship construction activity, (i.e., it excludes PENN Ship's effort), the data were not used in developing the CER's for this model.

Contract data information on the T-AO 191 are shown in Table 3-55.

TABLE 3-55

CONTRACT DATA FOR T-AO 191

Ship Type: T-AO 187 Class Oiler	**Contract Type:** FPI
Shipyard: Tampa Shipyards	**Contract No./Base Yr:** N/A
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 05/85
Cost Data Source: CPR[1]	**Start Construction:** 10/14/85
Date of Cost Source: 04/30/87	**Delivery:** 04/27/92
% Complete at Report: 100	**Months to Construct:** 78.5

Note: [1] Cost data represents only Tampa's effort to complete the construction.

Cost data for the T-AO 191 were extracted from a 1987 CPR prepared by Tampa Shipyards [Reference (32)]. The data included a SWBS breakdown of labor costs and total material costs. Total production costs (SWBS Groups 100-700 and 900) for the ship were 2026 kmhrs, and integration/engineering costs (SWBS Group 800) were 326 kmhrs giving a total ship effort of 2,352 kmhrs. Construction costs (SWBS Groups 100-700) for the ship were 1458 kmhrs.

Material costs for the T-AO 191 were given in the CPR as $71.4M, including escalation. After subtracting out escalation and inflating to FY 93 dollars, this amount becomes $95.7M.

Weight and cost data for the T-AO 191 are summarized in Table 3-56. Weight data for the ship represents the as-built lightship weight for T-AO 191, as provided by NAVSEA 05 [Reference (31)].

TABLE 3-56

T-AO 191 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	9,365	717	
200	1,122	48	
300	405	60	
400	105	38	
500	1,764	376	
600	1,142	219	
700	20	0	
800		326	
900		568	
TOTAL	13,923	2,352	95.7

3.3.6 AOE 6 Class Fast Combat Support Ship

The ships of the SUPPLY Class were designed to provide rapid replenishment at sea of petroleum, munitions, provisions and fleet freight. The ships accommodate three utility helicopters and have a cargo capacity of 156,000 barrels of fuel, 1800 tons of ammunition, 400 tons of refrigerated cargo, and 250 tons of general cargo. The SUPPLY Class ships are outfitted with four General Electric LM 2500 gas turbines for a total of 100,000 horsepower and can maintain a speed of 25 knots.

The lead ship of the class, AOE 6, is being built by NASSCO and is expected to be delivered in 1993. Contracts have been awarded to NASSCO for construction of the AOE 7 and 8. The AOE 9 was cancelled to cover program overruns. An RFP has been issued for construction of the AOE 10. The general characteristics of the AOE 6 are listed in Table 3-57.

TABLE 3-57

GENERAL CHARACTERISTICS OF AOE 6

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	754.0
	At Waterline (ft)	730.0
BEAM	Extreme (ft)	107.0
	At Waterline (ft)	107.0
DRAFT	Maximum Navigational (ft)	38.0
	Limiting (ft)	41.0
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	19,564
	Full Load (LT)	49,484
TOTAL ACCOMMODATIONS		667
SHAFT HORSEPOWER (SHP)		100,000
ENGINES	Number	4
	Manufacturer	General Electric
	Type	Gas Turbine
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	
	Type	
	KW	12,500

Contract data for the AOE 6 are provided in Table 3-58.

TABLE 3-58

CONTRACT DATA FOR AOE 6

Ship Type: AOE 6 Class Fast Combat Support Ship	**Contract Type:** FPI
Shipyard: NASSCO	**Contract No./Base Yr:** 87-C-2002
Cost Data Type: Return Cost, Lead Ship, Lead Yard	**Contract Award:** 01/22/87
Cost Data Source: CPR	**Start Construction:** 06/22/88

Date of Cost Source: 07/12/92	**Delivery:** 07/01/93
% Complete at Report: 90	**Months to Construct:** 60.3

Cost data for the AOE 6 were extracted from a 1992 CPR [Reference (33)] which provided a breakdown of manhours. Total material costs were provided by NCA in Reference (10) and weight data were reported by NAVSEA 05 in Reference (34). The breakdown of labor costs in the CPR did not follow an exact SWBS breakdown so the cost elements were assigned SWBS elements as described in the following paragraph, using Reference (35) for guidance.

The CPR cost element "Structural Steel" was assigned to SWBS Group 100 (Hull Structure). "Machinery" was assigned to SWBS Group 200 (Propulsion Plant). "Electrical" was split between SWBS Group 300 (Electric Plant) and SWBS Group 400 (Command and Surveillance), using the percentage distribution given in Reference (10). "Mechanical Outfitting" and "Ventilation" were assigned to SWBS Group 500 (Auxiliary Systems). "Sheet Metal and Outfit Steel" and "Blasting/Painting" were included in SWBS Group 600 (Outfit and Furnishings). No SWBS Group 700 labor costs were identified in the CPR. "Engineering", "Outfit Planning", "Supervision" and "PMO/Other" were assigned to SWBS Group 800 (Integration/Engineering). "Transportation and Rigging" and "Production Services" and "Undistributed", were assigned to SWBS Group 900 costs (Ship Assembly and Support Services).

Material costs for AOE 6 were $199.9M in base year 1987 dollars, as per Reference (33). When escalated to FY 93 dollars, this becomes $246.9M. This amount is very high for an auxiliary ship.

The high costs for the AOE 6 are related to a variety of factors. The ship contains gas turbine main propulsion systems. Many of the specifications for these systems were derived from the FFG 7 and DDG 51 specifications. In addition, the ship has experienced a number of problems, including 1-year delay in delivery of the reduction gears, which were a new design and originally envisioned to be contractor supplied equipment. Eventually the government was required to take over development of the reduction gear. During the delay, the entire aft end and some upper portion of the deckhouse could not be completed. In addition, the ship is designed to be shock qualified, which has caused redesign of major equipment foundations, etc. to meet shock requirement. A summary of weight and cost data for AOE 6 is given in Table 3-59.

Because of the significant differences between the equipment requirements of the AOE 6 and other ships in the auxiliary data set, the material costs of the AOE 6 were not included in the CER for this group.

TABLE 3-59

AOE 6 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	12,630	1,172	
200	977	146	
300	914	505	
400	192	181	
500	2,661	1,517	
600	1,388	1,002	
700	802	0	
800		2,972	
900		557	
TOTAL	19,564	8,052	246.9

3.3.7 T-AGS 45 Class Surveying Ships

T-AGS 45 is the only ship of the WATERS Class surveying ships and was built by Avondale Industries. The ship was ordered in April of 1990 for the purpose of supporting the

Integrated Underwater Surveillance System. The ship will carry a remote-controlled submersible. General characteristics of the T-AGS 45 are provided in Table 3-60.

TABLE 3-60

GENERAL CHARACTERISTICS OF T-AGS 45

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	442.0
	At Waterline (ft)	429.0
BEAM	Extreme (ft)	69.0
	At Waterline (ft)	N/A
DRAFT	Maximum Navigational (ft)	21.0
	Limiting (ft)	N/A
MATERIAL	Hull	Steel
	Superstructure	Steel
DISPLACEMENT	Light Ship (LT)	6,750
	Full Load (LT)	12,208
TOTAL ACCOMMODATIONS		N/A
SHAFT HORSEPOWER (SHP)		7,400
ENGINES	Number	2
	Manufacturer	
	Type	Integrated Diesel Electric
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	Diesel
	KW	12,900

Contract data for the T-AGS 45 are provided in Table 3-61.

TABLE 3-61

CONTRACT DATA FOR T-AGS 45

Ship Type: T-AGS 45 Class Surveying Ship	**Contract Type:** FPI
Shipyard: Avondale	**Contract No./Base Yr:** 90-C-2307

1381-68(4-EAM-4597)

Cost Data Type: Return cost, Lead Ship, Lead Yard	**Contract Award:** 04/04/90
Cost Data Source: CPR	**Start Construction:** 01/16/91
Date of Cost Source: 06/30/92	**Delivery:** 06/11/93
% Complete at Report: 79.6	**Months to Construct:** 28.8

Cost data for the T-AGS 45 were extracted from a 1992 CPR [Reference (36)] which provided a breakdown of manhours and total material costs. The breakdown of labor costs in the CPR did not follow an exact SWBS breakdown, so the cost elements were assigned to SWBS elements as described in the following paragraph.

The CPR cost element "Structural" was assigned to SWBS Group 100 (Hull Structure) and "Outfitting" was assigned to SWBS Group 600 (Outfit and Furnishings). "Mechanical" was assigned to reflect SWBS Groups 200 and 500. In concert with NCA, it was determined to distribute the costs between SWBS Groups 200 and 500, as well as between SWBS Groups 300 and 400 using historical data for the TAGOS 19. Since both ships are diesel electric propulsion, it was considered that the TAGOS 19 cost breakdown would be representative of the T-AGS 45 for these SWBS Groups. The TAGOS 19 breakdown indicated that SWBS Group 500 accounted for 92 percent of SWBS Groups 200 and 500 combined. This percentage breakdown was applied to TAGS 45, so 92 percent of the 320 kmhrs for "Mechanical" was assigned to SWBS Group 500 and the remainder assigned to SWBS Group 200. Similarly, "Electrical" was assumed to reflect SWBS Groups 300 and 400. The TAGOS 19 breakdown indicated that SWBS Group 300 accounted for 77 percent of SWBS Groups 300 and 400 combined. This 77 percent of "Electrical" was assigned to SWBS Group 300 and the remainder to SWBS Group 400. "Integration/Engineering" and "Program Management" were assigned to SWBS Group 800 (Integration/Engineering). "Test/Trials" and "Support Services" were assigned to SWBS Group 900 (Ship Assembly and Support Services).

Total material costs for T-AGS 45 were reported in the CPR as $63.7M in base year 1990 dollars. When escalated to FY 93 dollars, this amount becomes $70.5M.

A summary of weight and cost data for T-AGS 45 is given in Table 3-62.

TABLE 3-62

T-AGS 45 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100		595	
200		26	
300		175	
400		52	
500		294	
600		247	
700		0	
800		493	
900		254	
TOTAL	6,750.0	2,136	70.5

3.4 Other Ships Data

During development of this cost model, cost data were identified for a number of ships that did not fit into the surface combatant, amphibious, or auxiliary categories. These ships cost data are presented in the following sections.

3.4.1 LCAC 1 Class Landing Craft Air Cushion

The LCAC 1 Class, consisting of 63 vessels, was authorized in FY 1982. LCAC 34 was the lead ship in a follow yard, Avondale Shipyards, and was authorized in 1989. The last ship of the class was authorized in 1992. General characteristics of the LCAC 34 are listed in Table 3-63. The LCAC is an air-cushion vehicle landing craft designed to be carried on LHD 1, LHA 1, LPD 4, LSD 41, and LSD 36 Class ships. The LCAC is powered by four AVCO-Lycoming TF40B gas turbines. Two of these engines provide propulsion power to two shrouded reversible pitch airscrews; the other two provide lift through four double entry centrifugal fans. Armament consists of two 12.7 mm MGS.

The first 33 LCAC's were built at Textron Marine Systems. LCAC 34 to LCAC 96 were built at the Avondale Gulfport yard that was purchased from Lockheed Shipbuilding.

TABLE 3-63

GENERAL CHARACTERISTICS OF LCAC 34

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	81
	At Waterline (ft)	N/A
BEAM	Extreme (ft)	43
	At Waterline (ft)	N/A
DRAFT	Maximum Navigational (ft)	2.9
	Limiting (ft)	N/A
MATERIAL	Hull	Composite
	Superstructure	N/A
DISPLACEMENT	Light Ship (LT)	87
	Full Load (LT)	N/A
TOTAL ACCOMMODATIONS		24
SHAFT HORSEPOWER (SHP)		16,000
ENGINES	Number	4
	Manufacturer	Avco-Lycoming
	Type	Gas Turbine
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	N/A
	KW	120

Contract data for the LCAC 34 are provided in Table 3-64.

TABLE 3-64

CONTRACT DATA FOR LCAC 34

Ship Type: Air-Cushion Landing Craft	**Contract Type:** FPI
Shipyard: Avondale Gulfport	**Contract No./Base Yr:** 89-C-2110
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 12/13/88
Cost Data Source: CPR	**Start Construction:** 10/27/89
Date of Cost Source: 06/30/92	**Delivery:** 05/31/92
% Complete at Report: 100	**Months to Construct:** 31.1

Cost data for the LCAC 34 were extracted from a 1992 CPR prepared by Avondale Shipyards in Gulfport [Reference (37)]. The data consisted of total labor manhours and total material costs. Labor costs for SWBS Groups 800 and 900 were identified in the CPR, but no breakdown of construction costs (individual SWBS Groups 100-700) was available.

Material costs for the LCAC 34 were listed in the CPR as $7.1M in 1988 dollars. When escalated to FY 93 dollars, this amount becomes $8.6M.

A summary of weight and cost data for LCAC 34 is provided in Table 3-65.

TABLE 3-65

LCAC 34 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100			
200			
300			
400			
500			
600			
700			
100-700		87	
800		77	
900		54	
TOTAL	87.0	218	8.6

3.4.2 MHC 51 Coastal Minehunter

The MHC 51 is the lead ship of the OSPREY Class of coastal minehunters. In mid-1986, a project to construct 17 minesweepers was cancelled because the design, which was based on a surface effect ship, failed shock testing. The Secretary of Defense then indicated that $120.1 million of FY 1986 funds would be used to construct the lead ship of a new MHC class based on the Intermarine Lerici class of minesweeper/hunters. A design contract was awarded in August 1986, followed by the award of a construction contract in May 1987 for the lead ship, MHC 51. Intermarine Sarzana established Intermarine USA in conjunction with Hercules Aerospace Corporation of Salt Lake City and purchased Sayler Marine Corporation in Savannah, GA. The company has updated that yard to support construction of the OSPREY. In October 1989, Avondale Industries was named as the second construction source. Twelve of the class are to be built, followed by eight lengthened MHC(V) versions.

The ships are constructed of heavy GRP (glass reinforced plastic) throughout the hull, decks and bulkheads, thus eliminating frames. Main machinery is mounted on vibration dampers. The ships are equipped with navigation radars and high frequency active minehunting sonars. Both mechanical and magnetic influence sweep systems are being developed independently of the ship construction program. The general characteristics of the OSPREY Class are listed in Table 3-66.

TABLE 3-66

GENERAL CHARACTERISTICS OF MHC 51

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	188
	At Waterline (ft)	185
BEAM	Extreme (ft)	38
	At Waterline (ft)	36
DRAFT	Maximum Navigational (ft)	10
	Limiting (ft)	10
MATERIAL	Hull	Composite
	Superstructure	N/A
DISPLACEMENT	Light Ship (LT)	500
	Full Load (LT)	N/A
TOTAL ACCOMMODATIONS		51
SHAFT HORSEPOWER (SHP)		1,600
ENGINES	Number	2
	Manufacturer	Waukesha
	Type	Diesel
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	N/A
	KW	900

<u>MHC 51 Data</u>

Contract data for the MHC 51 are provided in Table 3-67.

TABLE 3-67

CONTRACT DATA FOR MHC 51

Ship Type: OSPREY Class Coastal Minehunter	**Contract Type:** FPI (F)
Shipyard: Intermarine	**Contract No./Base Yr:** 87-C-2136
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 05/22/87
Cost Data Source: CPR	**Start Construction:** 05/16/88
Date of Cost Source: 12/31/92	**Delivery:** 04/23/93
% Complete at Report: 97.8	**Months to Construct:** 59.2

Cost data for the MHC 51 were extracted from a 1992 CPR prepared by Intermarine USA [Reference (38)]. The data included total material costs and a SWBS breakdown of labor costs. Production costs (SWBS Groups 100-700 and 900) for the ship totaled 1,111 kmhrs and construction costs (SWBS Groups 100-700) were 811 kmhrs. Integration/Engineering costs (SWBS Group 800) were 626 kmhrs, leaving 300 kmhrs for SWBS Group 900.

Material costs for MHC 51 were listed in the CPR is $87.0M in base year 1987 dollars. When escalated to FY 93 dollars, this amount becomes $107.4M.

A summary of weight and cost data for the MHC 51 is provided in Table 3-68.

TABLE 3-68

MHC 51 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	350	333	
200	30	27	
300	38	136	
400	72	39	
500	113	198	
600	81	76	
700	6	2	
800		626	
900		300	
TOTAL	690	1,737	107.4

MHC 53 Data

MHC 53 was the lead ship built by the follow yard Avondale Shipyards. Contract data for this ship are listed in Table 3-69.

TABLE 3-69

CONTRACT DATA FOR MHC 53

Ship Type: OSPREY Class Coastal Minehunter	**Contract Type:** FPI (F)
Shipyard: Avondale Gulfport	**Contract No./Base Yr:** 89-C-2162
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 10/03/89
Cost Data Source: CPR	**Start Construction:** 05/06/91
Date of Cost Source: 6/30/92	**Delivery:** 03/30/94
% Complete at Report: 55	**Months to Construct:** 34.8

Cost data for the MHC 53 were extracted from a 1992 CPR prepared by Avondale [Reference (39)]. The data included total material costs and a SWBS breakdown of labor costs. Production costs (SWBS Groups 100-700 and 900) for the ship totaled 517 kmhrs, while construction costs (SWBS Groups 100-700) were 397 kmhrs. Integration/Engineering costs (SWBS Group 800) were 375 kmhrs, leaving 120 kmhrs for SWBS Group 900.

Material costs for MHC 53 were listed in the CPR as $62.4M in base year 1988 dollars. When escalated to FY 93 dollars, this amount becomes $74.8M.

A summary of weight and cost data for the MHC 53 is provided in Table 3-70. The cost data in the table represent the "Latest Revised Estimate" of total costs for the MHC 53 when it was about 75 percent complete (as estimated by the amount of work completed at the time of the report).

TABLE 3-70

MHC 53 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100	350	269	
200	30	13	
300	38	30	
400	72	19	
500	113	57	
600	81	28	
700	6	1	
800		375	
900		120	
TOTAL	690	912	74.8

3.4.3 MCM-1 Class Mine Countermeasure Vessel

MCM-1 is the lead ship of 14 ships in the AVENGER Class of mine countermeasure vessels. The contract for the MCM was awarded in June 1982. The hull of the ship is constructed of oak, Douglas fir and Alaskan cedar, with a thin coating of fiberglass on the outside. MCM-1 and MCM-2 are outfitted with four Waukesha L-1616 diesels. A problem of engine rotation with the Waukesha diesels led to their replacement with low magnetic signature engines manufactured by Isotta-Fraschini of Milan, Italy for MCM-3 and follow. The AVENGER Class ships are equipped with a surface search radar and high frequency active minehunting sonars. Countermeasures include two SLQ-48, ROV mine neutralization systems, including cable with cutter and countermining charge, SLQ 37(V)2, and magnetic/acoustic influence sweep equipment. The general characteristics of MCM-1 are listed in Table 3-71.

TABLE 3-71

GENERAL CHARACTERISTICS OF MCM 1

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	224
	At Waterline (ft)	217
BEAM	Extreme (ft)	39
	At Waterline (ft)	38
DRAFT	Maximum Navigational (ft)	12
	Limiting (ft)	13
MATERIAL	Hull	Wood
	Superstructure	N/A
DISPLACEMENT	Light Ship (LT)	1,186
	Full Load (LT)	1,260
TOTAL ACCOMMODATIONS		81
SHAFT HORSEPOWER (SHP)		2400
ENGINES	Number	2
	Manufacturer	Isotta Fraschini
	Type	Diesel
MAIN REDUCTION GEARS	Manufacturer	N/A
	Type	N/A
MAIN GENERATORS	Number	N/A
	Type	N/A
	KW	N/A

MCM 1 Data

Contract data for MCM 1 are provided in Table 3-72.

TABLE 3-72

CONTRACT DATA FOR MCM 1

Ship Type: MCM 1 Class Mine Countermeasure Vessel	**Contract Type:** CPIF
Shipyard: Peterson	**Contract No./Base Yr:** 82-C-2121
Cost Data Type: Lead Ship, Lead Yard	**Contract Award:** 06/82
Cost Data Source: CPR	**Start Construction:** 12/13/82
Date of Cost Source: 02/28/88	**Delivery:** 08/28/87
% Complete at Report: 100	**Months to Construct:** 57.5

Cost data for the MCM 1 were extracted from a 1988 CPR prepared by Peterson Builders [Reference (40)]. The data consisted of total manhours and total material costs. Labor costs for SWBS Groups 800 and 900 were identified in the CPR, but no SWBS breakdown of construction costs were available. Total construction costs (SWBS Groups 100-700) for the ship were 1156 kmhrs. Integration/Engineering (SWBS Group 800) costs were 332 kmhrs and Support Services (SWBS Group 900) costs were 446 kmhrs.

The MCM 1 was awarded as a CPIF contract. In a CPIF contract, material costs are reported in the CPR as current dollars for the date of the report. Since the CPR was from 1988, the total material costs of $66.0M were escalated over 5 years to a FY 93 value of $79.2M.

A summary of weight and cost data for the MCM 1 is provided in Table 3-73.

TABLE 3-73

MCM 1 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
1			
2			
3			
4			
5			
6			
7			
TOTAL 1-7		1,156	
8		332	
9		446	
TOTAL	1,186	1,934	79.2

MCM 2 Data

MCM 2 was built by Marinette Marine Corporation. Contract data for this ship are listed in Table 3-74.

TABLE 3-74

CONTRACT DATA FOR MCM 2

Ship Type: MCM 1 Class Mine Countermeasure Vessel	**Contract Type:** CPI w/cap
Shipyard: Marinette	**Contract No./Base Yr:** N/A
Cost Data Type: Lead Ship, Follow Yard	**Contract Award:** 05/83
Cost Data Source: CPR	**Start Construction:** 10/24/83
Date of Cost Source: 11/09/88	**Delivery:** 09/08/89
% Complete at Report: 83.7	**Months to Construct:** 70.5

Cost data for the MCM 2 were extracted from a 1988 CPR prepared by Marinette Marine Corp. [Reference (41)]. The data included total material costs and a SWBS breakdown of labor costs. Total construction costs (SWBS Groups 100-700) for the ship were 941 kmhrs. Integration/Engineering (SWBS Group 800) costs were 584 kmhrs and Support Services (SWBS Group 900) costs were 200 kmhrs.

The MCM 2 was awarded as a CPI contract (with ceiling). In this contract, material costs are reported in the CPR as current dollars for the date of the report. Since the report was from 1988, the total material costs of $36.1M were escalated over 5 years to a FY 93 value of $43.3M.

A summary of weight and cost data for the MCM 2 is provided in Table 3-75. The cost data in the table represent the "Latest Revised Estimate" of total costs for the MCCM 2 when it was about 84 percent complete (as estimated by the amount of work completed at the time of the report).

TABLE 3-75

MCM 2 WEIGHT AND COST DATA SUMMARY

SWBS	Weight (LT)	Labor Cost (KMHRS)	Material Cost (FY 93) ($M)
100		250	
200		77	
300		81	
400		86	
500		281	
600		162	
700		4	
800		584	
900		200	
TOTAL	1,186	1,725	43.3

:^O^P"^A^A^R

4.0 COST ESTIMATING RELATIONSHIPS

The cost estimating relationships (CER's) developed for this model provide a means for estimating lead construction labor costs in manhours and lead ship material costs in FY 93 dollars for the following U.S. Naval ship types: Surface Combatants, Amphibious Ships, and Auxiliary Ships.

The CER's, which are grouped by ship type, relate the historical ship cost data presented in Chapter 3 to ship's physical characteristics, most notably lightship weight. Labor CER's are categorized by the one digit SWBS breakdown shown in Table 1-1. In addition, summary labor CER's are provided for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700, 900) and total contract costs (SWBS Groups 100-900). Material CER's are presented at the total contract level (SWBS Groups 100-900).

Linear, non-linear, and multi-variate analyses were considered in developing the CER's and a regression analysis was conducted to determine the statistical adequacy of the resultant CER's. Linear regressions were primarily used for the CER's in this model, based on previous experience and the data trends. In addition, dividing the data base between ship types, and subdividing the labor costs by SWBS elements, appear to have obviated the need for multi-variate or dummy variable analysis.

Each CER is presented with a graphical representation, its equation and the following regression output:

- R^2 (correlation coefficient)^2

  This measures the correlation between x and y for the relationship. R^2 ranges between 0 and 1. An R^2 of "1" indicates perfect correlation while an R^2 of "0" indicates no correlation.

For the purposes of this model, the following assumptions were made in analyzing CERs:

$R^2 > .9$	- high correlation
$.7 < R^2 < .9$	- good correlation
$.5 < R^2 < .7$	- low correlation
$R^2 < .5$	- very low correlation

- <u>T statistic</u>

  This measures the significance of the regression coefficient. The T statistic is calculated as the ratio of the coefficient of the independent variable to the Standard Error of that same coefficient. (See "F statistic" for assumptions made when analyzing significance of T and F.)

$$T=\frac{A}{S_x}$$

where:

A = x coefficient of the regression equation
S_x = standard error of the coefficient

- <u>F statistic</u>

  This measures the overall significance of the regression equation, and is calculated using R^2, the number of independent variables, and the number of observations, using the following formula:

$$F = \frac{R^2/k}{(1-R^2)(n-k-1)}$$

where:

k = number of independent variables
n = number of observations
n-k-1 = degrees of freedom

Although multi-variate analyses were attempted, most CERs in the model are based on 1 variable, so the significance level of T and F are the same.

For the purposes of this model, the quality of each CER was judged using the following ground rules:

- significant at 95 percent - relationship is statistically significant
- significant at 90 percent - relationship is of questionable significance
- not significant at 90 percent - relationship is not statistically significant

- CV (coefficient of variation)

  CV is the statistic which allows the use of the standard error of the estimate to compare different regression lines. It is actually a relative standard error of the estimate since it becomes a dimensionless quantity. CV is calculated as the ratio of the standard error of the estimate to the mean ($\bar{y}$). A small CV indicates the model is a good predictor.

  For the purposes of this model, the quality of each CER was judged using the following ground rules:

CV < 20 percent	- model is an excellent predictor
20 < CV < 40 percent	- model is a good predictor
CV > 40 percent	- model is a poor predictor

In a number of cases, the statistics for the CER's do not accurately reflect the value of the CER as a predictive tool. This is due to a number of reasons. First is the limited data available and the spread of data. Often a CER is derived from two or three data points, or from a number of points clustered around two or three centers. In many of these cases there are insufficient data points for the relationship to be statistically significant. Also, a single outlier can cause the statistics to show mediocre to poor results for an otherwise good CER, or a single outlier at the extreme range of a CER may skew the regression and reduce the statistical quality of the CER.

Another problem is that many of the CER's approximate a constant. In these cases, small differences in the slope of the CER or in the dispersion of the data can cause large changes in the statistical characteristics of the CER. In these cases, it is recommended that a constant be used for the CER and the statistics ignored.

The CER's developed in this model are a refinement to CER's developed for NCA in previous lead ship construction cost models dating back to 1981 [References (1), (2), (43), (44)]. In previous models, shipyard derived lead ship return costs and cost estimates were related to a variety of ship's characteristics using a 22 cost group, two-digit SWBS breakdown developed for the model. A copy of the two-digit breakdown is provided in Appendix B. Shipyard estimators and shipyard cost data were used to assist in the interpretation of the data and CER's were developed that subdivided a cost group into different material or system options, such as gas turbine versus diesel propulsion plants.

The major limitation of the previous models was that the CER's tended to reflect a single shipyard's data and experience. In addition, the CER's contained estimated data, or CER's derived from single points using best engineering judgement. Finally, since the CER's were based on historical trends with limited data points, they tended to underestimate cost groups that experienced significant change in the 1980's, in particular SWBS Group 800.

The goal of this effort has been to develop new models based on shipyard return cost data as reported in the Cost Performance Report (CPR). CPR data is available for all major Naval ship acquisition programs and involves the U.S. shipyards currently constructing ships for the Navy. It represents the total cost to the government for the ship construction contracts, including change orders that occurred during the construction period. It also differentiates between labor costs (in both manhours and dollars) and material costs in dollars. Larger and more varied than the previous models' databases, the CPR database compiled for this effort represents a significant improvement and lends itself to meaningful statistical analysis.

As discussed in Chapter 3, the major limitation with CPR data is that it is often not in a SWBS format, nor can it easily be converted to a SWBS format. For example, material dollars are usually reported as a single line item. This limits the ability to subdivide costs by SWBS based cost groups, either at the base or two-digit level, with the confidence of such a breakdown being reduced with each level of subdivision.

As noted in Chapter 3, the CPR's typically provided sufficient labor data to differentiate between SWBS Groups 100-700, SWBS Group 800, and SWBS Group 900. Further subdivision of SWBS Groups 100-700 into individual one-digit cost groups was performed either by detailed analysis of the CPR or related data, or by comparison with historical trends at the shipyards concerned. This breakdown of manhours was then used to develop the labor CER's.

Lead ship data from lead and follow yards were used to develop labor CER's for SWBS Groups 100-700 and 900. The follow yard data was considered appropriate for these production costs. For SWBS Group 800, only lead yard lead ship data was used to develop labor CER's, since SWBS Group 800 includes significant non-recurring costs such as design and engineering.

Labor dollars were not analyzed due to the yard-to-yard variation in historical labor and overhead rates and uncertainty in future rates.

The benefits of the broader, updated and CPR based labor CER's outweighed the limitations resulting from the use of the CPR data. Even though the level of refinement of the cost group breakdown is less than in previous models, the confidence in the resultant cost estimate is higher given the improved data base.

The loss of refinement does affect the ability to differentiate between various options within a SWBS group or to estimate significant changes to a ship at the system or subsystem level. However, the consistency of the one-digit CER's within the ship types suggests that installation of the system or subsystem options do not significantly drive the labor costs at the total ship level.

Material dollars were escalated to FY 93 dollars and a single CER developed for each ship type. This CER is based on lead yard, lead ship material costs only. The reason for using only lead yard/lead ship material costs for the material CER is to assure that all costs for a lead ship are taken into account. For example, non-recurring costs (such as the cost of equipment needed to build the lead ship) are costs applied to the lead ship only (even though the equipment may be used to construct follow ships). Also, in a number of ship acquisition programs, significant amounts of equipment are provided for the follow ships as Government Furnished Equipment (GFE) or Class Buys. In this case, the material costs noted for the follow ship are significantly less than the first ship of the class. Since the material CER is meant to estimate the cost of a new lead ship, the use of material cost data from a follow ship may inaccurately skew the estimate down.

The single total ship CER provides NCA with an ability to estimate a total material cost for the ship. This should allow for a check of the total material costs proposed for a new ship. However, individual major component costs (such as steel, propulsion motors, etc.) should be compared to current vendor cost information to assess the reasonableness of the costs proposed.

4.1 Surface Combatant Type Ships

The CER's for the surface combatant type ships are developed using the ships shown in Table 4-1.

TABLE 4-1

SURFACE COMBATANT SHIPS

Ship	Class	Shipyard	Cost Data Type	Year Delivered
FFG 7	FFG 7 Class Frigate	BIW	Lead Ship/Lead Yard	1977
FFG 9	FFG 7 Class Frigate	Todd L.A.	Lead Ship/Follow Yard	1980
FFG 10	FFG 7 Class Frigate	Todd Seattle	Lead Ship/Follow Yard	1980
DD 963	DD 963 Class Destroyer	Ingalls	Lead Ship/Lead Yard	1975
CG 47	CG 47 Class Cruiser	Ingalls	Lead Ship/Lead Yard	1982
CG 51	CG 47 Class Cruiser	BIW	Lead Ship/Follow Yard	1987
DDG 51	DDG 51 Class Guided Missile Destroyer	BIW	Lead Ship/Lead Yard	1991
DDG 52	DDG 51 Class Guided Missile Destroyer	Ingalls	Lead Ship/Follow Yard	1992

The surface combatant CER's are based on the data presented in Section 3.1. Lightship weight is the principal independent variable, although CER's are developed using shaft horsepower in SWBS Group 200, total accommodations in SWBS Group 600, production manhours in SWBS Group 800, and months in the shipyard in SWBS Group 900.

CER's for labor manhours are provided by one-digit SWBS cost groups, and summary CER's for labor manhours are provided for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total costs (SWBS Groups 100-900). A CER for FY 93 material dollars is presented at the total cost level.

It should be noted that for the individual one-digit SWBS Groups 100-700 CER's, the DDG 51 labor manhours are consistently high. This is because the total SWBS Groups 100-700 labor manhours are very high compared to the other ships. When the SWBS Groups 100-700 data was apportioned to the one-digit groups, the disparity was carried to this level. The apportionment of the data is based on historical breakdown of Groups 100-700 at BIW for similar ships. This historical breakdown has been very consistent for previous ships and is considered adequate for the DDG 51 apportionment. The high construction costs for the DDG 51 were driven by broad issues that affected all SWBS groups and not by a few differences with other ships affecting individual SWBS groups. This conclusion is supported by the fact that the DDG 52 SWBS Groups 100-700 costs are consistent with other ships in the data set, as are the DDG 53 T-1 costs discussed in Section 3.1.

4.1.1 SWBS Group 100 - Hull Structure

This group includes erection of all the ship's structural components. Included are the following elements:

SWBS NUMBER	TITLE
110	Shell and Supporting Structure
120	Hull Structural Bulkheads
130	Hull Decks
140	Hull Platforms and Flats
150	Deckhouse Structure
160	Special Structures
170	Masts, Kingposts and Service Platforms
180	Foundations
190	Special Purpose Systems

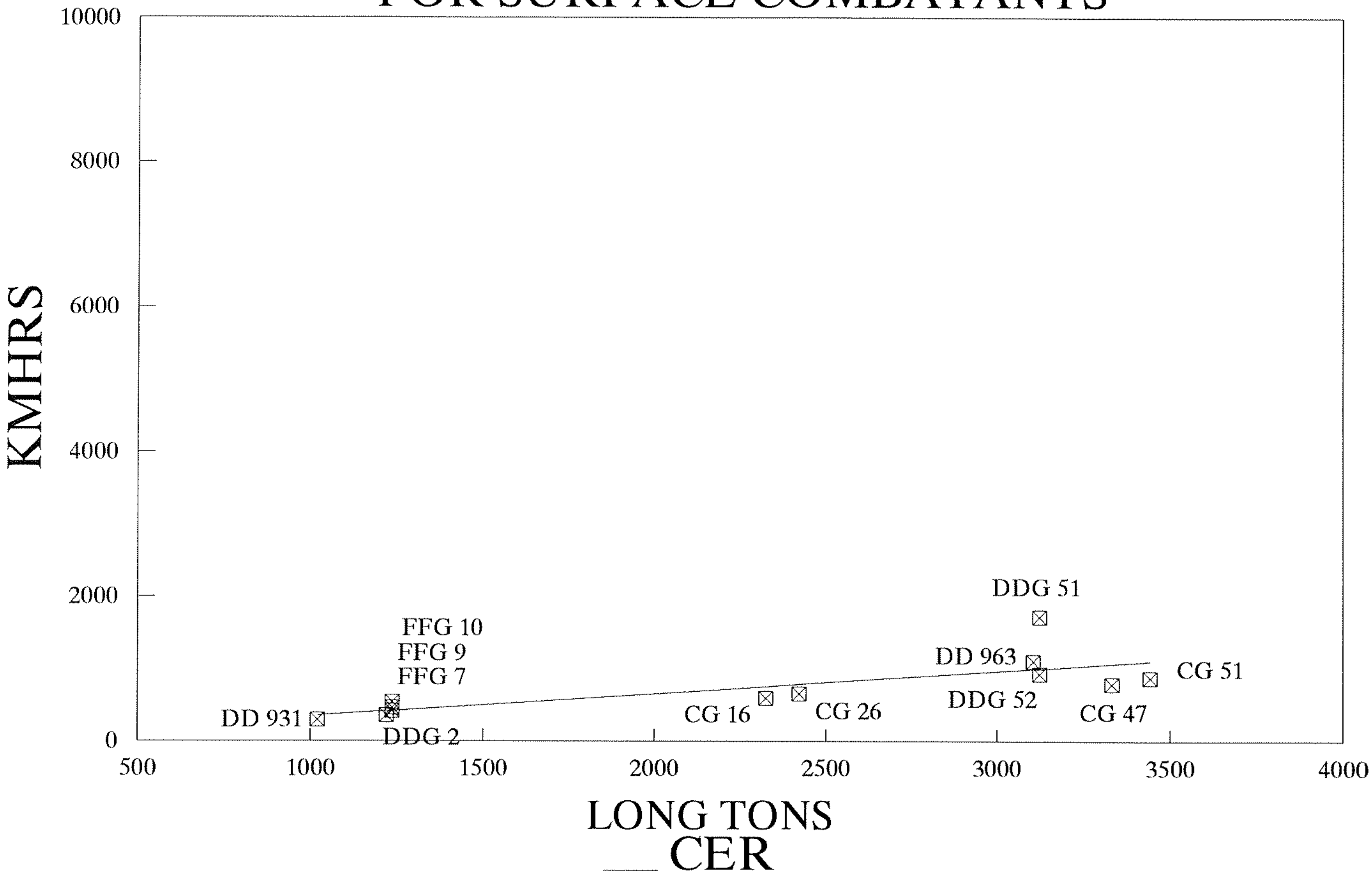
This group does not encompass non-structural items such as ship fittings, rails, stanchions, life lines, hull compartmentation (other than main watertight subdivisions which are included in

SWBS Group 100), non-structural bulkheads, deck covering, and other outfit and furnishings, which are contained in SWBS Group 600.

Figure 4-1 provides the CER regression output, and supporting data for the SWBS Group 100 CER based on lightship weight for the group. With the exception of DDG 51, which is high, the data appears to provide a good fit.

1381-68(4-EAM-4597) Figure 4-1 03-Jun-94

LABOR VS. WEIGHT IN GROUP 1
FOR SURFACE COMBATANTS



CER: KMHRS = 0.310 LT + 33.4; R^2 = 0.586; T and F are significant at 95%; CV = 36.9%

Regression Output:

Constant			33.4
Std Err of Y Est			268
R Squared			0.586
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		0.310	
Std Err of Coef.		0.082	
T =	3.763	F =	14.16
CV % =		36.9	

DATA

SHIPS	LT 1	LAB 1
DD 931	1,020	296
DDG 2	1,218	353
CG 16	2,325	589
CG 26	2,422	650
FFG 7	1,235	419
FFG 9	1,235	459
FFG 10	1,235	539
DD 963	3,105	1,105
CG 47	3,333	791
CG 51	3,442	873
DDG 51	3,124	1,710
DDG 52	3,124	928

The SWBS Group 100 CER of labor vs. weight for surface combatants is:

$$KMHRS = 0.310\ LT + 33.4$$

The R^2 value of 0.586 indicates a low correlation between labor and weight in SWBS Group 100 due in part to the high data point for DDG 51. With the DDG 51 considered an outlier, the data points would show a higher correlation and provide an excellent fit with the CER. Even with the DDG 51 included in the regression, T and F are significant at 95 percent, indicating the relationship is statistically significant. The CV of 36.9 percent also indicates that the model is a good predictor.

4.1.2 SWBS Group 200 - Propulsion Plant

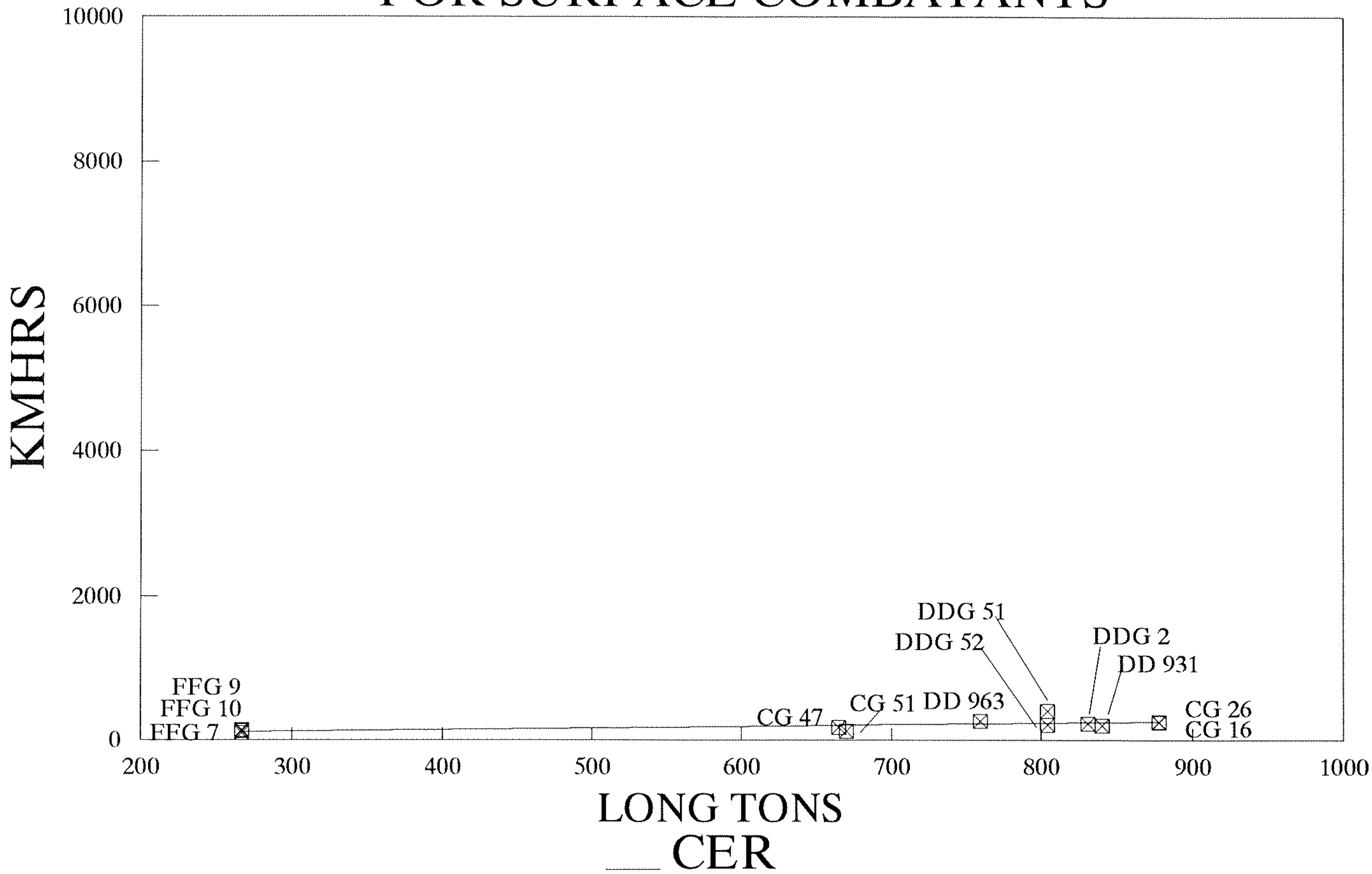
This group includes installation of the ships propulsion plant and drive train systems. Included are the following elements:

SWBS NUMBER	TITLE
220	Energy Generating System (Non-Nuclear)
230	Propulsion Units
240	Transmission and Propulsor Systems
250	Propulsion Support System (except fuel and lube oil)

This group does not include foundations (SWBS Group 100); electric plant systems (SWBS Group 300); propulsion electronics and monitoring systems (SWBS Group 400); and auxiliary systems, including bow thrusters, (SWBS Group 500).

Figure 4-2 provides the CER, regression output, and supporting data for the SWBS Group 200 CER based on lightship weight of the group.

LABOR VS. WEIGHT IN GROUP 2
FOR SURFACE COMBATANTS



CER: KMHRS = 0.234 LT + 51.8; R^2 = 0.475; T and F are significant at 95%; CV = 30.9%

Regression Output:

Constant			51.8
Std Err of Y Est			64
R Squared			0.475
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		0.234	
Std Err of Coef.		0.078	
T =	3.008	F =	9.05
	CV % =	30.9	

DATA

SHIPS	LT 2	LAB 2
DD 931	840	200
DDG 2	831	229
CG 16	878	252
CG 26	878	255
FFG 7	267	99
FFG 9	267	141
FFG 10	267	124
DD 963	760	261
CG 47	665	181
CG 51	670	120
DDG 51	804	404
DDG 52	804	213

The SWBS Group 200 CER labor vs. weight surface combatants is:

$$KMHRS = 0.234\ LT + 51.8$$

The R^2 value of 0.475 indicates a very low correlation between labor and weight in SWBS Group 200; however, there is little spread in the data points, which implies a fairly good fit with the CER. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 30.9 percent also indicates that the CER is a good predictor.

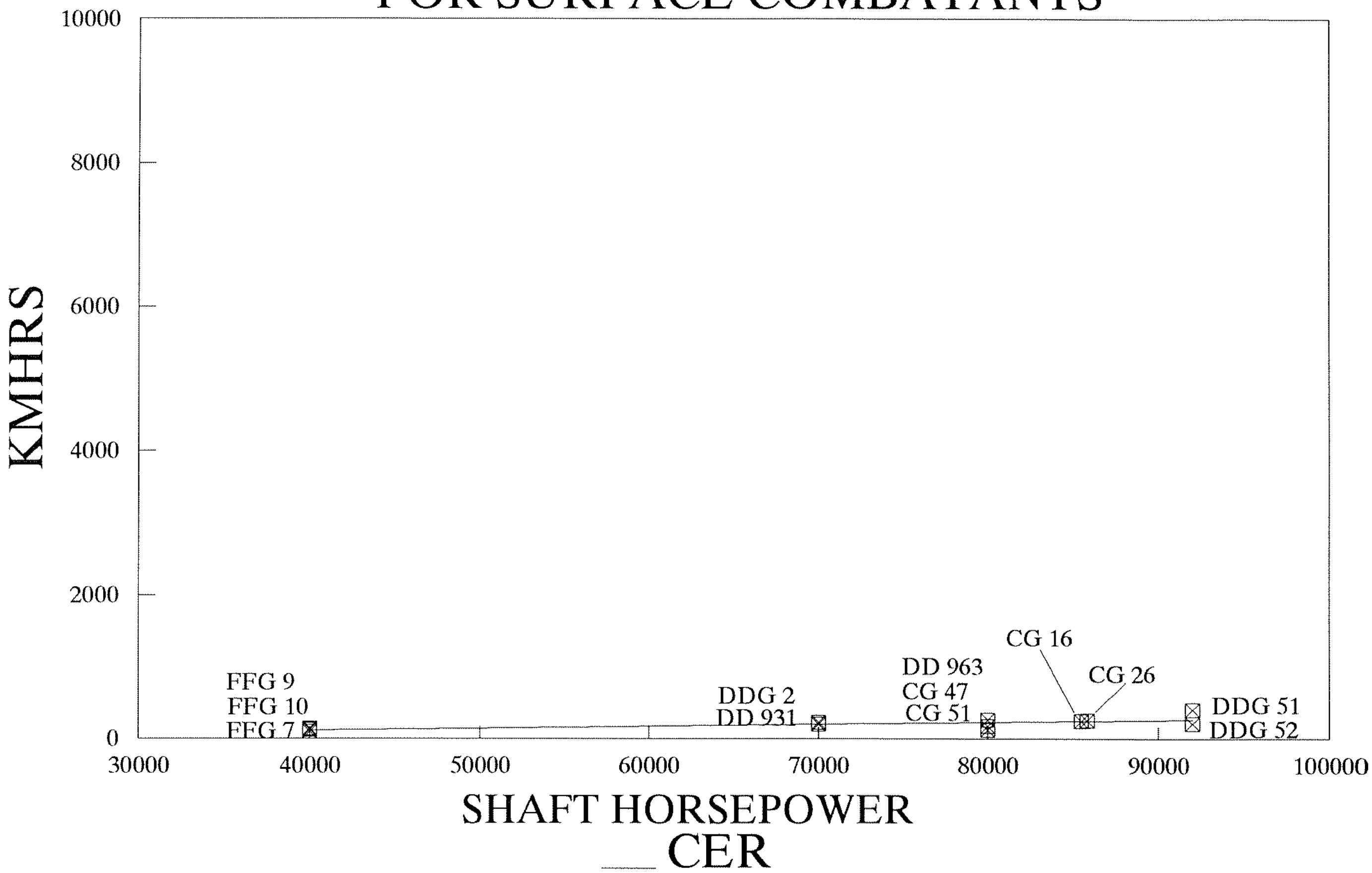
Figure 4-2a provides the CER, regression output and supporting data for the SWBS Group 200 CER based on ship's shaft horsepower.

The SWBS Group 200 CER of labor vs. shaft horsepower for surface combatants is:

$$KMHRS = 0.003\ SHP - 2.57$$

The R^2 value of 0.493 indicated a very low correlation between labor and shaft horsepower; however, the data points show a fairly good fit with the CER. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 30.4 percent indicates that the model is a good predictor.

LABOR VS. SHAFT HORSEPOWER IN GROUP 2
FOR SURFACE COMBATANTS



CER: KMHRS = 0.003 SHP – 2.57; R^2 = 0.493; T and F are significant at 95%; CV = 30.4%

NOTE: SHP data for DDG 51 & 52 was not available in Naval Vessel Register; data was taken from Jane's.

Regression Output:

Constant			–2.57
Std Err of Y Est			63
R Squared			0.493
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		0.003	
Std Err of Coef.		0.001	
T =	3.117	F =	9.72
	CV % =	30.4	

DATA

SHIPS	LAB 2	SHP
DD 931	200	70,000
DDG 2	229	70,000
CG 16	252	85,500
CG 26	255	85,850
FFG 7	99	40,000
FFG 9	141	40,000
FFG 10	124	40,000
DD 963	261	80,000
CG 47	181	80,000
CG 51	120	80,000
DDG 51	404	92,000
DDG 52	213	92,000

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4.1.3 SWBS Group 300 - Electric Plant

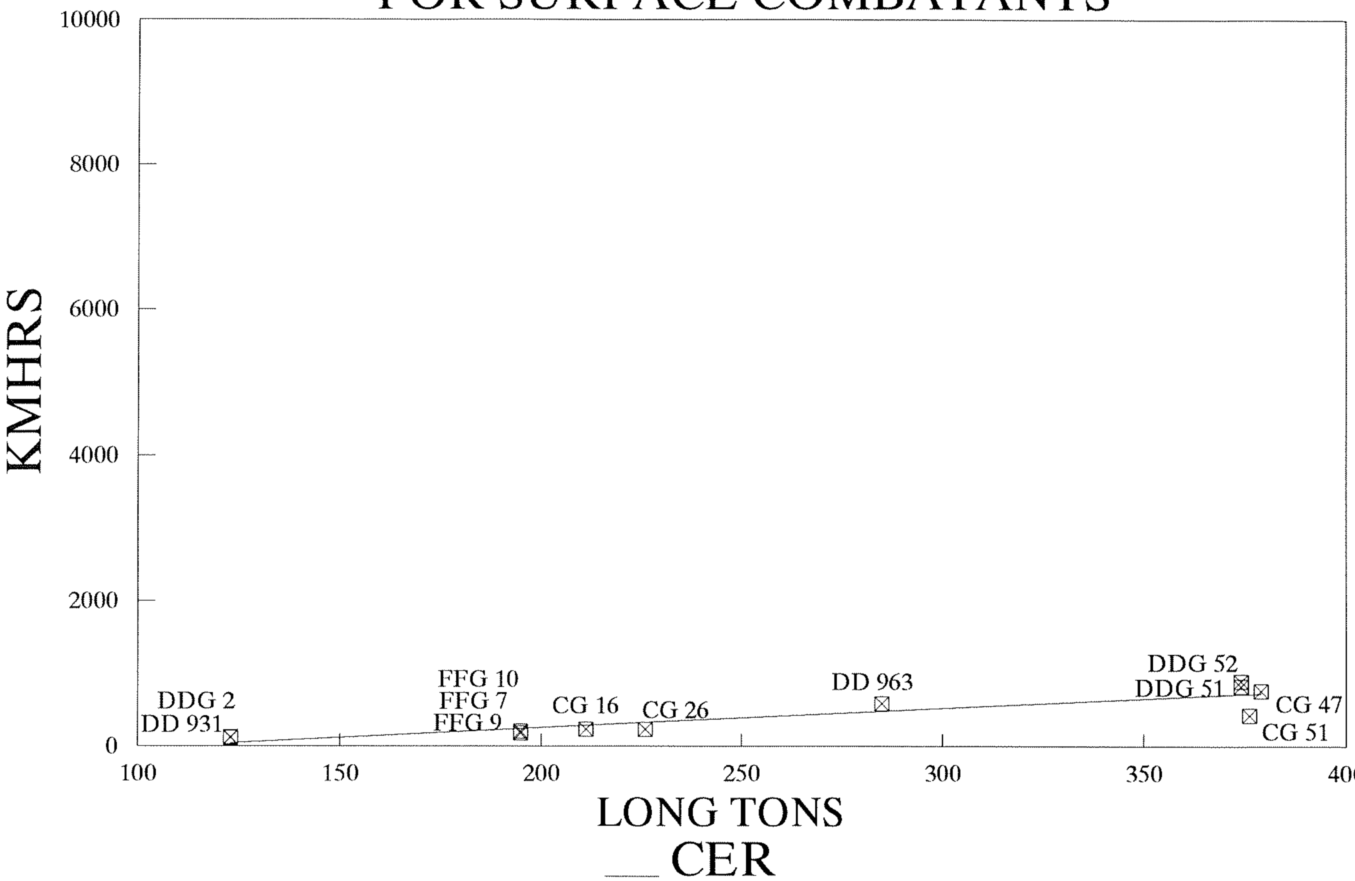
This group includes installation of the ship's electric power generation and distribution plant. Included are the following elements:

SWBS NUMBER	TITLE
310	Electrical Power Generation
320	Power Distribution Systems
330	Lighting Systems
340	Power Generation Support Systems
390	Special Purpose Systems

This group does not include foundations (SWBS Group 100); propulsion electric systems (SWBS Group 200); and command and surveillance systems (SWBS Group 400).

Figure 4-3 provides the CER, regression output, and supporting data for the SWBS Group 300 CER based on lightship weight of the group.

LABOR VS. WEIGHT IN GROUP 3
FOR SURFACE COMBATANTS



CER: KMHRS = 2.65 LT − 277.8; R^2 = 0.817; T and F are significant at 95%; CV = 32.7%

Regression Output:

Constant			−277.8
Std Err of Y Est			130
R Squared			0.817
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		2.650	
Std Err of Coef.		0.396	
T =	6.688	F =	44.72
	CV % =	32.7	

DATA

SHIPS	LT 3	LAB 3
DD 931	123	117
DDG 2	123	121
CG 16	211	228
CG 26	226	231
FFG 7	195	202
FFG 9	195	177
FFG 10	195	207
DD 963	285	586
CG 47	379	757
CG 51	376	426
DDG 51	374	825
DDG 52	374	889

The SWBS Group 300 CER of labor vs. weight for surface combatants is:

$$KMHRS = 2.65\ LT - 277.8$$

The R^2 value of 0.817 indicates a good correlation between labor and weight in SWBS Group 300. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 32.7 percent also indicates that the model is a good predictor.

4.1.4 SWBS Group 4 - Command and Surveillance

This group includes installation of all command and surveillance systems, both for ship operations and combat systems/weapons. Included are the following elements:

SWBS NUMBER	TITLE
410	Command and Control Systems
420	Navigation Systems
430	Interior Communications
440	Exterior Communications
450	Surveillance Systems (surface)
460	Surveillance Systems (underwater)
470	Countermeasures
480	Fire Control Systems
490	Special Purpose Systems

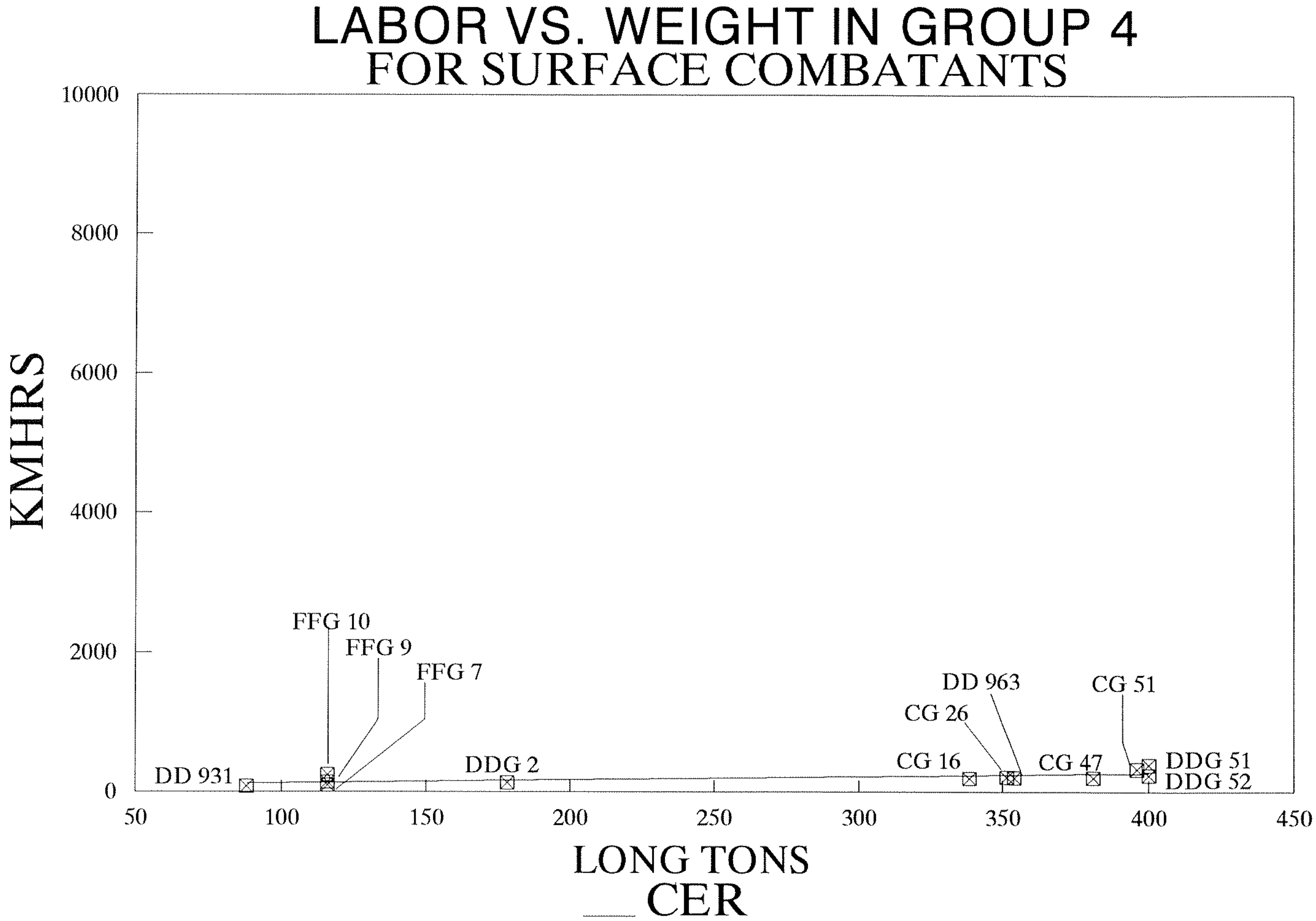
This group does not include masts, yardarms or foundations (SWBS Group 100); power conversion systems, lighting or power cable (SWBS Group 300); cooling systems (SWBS Group 500); or weapons (SWBS Group 700).

Figure 4-4 provides the CER, regression output, and supporting data for the SWBS Group 400 CER based on lightship weight of the group.

The SWBS Group 400 CER of labor vs. weight for surface combatants is:

$$KMHRS = 0.489\ LT + 74.9$$

The R^2 value of 0.513 indicates a low correlation between labor and weight in SWBS Group 400, although the data points seem to fit the CER fairly well. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 32.0 percent also indicates that the model is a good predictor.



CER: KMHRS = 0.489 LT + 74.9; R^2 = 0.513; T and F are significant at 95%; CV = 32.0%

Regression Output:

Constant		74.9
Std Err of Y Est		66.1
R Squared		0.513
No. of Observations		12
Degrees of Freedom		10
# Variables		1
X Coefficient(s)	0.489	
Std Err of Coef.	0.150	
T = 3.247	F =	10.54
CV % =	32.0	

DATA

SHIPS	LT 4	LAB 4
DD 931	88	77
DDG 2	178	134
CG 16	339	195
CG 26	351	215
FFG 7	116	96
FFG 9	116	141
FFG 10	116	249
DD 963	354	207
CG 47	381	207
CG 51	396	324
DDG 51	400	392
DDG 52	400	243

4.1.5 SWBS Group 500 - Auxiliary Systems

This group includes installation of the ship's environmental, fluid, maneuvering and equipment handling systems. Included are the following elements:

SWBS NUMBER	TITLE
510	Climate Control
520	Sea Water Systems
530	Fresh Water Systems
540	Fuels and Lubricants, Handling and Storage
550	Air, Gas, and Miscellaneous Fluid Systems
560	Ship Control Systems
570	Underway Replenishment Systems
580	Mechanical Handling Systems
590	Special Purpose Systems

This group does not include foundations, fan rooms, structural penetrations, permanent ballast, integral tanks, sea chests, (SWBS Group 100); propulsion systems including circulation and cooling pumps and piping, fuel service pumps and piping, main propulsion lube oil system, propulsion and propulsion train (SWBS Group 200); batteries, electrical systems, electrical generator support systems, power cabling (SWBS Group 300); alarm systems (SWBS Group 400); cargo stowage, hull fittings (SWBS Group 600), and handling and stowage of weapons (SWBS Group 700).

Figure 4-5 provides the CER, regression output, and supporting data for the SWBS Group 500 CER, based on lightship weight of the group.

The SWBS Group 500 CER of labor vs. weight for surface combatants is:

$$KMHRS = 1.14\ LT - 52.0$$

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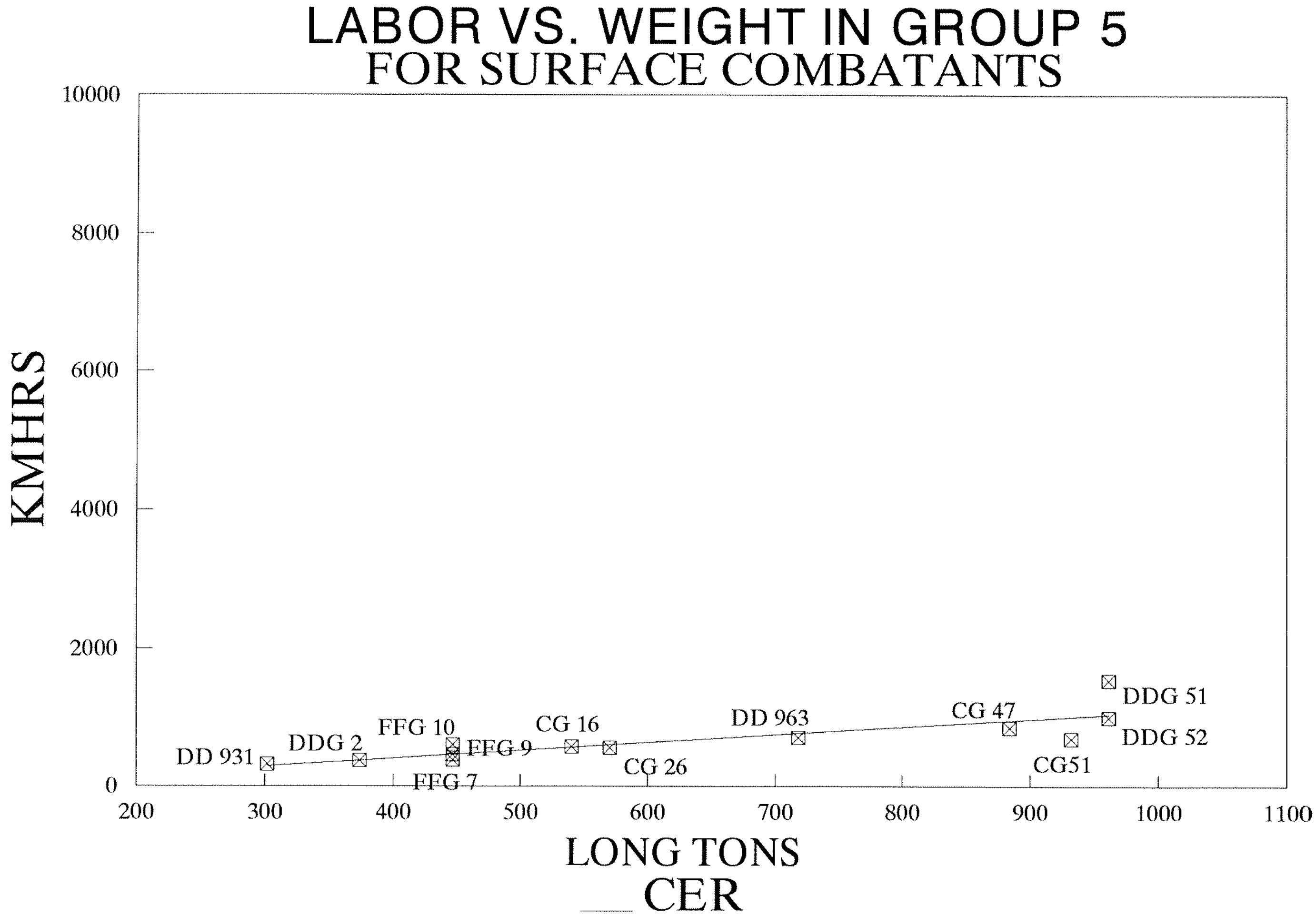
The R^2 value of 0.687 indicates a low correlation between labor and weight in SWBS Group 500, although the data points seem to fit the CER fairly well. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 29.7 percent also indicates that the CER is a good predictor.



CER: KMHRS = 1.141 LT – 52.0; R^2 = 0.687; T and F are significant at 95%; CV = 29.7%

Regression Output:

Constant		–52.0
Std Err of Y Est		199
R Squared		0.687
No. of Observations		12
Degrees of Freedom		10
# Variables		1
X Coefficient(s)	1.141	
Std Err of Coef.	0.243	
T = 4.687	F =	21.97
CV % =	29.7	

DATA

SHIPS	LT 5	LAB 5
DD 931	302	319
DDG 2	374	367
CG 16	540	572
CG 26	570	558
FFG 7	447	376
FFG 9	447	459
FFG 10	447	601
DD 963	718	706
CG 47	884	849
CG 51	932	686
DDG 51	961	1,537
DDG 52	961	997

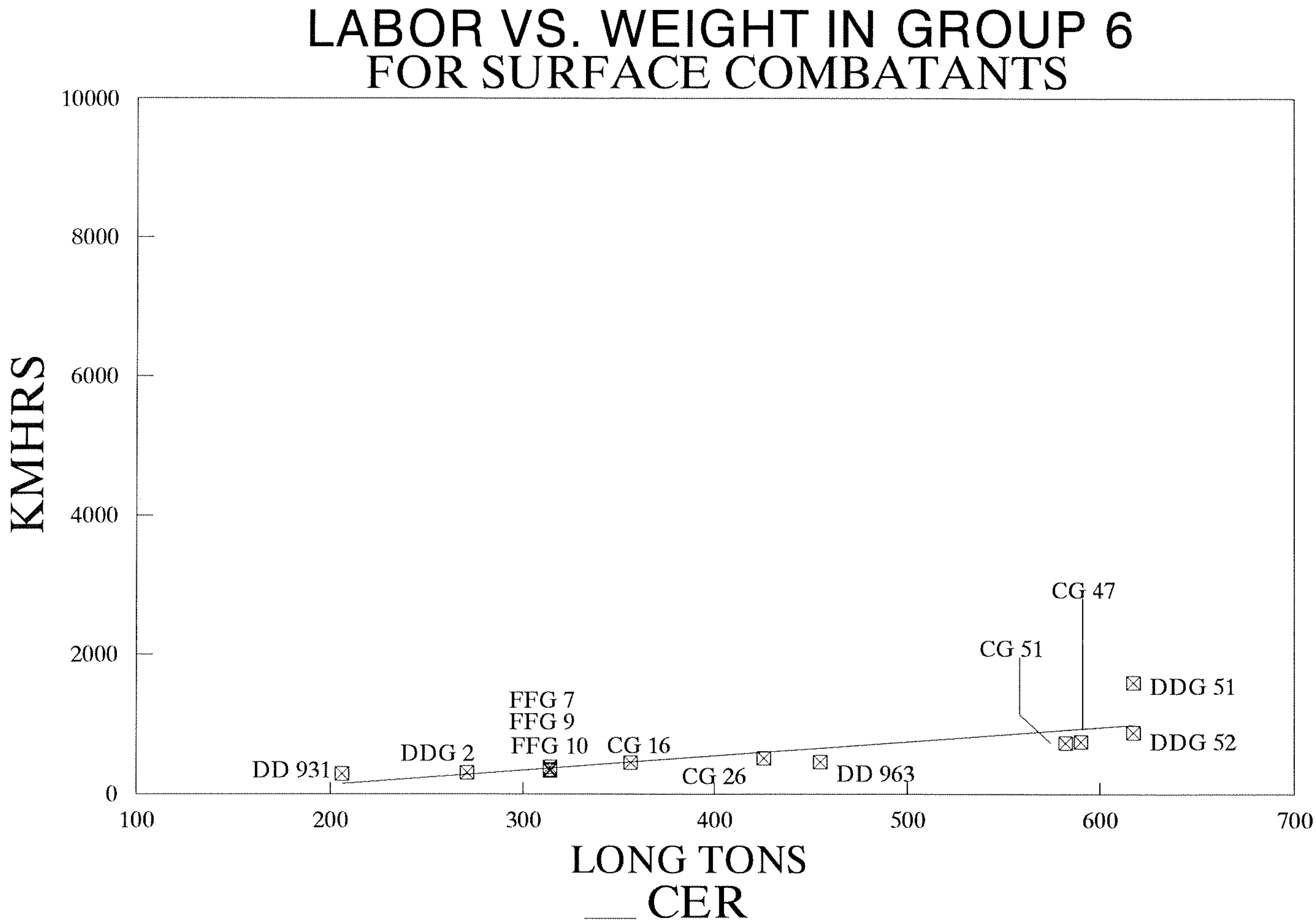
4.1.6 SWBS Group 600 - Outfit and Furnishings

This group includes installation of the ship's hull fittings, non-structural subdivision, preservation, ship support and habitability items. Included are the following elements:

SWBS NUMBER	TITLE
610	Ship Fittings
620	Hull Compartmentation
630	Preservatives and Coverings
640	Living Spaces
650	Service Spaces
660	Working Spaces
670	Stowage Spaces
690	Special Purpose Systems

This group does not include structural components, flight decks, tanks/voids/trunks, structural and watertight subdivision bulkheads, structural closures, sea chests, (SWBS Group 100); propulsion shafting, (SWBS Group 200); batteries, ships service power cable, lighting distribution and fixtures (SWBS Group 300); refrigeration systems, boat handling, cargo handling, replenishment at sea system, mooring, towing and anchor handling, life saving equipment, lagging (SWBS Group 500); and weapons handling (SWBS Group 700).

Figure 4-6 provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on lightship weight of the group.



CER: KMHRS = 2.048LT – 275.4; R^2 = 0.66; T and F are significant at 95%; CV = 38.7%

Regression Output:

Constant			–275.4
Std Err of Y Est			228
R Squared			0.660
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		2.048	
Std Err of Coef.		0.465	
T =	4.404	F =	19.40
	CV % =	38.7	

DATA

SHIPS	LT 6	LAB 6
DD 931	206	287
DDG 2	271	313
CG 16	356	446
CG 26	425	509
FFG 7	314	391
FFG 9	314	353
FFG 10	314	331
DD 963	455	462
CG 47	590	751
CG 51	582	734
DDG 51	617	1,599
DDG 52	617	882

The SWBS Group 600 CER of labor vs. weight for surface combatants is:

$$KMHRS = 2.048\ LT - 275.4$$

The R^2 value of 0.66 indicates a low correlation between labor and weight in SWBS Group 600. However, T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 38.7 percent also indicates that the model is a good predictor. The model would be a better predictor except that the DDG 51 data point is high.

Figure 4-6a provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on total accommodations on the ship.

The SWBS Group 600 CER of labor vs. total accommodations for surface combatants is:

$$KMHRS = .324\ \text{accommodations} + 474.8$$

The R^2 value of .009 indicates a very low correlation between labor manhours in SWBS Group 600 and total accommodations for surface combatants. The spread in the data also implies a poor fit to the CER. T and F are not significant at 90 percent, and the CV of 62.5 percent indicates the model is a poor predictor. This CER is, nevertheless, included as a comparison to similar CER's for auxiliary, amphibious and other ship classes.

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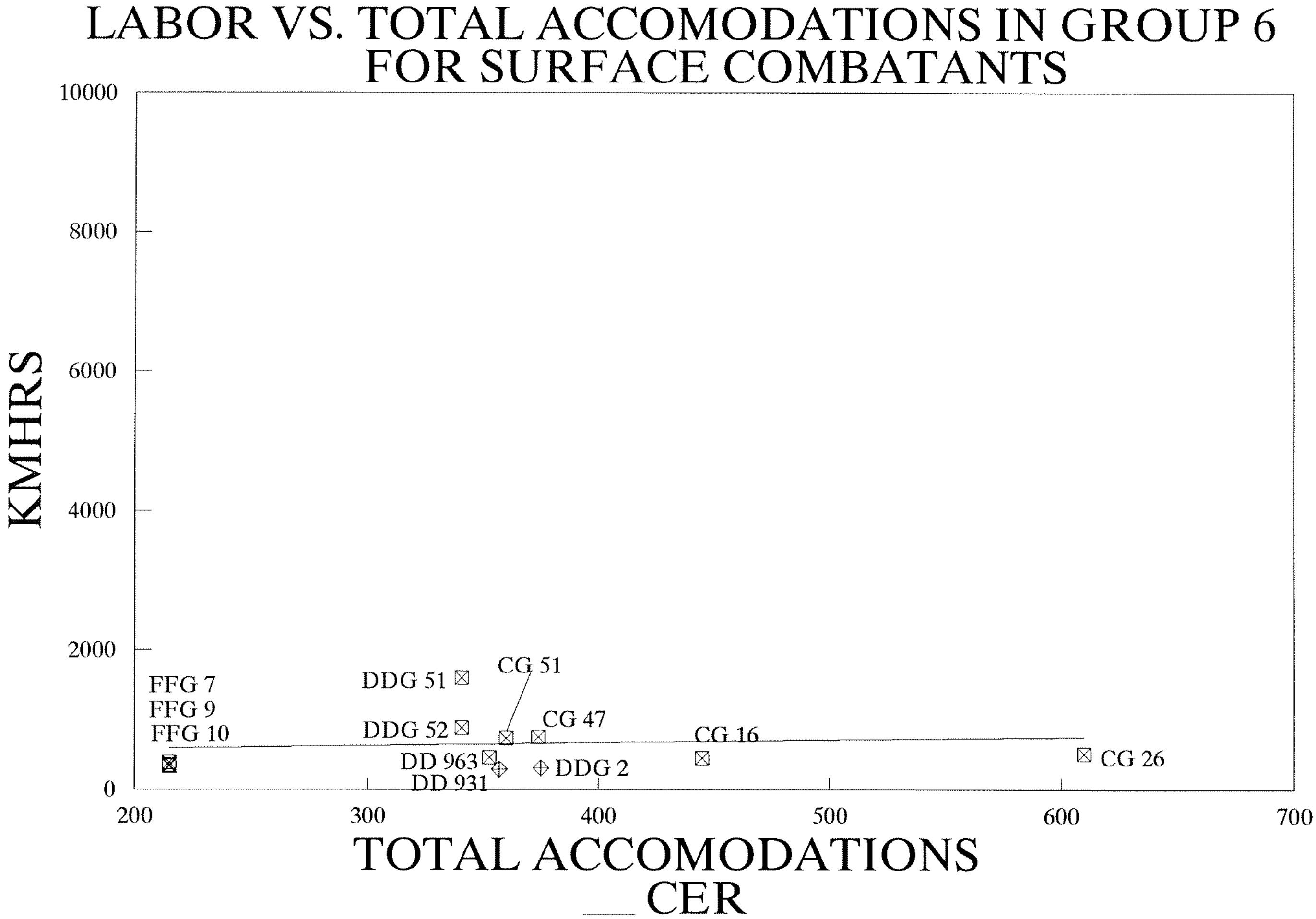


CER: KMHRS = .324 ACCOM + 474.8; R^2 = 0.009; T and F not significant at 90%; CV = 62.5%

NOTE: DD 931 and DDG 2 are shown for info only and are not included in the regression.

Regression Output:

Constant			504.5
Std Err of Y Est			403
R Squared			0.017
No. of Observations			10
Degrees of Freedom			8
# Variables			1
X Coefficient(s)		0.408	
Std Err of Coef.		1.110	
T =	0.367	F =	0.13
CV % =		62.5	

DATA

SHIPS	TOT ACC	LAB 6
CG 16	445	446
CG 26	610	509
FFG 7	215	391
FFG 9	215	353
FFG 10	215	331
DD 963	353	462
CG 51	374	751
CG 47	360	734
DDG 51	341	1,599
DDG 52	341	882

4.1.7 SWBS Group 700 - Armament

This group includes installation of the ship's armament and armament handling systems. Included are the following elements:

SWBS NUMBER	TITLE
710	Guns and Ammunition
720	Missile and Rockets
730	Mines
740	Depth Charges
750	Torpedoes
760	Small Arms and Pyrotechnics
770	Cargo Munitions
780	Aircraft Related Weapons
790	Special Purpose Systems

This group does not include foundations, hull penetrations, (SWBS Group 100); non-integral electrical systems, (SWBS Group 300); non-integral electronics systems (SWBS Group 400); non-integral auxiliary systems, (SWBS Group 500), and ship's outfit and furnishings (SWBS Group 600). In addition, this group does not include the actual weapons systems which are normally GFE.

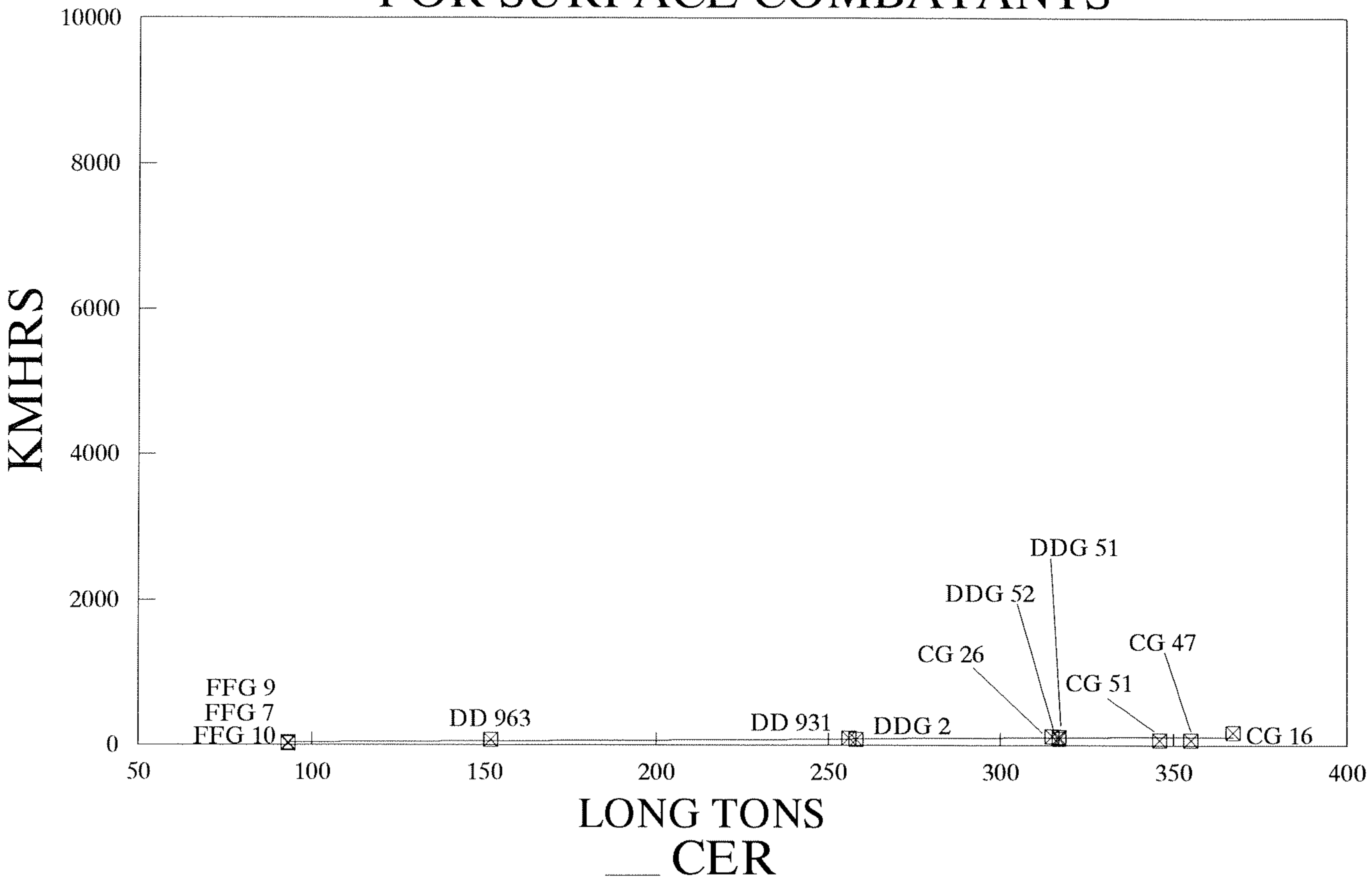
Figure 4-7 provides the CER, regression output, and supporting data for the SWBS Group 700 CER.

The SWBS Group 700 CER of labor vs. weight for surface combatants is:

$$\text{KMHRS} = 0.307\ \text{LT} + 4.5$$

The R^2 value of 0.599 indicates a low correlation between labor manhours and weight in SWBS group 200 for surface combatants. However, T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 35.8 percent also indicates that the model is a good predictor.

LABOR VS. WEIGHT IN GROUP 7
FOR SURFACE COMBATANTS



CER: KMHRS = 0.307 LT + 4.5; R^2 = 0.599; T and F are significant at 95%; CV = 35.8%

Regression Output:

Constant			4.5
Std Err of Y Est			29
R Squared			0.599
No. of Observations			12
Degrees of Freedom			10
# Variables			1
X Coefficient(s)		0.307	
Std Err of Coef.		0.079	
T =	3.867	F =	14.96
CV % =		35.8	

DATA

SHIPS	LT 7	LAB 7
DD 931	256	97
DDG 2	258	75
CG 16	367	174
CG 26	315	121
FFG 7	93	28
FFG 9	93	35
FFG 10	93	21
DD 963	152	70
CG 47	355	72
CG 51	346	70
DDG 51	317	115
DDG 52	317	85

4.1.8 SWBS Group 800 - Integration/ Engineering (Shipbuilder Response)

This group includes installation of the cost of the labor of those program management and engineering services associated with the design, development, production, testing and delivery of the ships. Included are the following elements:

SWBS NUMBER	TITLE
800	Shipbuilder Drawings
810	Production Engineering
830	Design Support
840	Quality Assurance
850	Integrated Logistics Support Engineering
890	Special Purpose Items
891	Safety
892	Human Factors
893	Standardization
894	Value Engineering
895	Reliability
896	Maintainability
897	Data Management
898	Project Management

This group does not include shipyard standard drawings; or molds and templates, which are included in SWBS Group 900.

Figure 4-8 provides the CER, regression output, and supporting data for the SWBS Group 800 CER based on lightship weight of the group.

The SWBS Group 800 CER of labor vs. weight for surface combatants is:

$$KMHRS = 1.27\ LT - 239.2$$

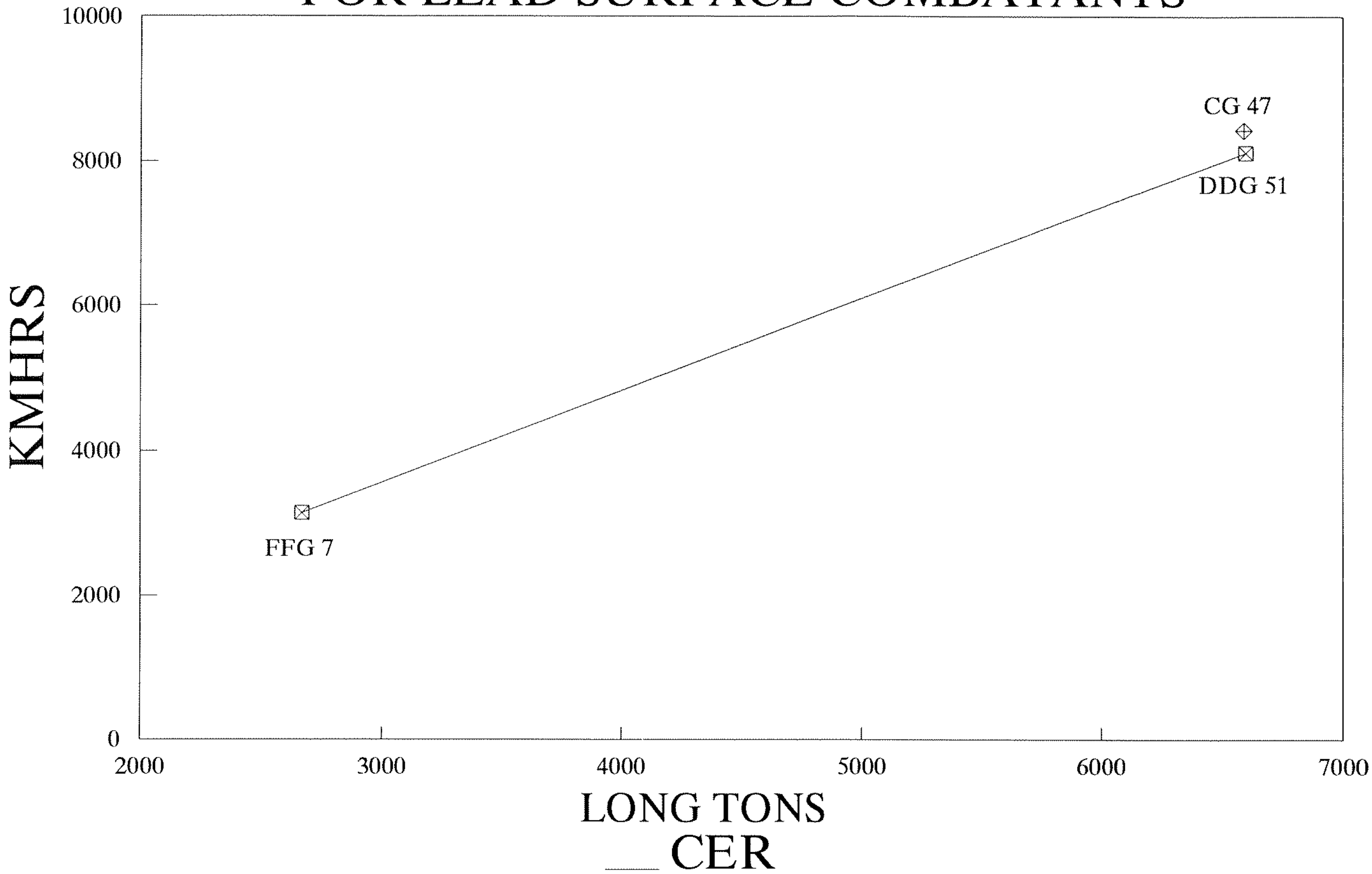
There are not enough data points for statistical analysis of this CER due to the limited number of lead ships in lead yards for which complete data was available. However, the CER is considered to be a fair predictor of SWBS Group 800 costs, especially since the CG 47 estimated cost lies very close to the line.

The SWBS 800 CER contains a high percentage of non-recurring costs for engineering, design, project management and other lead ship integration activities. For this reason, only lead ship data is included in the SWBS Group 800 CER.

For the surface combatants built at BIW (FFG 7 and DDG 51), a large portion of the design and engineering was contracted to Gibbs & Cox, Inc. The Gibbs & Cox, Inc. effort was under a separate contract for the FFG 7, and reported as a direct expense on the CPR for the DDG 51. For both the FFG 7 and DDG 51 data points on the CER, the Gibbs & Cox, Inc. manhours have been added to the SWBS Group 800 labor cost reported by the shipyard to obtain a total SWBS Group 800 cost to the Navy. This data is further discussed in Section 3.1.

The CG 47 is a modification of the DD 963 Class Destroyers. As discussed in Section 3.1, the 4559 labor manhours for SWBS Group 800 reported in the CPR are not reflective of a total new design effort. To account for this, an estimate was developed in Reference (3) to identify the additional manhours required to adjust the SWBS Group 800 costs to reflect a new ship design. These additional 3871 manhours have been added to the CG 47 data point noted on the CER. Since the CG 47 SWBS Group 800 labor manhours are not totally derived from CPR return cost data, the CG 47 data was not used in developing the CER. It is provided for comparison purposes only.

LABOR VS. WEIGHT IN GROUP 8
FOR LEAD SURFACE COMBATANTS



CER: KMHRS = 1.27 LT − 239.2; R^2 = 1.000; T and F not applicable; CV = N/A

NOTE: DD 963 is not included in the regression since detail design costs were reported under separate contract.

NOTE: CG 47 is not included in the regression since it has estimated detail design cost.

Regression Output:

Constant		−239.2
Std Err of Y Est		N/A
R Squared		1.000
No. of Observations		2
Degrees of Freedom		0
# Variables		1
X Coefficient(s)	1.267	
Std Err of Coef.	N/A	

T = N/A F = N/A

CV % = N/A

DATA

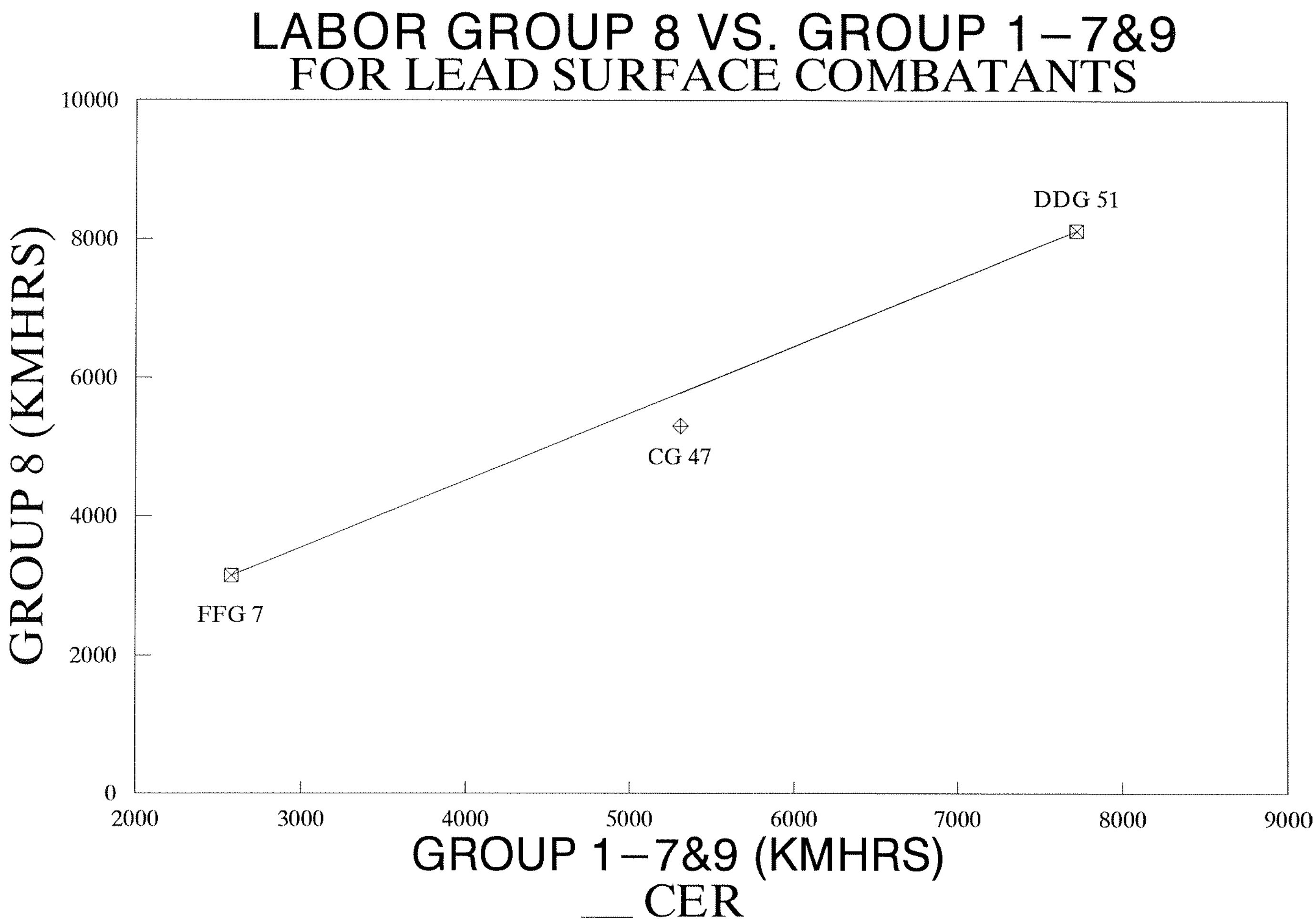
SHIPS	LT 1−7	LAB 8
FFG 7	2,667	3,141
CG 47	6,587	8,430
DDG 51	6,597	8,122

Figure 4-8a provides the CER, regression output, and supporting data for the SWBS Group 800 CER based on total production manhours.

The CER for SWBS Group 800 costs vs. production costs for surface combatants is:

$$\text{Group 8 (KMHRS)} = 0.967 \text{ Group 1-7 \& 9 (KMHRS)} + 649$$

There are not enough data points for statistical analysis of the CER due to the limited number of lead ships in lead yards for which complete data was available. This CER is useful for providing a conservative estimate of SWBS Group 800 costs based on production costs.



CER: (GRP 8) = 0.967 (GRP 1-7&9) + 649; R^2 = 1.000; T and F not applicable; CV = N/A

Regression Output:

Constant	648.7
Std Err of Y Est	N/A
R Squared	1.000
No. of Observations	2
Degrees of Freedom	0
# Variables	1
X Coefficient(s)	0.967
Std Err of Coef.	N/A

T = N/A F = N/A

CV % = N/A

DATA

SHIPS	LAB 1-7&9	LAB 8
FFG 7	2,577	3,141
DDG 51	7,725	8,122
CG 47	5,310	8,430

4.1.9 SWBS Group 900 - Ship Assembly and Support Services

This group includes the cost of contractual, production, and construction support services. Included are the following elements:

SWBS NUMBER	TITLE
980	Contractual and Production Support Services
981	Insurance
982	Trials
983	Delivery
984	Open and Inspect (Conversions Only)
985	Fire and Flooding Protection
986	Test and Inspection
987	Weighing and Recording
988	Contract Data Requirements (Administrative)
989	Fitting Out
990	Construction Support
991	Staging, Scaffolding and Cabling
992	Temporary Utilities and Services
993	Material Handling and Removal
994	Cleaning Services
995	Molds and Templates, Jigs, Fixtures and Special Tools
996	Launching
997	Drydocking

SWBS Group 900 is used for the identification of assemblies and monitoring the ship construction by erection section or similar construction grouping. Actual costs accumulated against these elements are translated to the appropriate elements covering the system involved. The costs accumulated under SWBS Group 900 are for the cost of contractual, production, and construction support services.

Figure 4-9 provides the CER, regression output, and supporting data for the SWBS Group 900 CER based on lightship weight of the ship.

The SWBS Group 900 CER of labor vs. weight for surface combatants is:

$$KMHRS = 0.258\ LT + 104.6$$

The R^2 value of 0.610 indicates low correlation between shipyard production support and lightship weight. However, T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 31.5 percent also indicates the CER is a good predictor.

Of interest in this CER is that the DDG 51 is low compared to the other ships. This offsets a portion of the high costs for SWBS Groups 100 - 700. Given this anomaly, the data was rechecked to see if the original SWBS assignments appeared logical. Based on the allocation of manhours among the trades cited in the CPR, however, no changes to the allocation were identifiable and the allocations were kept as shown.

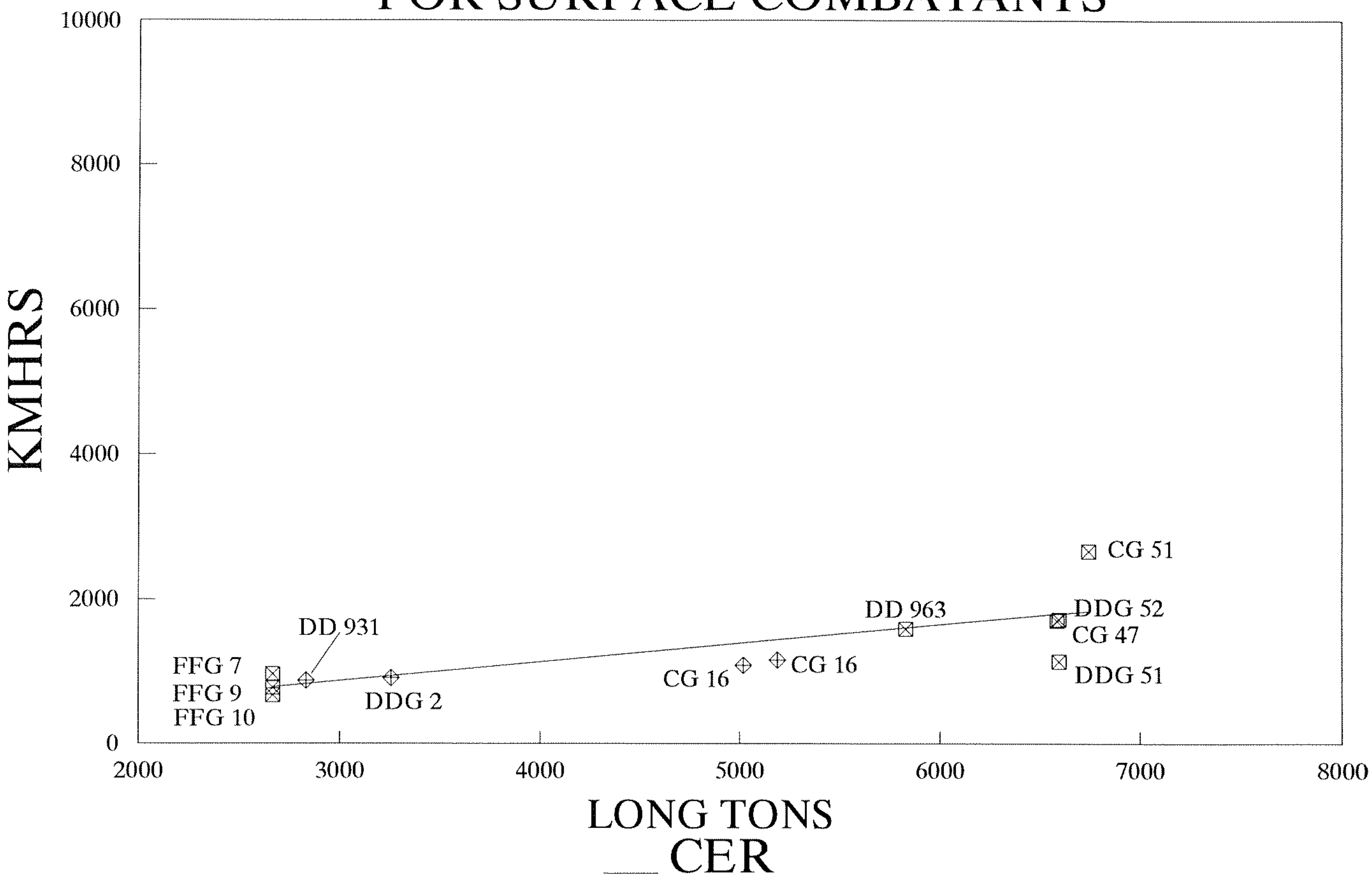
Figure 4-9a provides the CER, regression output, and supporting data for the SWBS Group 900 CER based on months in the shipyard.

The SWBS Group 900 CER of labor vs. months in shipyard for shipyard surface combatants is:

$$KMHRS = 86.8\ MONTHS - 1909$$

The R^2 value of 0.466 indicates a very low correlation between shipyard production support and the number of months the ships were in the shipyards. However, the data points do support the CER relatively well. T and F are significant at 90 percent, indicating relationship is of questionable significance. The CV of 36.9 indicates that the model is a good predictor.

LABOR VS. WEIGHT IN GROUP 9
FOR SURFACE COMBATANTS



CER: KMHRS = 0.258 LT + 104.6; R^2 = 0.610; T and F are significant at 95%; CV = 31.5%
NOTE: DD 931, DDG 2, CG 16 and CG 26 are shown for info only and are not included in the regression.

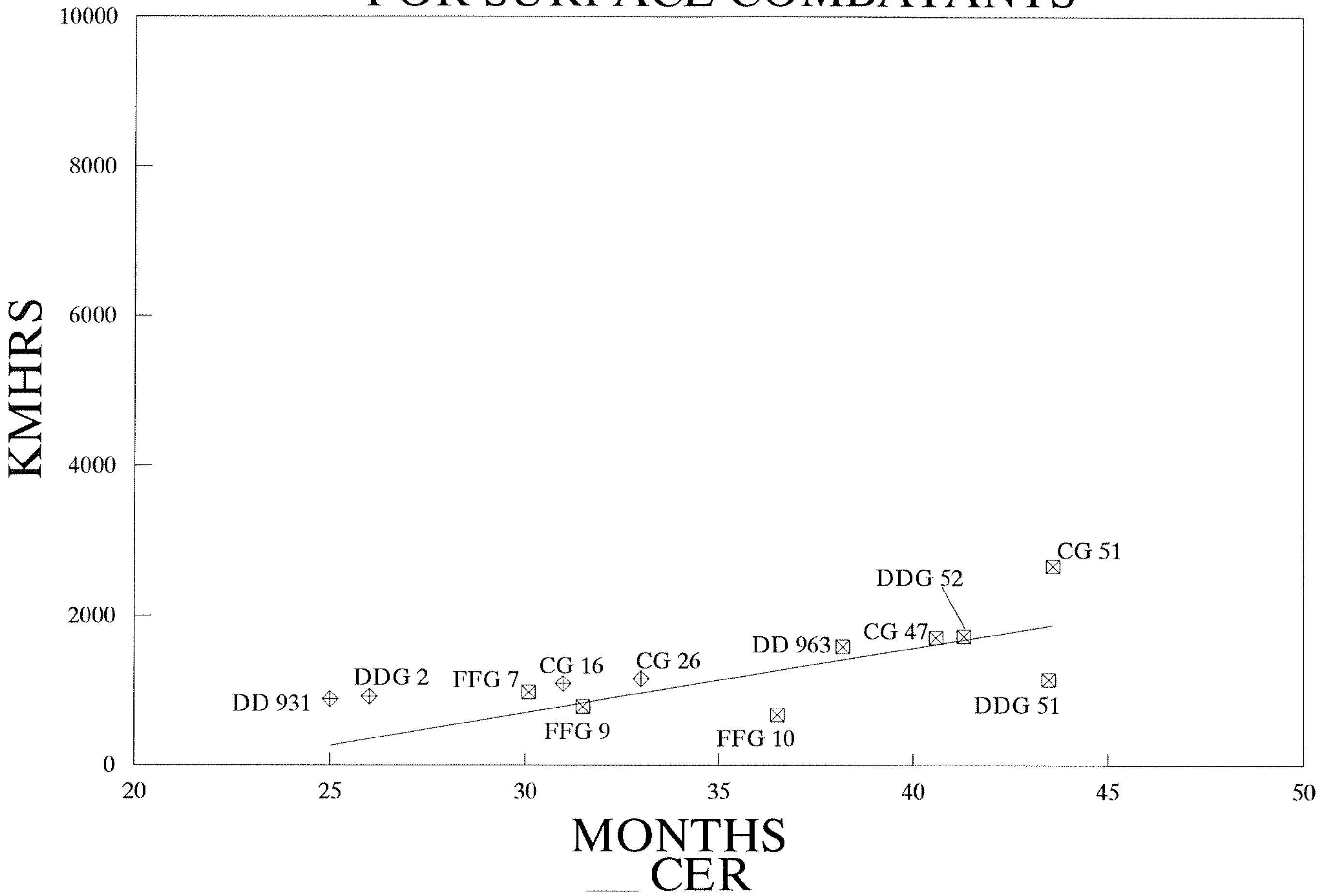
Regression Output:

Constant		104.6
Std Err of Y Est		442
R Squared		0.610
No. of Observations		8
Degrees of Freedom		6
# Variables		1
X Coefficient(s)	0.258	
Std Err of Coef.	0.084	
T = 3.061	F =	9.37
CV % =	31.5	

DATA

SHIPS	LT 1-7	LAB 9
FFG 7	2,667	966
FFG 9	2,667	775
FFG 10	2,667	668
DD 963	5,828	1,586
CG 47	6,587	1,702
CG 51	6,744	2,664
DDG 51	6,597	1,144
DDG 52	6,597	1,723

LABOR VS. MONTHS IN SHIPYARD IN GROUP 9 FOR SURFACE COMBATANTS



CER: KMHRS = 86.8 MON − 1909; R^2 = 0.466; T and F are significant at 90%; CV = 34.4%
NOTE: DD 931, DDG 2, CG 16 and CG 26 are shown for info only and are not included in the regression.

Regression Output:

Constant			−1909.2
Std Err of Y Est			517
R Squared			0.466
No. of Observations			8
Degrees of Freedom			6
# Variables			1
X Coefficient(s)		86.804	
Std Err of Coef.		37.945	
T =	2.288	F =	5.23
CV % =		36.9	

DATA

SHIPS	MONTHS	LAB 9
FFG 7	30.1	966
FFG 9	31.5	775
FFG 10	36.5	668
DD 963	38.2	1,586
CG 47	40.6	1,702
DDG 52	41.3	1,723
DDG 51	43.5	1,144
CG 51	43.6	2,664
DD 931	25.0	875
DDG 2	26.0	910
CG 16	31.0	1,085
CG 26	33.0	1,155

4.1.10 Summary Labor CERs

Figures 4-10, 4-11 and 4-12 are summary labor CER's for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total contract costs (SWBS Groups 100-900). These three groupings reflect different categorizations typically used in previous models or found in CPR's.

Construction costs have been used in previous models to define the actual ship construction activities, exclusive of design and integration, and shipyard services. The CER for construction labor costs, presented in Figure 4-10, was developed by summing the individual one-digit SWBS Groups 100 to 700 costs and is based on total lightship weight. Construction labor costs have exhibited a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship construction costs in a follow yard are similar to those in a lead yard. The relatively good correlation between one-digit SWBS Groups 100 to 700 values to the aggregate SWBS Groups 100 through 700 values has also allowed for allocation of the aggregate SWBS Groups 100 through 700 manhours to individual one-digit SWBS Groups 100 to 700. As noted in Chapter 3, most of the CPR's provided cost breakdowns that allowed for the construction costs to be differentiated from SWBS Groups 800 and 900 costs.

The SWBS Group 100 - 700 summary CER (Figure 4-10) of labor vs. weight for surface combatants is:

$$\text{KMHRS} = 0.669\ \text{LT} - 285.5$$

The R^2 value of 0.641 indicates a low correlation between construction labor costs and lightship weight for surface combatants. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 32.4 percent also indicates the CER model is a good predictor. Note that with the DDG 51 considered an outlier, the statistical significance of this CER would improve.

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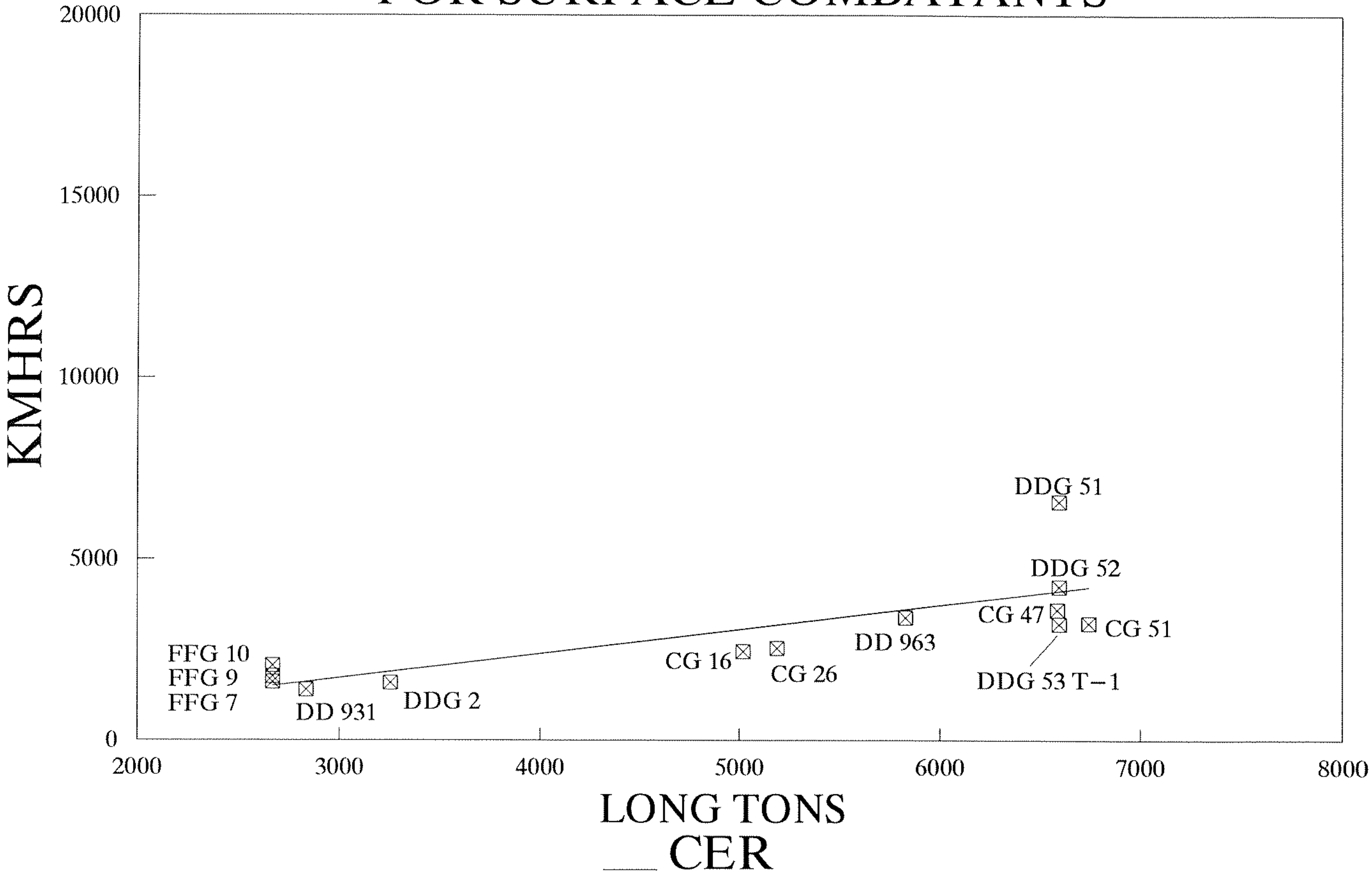
The data point for the DDG 53 backed up the learning curve to represent a lead ship (DDG 53 T-1) is shown for information only and is not included in the regression.

LABOR VS. WEIGHT IN GROUPS 1–7
FOR SURFACE COMBATANTS



CER: KMHRS = 0.669 LT – 285.5; R^2 = 0.641; T and F are significant at 95%; CV = 32.4%

NOTE: DDG 53 T–1 is shown for info only and is not included in the regression.

Regression Output:

Constant		–285.5
Std Err of Y Est		931
R Squared		0.641
No. of Observations		12
Degrees of Freedom		10
# Variables		1
X Coefficient(s)	0.669	
Std Err of Coef.	0.158	
T = 4.223	F =	17.83
CV % =	32.4	

DATA

SHIPS	LT 1–7	LAB 1–7
DD 931	2,835	1,394
DDG 2	3,253	1,592
CG 16	5,016	2,456
CG 26	5,188	2,539
FFG 7	2,667	1,611
FFG 9	2,667	1,767
FFG 10	2,667	2,071
DD 963	5,828	3,398
CG 47	6,587	3,608
CG 51	6,744	3,233
DDG 51	6,597	6,581
DDG 52	6,597	4,237
DDG53 T–1	6,597	3,215

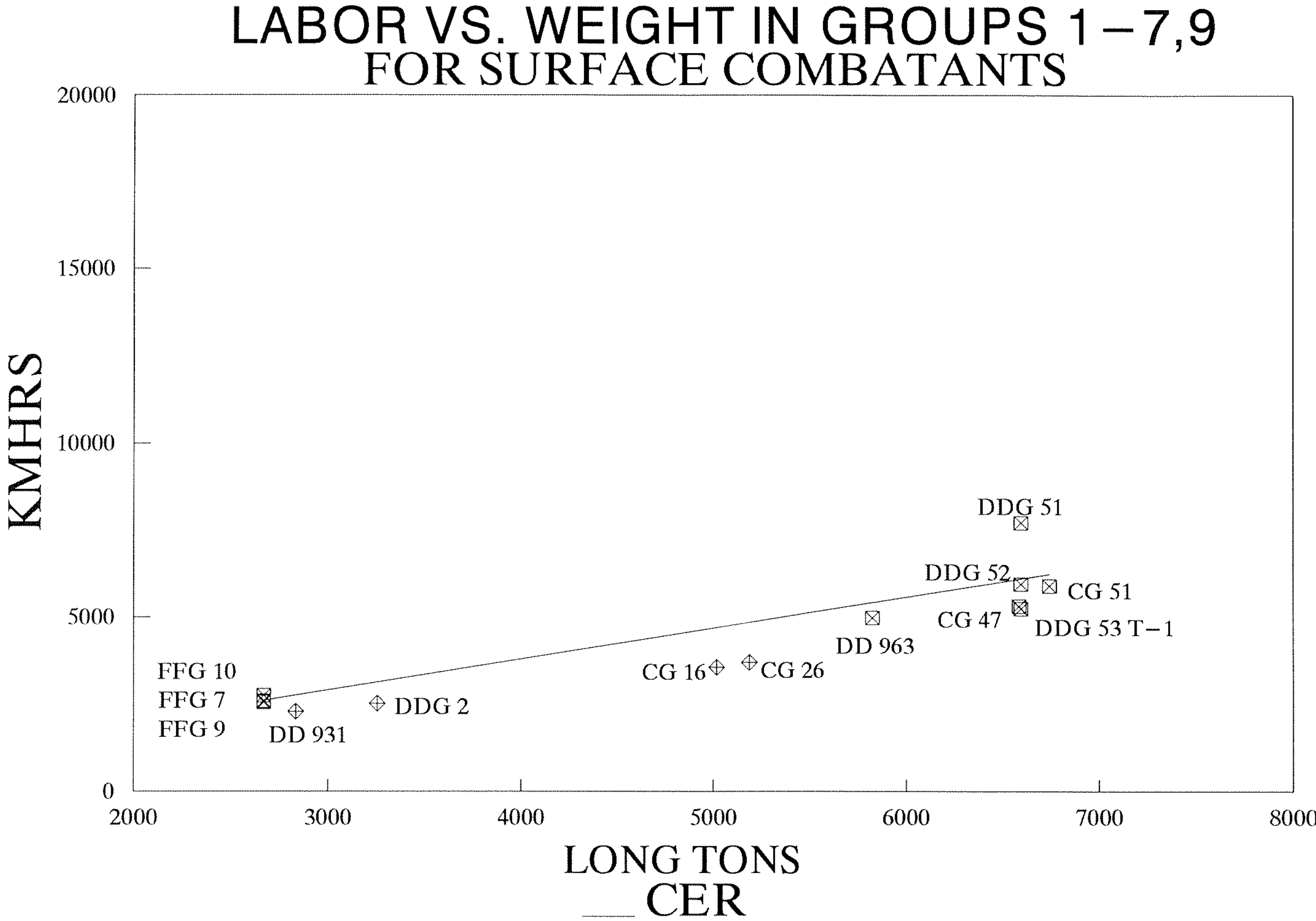
Production costs are reported by shipyards in CPR's and roughly correlate to SWBS Groups (100-700 and 900). The CER for production costs based on total ship lightship weight is shown in Figure 4-11. It shows a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship production costs in a follow yard are similar to those in a lead yard.

The SWBS Group 100 - 700 and 900 CER of labor vs. weight for surface combatants is:

$$KMHRS = 0.893 \; LT + 214$$

The R^2 value of 0.860 indicates a good correlation between production labor costs and lightship weight. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 16.4 percent also indicates that the CER is an excellent predictor. Note that with the DDG 51 considered an outlier, the CER would have greater statistical significance.

The data point for the DDG 53, backed up the learning curve as a lead ship (DDG 53 T-1), is shown for information only and is not included in the regression.



CER: KMHRS = 0.893 LT + 214; R^2 = 0.860; T and F are significant at 95%; CV = 16.4%

NOTE: DDG 53 T–1, DD 931, DDG 2, CG 16 and CG 26 are shown for info only and are not included in the regression.

Regression Output:			
Constant			214.0
Std Err of Y Est			773
R Squared			0.860
No. of Observations			8
Degrees of Freedom			6
# Variables			1
X Coefficient(s)		0.893	
Std Err of Coef.		0.147	
T =	6.070	F =	36.85
CV % =		16.4	

DATA

SHIPS	LT 1–7	LAB 1–7,9
FFG 7	2,667	2,577
FFG 9	2,667	2,542
FFG 10	2,667	2,740
DD 963	5,828	4,984
CG 47	6,587	5,310
CG 51	6,744	5,897
DDG 51	6,597	7,725
DDG 52	6,597	5,960

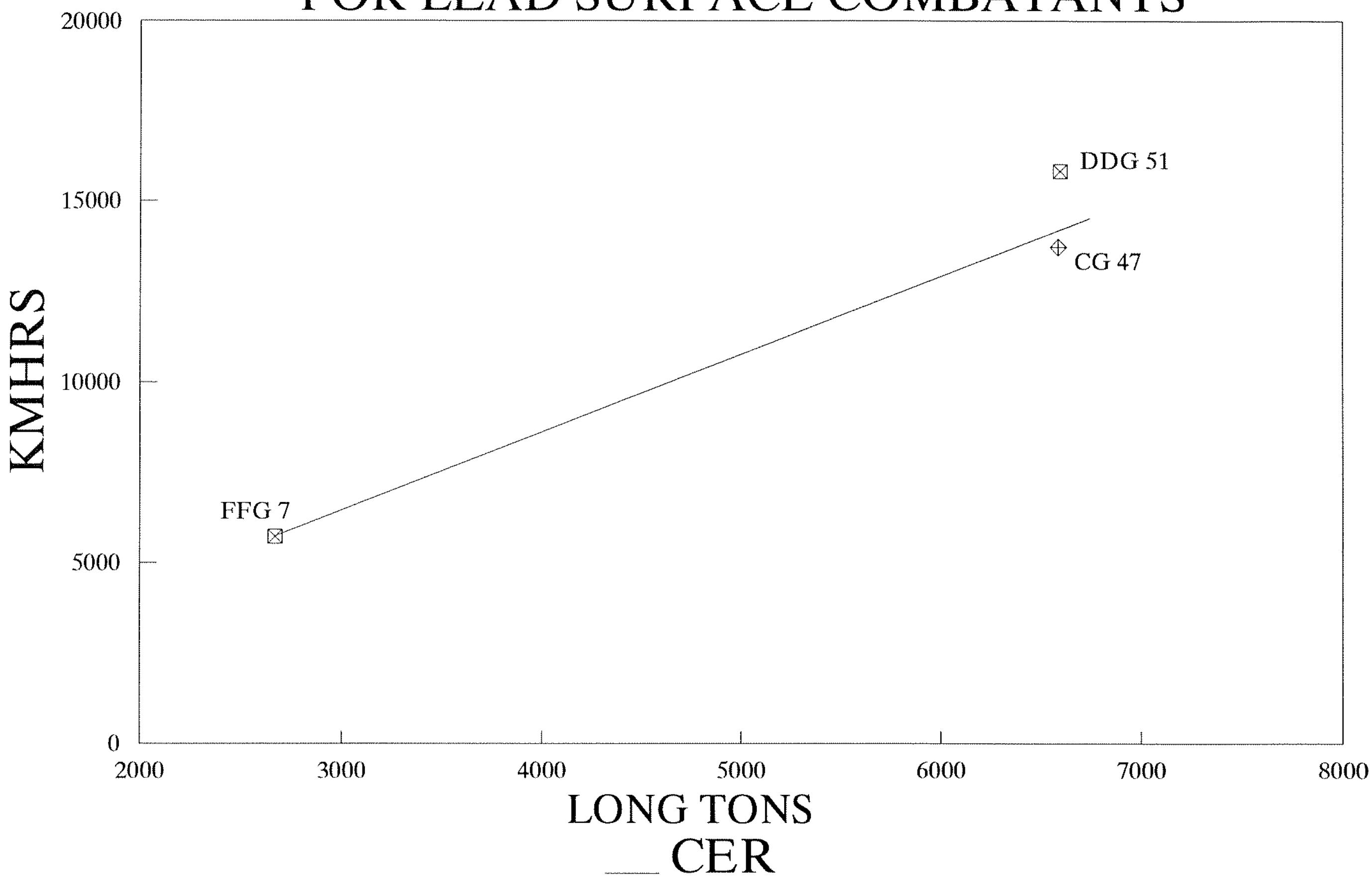
Total contract labor costs for the lead ship in a lead yard include all recurring and non-recurring costs, including all detail design and production engineering. Because of this addition of the SWBS Group 800 costs, only lead ship in a lead yard data is applicable. In developing the CER for SWBS Groups 100-900 based on total ship lightship weight as shown in Figure 4-12, the SWBS Group 800 labor cost CER was superimposed upon the production labor cost CER. In this way, the larger data base of lead ships at lead and follow yards for the production cost CER could be taken advantage of, while the more limited data set of lead ships in lead yards used to derive the CER for SWBS Group 800 could be used.

The SWBS Group 100 - 900 summary CER of labor vs. weight for surface combatants is:

$$KMHRS = 2.16\ LT - 25.2$$

This CER was derived by adding the SWBS Group 800 CER to the production (SWBS Group 100 - 700 and 900) CER. Because of the difference in number of ships used to develop the engineering and production CER's, no statistics apply to the total contract labor cost CER. The data points are provided for comparison purposes.

LABOR VS. WEIGHT IN GROUPS 1-9
FOR LEAD SURFACE COMBATANTS



CER: KMHRS = 2.16 LT - 25.2

Group 8	KMHRS =	1.267	LT +	-239.2
+ Group 1-7&9	KMHRS =	0.893	LT +	214.0
Group 1-9	KMHRS =	2.160	LT +	-25.2

4.1.11 Material Costs

Material costs include all the materials and equipment purchased by the shipyard under the construction contract. It does not include the material and equipment provided by the government as government furnished equipment (GFE). Material costs are reported in the CPR's in dollars often as a single dollar figure. The method of reporting material dollars in a CPR is dependent upon the contract type and the accounting system of the shipyard. As discussed in Chapter 3, the material costs are reported in either base year or report year dollars, depending upon whether the contract is a fixed price or cost reimbursed type contract. In addition, the shipyards can take both G&A and fee on material costs in accordance with their individual accounting procedures.

In order to limit uncertainty in material costs, only lead ship in a lead yard, unburdened material costs, escalated to FY 93 dollars were used to develop the CER shown in Figure 4-13. Follow ship material costs often contain a different mix of GFE or material cost factors than lead ships, due to Class buys, non-recurring costs, or other changes. Because of this, their costs are not used in the CER. The material cost CER is based on total ship lightship weight. Given the lack of detail in the CPR's, only total material dollars are used in the CER.

Reference (5) was used to escalate the material dollars to FY 93 dollars and should be used to escalate estimates obtained from this model to future year dollars. The escalation of dollars is a source of uncertainty in the model and may cause older material costs to be more suspect compared to similar, more recent ships. Technology changes and fluctuating market values also contribute to the uncertainty of material cost data, even among similar ships.

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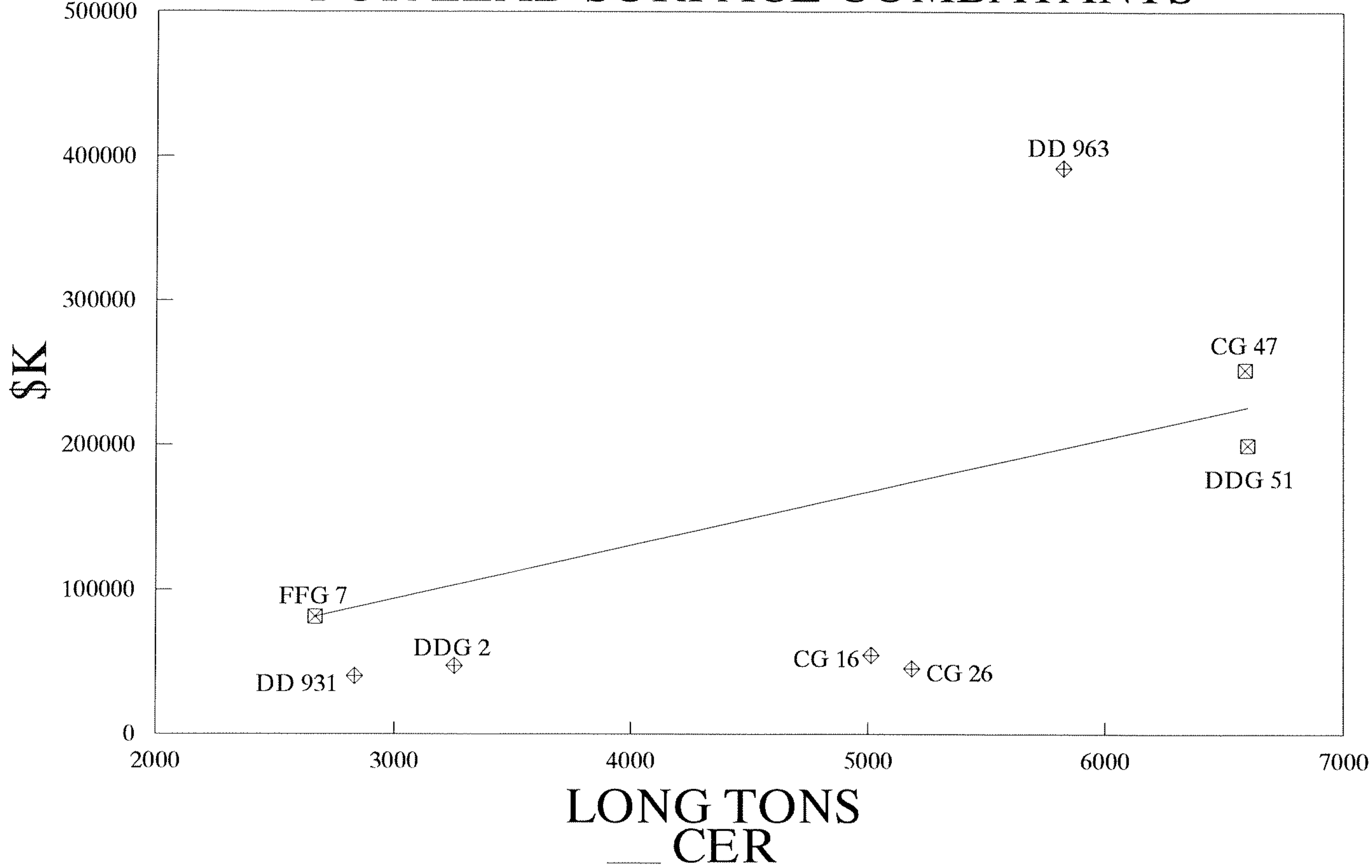
MATERIAL COST VS. LIGHTSHIP WEIGHT
FOR LEAD SURFACE COMBATANTS



CER: $K = 36.90 LT – 17,206;   R^2 = 0.909; T and F are significant at 95%; CV = 20.3%

NOTE: Only Lead Ships are included in the regression: FFG 7, CG 47, and DDG 51. DD 963 is not included in the regression since material costs reported included follow ships (DD 963 was negotiated as a total package procurement).

Regression Output:

Constant			–17206
Std Err of Y Est			37,410
R Squared			0.909
No. of Observations			3
Degrees of Freedom			1
# Variables			1
X Coefficient(s)		36.905	
Std Err of Coef.		11.673	
T =	3.162	F =	10.00
CV % =		21.0	

DATA

SHIPS	LT 1–7	FY93($K)
FFG 7	2,667	81,152
CG 47	6,587	252,373
DDG 51	6,597	199,837
DD 931	2,835	40,292
DDG 2	3,253	47,077
CG 16	5,016	54,562
CG 26	5,188	45,575
DD 963	5,828	392,037

The material CER for surface combatants is (as shown in Figure 4-13):

$$\$K = 36.9\ LT - 17{,}206$$

The R^2 value of 0.909 indicates a high correlation between material costs and lightship weight for surface combatants. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 21.0 percent indicates that the CER is a good predictor.

Material costs for an individual ship are dependent upon the specific configuration of the ship, the actual mix of shipyard responsible items and GFE, as well as the current market value of the shipyard responsible items. This covers a wide range of items, including structural material (e.g., steel, aluminum, composites), equipment (e.g., propulsion systems, electric plant, electronics) as well as distributive systems (e.g., power cable, ducting, piping). Given this, and the limited data available, the material CER provides only a rough estimate for lead ship material costs. This estimate should be compared with the actual material cost estimate prepared for the ship by NAVSEA. The completeness of the NAVSEA estimate and the current vendor costs for major elements of the material costs should be independently checked. If reasonable, consideration should be given to using the NAVSEA estimate in lieu of the CER estimate for the material costs.

4.1.12 Summary of CER's for Surface Combatants

Table 4-2 shows each CER for Surface Combatants with its associated statistics listed by cost group.

TABLE 4-2

SURFACE COMBATANT CER's

COST GROUP	RELATIONSHIP	STATISTICS
100	Group 1 (KMHRS) = 0.31 (WT) + 33.4	R^2=.59; T,F at 95%; CV=37%
200	Group 2 (KMHRS) = 0.23 (WT) + 51.8	R^2=.48; T,F at 95%; CV=31%
200	Group 2 (KMHRS) = 0.003 (WT) - 2.57	R^2=.49; T,F at 95%; CV=30%
300	Group 3 (KMHRS) = 2.65 (WT) - 278	R^2=.82; T,F at 95%; CV=33%

COST GROUP	RELATIONSHIP	STATISTICS
400	Group 4 (KMHRS) = 0.49 (WT) + 74.9	R^2=.51; T,F at 95%; CV=32%
500	Group 5 (KMHRS) = 1.14 (WT) - 52.0	R^2=.69; T,F at 95%; CV=30%
600	Group 6 (KMHRS) = 2.05 (WT) - 275	R^2=.66; T,F at 95%; CV=39%
600	Group 6 (KMHRS) = 0.32 (WT) + 47	R^2=.01; T,F at <90%; CV=63%
700	Group 7 (KMHRS) = 0.31 (WT) + 4.5	R^2=.60; T,F at 95%; CV=36%
800	Group 8 (KMHRS) = 1.27 (WT) - 239	N/A
800	Group 8 (KMHRS) = 0.97 (1-7 &9) + 644	N/A
900	Group 9 (KMHRS) = 0.26 (WT) + 105	R^2=.61; T,F at 95%; CV=32%
900	Group 9 (KMHRS) = 86.8 (WT) - 1909	R^2=.47; T,F at 90%; CV=37%
SUMMARY CER's:		
100-700	Group 1-7 (KMHRS) = 0.67 (WT) - 286	R^2=.64; T,F at 95%; CV=32%
100-700 & 900	Group 1-7 & 9 (KMHRS) = 0.89 (WT) + 214	R^2=.86; T,F at 95%; CV=16%
100-900	Group 1-9 (KMHRS) = 2.16 (WT) - 25.2	
Material Cost	Mat ($K) = 36.9 (WT) - 17,206	R^2=.91; T,F at 95%; CV=21%

4.1.13 Comparison of Actual Versus Estimated Costs

As noted earlier, the limited number of data points and the characteristics of the data spread affect the statistical analysis of the CER's. As a check on the ability of the model to predict actual return costs, a comparison was made between the return costs for the ships in the database and the estimated costs for the ships using the CER's. This comparison uses the ships that constitute the database; however, no other data was available to check the model, and this was considered satisfactory since the database comprises most of the recent ship classes built. This comparison was performed at the construction, production and total cost levels for labor costs, and at the total cost level for material costs. The labor costs were developed by summing the estimated one-digit labor manhours. The comparison is made at the summary levels, since the model is designed to be used at the total ship level. The comparisons are provided for all ships at the construction and production labor costs summary level, and only for the lead yard ships, FFG 7, CG 47 and DDG 51, at the total labor and material cost level.

Table 4-3 provides the results of the comparison. The effects of the high DDG 51 construction labor costs are reflected in the CER's. The model consistently underestimates the DDG 51 and, with the exception of FFG 10, overestimates the other ships. The percent difference is most pronounced at the construction cost level, where DDG 51 is underestimated in labor manhours by 34 percent and the other ships are overestimated by as much as 34 percent (although, on average, it is over by 12 percent). The addition of SWBS Group 900 manhours reduces these percentile differences, since the DDG 51 actual return costs for SWBS Group 900 are low compared to the CER. These percentage differences are also reduced with the addition of SWBS Group 800 labor costs because the CER is based on only the FFG 7 and DDG 51 returns; thus, it estimates the same costs for the DDG 51 as the actual return costs. The addition of Group 800 and 900 costs further reduces the percentage difference because they contribute a large number of manhours, which makes the ratio of SWBS Group 100 through 700 contribution to the total percentage much smaller. At the production cost level, the percent difference ranges from 18 percent under estimate for DDG 51 to 14 percent over estimate for CG 47. However, the average is 9 percent under estimate and 4 percent over estimate. At the total contract level, the range is from 10 percent under estimate for the DDG 51, to 3 percent over estimate for the CG 47, with the model exactly predicting the FFG 7 costs.

Comparison of the material costs for the lead ships in a lead yard indicated that the model range of difference is a 13 percent over estimate for the DDG 51 and an 10 percent under estimate for the CG 47, with the model exactly predicting the FFG 7. Given the limited data points, their relative point in the CER, and the fact that the CER comprises only these three points, it is not unreasonable to expect this good relationship.

For purposes of comparison, the CG 47 total labor costs are presented in Table 4-3. The return cost value includes the added manhours in SWBS Group 800 to account for a new ship design effort. Since this represents modified return cost data it is not used in the development of the CER's for SWBS Group 800 or for total contract labor. However, Table 4-3 shows that the modified CG 47 return costs compare well with the model estimate.

Given the good correlation between the total estimated labor manhours and material costs and the return labor manhours and material costs for the FFG 7 and DDG 51, supported by a similarly good correlation between the estimated and modified return costs for the CG 47, it is considered that the model satisfactorily predicts total contract costs for labor manhours and material costs for the surface combatants. It is further considered that the model is conservative for estimating construction and production labor manhours due to the influence of the DDG 51 costs. However, given the experience of the DDG 51, the conservatism may be warranted in estimating future surface combatant lead ship costs.

Table 4-3

COMPARISON OF ACTUAL VS. ESTIMATED COSTS

FOR SURFACE COMBATANTS

	SWBS	Lead Ship / Lead Yard								
		FFG 7			CG 47			DDG 51		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	1,611	1,760	9	3,608	4,264	18	6,581	4,360	(34)
Production Manhours	100 - 700, 900	2,577	2,551	(1)	5,310	6,065	14	7,547	6,163	(18)
Total Manhours	100 - 900	5,718	5,692	(0)	13,741	14,175	3	15,847	14,285	(10)
Total FY93 Material Cost $K	100 - 900	81.2	81.2	0	252.4	225.9	(10)	199.8	226.3	13

	SWBS	Lead Ship / Follow Yard											
		FFG 9			FFG 10			CG 51			DDG 52		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	1,767	1,760	0	2,071	1,760	(15)	3,233	4,334	34	4,237	4,360	3
Production Manhours	100 - 700, 900	2,542	2,551	0	2,740	2,551	(7)	5,897	6,176	5	5,960	6,163	3
Total Manhours	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total FY93 Material Cost $K	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

4.2 Amphibious Type Ships

The CER's for the amphibious type ships are developed using the ships shown in Table 4-4.

TABLE 4-4

AMPHIBIOUS SHIPS

Ship	Class	Shipyard	Cost Data Type	Year Delivered
LST 1182	LST 1179 Class Tank Landing Ship	NASSCO	Lead Ship/ Follow Yard	1969
LSD 41	LSD 41 Class Dock Landing Ship	Lockheed	Lead Ship/Lead Yard	1985
LSD 44	LSD 41 Class Dock Landing Ship	Avondale	Lead Ship/ Follow Yard	1989
AD 41	AD 41 Class Destroyer Tender	NASSCO	Lead Ship/ Follow Yard	1980
LHD 1	LHD 1 Class Amphibious Assault Ship	Ingalls	Lead Ship/Lead Yard	1989

The amphibious ship CER's are based on the data presented in Section 3.2. Lightship weight is the principal independent variable, although CER's are developed using shaft horsepower in SWBS Group 200, total accommodations in SWBS Group 600, production manhours in SWBS Group 800 and months in the shipyard in SWBS Group 900.

CER's for labor manhours are provided by one-digit SWBS cost groups, and summary CER's for labor manhours are provided for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total costs (SWBS Groups 100-900). A CER for FY 93 material dollars is presented at the total cost level.

4.2.1 SWBS Group 100 - Hull Structure

This group includes erection of all the ship's structural components. Included are the following elements:

SWBS NUMBER	TITLE
110	Shell and Supporting Structure
120	Hull Structural Bulkheads
130	Hull Decks
140	Hull Platforms and Flats
150	Deckhouse Structure
160	Special Structures
170	Masts, Kingposts and Service Platforms
180	Foundations
190	Special Purpose Systems

This group does not encompass non-structural items such as ship fittings, rails, stanchions, life lines, hull compartmentation, non-structural bulkheads, deck covering, and other outfit and furnishings, which are contained in SWBS Group 600.

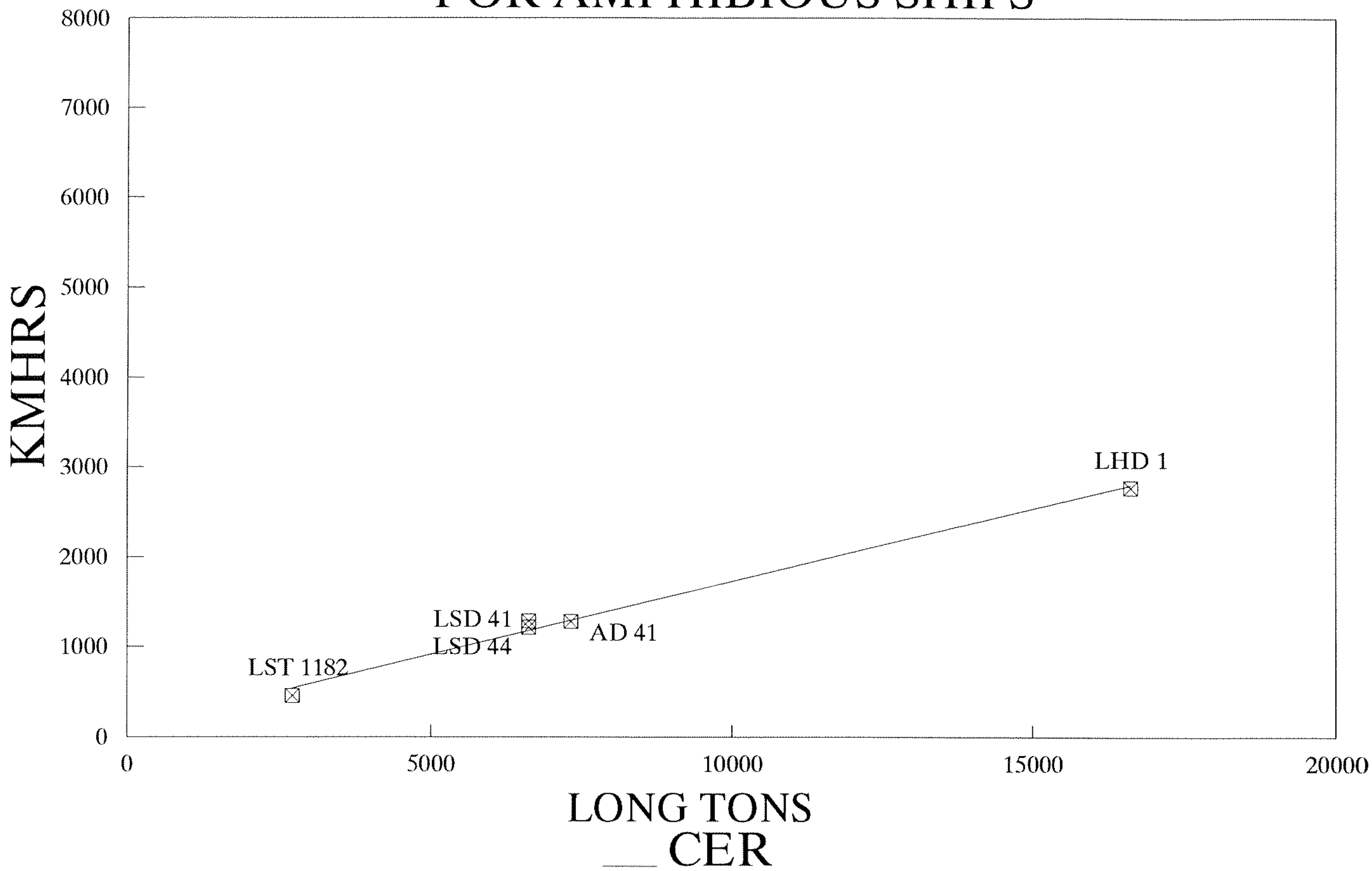
Figure 4-14 provides the CER regression output, and supporting data for the SWBS Group 100 CER based on lightship weight for the group.

The SWBS Group 100 CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.163\ LT + 101.7$$

The R^2 value of 0.993 indicates a high correlation between labor and weight in SWBS Group 100. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 5.9 percent indicating that the CER is also an excellent predictor.

LABOR VS. WEIGHT IN GROUP 1
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.163 LT + 101.7; R^2 = 0.993; T and F are significant at 95%; CV = 5.9%

Regression Output:

Constant			101.7
Std Err of Y Est			83
R Squared			0.993
No. of Observations			5
Degrees of Freedom			3
# Variables			1
X Coefficient(s)		0.163	
Std Err of Coef.		0.008	
T =	20.335	F =	413.51
CV % =		5.9	

DATA

SHIPS	LT 1	LAB 1
LST 1182	2,707	455
LSD 41	6,627	1,215
LSD 44	6,627	1,282
AD 41	7,333	1,281
LHD 1	16,614	2,773

4.2.2 SWBS Group 200 - Propulsion Plant

This group includes installation of the ships propulsion plant and drive train systems. Included are the following elements:

SWBS NUMBER	TITLE
220	Energy Generating System (Non-Nuclear)
230	Propulsion Units
240	Transmission and Propulsor Systems
250	Propulsion Support System (except fuel and lube oil)

This group does not include foundations (SWBS Group 100); electric plant systems (SWBS Group 300); propulsion electronics and monitoring systems (SWBS Group 400); and auxiliary systems, including bow thrusters, (SWBS Group 500).

Figure 4-15 provides the CER, regression output, and supporting data for the SWBS Group 200 CER based on lightship weight of the group.

The SWBS Group 200 CER labor vs. weight for amphibious ships is:

$$\text{KMHRS} = 0.042\ \text{LT} + 149.1$$

The R^2 value of 0.048 indicates a very low correlation between labor and weight in SWBS Group 200. T and F are not significant at 90 percent, indicating the relationship is not statistically significant. The CV for this relationship is 48.3 percent, indicating that the model is a poor predictor. The low correlation between the data and the CER is caused by the fact that the CER approaches a constant where the statistical correlations approach zero. Given this, and the good relationship between the data and the CER, it is considered that the CER is a good predictor of costs. Consideration can be given by NCA to presenting this CER as a constant for statistical purposes.

Figure 4-15a provides the CER, regression output and supporting data for the SWBS Group 200 CER based on the ships shaft horsepower.

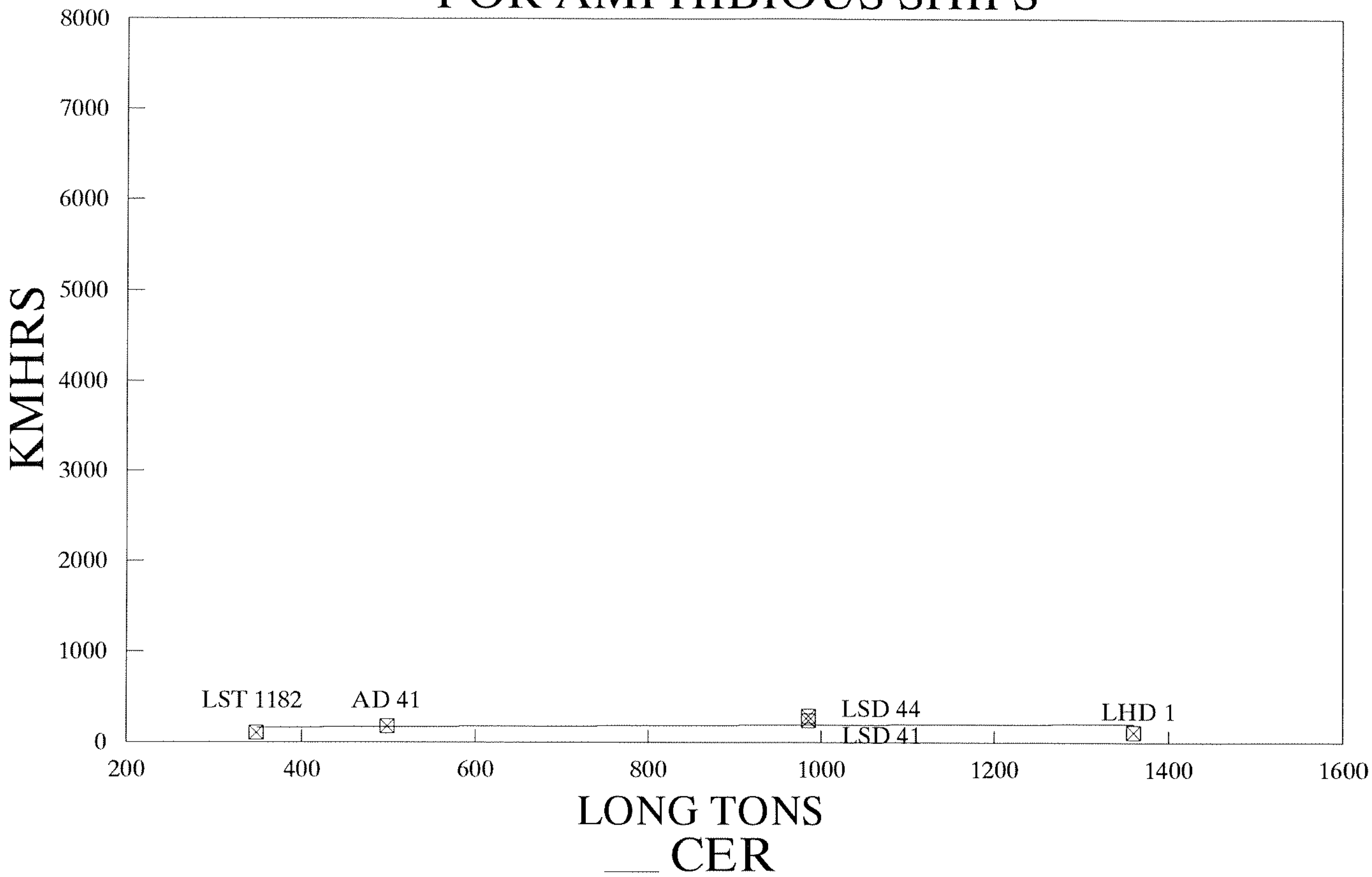
The SWBS Group 200 CER of labor vs. shaft horsepower for amphibious ships is:

$$KMHRS = -0.001\ SHP + 205.8$$

The R^2 value of 0.028 indicates a very low correlation between labor costs and shaft horsepower for surface combatants. T and F are not significant at 90 percent, indicating the relationship is not statistically significant. The CV for this relationship is 48.8 percent, indicating the CER is a poor predictor.

The low correlation between the data and the CER is caused by the fact that the CER approaches a constant where the statistical correlations approach zero. Given this, and the good relationship between the data and the CER, it is considered that the CER is a good predictor of costs. Consideration can be given by NCA to presenting this CER as a constant for statistical purposes.

LABOR VS. WEIGHT IN GROUP 2 FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.042 LT + 149.1; R^2 = 0.048; T and F are not significant at 90%; CV = 48.3%

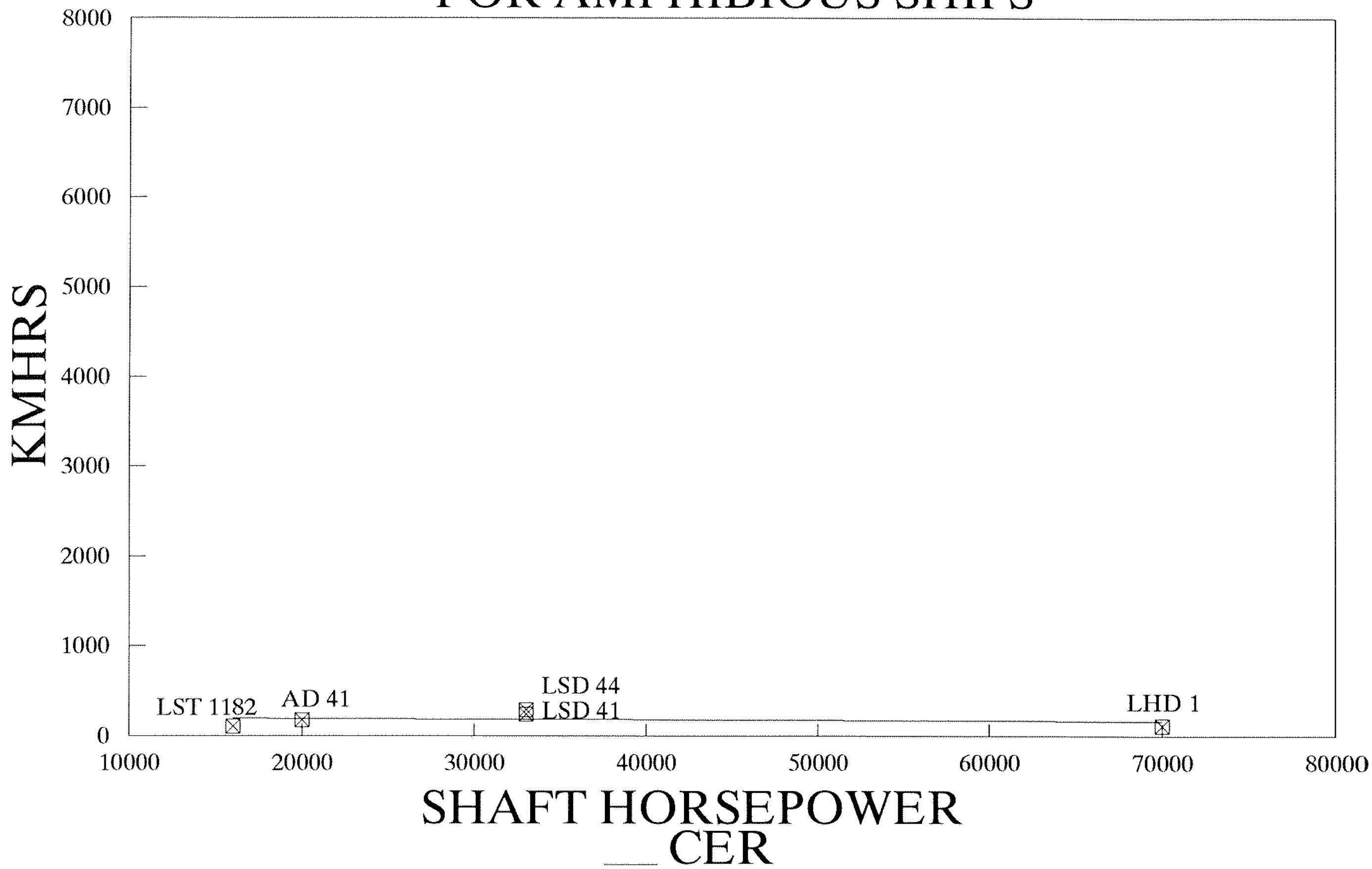
Regression Output:

Constant		149.1
Std Err of Y Est		89
R Squared		0.048
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	0.042	
Std Err of Coef.	0.109	
T = 0.389	F =	0.15
CV % =	48.3	

DATA

SHIPS	LT 2	LAB 2
LST 1182	348	103
LSD 41	985	239
LSD 44	985	287
AD 41	498	179
LHD 1	1,360	115

LABOR VS. SHAFT HORSEPOWER IN GRP 2
FOR AMPHIBIOUS SHIPS



CER: KMHRS = –0.001 SHP + 205.8; R^2 = 0.028; T and F not significant at 90%; CV = 48.8%

Regression Output:

Constant		205.8
Std Err of Y Est		90
R Squared		0.028
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	–0.001	
Std Err of Coef.	0.002	
T = –0.294	F =	0.09
CV % =	48.8	

DATA

SHIPS	LAB 2	SHP
LST 1182	103	16,000
LSD 41	239	33,000
LSD 44	287	33,000
AD 41	179	20,000
LHD 1	115	70,000

4.2.3 SWBS Group 300 - Electric Plant

This group includes installation of the ship's electric power generation and distribution plant. Included are the following elements:

SWBS NUMBER	TITLE
310	Electrical Power Generation
320	Power Distribution Systems
330	Lighting Systems
340	Power Generation Support Systems
390	Special Purpose Systems

This group does not include foundations (SWBS Group 100); propulsion electric systems (SWBS Group 200); and command and surveillance systems (SWBS Group 400).

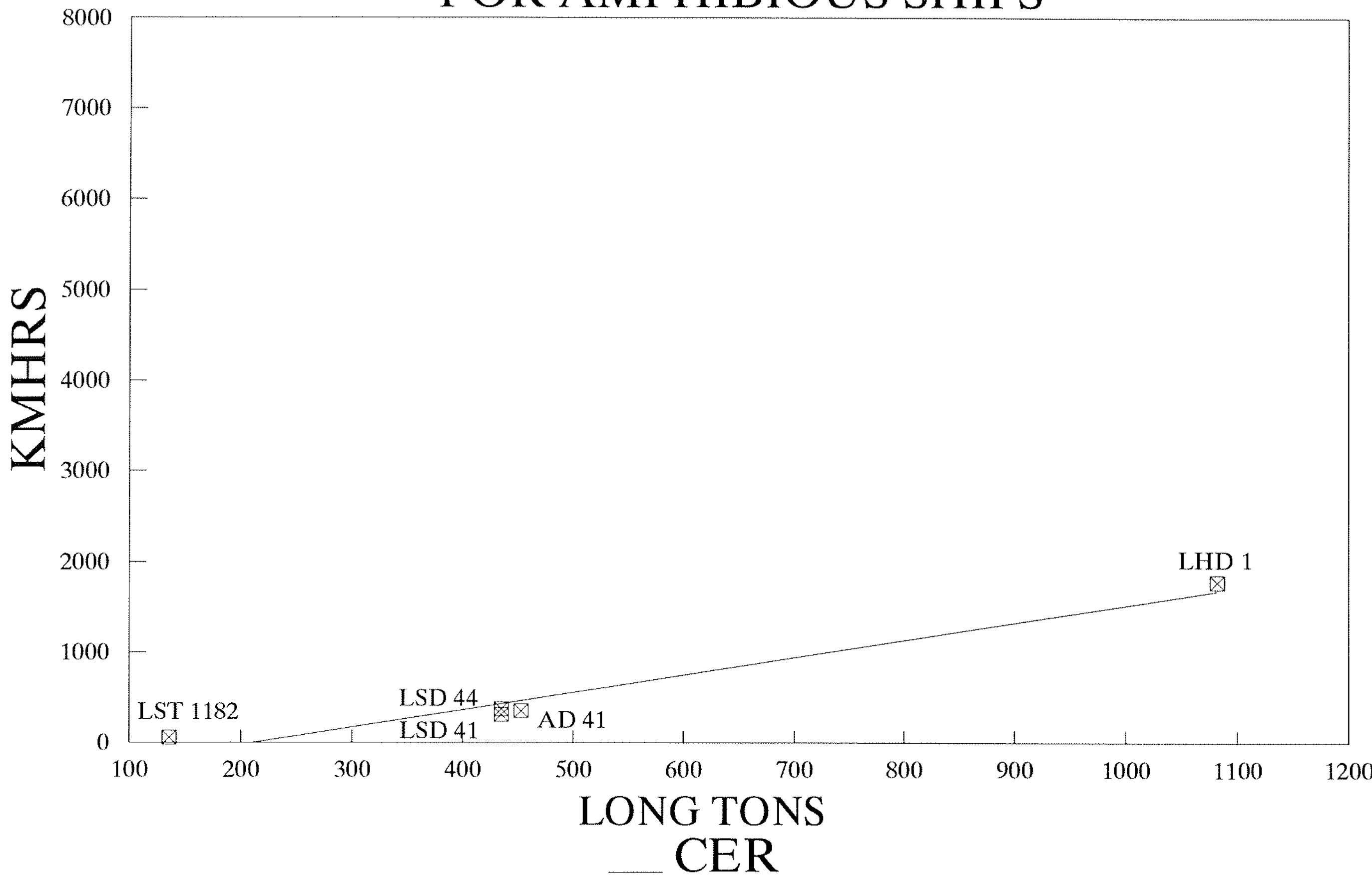
Figure 4-16 provides the CER, regression output, and supporting data for the SWBS Group 300 CER based on lightship weight of the group.

The SWBS Group 300 CER of labor vs. weight for amphibious ships is:

$$KMHRS = 1.93\ LT - 406$$

The R^2 value of 0.956 indicates a high correlation between labor and weight in SWBS Group 300. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV is 28.8 percent, indicating that the CER is also a good predictor.

LABOR VS. WEIGHT IN GROUP 3
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 1.93 LT – 406; R^2 = 0.956; T and F are significant at 95%; CV = 28.8%

Regression Output:

Constant		–406.5
Std Err of Y Est		165
R Squared		0.956
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	1.929	
Std Err of Coef.	0.238	
T = 8.107	F =	65.73
CV % =	28.8	

DATA

SHIPS	LT 3	LAB 3
LST 1182	136	57
LSD 41	435	310
LSD 44	435	374
AD 41	453	351
LHD 1	1,082	1,777

4.2.4 SWBS Group 4 - Command and Surveillance

This group includes installation of all command and surveillance systems, both for ship operations and combat systems/weapons. Included are the following elements:

SWBS NUMBER	TITLE
410	Command and Control Systems
420	Navigation Systems
430	Interior Communications
440	Exterior Communications
450	Surveillance Systems (surface)
460	Surveillance Systems (underwater)
470	Countermeasures
480	Fire Control Systems
490	Special Purpose Systems

This group does not include masts, yardarms, or foundations (SWBS Group 100); power conversion systems, lighting or power cable (SWBS Group 300); cooling systems (SWBS Group 500); or weapons (SWBS Group 700).

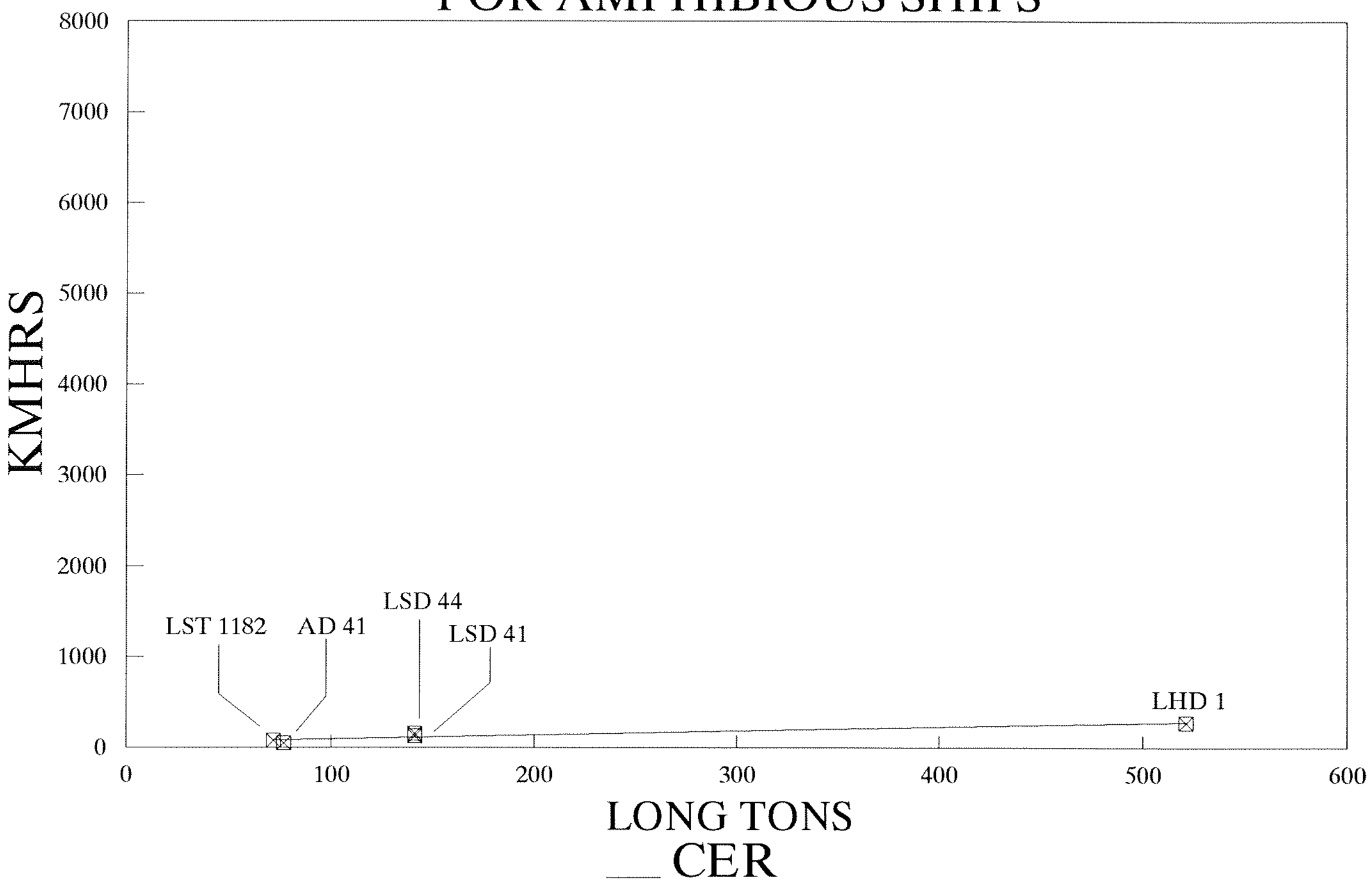
Figure 4-17 provides the CER, regression output, and supporting data for the SWBS Group 400 CER based on lightship weight of the group.

The SWBS Group 400 CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.453\ LT + 49.5$$

The R^2 value of 0.891 indicates a good correlation between labor and weight in SWBS Group 400. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 25.4 percent, indicating the model is also a good predictor.

LABOR VS. WEIGHT IN GROUP 4
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.453 LT + 49.5; R^2 = 0.891; T and F are significant at 95%; CV = 25.4%

Regression Output:

Constant		49.5
Std Err of Y Est		34
R Squared		0.891
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	0.453	
Std Err of Coef.	0.092	
T = 4.945	F =	24.45
CV % =	25.4	

DATA

SHIPS	LT 4	LAB 4
LST 1182	77	45
LSD 41	141	125
LSD 44	141	155
AD 41	72	75
LHD 1	521	278

4.2.5 SWBS Group 500 - Auxiliary Systems

This group includes installation of the ship's environmental, fluid, maneuvering and equipment handling systems. Included are the following elements:

SWBS NUMBER	TITLE
510	Climate Control
520	Sea Water Systems
530	Fresh Water Systems
540	Fuels and Lubricants, Handling and Storage
550	Air, Gas, and Miscellaneous Fluid Systems
560	Ship Control Systems
570	Underway Replenishment Systems
580	Mechanical Handling Systems
590	Special Purpose Systems

This group does not include foundations, fan rooms, structural penetrations, permanent ballast, integral tanks, sea chests, (SWBS Group 100); propulsion systems including circulation and cooling pumps and piping, fuel service pumps and piping, main propulsion lube oil system, propulsion and propulsion train (SWBS Group 200); batteries, electrical systems, electrical generator support systems, power cabling (SWBS Group 300); alarms systems (SWBS Group 400); spaces, cargo stowage, hull fittings (SWBS Group 600), and handling and stowage of weapons (SWBS Group 700).

Figure 4-18 provides the CER, regression output, and supporting data for the SWBS Group 500 CER, based on lightship weight of the group.

The SWBS Group 500 CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.452\ LT + 237$$

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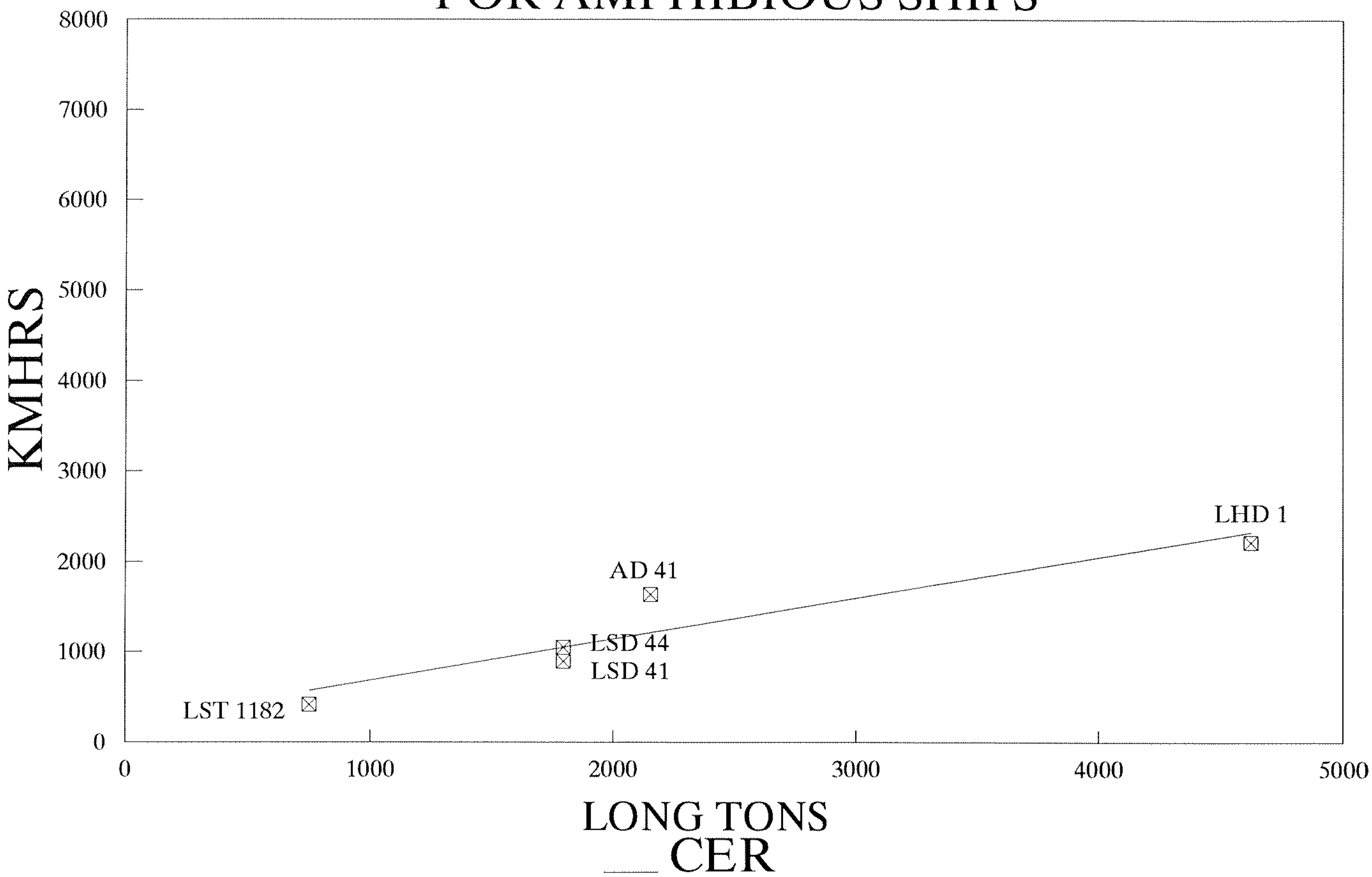
The R^2 value of 0.874 indicates a good correlation between labor and weight in SWBS Group 500. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 23.0 percent, indicating the CER is also a good predictor.

LABOR VS. WEIGHT IN GROUP 5
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.452 LT + 237; R^2 = 0.874; T and F are significant at 95%; CV = 23.0%

Regression Output:

Constant		236.5
Std Err of Y Est		286
R Squared		0.874
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	0.452	
Std Err of Coef.	0.099	
T = 4.564	F =	20.83
CV % =	23.0	

DATA

SHIPS	LT 5	LAB 5
LST 1182	750	416
LSD 41	1,796	897
LSD 44	1,796	1,049
AD 41	2,157	1,640
LHD 1	4,622	2,214

4.2.6 SWBS Group 600 - Outfit and Furnishings

This group includes installation of the ship's hull fittings, non-structural subdivision, preservation, ship support and habitability items. Included are the following elements:

SWBS NUMBER	TITLE
610	Ship Fittings
620	Hull Compartmentation
630	Preservatives and Coverings
640	Living Spaces
650	Service Spaces
660	Working Spaces
670	Stowage Spaces
690	Special Purpose Systems

This group does not include structural components, flight decks, tanks/voids/trunks, structural and watertight subdivision bulkheads, structural closures, sea chests, (SWBS Group 100); propulsion shafting, (SWBS Group 200); batteries, ships service power cable, lighting distribution and fixtures (SWBS Group 300); refrigeration systems boat handling, cargo handling, replenishment at sea system, mooring, towing and anchor handling, life saving equipment, lagging (SWBS Group 500); and weapons handling (SWBS Group 700).

Figure 4-19 provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on lightship weight of the group.

The SWBS Group 600 CER of labor vs. weight for amphibious ships is:

$$\text{KMHRS} = 0.626 \text{ LT} - 289$$

The R^2 value of 0.792 indicates a good correlation between labor and weight in SWBS Group 600. T and F are significant at 95 percent, indicating a statistically significant relationship. However, the CV for this relationship is 55.4 percent indicating the CER is a poor predictor.

The model would be a better predictor if the LHD 1 were considered an outlier. However, there were no technical reasons for deleting the LHD 1 data; especially given the good relationship shown in Figure 4-19a. It does indicate that accommodations are a better independent variable for SWBS Group 600 for these ships.

Figure 4-19a provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on total accommodations on the ship.

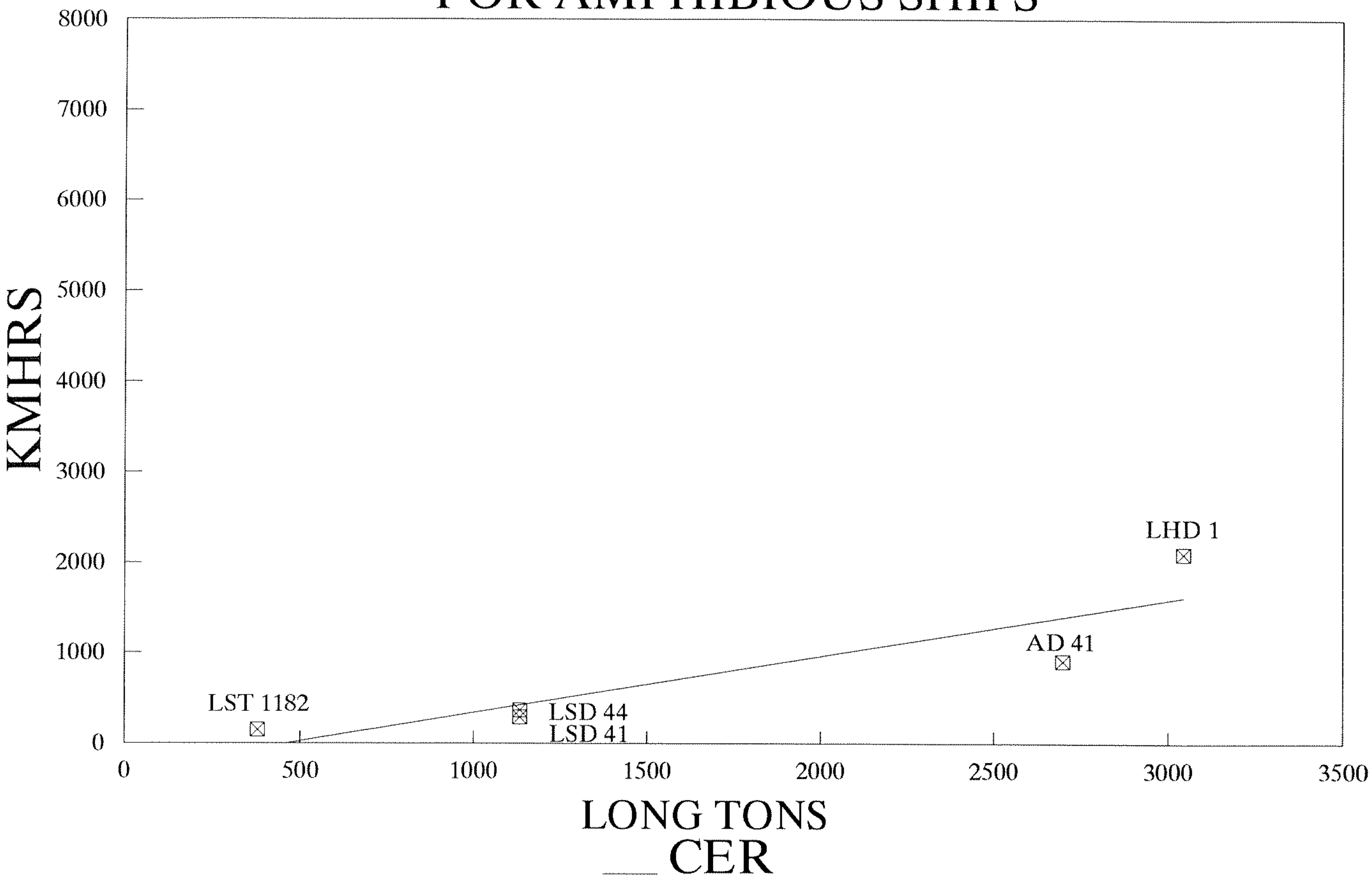
The SWBS Group 600 CER of labor vs. total accommodations for amphibious ships is:

$$\text{KMHRS} = 0.771 \text{ accommodations} - 347$$

The R^2 value of 0.998 indicates a high correlation between labor costs and total accommodations for surface combatants. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 5.8 percent, indicating that the CER is also an excellent predictor.

1381-68(4-EAM-4597) Figure 4-19 03-Jun-94

LABOR VS. WEIGHT IN GROUP 6
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.626 LT − 289; R^2 = 0.792; T and F are significant at 95%; CV = 55.4%

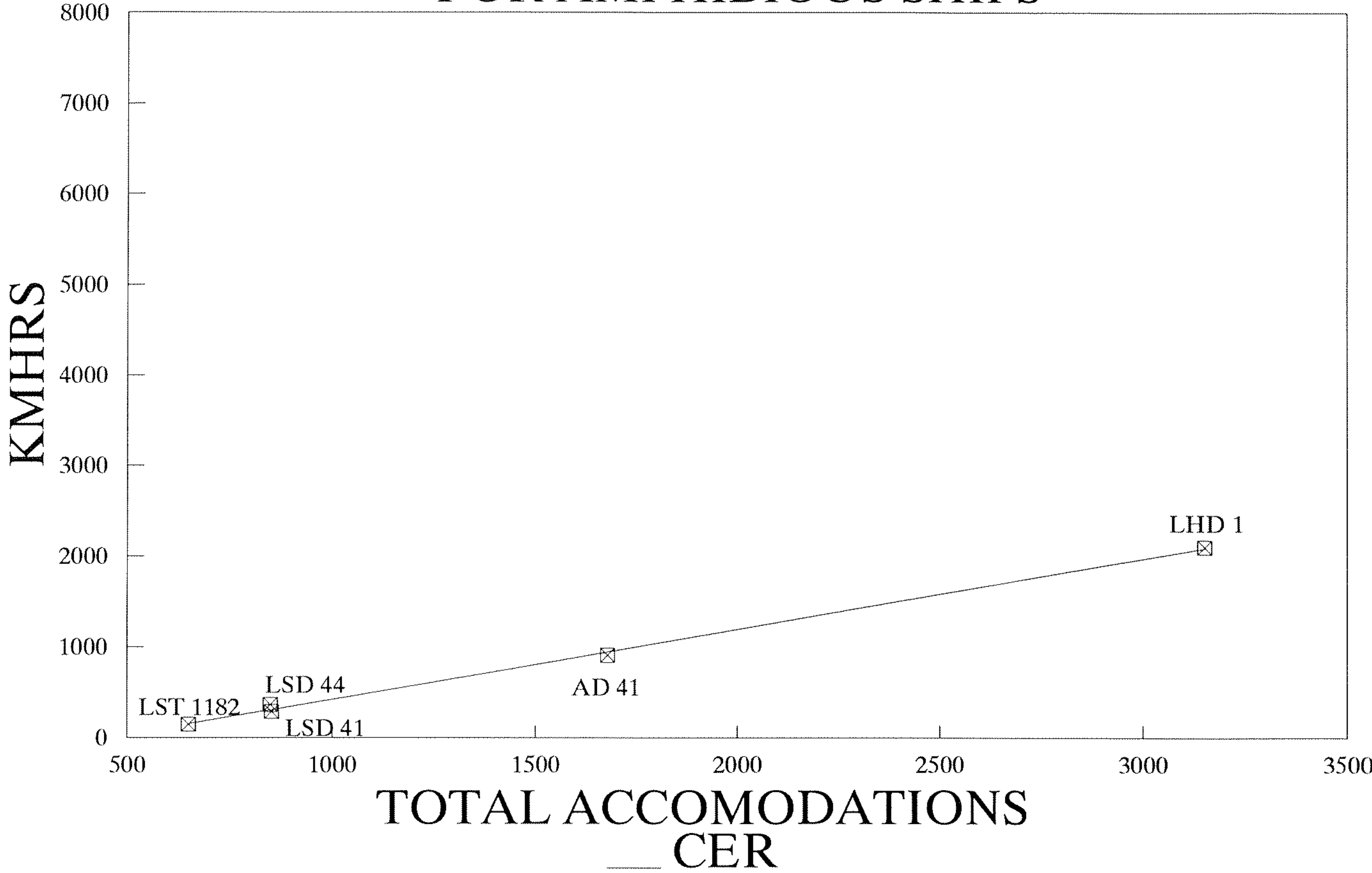
Regression Output:

Constant			−288.9
Std Err of Y Est			422
R Squared			0.792
No. of Observations			5
Degrees of Freedom			3
# Variables			1
X Coefficient(s)		0.626	
Std Err of Coef.		0.185	
T =	3.381	F =	11.43
CV % =		55.4	

DATA

SHIPS	LT 6	LAB 6
LST 1182	379	147
LSD 41	1,134	288
LSD 44	1,134	366
AD 41	2,698	909
LHD 1	3,043	2,097

LABOR VS. TOTAL ACCOMODATIONS IN GROUP 6 FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.771 ACCOM − 347; R^2 = 0.998; T and F significant at 95%; CV = 5.8%

Regression Output:

Constant		−346.5
Std Err of Y Est		44
R Squared		0.998
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	0.771	
Std Err of Coef.	0.021	

T = 36.439 F = 1327.82

CV % = 5.8

DATA

SHIPS	TOT ACC	LAB 6
LST 1182	650	147
LSD 44	849	366
LSD 41	852	288
AD 41	1,681	909
LHD 1	3,150	2,097

4.2.7 SWBS Group 700 - Armament

This group includes installation of the ship's armament and armament handling systems. Included are the following elements:

SWBS NUMBER	TITLE
710	Guns and Ammunition
720	Missile and Rockets
730	Mines
740	Depth Charges
750	Torpedoes
760	Small Arms and Pyrotechnics
770	Cargo Munitions
780	Aircraft Related Weapons
790	Special Purpose Systems

This group does not include foundations, hull penetrations, (SWBS Group 100); non-integral electrical systems, (SWBS Group 300); non-integral electronics systems (SWBS Group 400); non-integral auxiliary systems, (SWBS Group 500), and ship's outfit and furnishings (SWBS Group 600). Nor does it include the actual weapons systems, which are normally GFE.

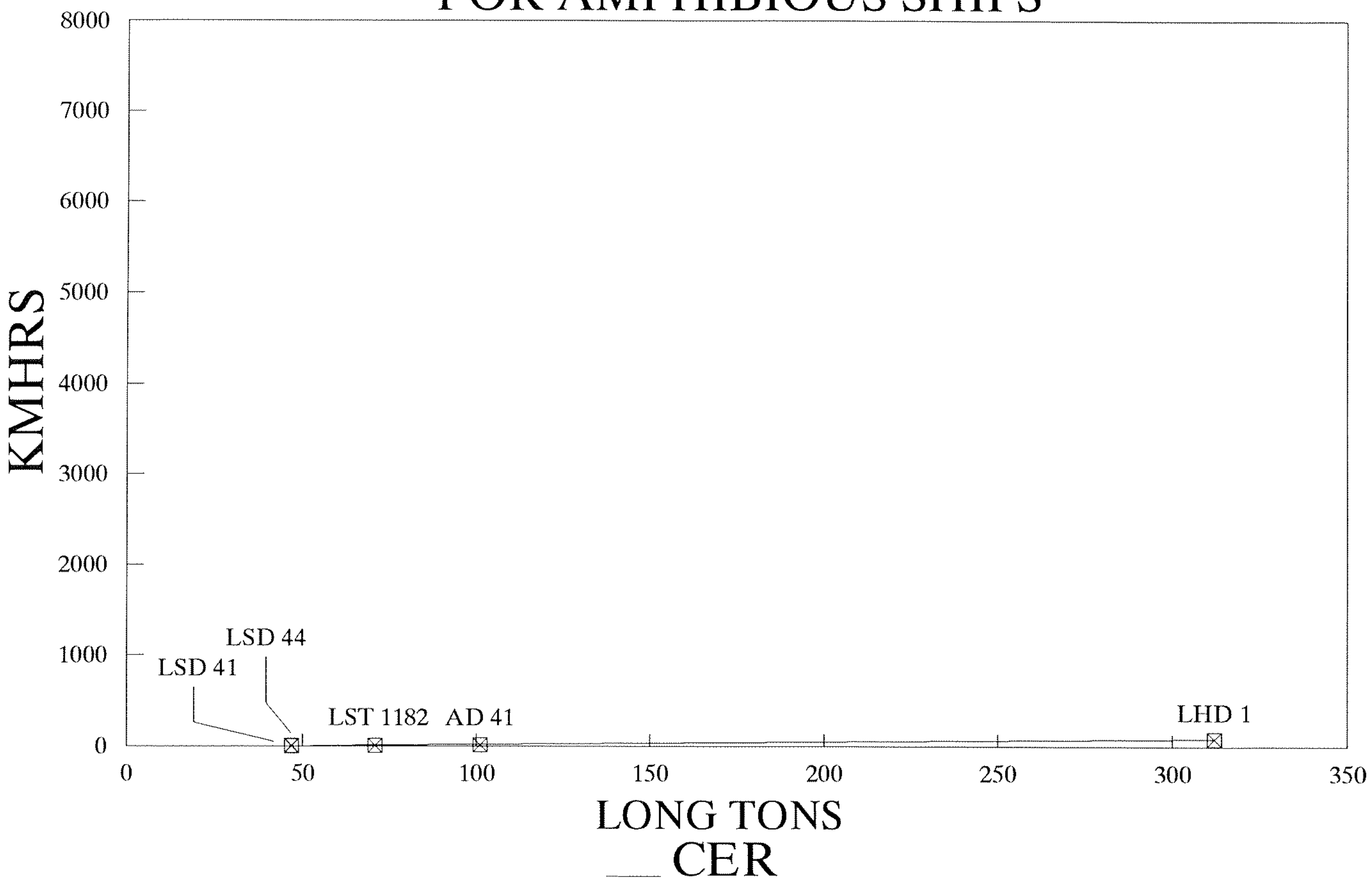
Figure 4-20 provides the CER, regression output, and supporting data for the SWBS Group 700 CER.

The SWBS Group 700 CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.305\ LT - 11.3$$

The R^2 value of 0.994 indicates a high correlation between labor and weight in SWBS group 700. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 12.4 percent, indicating that the CER is also an excellent predictor.

LABOR VS. WEIGHT IN GROUP 7
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.305 LT – 11.3; R^2 = 0.994; T and F are significant at 95%; CV = 12.4%

Regression Output:

Constant		–11.3
Std Err of Y Est		3
R Squared		0.994
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	0.305	
Std Err of Coef.	0.013	
T = 23.026	F =	530.21
CV % =	12.4	

DATA

SHIPS	LT 7	LAB 7
LST 1182	71	7
LSD 41	47	4
LSD 44	47	6
AD 41	101	18
LHD 1	312	84

4.2.8 SWBS Group 800 - Integration/ Engineering Shipbuilder Response)

This group includes installation of the cost of the labor of those program management and engineering services associated with the design, development, production, testing and delivery of the ships. Included are the following elements:

SWBS NUMBER	TITLE
800	Shipbuilder Drawings
810	Production Engineering
830	Design Support
840	Quality Assurance
850	Integrated Logistics Support Engineering
890	Special Purpose Items
891	Safety
892	Human Factors
893	Standardization
894	Value Engineering
895	Reliability
896	Maintainability
897	Data Management
898	Project Management

This group does not include shipyard standard drawings; or molds and templates which are included in SWBS Group 900.

Figure 4-21 provides the CER and supporting data for the SWBS Group 800 CER based on lightship weight of the group. Note that detail design costs are included in the SWBS Group 800 costs for amphibious ships.

The SWBS Group 800 CER of labor vs. weight for amphibious ships is:

$$\text{KMHRS} = 0.285 \text{ LT} - 1161$$

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No statistical data is available since there are not enough data points. The CER is the line that contains both the LSD 41 and LHD 1. The LST 1182 and the AD 41 are not included in the regression since they are estimates, and only lead ships in lead yards data are used in developing the SWBS Group 800 CER.

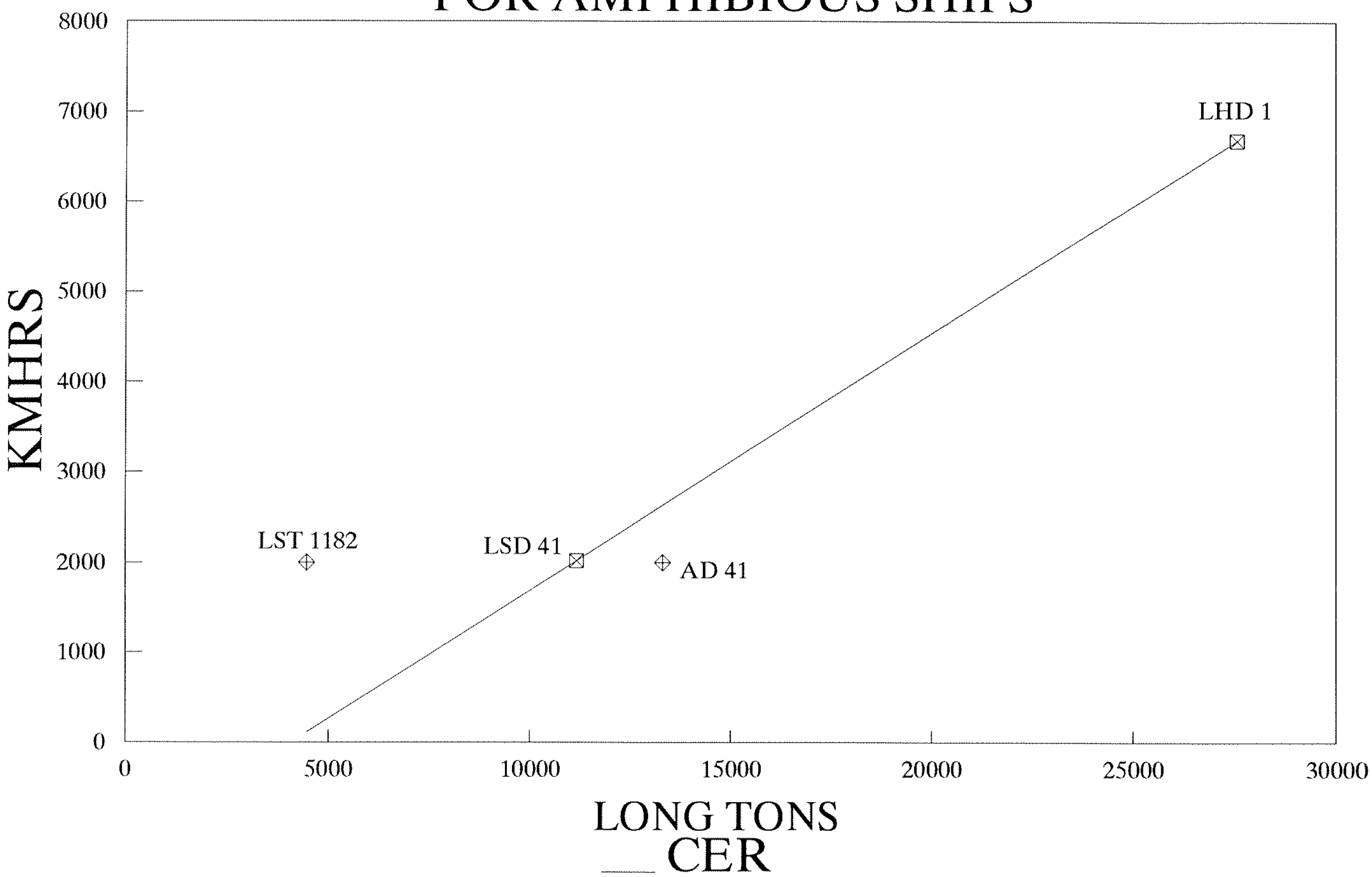
Figure 4-21a provides the CER and supporting data for the SWBS Group 800 CER based on total production manhours.

The CER for SWBS Group 800 costs vs production costs for amphibious ships is:

$$\text{Group 8 (KMHRS)} = 0.541 \text{ Group 1-7 \& 9 (KMHRS)} - 334$$

No statistical data is available for the same reasons noted above.

LABOR VS. WEIGHT IN GROUP 8
FOR AMPHIBIOUS SHIPS



CER: KMHRS= 0.285 LT − 1161; R^2 = 1.000; T and F are not applicable; CV = N/A

NOTE: LST 1182 and AD 41 are not inclucled in regression since they are estimates.

Regression Output:

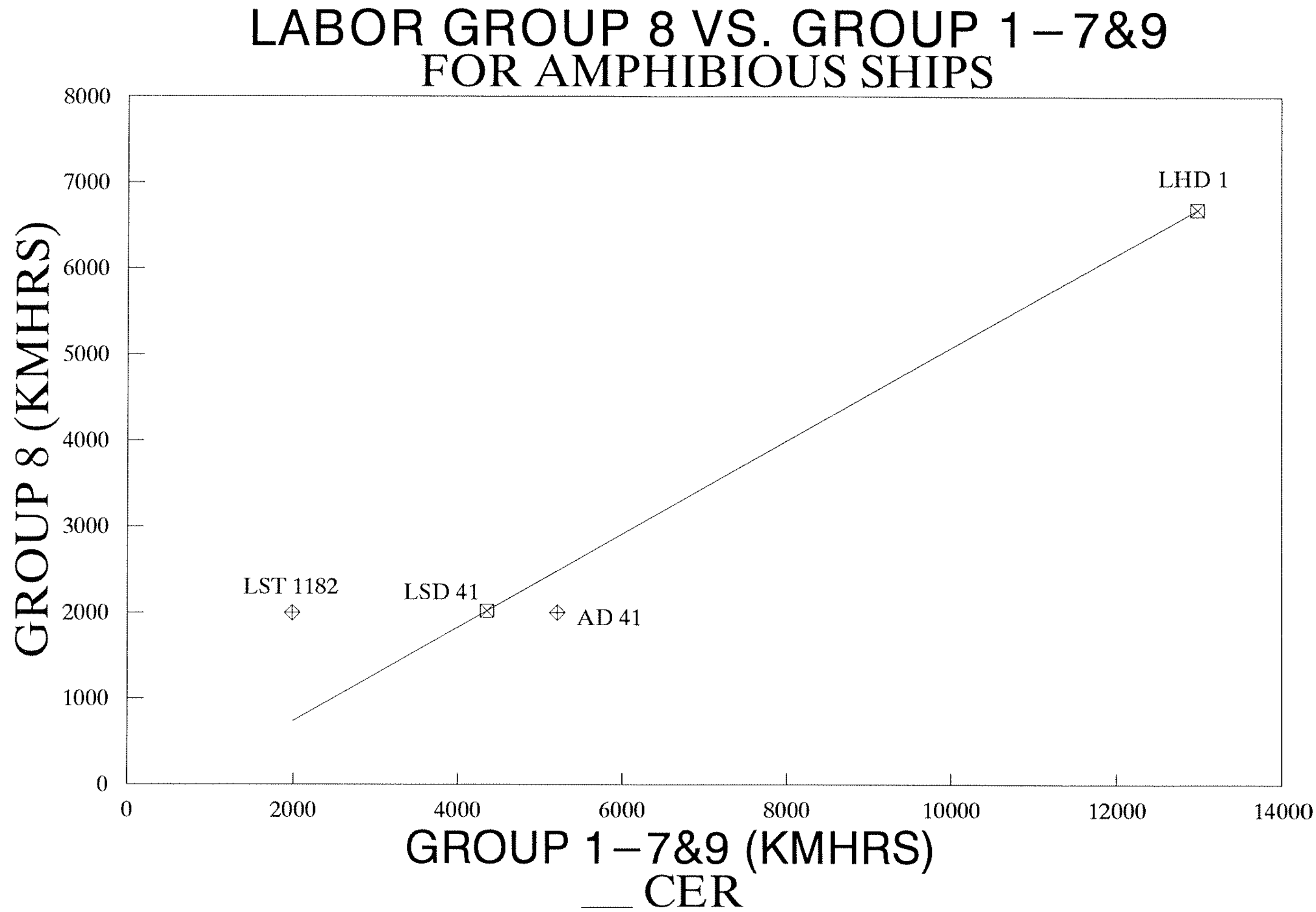
Constant		−1160.7
Std Err of Y Est		N/A
R Squared		1.000
No. of Observations		2
Degrees of Freedom		0
# Variables		1
X Coefficient(s)	0.285	
Std Err of Coef.	N/A	

T = N/A F = N/A

CV % = N/A

DATA

SHIPS	LT 1−7	LAB 8
LST 1182	4,468	2,000
LSD 41	11,165	2,020
AD 41	13,312	2,000
LHD 1	27,554	6,688



CER: (GRP 8) = 0.541 (GRP 1–7&9) – 334; R^2 = 1.000; T and F not applicable; CV = N/A

NOTE: LST 1182 and AD 41 are not included in regression since they are estimates.

Regression Output:

Constant		–333.6
Std Err of Y Est		N/A
R Squared		1.000
No. of Observations		2
Degrees of Freedom		0
# Variables		1
X Coefficient(s)	0.541	
Std Err of Coef.	N/A	
T = N/A	F =	N/A
CV % =	N/A	

DATA

SHIPS	LAB 1–7,9	LAB 8
LST 1182	1,979	2,000
LSD 41	4,348	2,020
AD 41	5,202	2,000
LHD 1	12,973	6,688

4.2.9 SWBS Group 900 - Ship Assembly and Support Services

This group includes the cost of contractual, production, and construction support services. Included are the following elements:

SWBS NUMBER	TITLE
980	Contractual and Production Support Services
981	Insurance
982	Trials
983	Delivery
984	Open and Inspect (Conversions Only)
985	Fire and Flooding Protection
986	Test and Inspection
987	Weighting and Recording
988	Contract Data Requirements (Administrative)
989	Fitting Out
990	Construction Support
991	Staging, Scaffolding and Cabling
992	Temporary Utilities and Services
993	Material Handling and Removal
994	Cleaning Services
995	Molds and Templates, Jigs, Fixtures and Special Tools
996	Launching
997	Drydocking

SWBS Group 900 is used for the identification of assemblies and monitoring the ship construction by erection section or similar construction grouping. Actual costs accumulated against these elements are translated to the appropriate elements covering the system involved. The costs accumulated under SWBS Group 900 are for the cost of contractual, production, and construction support services.

Figure 4-22 provides the CER, regression output, and supporting data for the SWBS Group 900 CER based on lightship weight of the ship.

The SWBS Group 900 CER of labor vs. weight for amphibious ships is:

KMHRS = 0.157 LT - 689

The R^2 value of 0.981 indicates a high correlation between shipyard production support and lightship weight for Amphibious Ships. T and F are significant at 90 percent, indicating a relationship of questionable significance. The CV for this relationship is 15.1 percent, indicating that the CER is also an excellent predictor. Note that the AD 41 and LST 1182 are not included in the regression since they are estimates.

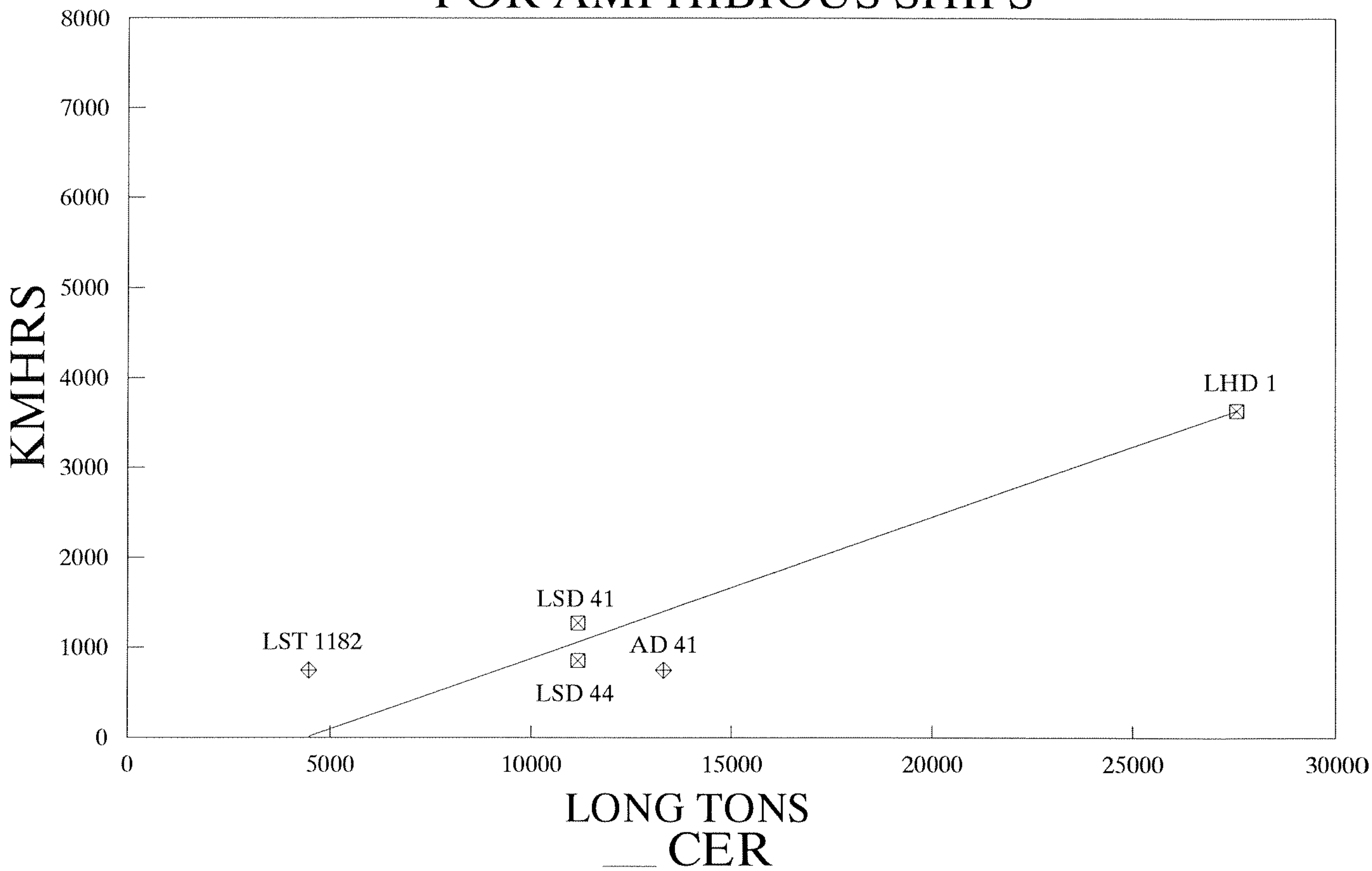
Figure 4-22a provides the CER, regression output, and supporting data for the SWBS Group 900 CER based on months in the shipyard.

The SWBS Group 900 CER of labor vs. months in shipyard for amphibious ships is:

KMHRS = 154.4 MONTHS - 5397

The R^2 value of 0.969 indicates a high correlation between shipyard production support and the number of months the ships were in the shipyards. T and F are significant at 90 percent, indicating a relationship of questionable significance. The CV for this relationship is 19.7 percent, indicating that the model is also an excellent predictor. Note that the AD 41 and LST 1182 are not included in the regression, since they are estimates.

LABOR VS. WEIGHT IN GROUP 9 FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.157 LT − 689; R^2 = 0.981; T and F are significant at 90%; CV = 15.1%

NOTE: AD 41 and LST 1182 are estimates and are not included in the regression.

Regression Output:

Constant		−689.1
Std Err of Y Est		291
R Squared		0.981
No. of Observations		3
Degrees of Freedom		1
# Variables		1
X Coefficient(s)	0.157	
Std Err of Coef.	0.022	

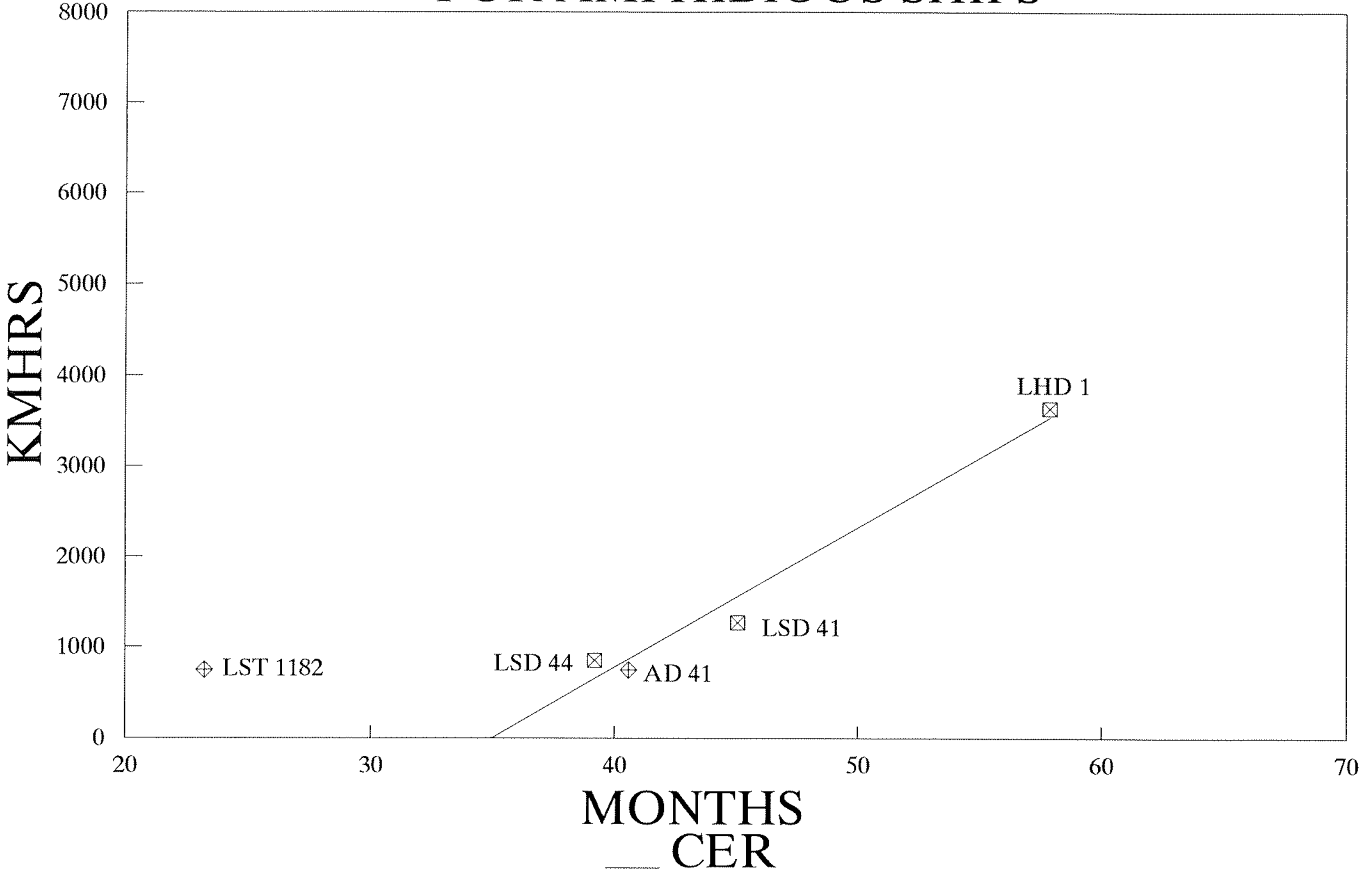
T = 7.224 F = 52.18

CV % = 15.1

DATA

SHIPS	LT 1-7	LAB 9
LST 1182	4,468	750
LSD 41	11,165	1,268
LSD 44	11,165	857
AD 41	13,312	750
LHD 1	27,554	3,634

LABOR VS. MONTHS IN SHIPYARD IN GROUP 9 FOR AMPHIBIOUS SHIPS



CER: KMHRS = 154.4 MON – 5397; R^2 = 0.969; T and F are significant at 90%; CV = 19.7%

NOTE: LST 1182 and AD 41 are not included in regression since they are estimates.

Regression Output:

Constant		–5396.6
Std Err of Y Est		371
R Squared		0.969
No. of Observations		3
Degrees of Freedom		1
# Variables		1
X Coefficient(s)	154.355	
Std Err of Coef.	27.474	
T = 5.618	F =	31.57
CV % =	19.7	

DATA

SHIPS	MONTHS	LAB 9
LST 1182	23	750
LSD 44	39	857
AD 41	41	750
LSD 41	45	1,268
LHD 1	58	3,634

4.2.10 Summary Labor CERs

Figures 4-23, 4-24 and 4-25 are summary labor CER's for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total contract costs (SWBS Groups 100-900). These three groupings reflect different categorizations typically used in previous models or found in CER's.

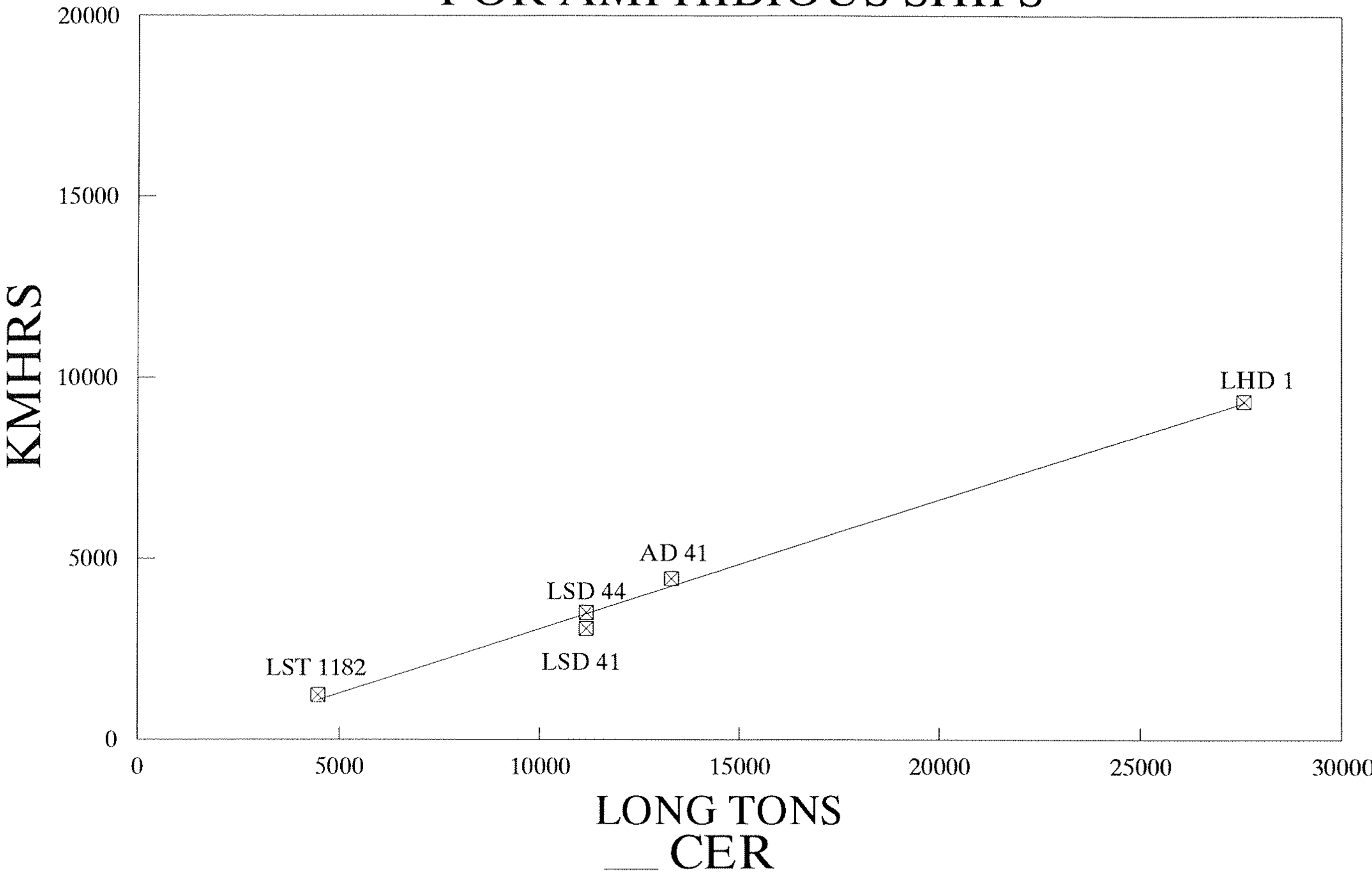
Construction costs have been used in previous models to define the actual ship construction activities, exclusive of design and integration, and shipyard services. The CER for construction labor costs, presented in Figure 4-23, was developed by summing the individual one-digit SWBS Groups 100 to 700 costs and is based on total lightship weight. Construction labor costs have exhibited a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship construction costs in a follow yard are similar to those in a lead yard. The relatively good correlation between one-digit SWBS Groups 100 to 700 values to the aggregate SWBS Groups 100 through 700 values has also allowed for allocation of the aggregate SWBS Groups 100 through 700 manhours to individual one-digit SWBS Groups 100 to 700. As noted in Chapter 3, most of the CPR's provided cost breakdowns that allowed for the construction costs to be differentiated from SWBS Groups 800 and 900 costs.

The SWBS Group 100-700 summary CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.356\ LT - 491.2$$

The R^2 value of 0.994 indicates a high correlation between construction labor costs and lightship weight for amphibious ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 6.3 percent, indicating that the CER is also an excellent predictor.

LABOR VS. WEIGHT IN GROUPS 1–7
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.356 LT – 491.2; R^2 = 0.994; T and F are significant at 95%; CV = 6.3%

Regression Output:

Constant			–491.2
Std Err of Y Est			273
R Squared			0.994
No. of Observations			5
Degrees of Freedom			3
# Variables			1
X Coefficient(s)		0.356	
Std Err of Coef.		0.016	
T =	22.210	F =	493.27
	CV % =	6.3	

DATA

SHIPS	LT 1–7	LAB 1–7
LST 1182	4,468	1,229
LSD 41	11,165	3,080
LSD 44	11,165	3,519
AD 41	13,312	4,452
LHD 1	27,554	9,338

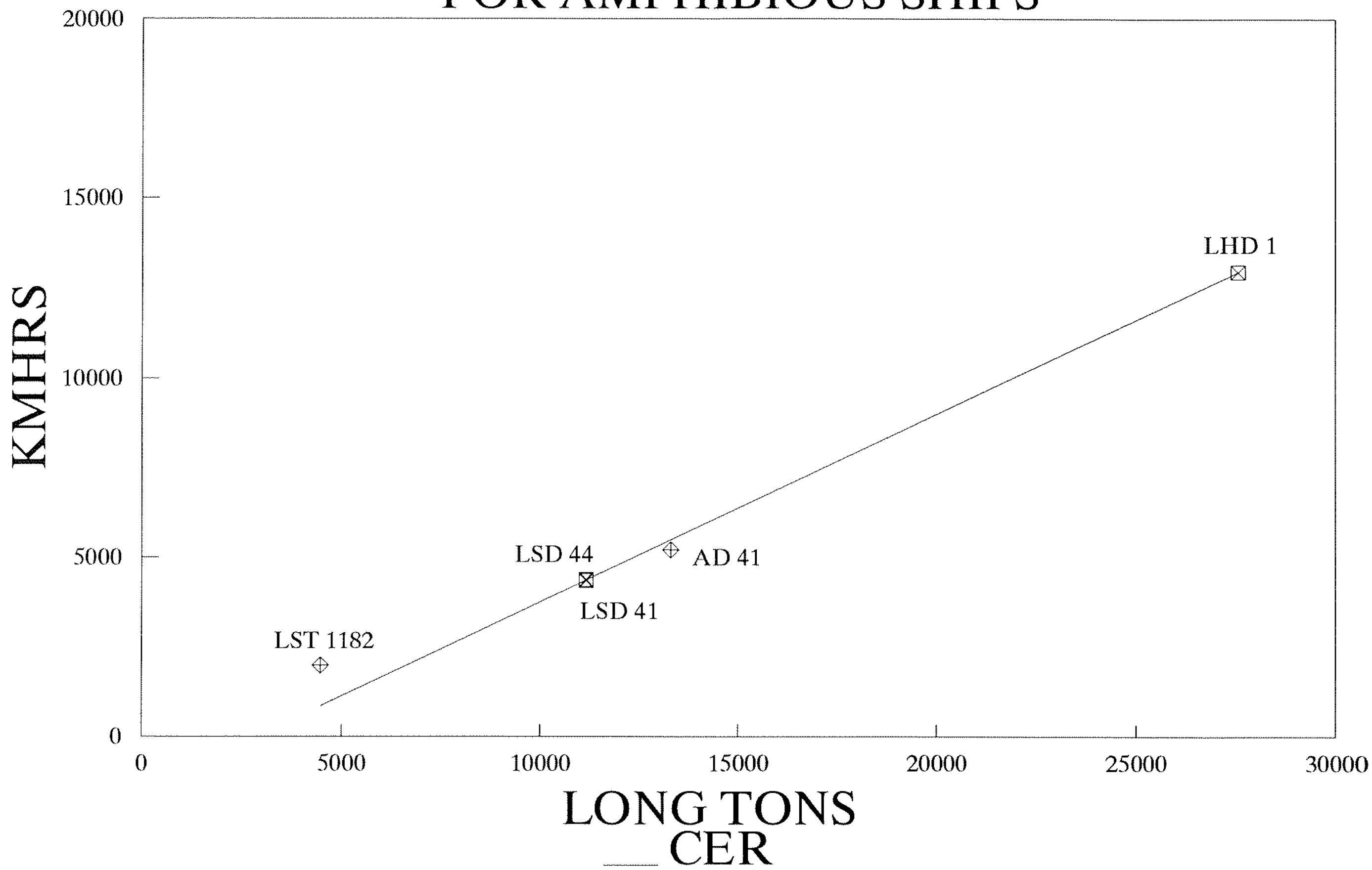
Production costs are reported by shipyards in CPR's and roughly correlate to SWBS Groups (100-700, 900). The CER for production costs based on total ship lightship weight is shown in Figure 4-24. It indicates a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship production costs in a follow yard are similar to those in a lead yard.

The SWBS Group 100-700 and 900 summary CER of labor vs. weight for amphibious ships is:

$$\text{KMHRS} = 0.525\ \text{LT} - 1504$$

The R^2 value of 1.000 indicates a perfect correlation between production labor costs and lightship weight for amphibious ships. T and F are significant at 95 percent, indicating an excellent relationship. The CV for this relationship is 0.3 percent, indicating that the model is also an excellent predictor. Note that the LST 1182 and AD 41 are not used to develop the CER since they are based on estimated SWBS Group 900 costs.

LABOR VS. WEIGHT IN GROUPS 1−7,9
FOR AMPHIBIOUS SHIPS



CER: KMHRS = 0.525 LT − 1504; R^2 = 1.000; T and F are significant at 95%; CV = 0.3%

NOTE: LST 1182 and AD 41 are not included in regression since they are estimates.

Regression Output:

Constant		−1504.2
Std Err of Y Est		20
R Squared		1.000
No. of Observations		3
Degrees of Freedom		1
# Variables		1
X Coefficient(s)	0.525	
Std Err of Coef.	0.001	
T = 350.989	F =	123193.38
CV % =	0.3	

DATA

SHIPS	LT 1−7	LAB 1−7,9
LST 1182	4,468	1,979
LSD 41	11,165	4,348
LSD 44	11,165	4,376
AD 41	13,312	5,202
LHD 1	27,554	12,973

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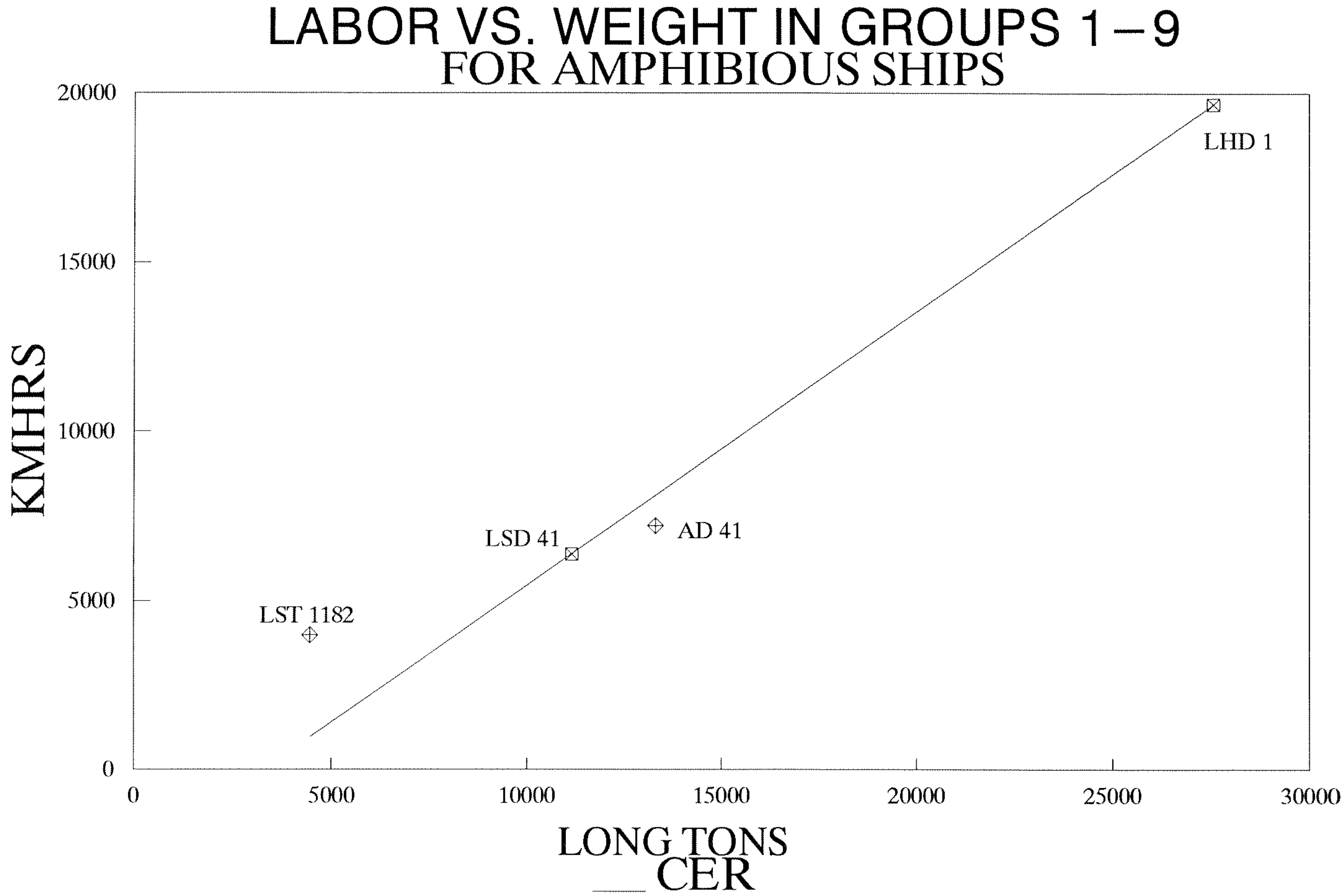
Total contract labor costs for the lead ship in a lead yard include all recurring and non-recurring costs, including all detail design and production engineering. The detail design costs are included in the SWBS Group 800 costs for amphibious ships. Because of this addition of the SWBS Group 800 costs, only lead ship in a lead yard data is applicable. In developing the CER for SWBS Groups 100-900 based on total ship lightship weight and shown in Figure 4-25, the SWBS Group 800 labor cost CER was superimposed upon the production labor cost CER. In this way, the larger data base of lead ships at lead and follow yards for the production cost CER could be taken advantage of, while the more limited data set of lead ships in lead yards used to derive the CER for SWBS Group 800 could be used.

The SWBS Group 100-900 summary CER of labor vs. weight for amphibious ships is:

$$KMHRS = 0.810\ LT - 2664.9$$

No statistical information is available for this CER since it was developed by adding the SWBS Group 800 CER (Figure 4-21) and the SWBS Group 100-700 and 900 CER (Figure 4-24). This was done to take advantage of the larger data base of lead ships at both lead and follow yards for the production cost CER, since the SWBS Group 800 CER is limited to lead ships in lead yards only. The data points are shown for comparison purposes. Note that the LST 1182 and AD 41 are not included in the CER since they are based on estimated SWBS Group 800 and 900 costs.



Group 8	KMHRS =	0.285	LT +	−1160.7
+ Group 1−7&9	KMHRS =	0.525	LT +	−1504.2
Group 1−9	KMHRS =	0.810	LT +	−2664.9

4.2.11 Material Costs

Material costs include all the materials and equipment purchased by the shipyard under the construction contract. It does not include the material and equipment provided by the government as government furnished equipment (GFE). Material costs are reported in the CPR's in dollars often reported as a single dollar figure. The method of reporting material dollars in a CPR is dependent upon the contract type and the accounting system of the shipyard. As discussed in Chapter 3, the material costs are reported in either base year or report year dollars, depending upon whether the contract is a fixed price or cost reimbursed type contract. In addition, the shipyards can take G&A and fee on material costs if their accounting procedures permit it.

In order to limit uncertainty in material costs, only lead ship in a lead yard, unburdened material costs, escalated to FY 93 dollars were used to develop the CER shown in Figure 4-26. Follow ship material costs often contain a different mix of GFE or material cost factors than lead ships, due to class buys, non-recurring costs, or other changes. Because of this, their costs are not used in the CER. The material cost CER is based on total ship lightship weight. Given the lack of detail in the CPR's, only total material dollars are used in the CER.

Reference (5) was used to escalate the material dollars to FY 93 dollars and should be used to escalate estimates obtained from this model to future year dollars. The escalation of dollars is a source of uncertainty in the model and may cause older material costs to be more suspect compared to similar, more recent ships. Technology changes and fluctuating market values also contribute to the uncertainty of material cost data, even among similar ships.

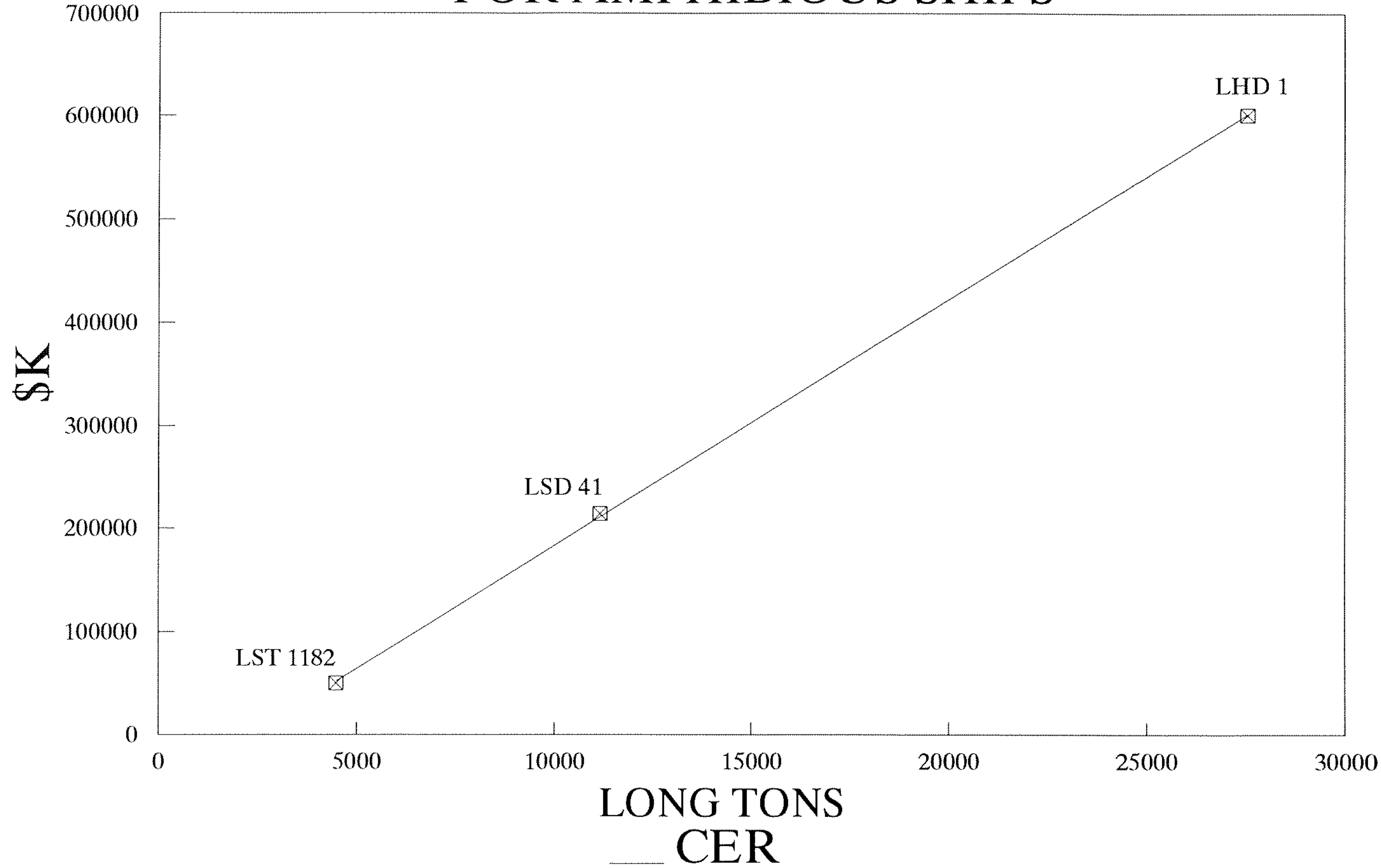
The material cost CER for amphibious ships (shown in Figure 4-26) is:

$$\$K = 23.84\ LT - 54{,}557$$

The R^2 value of 1.000 indicates a perfect correlation between material costs and lightship weight of amphibious ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 1.2 percent, indicating that the model is also an excellent predictor. Note that only three data points were used in developing this CER.

Material costs for an individual ship are dependent upon the specific configuration of the ship, the actual mix of shipyard responsible items and GFE, as well as the current market value of the shipyard responsible items. This covers a wide range of items, including structural material (e.g., steel, aluminum, composites), equipment (e.g., propulsion systems, electric plant, electronics) as well as distributive systems (e.g., power cable, ducting, piping). Given this, and the limited data available, the material cost CER provides only a rough estimate for lead ship material costs. This estimate should be compared with the actual material cost estimate prepared for the ship by NAVSEA. The completeness of the NAVSEA estimate and the current vendor costs for major elements of the material costs should be independently checked. If reasonable, consideration should be given to using the NAVSEA estimate in lieu of the CER estimate for the material costs.

MATERIAL COST VS. LIGHTSHIP WEIGHT
FOR AMPHIBIOUS SHIPS



CER: $K = 23.84 LT - 54,557; R^2 = 1.000; T and F are significant at 95%; CV = 1.2%

Regression Output:

Constant			-54557
Std Err of Y Est			3,576
R Squared			1.000
No. of Observations			3
Degrees of Freedom			1
# Variables			1
X Coefficient(s)		23.838	
Std Err of Coef.		0.213	
T =	111.964	F =	12535.92
CV % =		1.2	

DATA

SHIPS	LT 1-7	FY93($K)
LST 1182	4,468	49,936
LSD 41	11,165	214,431
LHD 1	27,554	601,449

4.2.12 Summary of CER's for Amphibious Ships

Table 4-5 shows each CER for Amphibious Ships with its associated statistics listed by cost group.

TABLE 4-5

AMPHIBIOUS SHIP CER's

COST GROUP	RELATIONSHIP	STATISTICS
100	Group 1 (KMHRS) = 0.16 (WT) + 102	R^2=.99; T,F at 95%; CV=5.9%
200	Group 2 (KMHRS) = 0.04 (WT) + 149	R^2=.05; T,F at <90%; CV=48%
200	Group 2 (KMHRS) = 0.001 (WT) + 206	R^2=.03; T,F at <90%; CV=49%
300	Group 3 (KMHRS) = 1.93 (WT) - 406	R^2=.96; T,F at 95%; CV=29%
400	Group 4 (KMHRS) = 0.45 (WT) + 49.5	R^2=.89; T,F at 95%; CV=25%
500	Group 5 (KMHRS) = 0.45 (WT) + 237	R^2=.87; T,F at 95%; CV=23%
600	Group 6 (KMHRS) = 0.63 (WT) - 289	R^2=.79; T,F at 95%; CV=55%
600	Group 6 (KMHRS) = 0.77 (ACC) - 347	R^2=1.0; T,F at 95%; CV=5.8%
700	Group 7 (KMHRS) = 0.31 (WT) - 11.3	R^2=.99; T,F at 95%; CV=12%
800	Group 8 (KMHRS) = 0.29 (WT) - 1161	N/A
800	Group 8 (KMHRS) = 0.54 (1-7 &9) - 334	N/A
900	Group 9 (KMHRS) = 0.16 (WT) - 689	R^2=.98; T,F at 90%; CV=15%
900	Group 9 (KMHRS) = 154 (MON) - 5397	R^2=.97; T,F at 90%; CV=20%
SUMMARY CER's:		
100-700	Group 1-7 (KMHRS) = 0.36 (WT) - 491	R^2=.99; T,F at 95%; CV=6.3%
100-700 & 900	Group 1-7 & 9 (KMHRS) = 0.53 (WT) - 1504	R^2=1.0; T,F at 95%; CV=0.3%
100-900	Group 1-9 (KMHRS) = 0.81 (WT) - 2665	
Material Cost	Mat ($K) = 23.8 (WT) - 55,557	R^2=1.0; T,F at 95%; CV=1.2%

4.2.13 Comparison of Actual Versus Estimated Costs

As noted earlier, the limited number of data points and the characteristics of the data spread affect the statistical analysis of the CER's. As a check on the ability of the model to predict actual return costs, a comparison was made between the return costs for the ships in the database and the estimated costs for the ships using the CER's. This comparison uses the ships that comprise the database; however, no other data was available to check the model, and this was considered satisfactory since the database comprises most of the recent ship classes built. This comparison was performed at the construction, production and total cost levels for labor costs, and at the total cost level for material costs. The labor costs were developed by summing the estimated one-digit labor manhours. The comparison is made at the summary levels, since the model is designed to be used at the total ship level. The comparisons are provided for all five amphibious ships at the construction labor costs summary level; the LSD 41, LSD 44 and LHD 1 at the production labor cost summary level; the LSD 41 and LHD 1 at the total labor cost summary level; and the LSD 41, and LHD 1 at the material cost summary level. Both the AD 41 and LST 1102 contain estimated costs for Groups 800 and 900, using constants contained in the previous model. Thus, they were not evaluated at the production or total labor cost levels, which contain these SWBS Groups. In addition, at the total labor cost level, only lead ships in lead yards were evaluated. Similarly, only lead ship in a lead yard data is evaluated in the material cost comparison. Table 4-6 provides the results of the comparison.

The model predicts very well the construction labor costs for all five ships. It also predicts very well the production and total labor costs, as well as the material costs, for the ships where there is data. However, this good correlation is partially due to the limited number of return cost data points that were used to develop the CER's in this comparison.

Given the good correlation for all ships at the construction labor cost level, and the corresponding good correlation for the more limited data sets for the other cost summary levels, combined with the fact that the data used contains return costs for the ships, it is considered that the model satisfactorily predicts the amphibious ship costs.

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TABLE 4-6

COMPARISON OF ACTUAL VS. ESTIMATED COSTS FOR AMPHIBIOUS SHIPS

		Lead Ship/Lead Yard					
	SWBS	LSD 41			LHD 1		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	3,080	3,391	10	9,338	9,008	(4)
Production Manhours	100 - 700, 900	4,348	4,454	2	12,973	12,642	(3)
Total Manhours	100 - 900	6,368	6,473	2	19,661	19,330	(2)
Total FY 93 Material Cost $K	100 - 900	214.4	211.6	(1)	601.4	602.3	0

		Lead and Follow Ship/Follow Yard								
	SWBS	LSD 44			LST 1182*			AD 41*		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	3,519	3,391	(4)	1,229	1,181	(4)	4,452	4,647	4
Production Manhours	100 - 700, 900	4,376	4,454	2	N/A	N/A	N/A	N/A	N/A	N/A
Total Manhours	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total FY 93 Material Cost	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

4.3 Auxiliary Type Ships

The CER's for the auxiliary type ships are developed using the ships shown in Table 4-7.

TABLE 4-7

AUXILIARY SHIPS

Ship	Class	Shipyard	Cost Data Type	Year Delivered
TAGOS 19	TAGOS 19 Class Ocean Surveillance Ship (SWATH)	McDermott MC	Lead Ship/Lead Yard	1991
AO 180 [1]	AO 177 Class Fleet Oiler	NASSCO	Follow Ship/Follow Yard	1982
AFS 6 [1]	AFS 1 Class Fast Combat Store Ship	NASSCO	Follow Ship/Lead Yard	1969
AOR 7	AOR 1 Class Replenishment Oiler	NASSCO	Lead Ship/Follow Yard	1976
TAO 187	T-AO 187 Class Oiler	Avondale	Lead Ship/Lead Yard	1986
TAO 191 [2]	T-AO 187 Class Oiler	Penn/Tampa	Lead Ship/Follow Yard	1992
AOE 6	AOE 6 Class Fast Combat Support	NASSCO	Lead Ship/Lead Yard	1993
TAGS 45	TAGS 45 Class Surveying Ship	Avondale	Lead Ship/Lead Yard	1993

NOTE:
1 This ship is priced out as Lead Ship by NASSCO as per Reference (2).
2 TAO 191 was not used in developing CERs since it represents a partial data po (Tampa portion only)

The auxiliary ships CER's were developed from the data presented in Section 3.3. Lightship weight is used as the principal independent variable, although CER's are developed using shaft horsepower in SWBS Group 200, total accommodations in SWBS Group 600, production manhours in SWBS Group 800, and months in the shipyard in SWBS Group 900.

CER's for labor manhours are provided by one-digit SWBS cost groups and summary CER's for labor manhours are provided for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total costs (SWBS Groups 100-900). A CER for FY 93 material dollars is presented at the total cost level.

It should be noted that this data set contains two ships, AO 180 and AFS 6, that are follow ships whose return costs were modified in the previous model (Reference 2) by NASSCO cost estimators to reflect lead ship costs. Their costs are used as data in developing CER's for SWBS Groups 100-700 and material costs where the data is considered appropriate. For SWBS Groups 800 and 900 the model does not provide raw data and only uses a constant. This constant was not used in developing the CER's.

The data for AOE 6 was used in developing the labor CER's, even though SWBS Groups 500 and 600 costs are high. This is because the AOE 6 is a recent program and considered essential for the model.

4.3.1 SWBS Group 100 - Hull Structure

This group includes erection of all the ship's structural components. Included are the following elements:

SWBS NUMBER	TITLE
110	Shell and Supporting Structure
120	Hull Structural Bulkheads
130	Hull Decks
140	Hull Platforms and Flats
150	Deckhouse Structure
160	Special Structures
170	Masts, Kingposts and Service Platforms
180	Foundations
190	Special Purpose Systems

This group does not encompass non-structural items such as ship fittings, rails, stanchions, life lines, hull compartmentation, non-structural bulkheads, deck covering, and other outfit and furnishings, which are contained in SWBS Group 600.

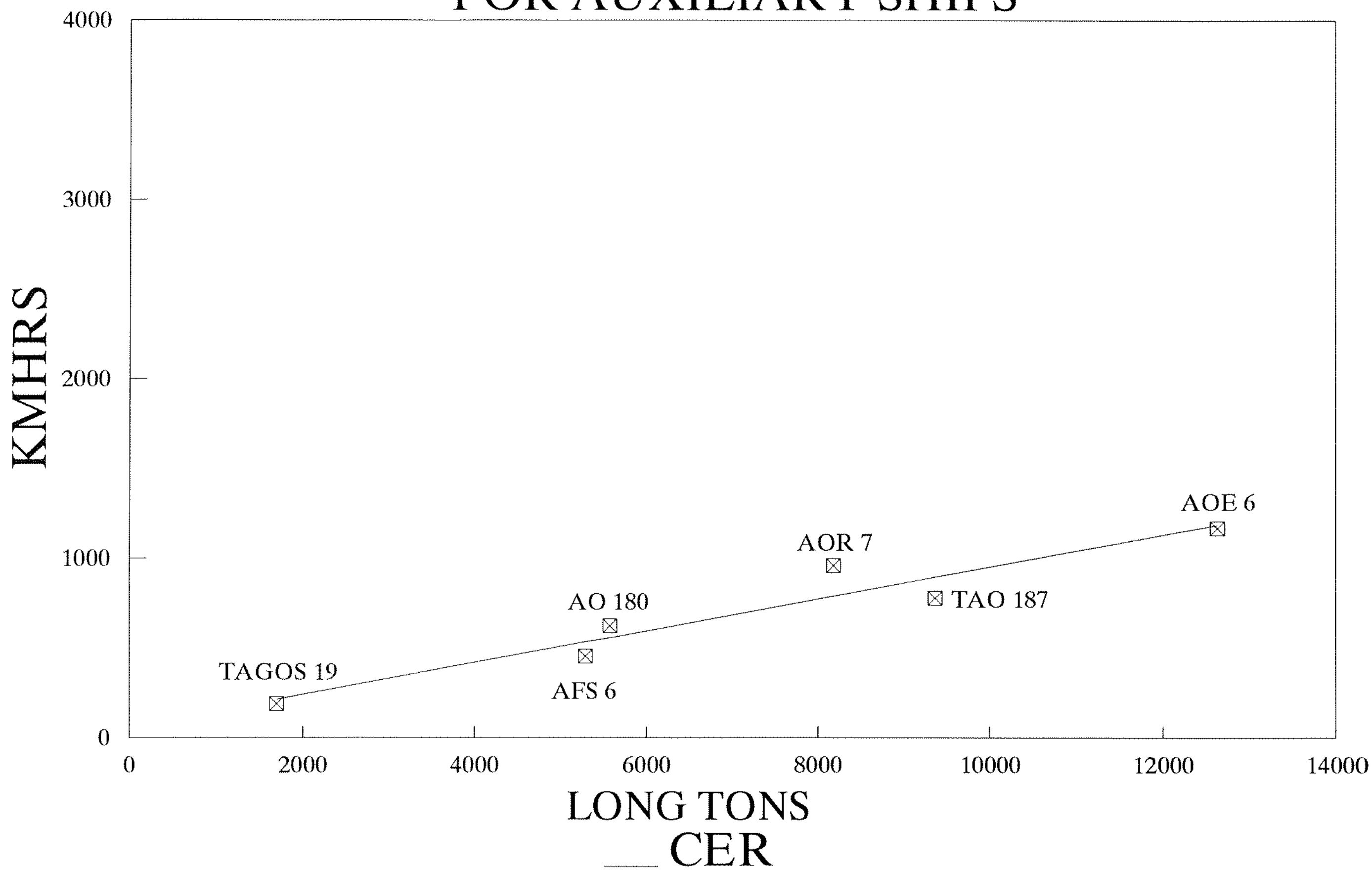
Figure 4-27 provides the CER regression output and supporting data for the SWBS Group 100 CER based on lightship weight for the group. The data appears to provide a good fit with the CER.

The SWBS Group 100 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.089\ LT + 67.6$$

The R^2 value for 0.913 indicates a high correlation between labor and weight in SWBS Group 100 for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 16.6 percent, indicating that the CER is also an excellent predictor.

LABOR VS. WEIGHT IN GROUP 1
FOR AUXILIARY SHIPS



CER: KMHRS = 0.089 LT + 67.6; R^2 = 0.913; T and F are significant at 95%; CV = 16.6%

NOTE: TAGS 45 weight data was not available for this group.

Regression Output:

Constant		67.6
Std Err of Y Est		116
R Squared		0.913
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	0.089	
Std Err of Coef.	0.014	
T = 6.460	F =	41.74
CV % =	16.6	

DATA

SHIPS	LT 1	LAB 1
TAGOS 19	1,692	194
AFS 6	5,287	458
AO 180	5,572	628
AOR 7	8,183	964
TAO 187	9,365	781
AOE 6	12,630	1,172

4.3.2 SWBS Group 200 - Propulsion Plant

This group includes installation of the ships propulsion plant and drive train systems. Included are the following elements:

SWBS NUMBER	TITLE
220	Energy Generating System (Non-Nuclear)
230	Propulsion Units
240	Transmission and Propulsor Systems
250	Propulsion Support System (except fuel and lube oil)

This group does not include foundations (SWBS Group 100); electric plant systems (SWBS Group 300); propulsion electronics and monitoring systems (SWBS Group 400); and auxiliary systems, including bow thrusters, (SWBS Group 500).

Figure 4-28 provides the CER, regression output, and supporting data for the SWBS Group 200 CER based on lightship weight of the group.

The SWBS Group 200 CER labor vs. weight for auxiliary ships is:

$$KMHRS = 0.111\ LT + 26.6$$

The R^2 value of 0.563 indicates a low correlation between labor and weight in SWBS Group 200 for auxiliary ships. T and F are significant at 90 percent, indicating a relationship of questionable significance. The CV for this relationship is 37.9 percent, indicating that the CER is a good predictor. Consideration can be given by NCA to presenting this CER as a constant for statistical purposes.

Figure 4-28a provides the CER, regression output and supporting data for the SWBS Group 200 CER based on the ships shaft horsepower.

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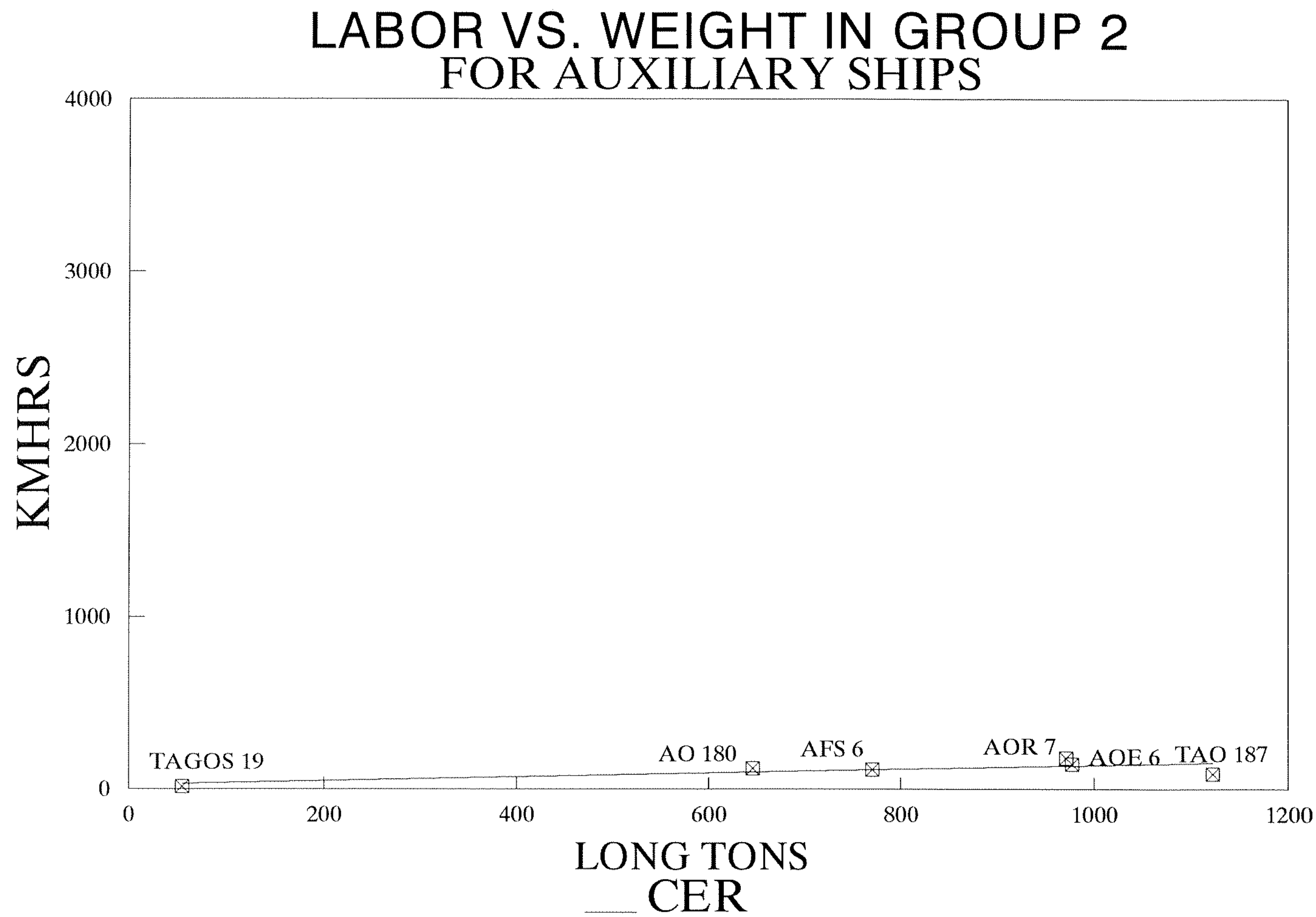
The SWBS Group 200 CER of labor vs. shaft horsepower for auxiliary ships is:

$$KMHRS = 0.001\ SHP + 62.7$$

The R^2 value of 0.377 indicates a very low correlation between labor and shaft horsepower for auxiliary ships. T and F are not significant at 90 percent, indicating the relationship is not statistically significant. The CV for this relationship is 53.4 percent, indicating that the model is a poor predictor. However, the data appear to fit the CER very well. Consideration should be given to presenting this CER as a constant for statistical purposes.



CER: KMHRS = 0.111 LT + 26.6; R^2 = 0.563; T and F are significant at 90%; CV = 37.9%

NOTE: TAGS 45 weight data was not available for this group.

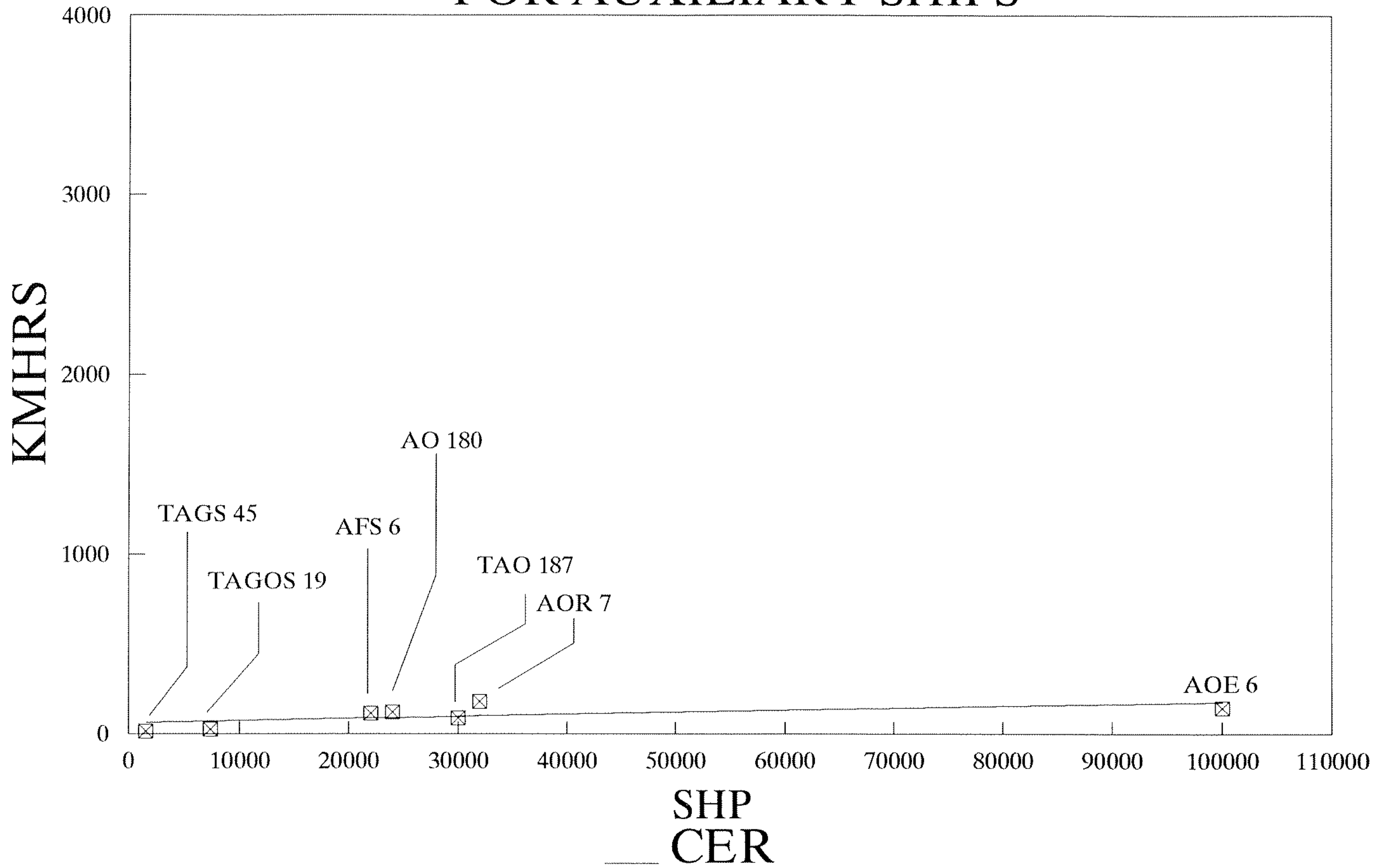
Regression Output:

Constant		26.6
Std Err of Y Est		42
R Squared		0.563
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	0.111	
Std Err of Coef.	0.049	
T = 2.268	F =	5.14
CV % =	37.9	

DATA

SHIPS	LT 2	LAB 2
TAGOS 19	55	14
AO 180	646	121
AFS 6	770	112
AOR 7	971	181
AOE 6	977	146
TAO 187	1,122	89

LABOR VS. SHAFT HORSEPOWER IN GROUP 2
FOR AUXILIARY SHIPS



CER: KMHRS = 0.001 SHP + 62.7; R^2 = 0.377; T and F not significant at 90%; CV = 53.4%

Regression Output:

Constant			62.7
Std Err of Y Est			53
R Squared			0.377
No. of Observations			7
Degrees of Freedom			5
# Variables			1
X Coefficient(s)		0.001	
Std Err of Coef.		0.001	
T =	1.740	F =	3.03
CV % =		53.4	

DATA

SHIPS	SHP	LAB 2
TAGOS 19	1,600	14
AO 180	24,000	121
AFS 6	22,000	112
AOR 7	32,000	181
TAO 187	30,000	89
AOE 6	100,000	146
TAGS 45	7,400	26

4.3.3 SWBS Group 300 - Electric Plant

This group includes installation of the ship's electric power generation and distribution plant. Included are the following elements:

SWBS NUMBER	TITLE
310	Electrical Power Generation
320	Power Distribution Systems
330	Lighting Systems
340	Power Generation Support Systems
390	Special Purpose Systems

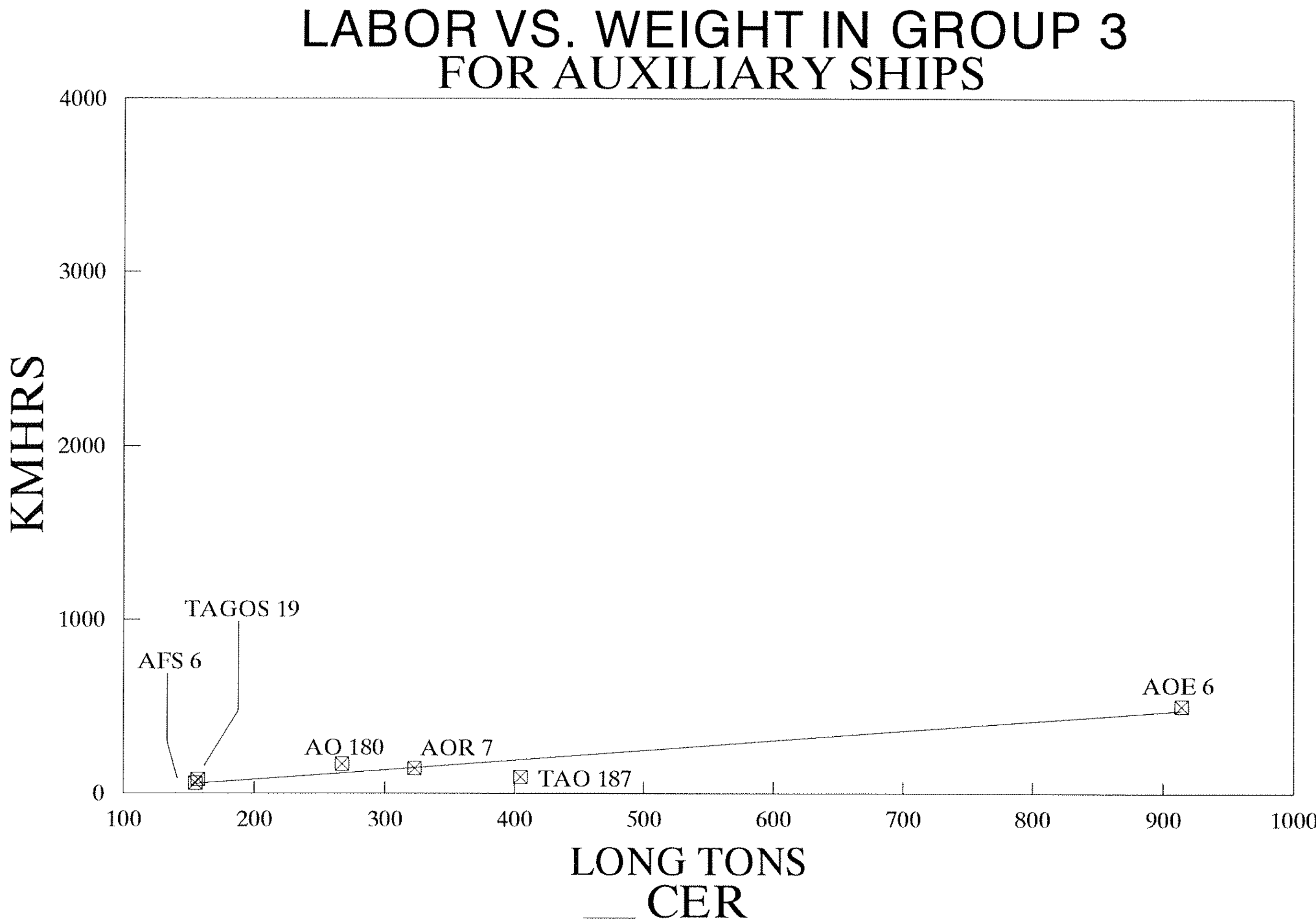
This group does not include foundations (SWBS Group 100); propulsion electric systems (SWBS Group 200); and command and surveillance systems (SWBS Group 400).

Figure 4-29 provides the CER, regression output, and supporting data for the SWBS Group 300 CER based on lightship weight of the group.

The SWBS Group 300 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.556\ LT - 29.8$$

The R^2 value of 0.896 indicates a good correlation between labor and weight in SWBS Group 300 for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 34.0 percent, indicating that the CER is a good predictor.



CER: KMHRS = 0.556 LT – 29.8; R^2 = 0.896; T and F are significant at 95%; CV = 34.0%

NOTE: TAGS 45 weight data was not available for this group.

Regression Output:

Constant		–29.8
Std Err of Y Est		60
R Squared		0.896
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	0.556	
Std Err of Coef.	0.094	
T = 5.884	F =	34.62
CV % =	34.0	

DATA

SHIPS	LT 3	LAB 3
AFS 6	155	61
TAGOS 19	157	82
AO 180	267	170
AOR 7	323	144
TAO 187	405	94
AOE 6	914	505

4.3.4 SWBS Group 4 - Command and Surveillance

This group includes installation of all command and surveillance systems both for ship operations and combat systems/weapons. Included are the following elements:

SWBS NUMBER	TITLE
410	Command and Control Systems
420	Navigation Systems
430	Interior Communications
440	Exterior Communications
450	Surveillance Systems (surface)
460	Surveillance Systems (underwater)
470	Countermeasures
480	Fire Control Systems
490	Special Purpose Systems

This group does not include masts, yardarms, or foundations (SWBS Group 100); power conversion systems, lighting or power cable (SWBS Group 300); cooling systems (SWBS Group 500); or weapons (SWBS Group 700).

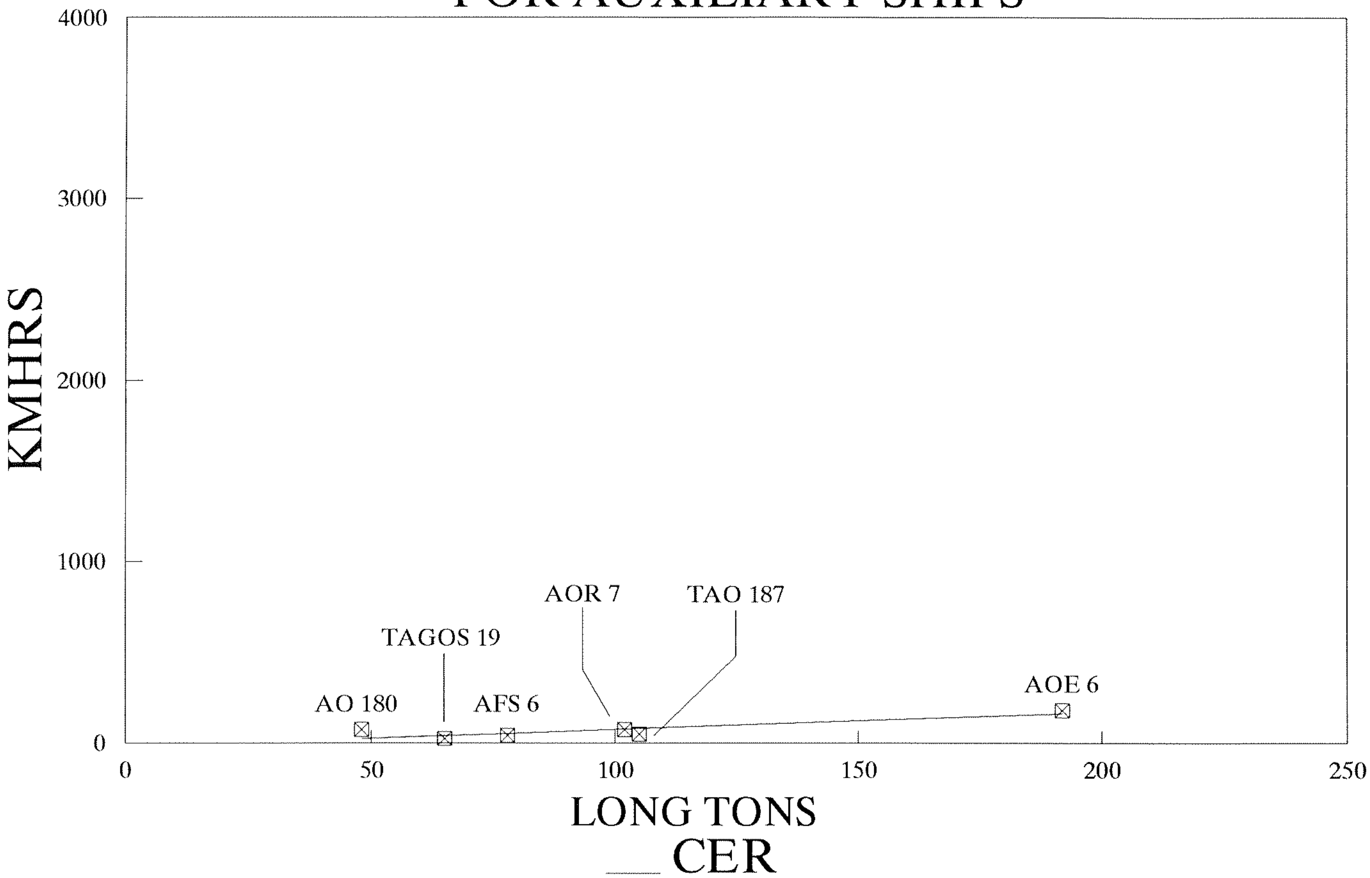
Figure 4-30 provides the CER, regression output, and supporting data for the SWBS Group 400 CER based on lightship weight of the group.

The SWBS Group 400 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.943\ LT - 19.0$$

The R^2 value of 0.735 indicates a good correlation between labor and weight in SWBS Group 400 for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. However, the CV for this relationship is 43.7 percent, indicating that the CER is a poor predictor. Since this CER approaches a constant, consideration can be given by NCA to presenting this CER as a constant for statistical purposes.

LABOR VS. WEIGHT IN GROUP 4
FOR AUXILIARY SHIPS



CER: KMHRS = 0.943 LT – 19.0; R^2 = 0.735; T and F are significant at 95%; CV = 43.7%

NOTE: TAGS 45 weight data was not available for this group.

Regression Output:

Constant			–19.0
Std Err of Y Est			32
R Squared			0.735
No. of Observations			6
Degrees of Freedom			4
# Variables			1
X Coefficient(s)		0.943	
Std Err of Coef.		0.283	
T =	3.327	F =	11.07
CV % =		43.7	

DATA

SHIPS	LT 4	LAB 4
TAGOS 19	65	24
AO 180	48	74
AFS 6	78	41
AOR 7	102	73
TAO 187	105	49
AOE 6	192	181

4.3.5 SWBS Group 500 - Auxiliary Systems

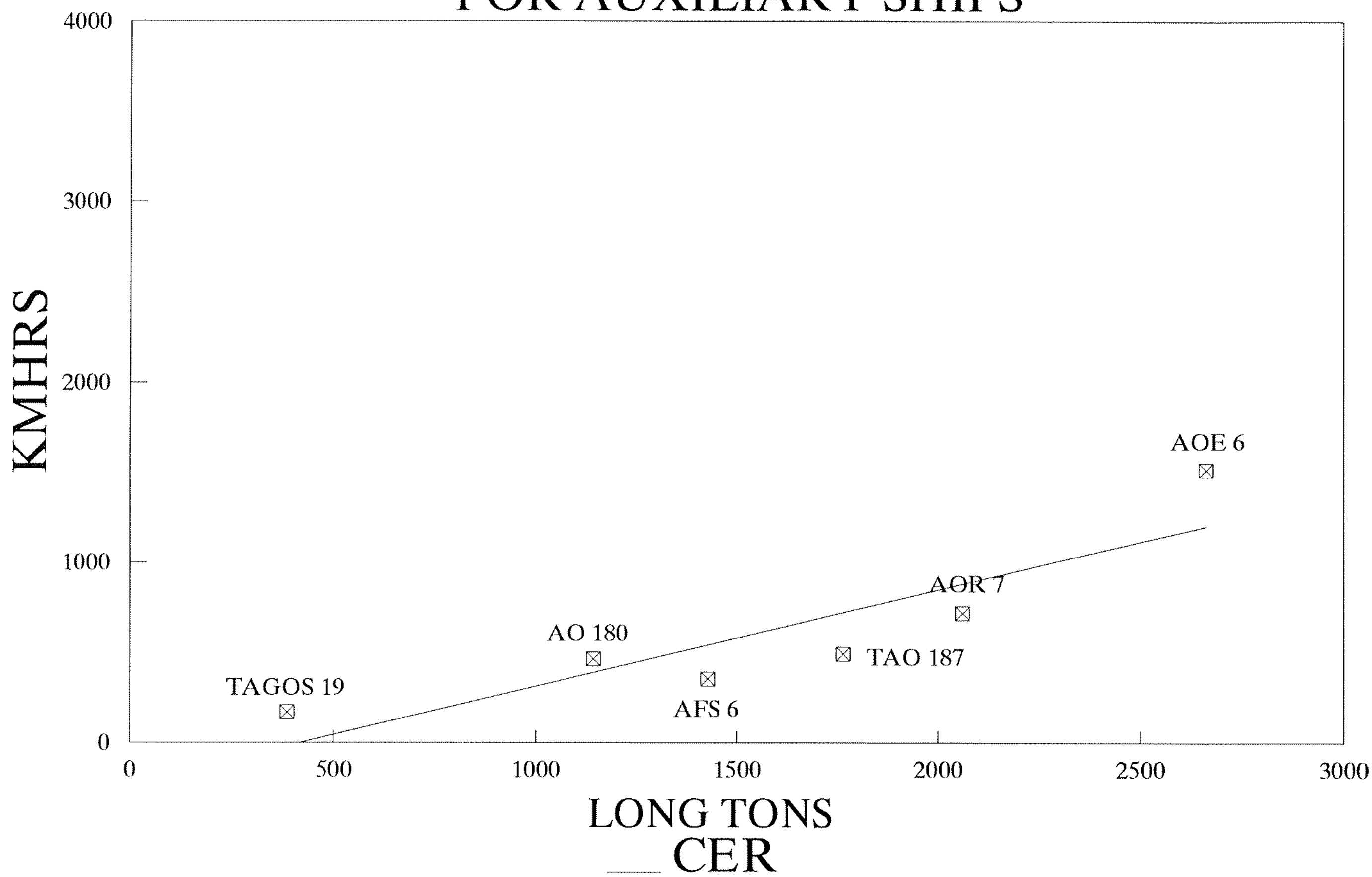
This group includes installation of the ship's environmental, fluid, maneuvering and equipment handling systems. Included are the following elements:

SWBS NUMBER	TITLE
510	Climate Control
520	Sea Water Systems
530	Fresh Water Systems
540	Fuels and Lubricants, Handling and Storage
550	Air, Gas, and Miscellaneous Fluid Systems
560	Ship Control Systems
570	Underway Replenishment Systems
580	Mechanical Handling Systems
590	Special Purpose Systems

This group does not include foundations, fan rooms, structural penetrations, permanent ballast, tanks, sea chests, (SWBS Group 100); propulsion systems including circulation and cooling pumps and piping, fuel service pumps and piping, main propulsion lube oil system, propulsion and propulsion train (SWBS Group 200); batteries, electrical systems, electrical generator support systems, power cabling (SWBS Group 300); alarms systems (SWBS Group 400); spaces, cargo stowage, hull fittings (SWBS Group 600), and handling and stowage of weapons (SWBS Group 700).

Figure 4-31 provides the CER, regression output, and supporting data for the SWBS Group 500 CER, based on lightship weight of the group.

LABOR VS. WEIGHT IN GROUP 5
FOR AUXILIARY SHIPS



CER: KMHRS = 0.534 LT – 222.1; R^2 = 0.776; T and F are significant at 95%; CV = 40.7%

NOTE: TAGS 45 weight data was not available for this group.

Regression Output:

Constant		−222.1
Std Err of Y Est		252
R Squared		0.776
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	0.534	
Std Err of Coef.	0.144	
T = 3.718	F =	13.82
CV % =	40.7	

DATA

SHIPS	LT 5	LAB 5
TAGOS 19	384	168
AO 180	1,145	463
AFS 6	1,428	353
TAO 187	1,764	492
AOR 7	2,060	717
AOE 6	2,661	1,517

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The SWBS Group 500 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.534\ LT - 222.1$$

The R^2 value of 0.776 indicates a good correlation between labor and weight in SWBS Group 500 for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 40.7 percent, indicating that the model is a poor predictor. Note that the AOE 6 is high for this group. If it were considered an outlier, the model would have a better CV value; however, the AOE 6 data was included since it represents a recent major ship construction program.

4.3.6 SWBS Group 600 - Outfit and Furnishings

This group includes installation of the ship's hull fittings, non-structural subdivision, preservation, ship support and habitability items. Included are the following elements:

SWBS NUMBER	TITLE
610	Ship Fittings
620	Hull Compartmentation
630	Preservatives and Coverings
640	Living Spaces
650	Service Spaces
660	Working Spaces
670	Stowage Spaces
690	Special Purpose Systems

This group does not include structural components, flight decks, tanks/voids/trunks structural and watertight subdivision bulkheads, structural closures, sea chests, (SWBS Group 100); propulsion shafting, (SWBS Group 200); batteries, ships service power cable, lighting distribution and fixtures (SWBS Group 300); refrigeration systems boat handling, cargo handling, replenishment at sea system, mooring, towing and anchor handling, life saving equipment, lagging (SWBS Group 500); and weapons handling (SWBS Group 700).

Figure 4-32 provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on lightship weight of the group.

The SWBS Group 600 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.447\ LT - 49.4$$

The R^2 value of 0.367 indicates a very low correlation between labor and weight in SWBS Group 600 for auxiliary ships. T and F are not significant at 90 percent, indicating the relationship is not statistically significant. The CV for this relationship is 78.0 percent, indicating that the model is a poor predictor. Note that the AOE 6 appears to be an outlier for this CER. One reason for this could be the delay in delivery of the reduction gears for this ship, which caused significant delays in outfitting. The effect of the AOE 6 is to cause the CER to overpredict other ships in the AOE 6's range and underpredict ships at the low end of the range. This contributed to the low R^2 value and high CV. However, the AOE 6 data was considered essential to the CER since it is a recent major ship construction program and the return costs are available. It is considered that this CER provides a reasonable and conservative prediction of actual costs for SWBS Group 600.

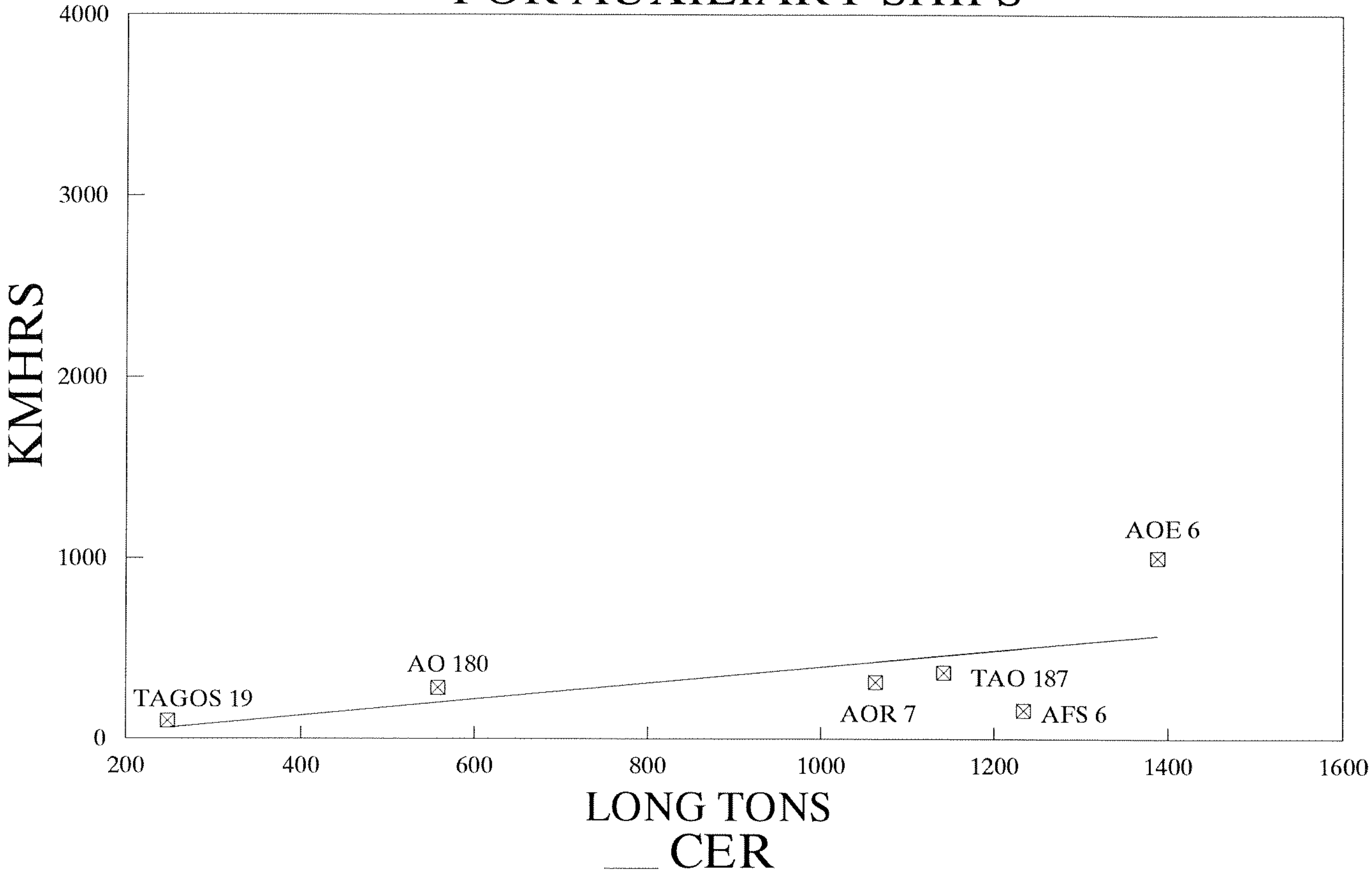
Figure 4-32a provides the CER, regression output, and supporting data for the SWBS Group 600 CER based on total accommodations on the ship.

The SWBS Group 600 CER of labor vs. total accommodations for auxiliary ships is:

$$KMHRS = 1.30\ \text{accommodations} - 156$$

The R^2 value of 0.437 indicates a very low correlation between labor costs and total accommodations of auxiliary ships. T and F are not significant at 90 percent, indicating the relationship is not statistically significant. The CV for this relationship is 79.9 percent, indicating that the model is a poor predictor. Again the AOE 6 contributes to the low R^2 and high CV for the same reasons as stated previously. Also, there are not enough data points to make a statistically significant relationship — total accommodations were not available for T-Ships.

LABOR VS. WEIGHT IN GROUP 6
FOR AUXILIARY SHIPS



CER: KMHRS = 0.447 LT – 49.4; R^2 = 0.367; T and F not significant at 90%; CV = 78.0%

NOTE: TAGS 45 weight data was not available for this group.

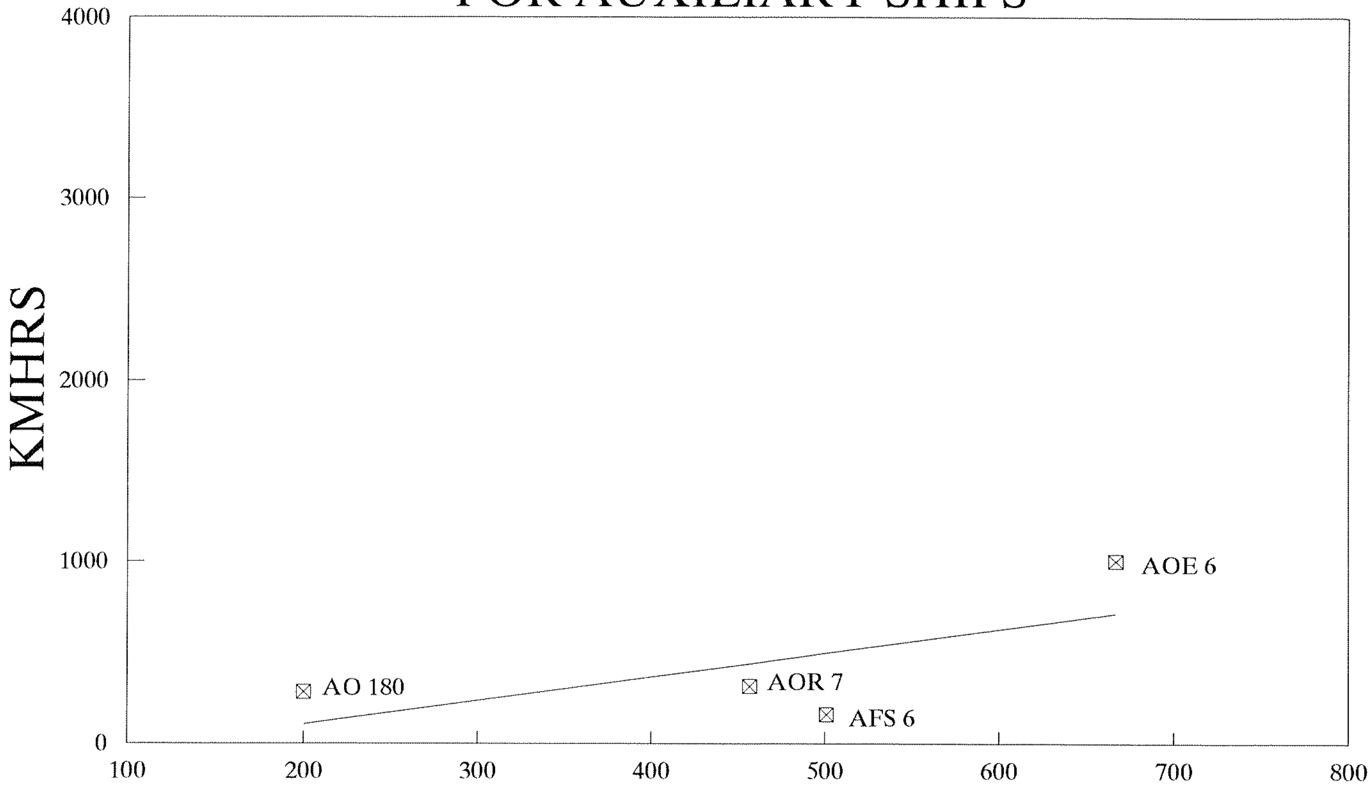
Regression Output:

Constant		–49.4
Std Err of Y Est		289
R Squared		0.367
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	0.447	
Std Err of Coef.	0.294	
T = 1.523	F =	2.32
CV % =	78.0	

DATA

SHIPS	LT 6	LAB 6
TAGOS 19	248	101
AO 180	558	282
AFS 6	1,234	157
AOR 7	1,063	314
TAO 187	1,142	368
AOE 6	1,388	1,002

LABOR VS. TOTAL ACCOMODATIONS IN GROUP 6 FOR AUXILIARY SHIPS



CER: KMHRS = 1.30 ACCOM − 156; R^2 = 0.437;T and F not significant at 90%; CV = 79.9%

NOTE: Total accomodations were not available for T-Ships.

Regression Output:

Constant		−156.2
Std Err of Y Est		351
R Squared		0.437
No. of Observations		4
Degrees of Freedom		2
# Variables		1
X Coefficient(s)	1.304	
Std Err of Coef.	1.047	
T = 1.245	F =	1.55
CV % =	79.9	

DATA

SHIPS	TOT ACC	LAB 6
AO 180	200	282
AOR 7	457	314
AFS 6	501	157
AOE 6	667	1,002

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4.3.7 SWBS Group 700 - Armament

This group includes installation of the ship's armament and armament handling systems. Included are the following elements:

SWBS NUMBER	TITLE
710	Guns and Ammunition
720	Missile and Rockets
730	Mines
740	Depth Charges
750	Torpedoes
760	Small Arms and Pyrotechnics
770	Cargo Munitions
780	Aircraft Related Weapons
790	Special Purpose Systems

This group does not include foundations, hull penetrations, (SWBS Group 100); non-integral electrical systems, (SWBS Group 300); non-integral electronics systems (SWBS Group 400); non-integral auxiliary systems, (SWBS Group 500), and ship's outfit and furnishings (SWBS Group 600). Nor does it include the actual weapons systems which are normally GFE.

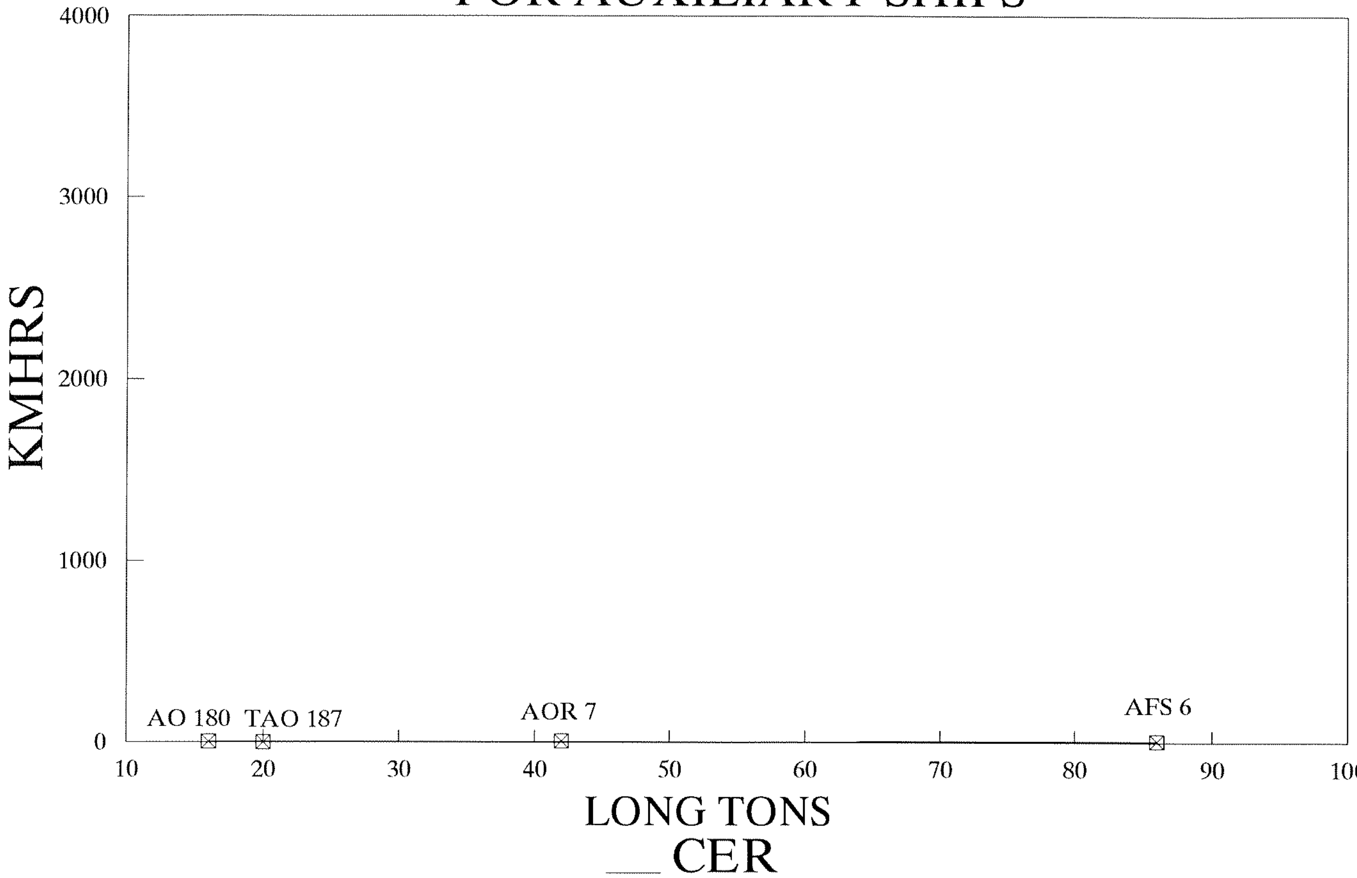
Figure 4-33 provides the CER, regression output, and supporting data for the SWBS Group 700 CER.

The SWBS Group 700 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.063\ LT + 1.71$$

The R^2 value of 0.880 indicates a good correlation between labor costs and weight in SWBS Group 700 for auxiliary ships. T and F are significant at 90 percent, indicating a relationship of questionable significance. The CV for this relationship is 21.2 percent, indicating that the CER is also a good predictor.

LABOR VS. WEIGHT IN GROUP 7
FOR AUXILIARY SHIPS



CER: KMHRS = 0.063 LT + 1.71; R^2 = 0.880; T and F are significant at 90%; CV = 21.2%

NOTE: TAGS 45, TAO 187, TAGOS 19 & AOE 6 are not included in the regression.

Regression Output:

Constant		1.71
Std Err of Y Est		0.907
R Squared		0.880
No. of Observations		4
Degrees of Freedom		2
# Variables		1
X Coefficient(s)	0.063	
Std Err of Coef.	0.016	
T = 3.838	F =	14.73
CV % =	21.2	

DATA

SHIPS	LT 7	LAB 7
AO 180	16	3.2
TAO 187	20	2.0
AOR 7	42	5.0
AFS 6	86	6.9

4.3.8 SWBS Group 800 - Integration/ Engineering Shipbuilder Response

This group includes installation of the cost of the labor of those program management and engineering services associated with the design, development, production, testing and delivery of the ships. Included are the following elements:

SWBS NUMBER	TITLE
800	Shipbuilder Drawings
810	Production Engineering
830	Design Support
840	Quality Assurance
850	Integrated Logistics Support Engineering
890	Special Purpose Items
891	Safety
892	Human Factors
893	Standardization
894	Value Engineering
895	Reliability
896	Maintainability
897	Data Management
898	Project Management

This group does not include shipyard standard drawings or molds and templates which are included in SWBS Group 900.

The SWBS 800 CER contains a high percentage of non-recurring costs for engineering, design, project management and other lead ship integration activities. For this reason, only lead ship data is included in the SWBS Group 800 CER. Note that detail design costs are included in the SWBS Group 800 costs for auxiliary ships.

Figure 4-34 provides the CER, regression output, and supporting data for the SWBS Group 800 CER based on lightship weight of the group.

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The SWBS Group 800 CER of labor vs. weight for auxiliary ships is:

KMHRS = 0.061 LT + 118 (T-Ships)

KMHRS = 0.061 LT + 1775 (A-Ships)

Statistics are available for T-Ships only. There are not enough data points for statistical significance of the A-Ships CER, since the values for the AO 180, AFS 6 and AOR 7 are based on an estimated constant predicted in the previous model. The A-ship CER was derived by creating a parallel line with the T-ship CER and passing it through the AOE 6 data point. The estimated data is provided for comparison. The R^2 value of 0.991 for the T-ships CER indicates a high correlation between integration/engineering costs and lightship weight for T-ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 7.9 percent, indicating the model is also an excellent predictor.

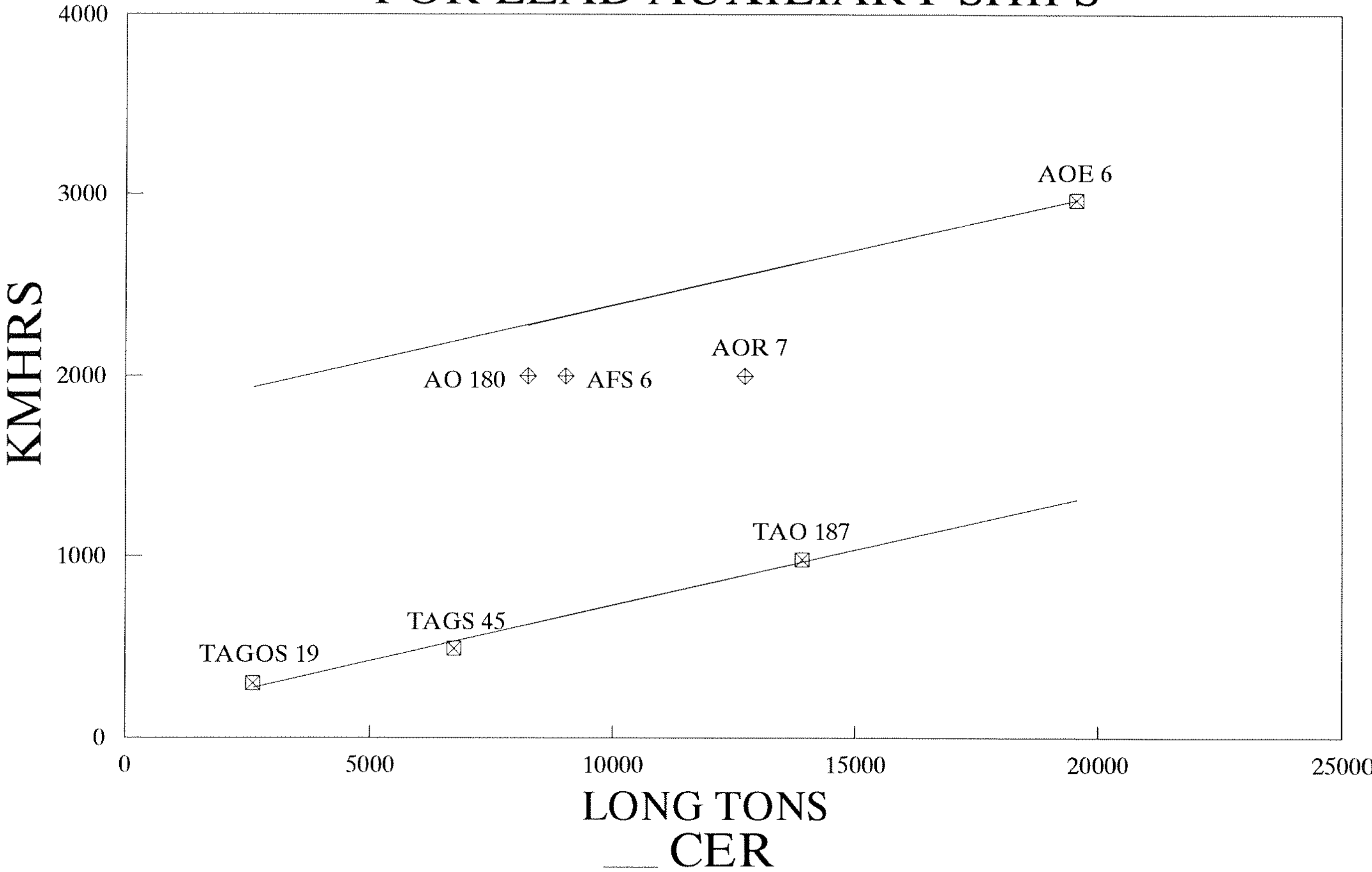
Figure 4-34a provides the CER, regression output, and supporting data for the SWBS Group 800 CER based on total production manhours.

The CER for SWBS Group 800 costs vs. production costs for auxiliary ships is:

Group 8 (KMHRS) = 0.654 SWBS Group 1-7 & 9 (KMHRS) - 417

The R^2 value of .983 indicates a high correlation between SWBS Group 800 labor costs and production manhours for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 10.1 percent, indicating the CER is an excellent predictor. Again, the values for the AOR 7, AO 180 and AFS 6 are based on constants in the previous model and provided for comparison.

LABOR VS. WEIGHT IN GROUP 8
FOR LEAD AUXILIARY SHIPS



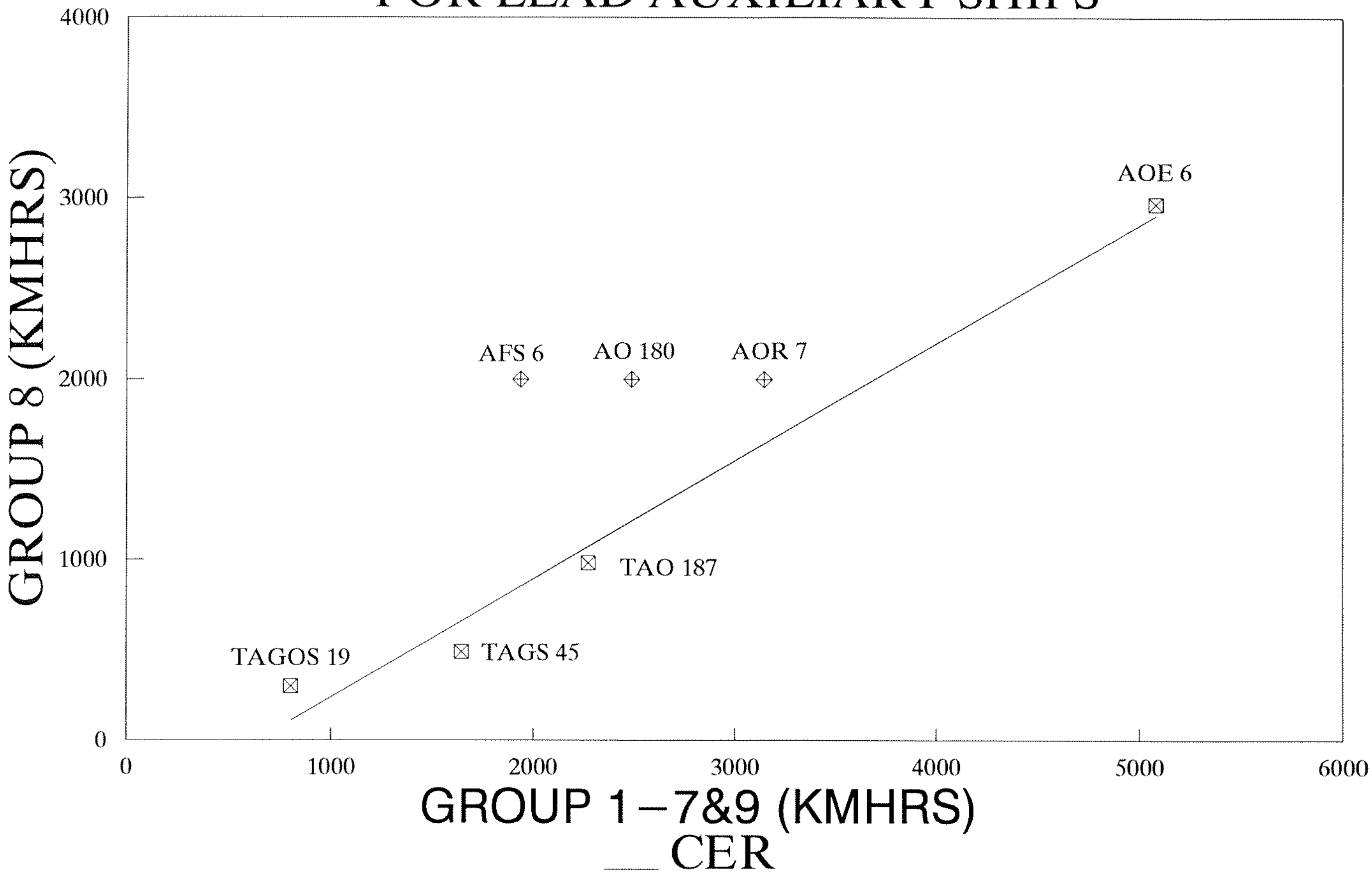
A-SHIPS: KMHRS = 0.061 LT + 1775; R^2 = 1.000; T and F are not applicable; CV = N/A
T-SHIPS: KMHRS = 0.061 LT + 118; R^2 = 0.991; T and F are significant at 95%; CV = 7.9%

NOTE: AO 180, AFS 6, and AOR 7 are not included in regression since they are estimates.

Regression Output:		T-Ships	A-Ships	SHIPS	LT 1-7	LAB 8
Constant		117.7	1775.5			
Std Err of Y Est		47	N/A	TAGOS 19	2,602	301
R Squared		0.991	1.000	TAGS 45	6,750	493
No. of Observations		3	1	TAO 187	13,923	983
Degrees of Freedom		1	0	AO 180	8,252	2,000
# Variables		1	0	AFS 6	9,038	2,000
X Coefficient(s)	0.061			AOR 7	12,744	2,000
Std Err of Coef.	0.006			AOE 6	19,564	2,972
T = 10.569	F =	111.70				
CV % =	7.9					

(DATA is the heading over the SHIPS, LT 1-7 and LAB 8 columns.)

LABOR GROUP 8 VS. GROUP 1-7&9 FOR LEAD AUXILIARY SHIPS



CER: (GRP 8) = 0.654 (1-7&9) - 417; R^2 = 0.983; T and F are significant at 95%; CV = 10%

Regression Output:

Constant		-416.9
Std Err of Y Est		196
R Squared		0.983
No. of Observations		4
Degrees of Freedom		2
# Variables		1
X Coefficient(s)	0.654	
Std Err of Coef.	0.061	
T = 10.718	F =	114.89
CV % =	10.1	

DATA

SHIPS	LAB 1-7&9	LAB 8
TAGOS 19	802	301
TAGS 45	1,643	493
TAO 187	2,277	983
AO 180	2,491	2,000
AFS 6	1,938	2,000
AOR 7	3,147	2,000
AOE 6	5,080	2,972

4.3.9 SWBS Group 900 - Ship Assembly and Support Services

This group includes the cost of contractual, production, and construction support services. Included are the following elements:

SWBS NUMBER	TITLE
980	Contractual and Production Support Services
981	Insurance
982	Trials
983	Delivery
984	Open and Inspect (Conversions Only)
985	Fire and Flooding Protection
986	Test and Inspection
987	Weighing and Recording
988	Contract Data Requirements (Administrative)
989	Fitting Out
990	Construction Support
991	Staging, Scaffolding and Cabling
992	Temporary Utilities and Services
993	Material Handling and Removal
994	Cleaning Services
995	Molds and Templates, Jigs, Fixtures and Special Tools
996	Launching
997	Drydocking

SWBS Group 900 is used for the identification of assemblies and monitoring the ship construction by erection section or similar construction grouping. Actual costs accumulated against these elements are translated to the appropriate elements covering the system involved. The costs accumulated under SWBS Group 900 are for the cost of contractual, production, and construction support services.

Figure 4-35 provides the CER, regression output, and supporting data for the SWBS Group 900 CER based on lightship weight of the ship.

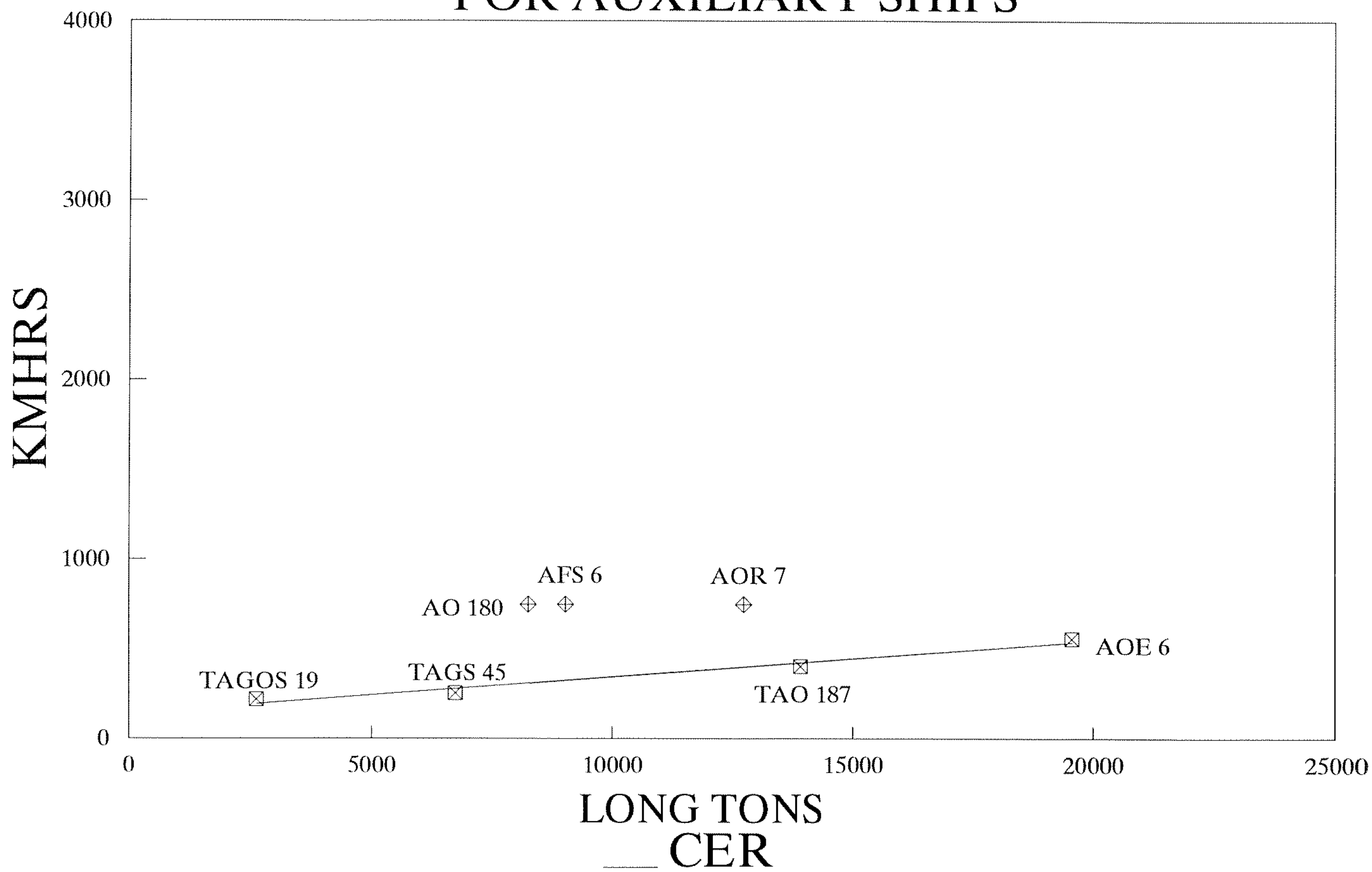
The SWBS Group 900 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.020\ LT + 140.9$$

The R^2 value of 0.972 indicates a high correlation between shipyard production support and lightship weight for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 8.8 percent, indicating that the CER is also an excellent predictor. Note that the AO 180, AFS 6 and AOR 7 are not used in developing the CER since they are based on constants provided in the previous model. They are shown for comparison.

The SWBS Group 900 CER, based on the number of months in the shipyard, was not included because the relationship showed no significance at all.

LABOR VS. WEIGHT IN GROUP 9
FOR AUXILIARY SHIPS



CER: KMHRS = 0.020 LT + 140.9; R^2 = 0.972; T and F are significant at 95%; CV = 8.8%

NOTE: AO 180, AFS 6 and AOR 7 are estimates and are not included in the regression.

Regression Output:

Constant				140.9
Std Err of Y Est				32
R Squared				0.972
No. of Observations				4
Degrees of Freedom				2
# Variables				1
X Coefficient(s)		0.020		
Std Err of Coef.		0.002		
T =	8.345		F =	69.63
	CV % =	8.8		

DATA

SHIPS	LT 1–7	LAB9
TAGOS 19	2,602	219
TAGS 45	6,750	254
TAO 187	13,923	402
AOE 6	19,564	557
AO 180	8,252	750
AFS 6	9,038	750
AOR 7	12,744	750

4.3.10 Summary Labor CERs

Figures 4-36, 4-37 and 4-38 are summary labor CER's for construction costs (SWBS Groups 100-700), production costs (SWBS Groups 100-700 and 900) and total contract costs (SWBS Groups 100-900). These three groupings reflect different categorizations typically used in previous models or found in CER's.

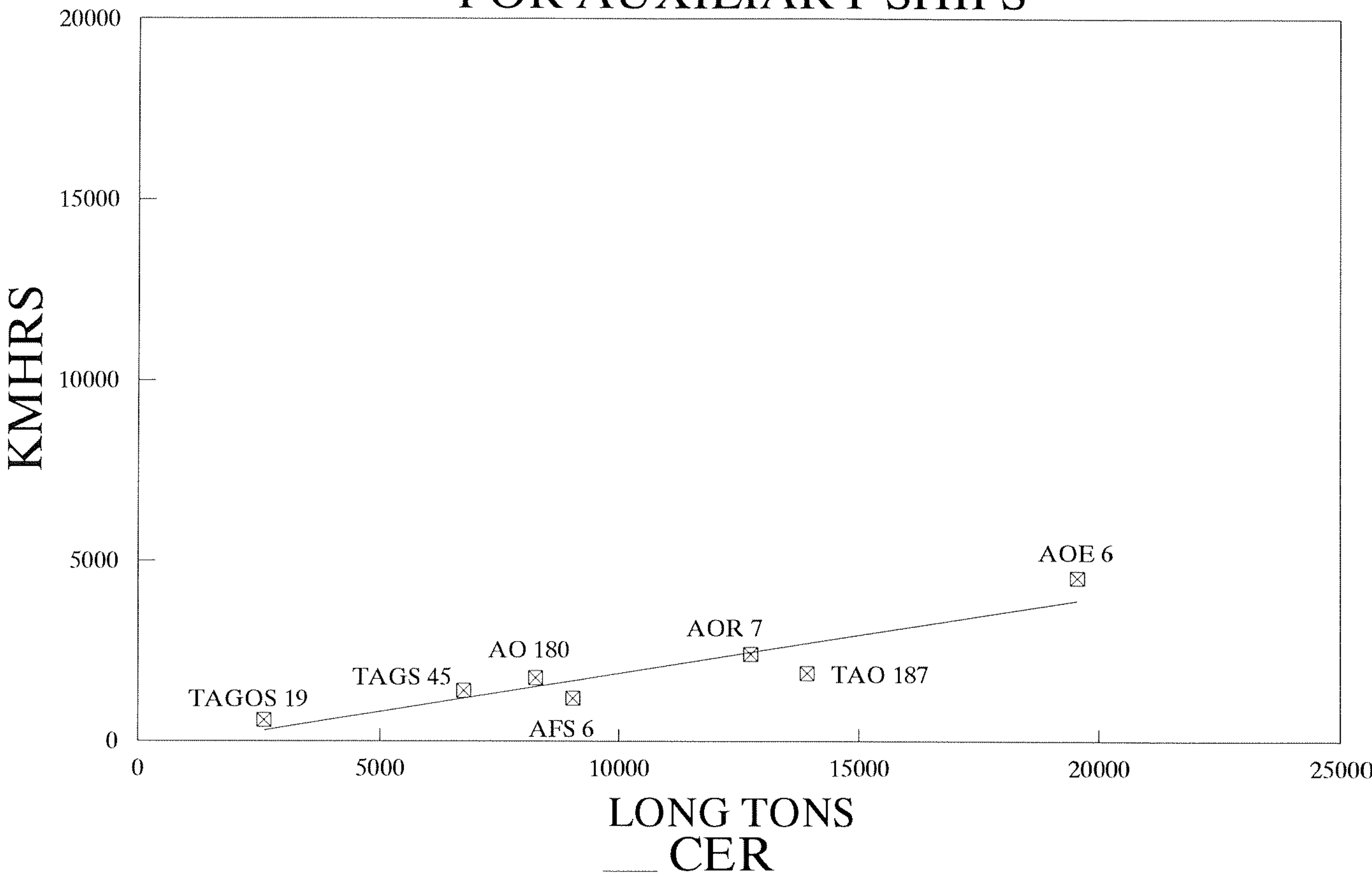
Construction costs have been used in previous models to define the actual ship construction activities, exclusive of design and integration, and shipyard services. The CER for construction labor costs, presented in Figure 4-36, was developed by summing the individual one-digit SWBS Groups 100 to 700 costs and is based on total lightship weight. Construction labor costs have exhibited a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship construction costs in a follow yard are similar to those in a lead yard. The relatively good correlation between one-digit SWBS Groups 100 to 700 values to the aggregate SWBS Groups 100 through 700 values has also allowed for allocation of the aggregate SWBS Groups 100 through 700 manhours to individual one-digit SWBS Groups 100 to 700. As noted in Chapter 3, most of the CPR's provided cost breakdowns that allowed for the construction costs to be differentiated from SWBS Groups 800 and 900 costs.

The SWBS Group 100 - 700 summary CER of labor vs. weight for auxiliary ships (as shown in Figure 4-36) is:

$$\text{KMHRS} = 0.211\ \text{LT} - 242$$

The R^2 value of 0.845 indicates a good correlation between construction labor costs and lightship weight for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 27.9 percent, indicating that the model is a good predictor.

LABOR VS. WEIGHT IN GROUPS 1-7
FOR AUXILIARY SHIPS



CER: KMHRS = 0.211 LT − 242; R^2 = 0.845; T and F are significant at 95%; CV = 27.9%

Regression Output:

Constant			−242.3
Std Err of Y Est			546
R Squared			0.845
No. of Observations			7
Degrees of Freedom			5
# Variables			1
X Coefficient(s)		0.211	
Std Err of Coef.		0.040	
T =	5.230	F =	27.35
	CV % =	27.9	

DATA

SHIPS	LT 1-7	LAB 1-7
TAGOS 19	2,602	584
TAGS 45	6,750	1,390
AO 180	8,252	1,741
AFS 6	9,038	1,188
AOR 7	12,744	2,397
TAO 187	13,923	1,874
AOE 6	19,564	4,523

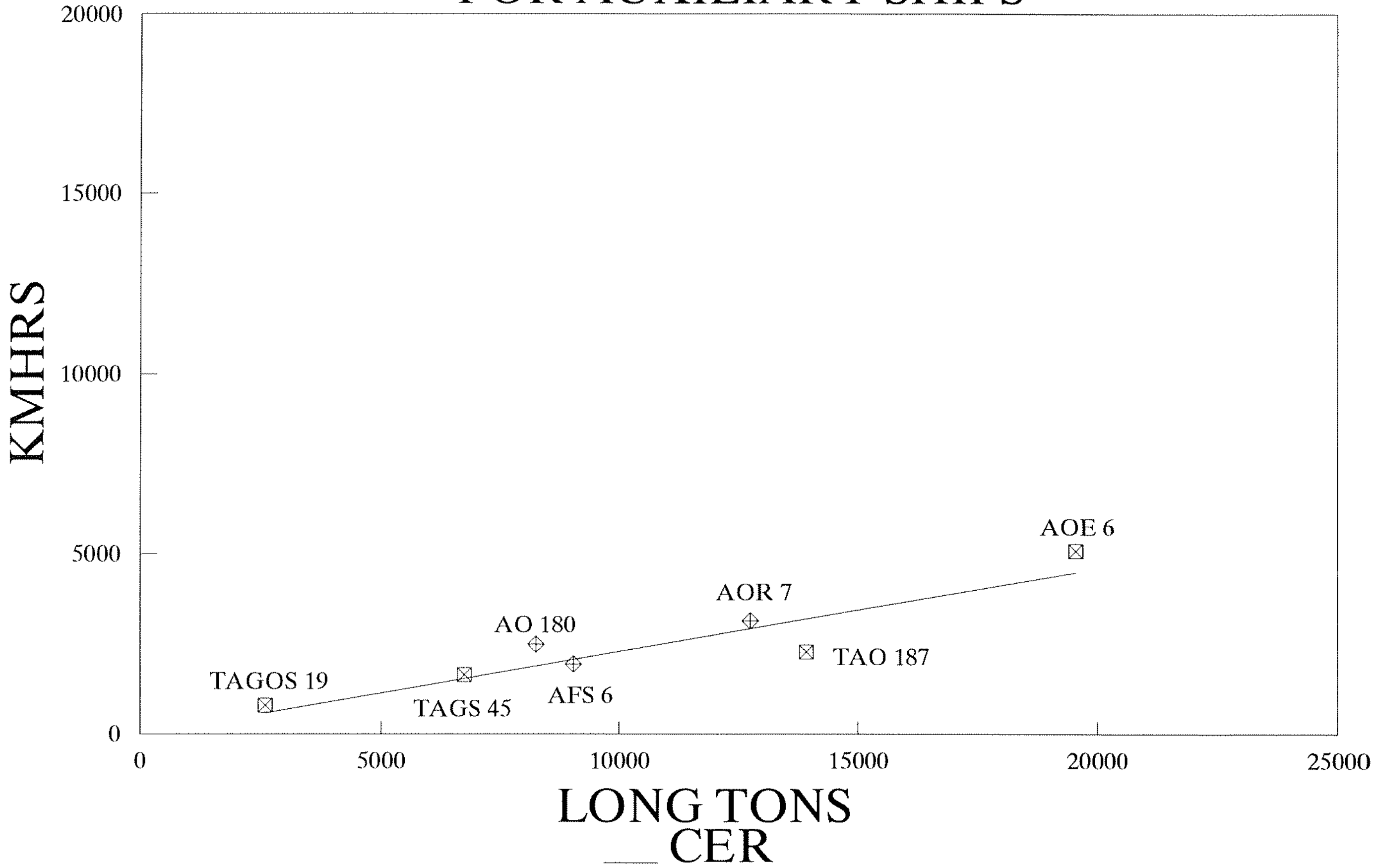
Production costs are reported by shipyards in CPR's and roughly correlate to SWBS Groups (100-700 and 900). The CER for production costs based on total ship lightship weight is shown in Figure 4-37 It indicates a good historical correlation between ships and shipyards. In addition, there is good correlation between lead ships in both lead and follow yards, supporting the assumption that the lead ship production costs in a follow yard are similar to those in a lead yard.

The SWBS Group 100 - 700 and 900 CER of labor vs. weight for auxiliary ships is:

$$KMHRS = 0.231\ LT - 22.2$$

The R^2 value of 0.880 indicates a correlation between production labor costs and lightship weight for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 32.2 percent, indicating that the model is a good predictor. Note that the AO 180, AFS 6 and AOR 7 are not used in developing the CER, since they are based on estimates provided in the previous model. They are shown for comparison.

LABOR VS. WEIGHT IN GROUPS 1–7,9 FOR AUXILIARY SHIPS



CER: KMHRS = 0.231 LT – 22.2; R^2 = 0.880; T and F are significant at 95%; CV = 32.2%

NOTE: AO 180, AFS 6, and AOR 7 are estimates for Group 9 and are not included on regression.

Regression Output:

Constant		–22.2
Std Err of Y Est		788
R Squared		0.880
No. of Observations		4
Degrees of Freedom		2
# Variables		1
X Coefficient(s)	0.231	
Std Err of Coef.	0.060	
T = 3.821	F =	14.60
CV % =	32.2	

DATA

SHIPS	LT 1–7	LAB 1–7,9
TAGOS 19	2,602	802
TAGS 45	6,750	1,643
TAO 187	13,923	2,277
AOE 6	19,564	5,080
AO 180	8,252	2,491
AFS 6	9,038	1,938
AOR 7	12,744	3,147

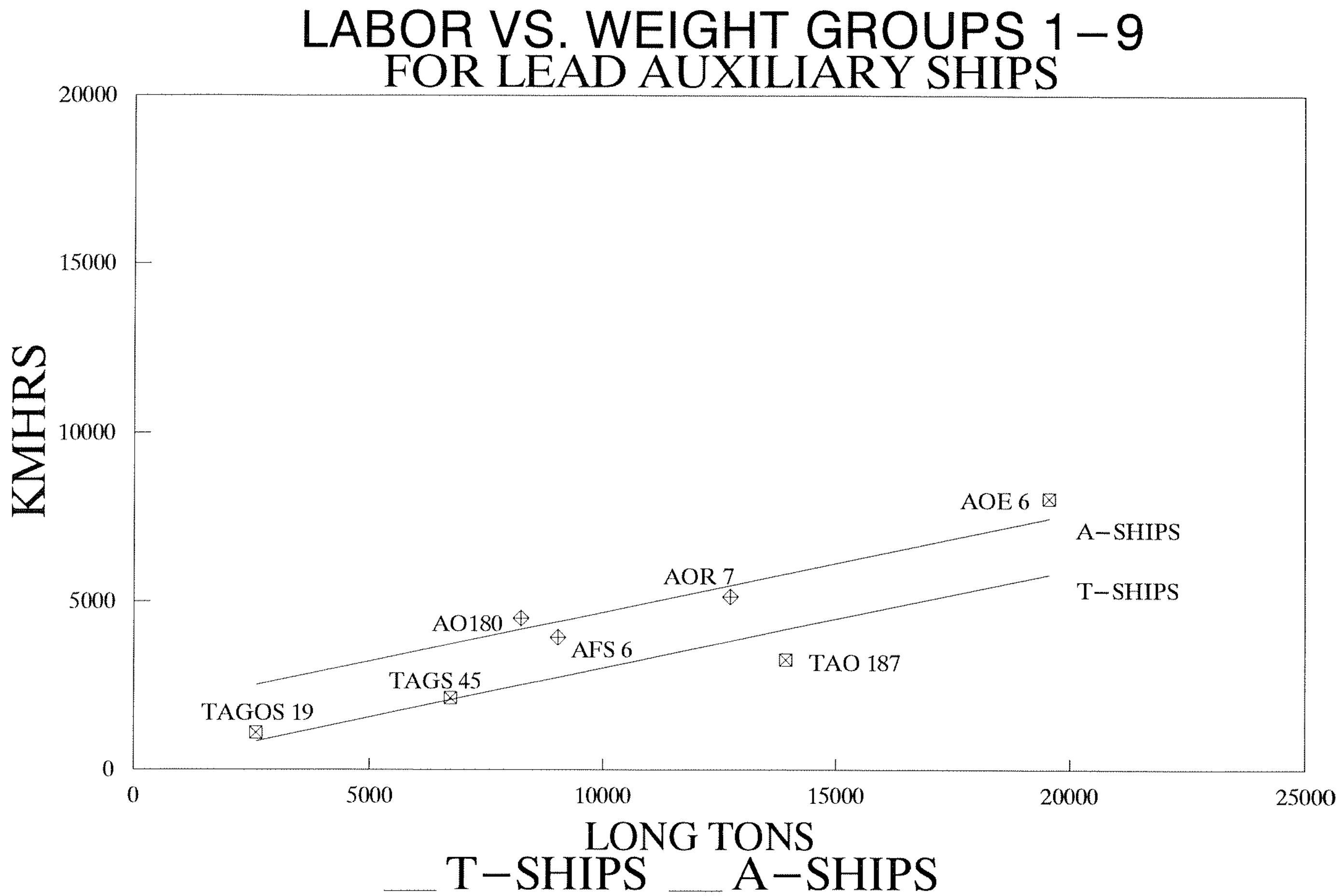
Total contract labor costs for the lead ship in a lead yard include all recurring and non-recurring costs, including all detail design and production engineering. The detail design costs are included in the SWBS Group 800 costs for auxiliary ships. Because of this addition of the SWBS Group 800 costs, only lead ship in a lead yard data is applicable. In developing the CER for SWBS Groups 100-900 based on total ship lightship weight and shown in Figure 4-38 the SWBS Group 800 labor cost CER was superimposed upon the production labor cost CER. In this way, the larger data base of lead ships at lead and follow yards for the production cost CER could be taken advantage of, while the more limited data set of lead ships in lead yards used to derive the CER for SWBS Group 800 could be used. Again note that the AO 180, AFS 6 and AOR 7 are not used in developing the CER, since they are based on estimates provided in the previous model. They are shown for comparison.

The SWBS Group 100 - 900 summary CER of labor vs. weight for auxiliary ships (as shown in Figure 4-38) is:

$$\text{KMHRS} = 0.292 \text{ LT} + 95.6 \text{ (T-Ships)}$$

$$\text{KMHRS} = 0.292 \text{ LT} + 1753.3 \text{ (A-Ships)}$$

Both CER's were developed by adding the respective SWBS Group 800 CER to the SWBS Group 100 - 700 and 900 CER. Because of this, no statistics are available.



Group 8 A–Ships	KMHRS =	0.061	LT +	1775.5
+ Group 1–7&9	KMHRS =	0.231	LT +	–22.2
Group 1–9 A–Ships	KMHRS =	0.292	LT +	1753.3

Group 8 T–Ships	KMHRS =	0.061	LT +	117.7
+ Group 1–7&9	KMHRS =	0.231	LT +	–22.2
Group 1–9 T–Ships	KMHRS =	0.292	LT +	95.6

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4.3.11 Material Costs

Material costs include all the materials and equipment purchased by the shipyard under the construction contract. It does not include the material and equipment provided by the government as government furnished equipment (GFE). Material costs are reported in the CPR's as a dollar figure, and are often reported as a single entity. The method of reporting material dollars in a CPR is dependent upon the contract type and the accounting system of the shipyard. As discussed in Chapter 3, the material costs are reported in either base year or report year dollars, depending upon whether the contract is a fixed price or cost reimbursed type contract. In addition, the shipyards can take G&A and fee on material costs if their accounting procedures permit it.

In order to limit uncertainty in material costs, only lead ship in a lead yard, unburdened material costs, escalated to FY 93 dollars are used to develop the CER, shown in Figure 4-39. This CER is based on total ship lightship weight. Given the lack of detail in the CPR's, only total material dollars are used in the CER. Also, follow ship material costs often contain a different mix of GFE or material cost factors than lead ships, due to class buys, non-recurring costs, or other changes. Because of this, their costs are not used in the CER.

Reference (5) was used to escalate the material dollars to FY 93 dollars and should be used to escalate estimates obtained from this model to future year dollars. The escalation of dollars is a source of uncertainty in the model and may cause older material costs to be more suspect compared to similar, more recent ships. Technology changes and fluctuating market values also contribute to the uncertainty of material cost data, even among similar ships.

The material cost CER for auxiliary ships is:

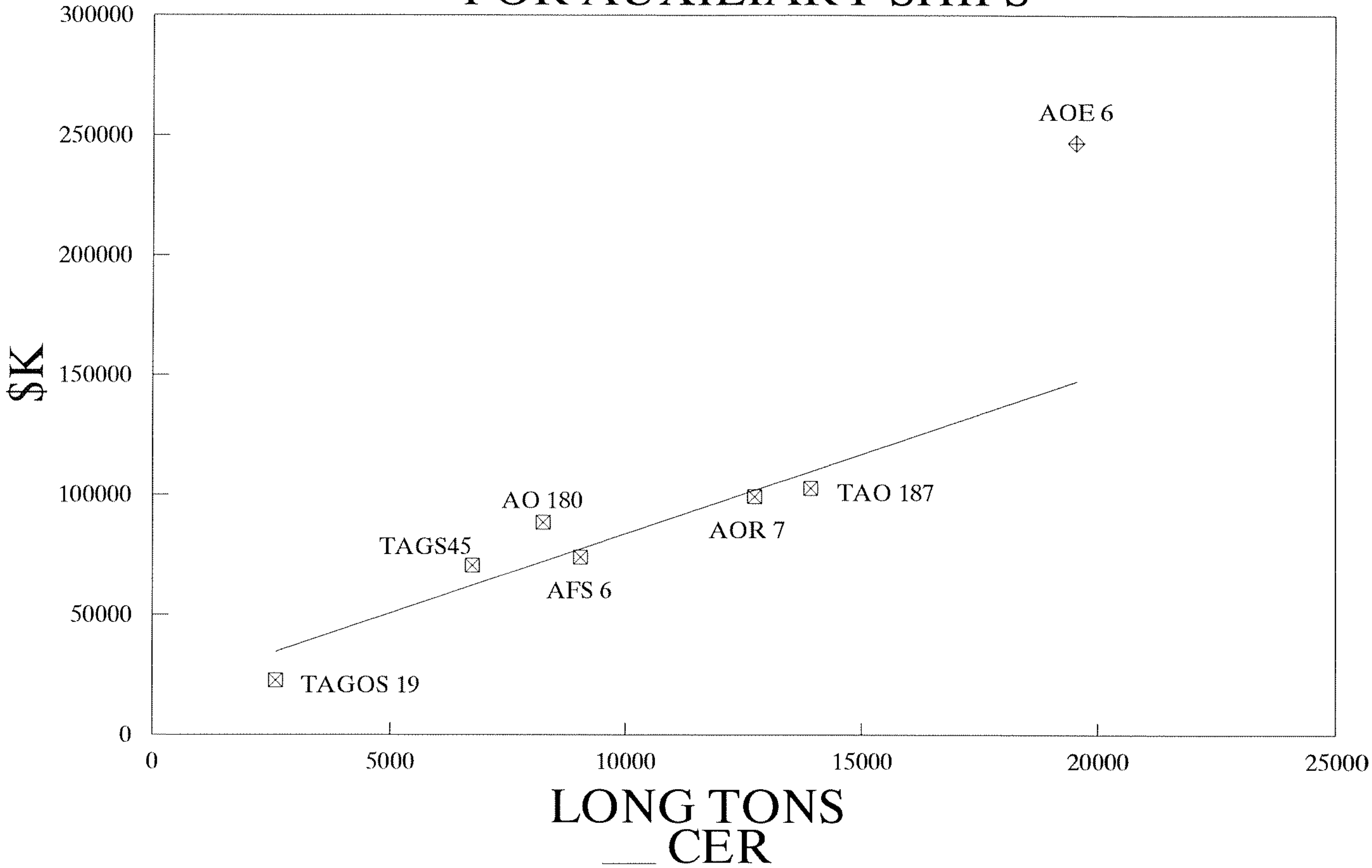
$$\$K = 6.65\ LT + 17{,}269$$

The R^2 value of 0.873 indicates a good correlation between total material costs and lightship weight for auxiliary ships. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV for this relationship is 15.3 percent, indicating that the model is also an excellent predictor. Note that the AOE 6 is not used in developing the CER due to its differences compared to other ships in the data base as derived in Section 3.3. The AOE 6 is shown for comparison. Note also that the AFS 6, AOE 7 and AO 180 were used in developing the CER. Even though they were not lead ships, their return costs were modified by NASSCO cost estimators in the previous model to reflect lead ship costs. This was considered satisfactory for this model.

Material costs for an individual ship are dependent upon the specific configuration of the ship, the actual mix of shipyard responsible items, and GFE, as well as the current market value of the shipyard responsible items. This covers a wide range of items, including structural material (e.g., steel, aluminum, composites), equipment (e.g., propulsion systems, electric plant, electronics) as well as distributive systems (e.g., power cable, ducting, piping). Given this and the limited data available, the material cost CER provides only a rough estimate for lead ship material costs. This estimate should be compared with the actual material cost estimate prepared for the ship by NAVSEA. The completeness of the NAVSEA estimate and the current vendor costs for major elements of the material costs should be independently checked. If reasonable, consideration should be given to using the NAVSEA estimate in lieu of the CER estimate for the material costs.

1381–68(4–EAM–4597) Figure 4–39 03–Jun–94

MATERIAL COST VS. LIGHTSHIP WEIGHT
FOR AUXILIARY SHIPS



CER: $K = 6.65 LT + 17269; R^2 = 0.873; T and F are significant at 95%; CV = 15.3%

NOTE: AOE 6 not included in regression since it is an outlier.
NOTE: AFS 6, AOR 7, & AO 180 are estimated to be lead ships in lead yard.

Regression Output:

Constant		17269.0
Std Err of Y Est		11646
R Squared		0.873
No. of Observations		6
Degrees of Freedom		4
# Variables		1
X Coefficient(s)	6.647	
Std Err of Coef.	1.265	

T = 5.254 F = 27.61

CV % = 15.3

DATA

SHIPS	MAT ($K)	LT 1–7
TAGOS 19	22,863	2,602
TAGS 45	70,471	6,750
AO 180	88,523	8,252
AFS 6	73,811	9,038
AOR 7	99,417	12,744
TAO 187	102,888	13,923
AOE 6	246,912	19,564

4.3.12 Summary of CER's for Auxiliary Ships

Table 4-8 shows each CER for Auxiliary Ships with its associated statistics listed by cost group.

TABLE 4-8

AUXILIARY SHIP CER's

COST GROUP	RELATIONSHIP	STATISTICS
100	Group 1 (KMHRS) = 0.09 (WT) + 67.6	R^2=.91; T,F at 95%; CV=17%
200	Group 2 (KMHRS) = 0.11 (WT) + 26.6	R^2=.56: T,F at 90%; CV=38%
200	Group 2 (KMHRS) = 0.001 (SHP) + 62.7	R^2=.38; T,F at <90%; CV=53%
300	Group 3 (KMHRS) = 0.56 (WT) - 29.8	R^2=.90; T,F at 95%; CV=34%
400	Group 4 (KMHRS) = 0.94 (WT) - 19.0	R^2=.74; T,F at 95%; CV=44%
500	Group 5 (KMHRS) = 0.53 (WT) - 222	R^2=.78; T,F at 95%; CV=41%
600	Group 6 (KMHRS) = 0.45 (WT) - 49.4	R^2=.37; T,F at <90%; CV=78%
600	Group 6 (KMHRS) = 1.30 (ACC) - 156 A-Ship	R^2=.44; T,F at <90%; CV=80%
700	Group 7 (KMHRS) = 0.06 (WT) + 1.71	R^2=.88; T,F at 90%; CV=21%
800	Group 8 (KMHRS) = 0.06 (WT) + 118 T-Ship	R^2=.99; T,F at 95%; CV=7.9%
800	Group 8 (KMHRS) = 0.06 (WT) + 1775 A-Ship	N/A
900	Group 8 (KMHRS) = 0.65 (1-7 &9) - 417	R^2=.98; T,F at 95%; CV=10%
900	Group (KMHRS) = 0.02 (MON) + 141	R^2=.97; T,F at 95%; CV=8.8%
SUMMARY CER's:		
100-700	Group 1-7 (KMHRS) = 0.21 (WT) - 242	R^2=.85; T,F at 95%; CV=28%
100-700 & 900	Group 1-7 & 9 (KMHRS) = 0.23 (WT) - 222	R^2=.88; T,F at 95%; CV=32%
	Group 1-9 (KMHRS) = 0.29 (WT) + 95.6 T-Ship	
100-900	Group 1-9 (KMHRS) = 0.29 (WT) + 1753 A-Ship	
Material Cost	Mat ($K) = 6.65 (WT) + 17,269	R^2=.87; T,F at 95%; CV=15%

4.3.13 Comparison of Actual Versus Estimated Costs

As noted earlier, the limited number of data points and the characteristics of the data spread affect the statistical analysis of the CER's. As a check on the ability of the model to predict actual return costs, a comparison was made between the return costs for the ships in the database and the estimated costs for the ships using the CER's. This comparison uses the ships that comprise the database; however, no other data was available to check the model, and this was considered satisfactory since the database comprises most of the recent ship classes built. This comparison was performed at the construction, production and total cost levels for labor costs, and at the total cost level for material costs. The labor costs were developed by summing the estimated one-digit labor manhours. The comparison is made at the summary levels, since the model is designed to be used at the total ship level. The comparisons are provided for all ships at the construction labor costs summary level; for the AOE 6, T-AGOS 19, T-AO 187, and T-AGS 45 at the production labor cost summary level; and the ships used in the production labor cost summary level at the total ship labor costs level. For the material costs, the T-AGOS 19, T-AO 187, T-AGS 45, AO 180 and AFS 6 costs were compared. The T-AO 191 is not included in any cost comparison since the data for this ship represents only the portion of costs incurred at Tampa Shipyard.

Even though the AO 180 and AFS 6 are follow ships, their return costs were modified by NASSCO cost estimators in the previous model, to reflect lead ship costs. This data was considered valid for SWBS Groups 100 - 700 labor costs and, thus, all ships could be used to develop and compare the construction cost CER's. For SWBS Groups 800 and 900, the previous model provides a constant and not the raw data and, as such, the ships used in the previous model (AO 180, AFS 6, AOR 7) are not used in developing or comparing the production or total ship labor costs. Finally, only lead ships in a lead yard are used in developing and comparing the CER for SWBS Group 800. These comparisons are provided in Table 4-9.

The material cost comparison is provided for lead ships in lead yards and for the ships used in the previous model (AO 180, AFS 6, AOR 7), where return costs were modified by NASSCO cost estimators to reflect lead ships in a lead yard. Although a lead ship in a lead yard, the material costs for the AOE 6 are an outlier due to differences between the AOE 6 and other ships in the data set. As such, they are not used in comparison of the material CER.

The auxiliary model shows more disparity between the actual and estimated data than do the other models. Part of the reason for this is caused by the lower manhour and dollar values to build these ships as well as the different types of ships in the data set. Cost variances among these ships reflect a larger percent difference than do similar size variances on the amphibious on surface combatant ships.

Another factor is that the AOE 6 has an exceptionally large labor costs for SWBS Groups 500 and 600, which affects the CER's for these groups. Because of the configuration of the data, the effect of the AOE 6 is to increase and rotate the linear CER. This causes the CER to underestimate ships at both ends of the spectrum, in particular T-AGOS 19 and AOE 6, and overestimate the ships in the midrange. Consideration was given to using a non-linear CER; however, it would be inconsistent with the experiences on other ship types for these SWBS groups, and it would also provide unacceptable results for ships outside the data range. In addition, although the AOE 6 has experienced considerable construction problems, its cost data fits well with the other data for SWBS Groups 100 - 700. This, and the fact that the AOE 6 is a relevant and recent return cost data point resulted in it being retained in the CER's.

The resultant total ship labor cost comparison indicates that the CER both overestimates and underestimates ships within the range of the model and shows no consistent trend that would suggest an improvement to the CER. The magnitude of this variances ranges from overestimating the T-AO 187 by 20 percent to under estimating the T-AGOS 19 by 22 percent. With the exception of the T-AGOS 19, however, the total ship labor CER estimates within

±20 percent of the actual return costs. This indicates that the model satisfactorily estimates the auxiliary type ship labor costs, but there is inherent spread in the data set.

The comparison of the actual material costs for the ships and the model also indicates that the CER both overestimates and underestimates ships within the range of the model and that no better trend is readily identifiable. In this case, the AOE 6 data is not part of the CER due to its significantly different propulsion system configuration, compared to other ships in the data set. For this reason it is considered an outlier. The magnitude of the variance within the material costs range from overestimating T-AGOS 19 by 51 percent to underestimating AO 180 by 19 percent. With the exception of the T-AGOS 19, the material costs CER estimates within the +7 percent and -19 percent range. The comparison of the actual and estimated material costs indicates that the model satisfactorily estimates this material costs for the auxiliary type ships, but that there is inherent spread in the data.

Table 4-9
COMPARISON OF ACTUAL VS. ESTIMATED COSTS
AUXILIARY SHIPS

	SWBS	Lead Ship / Lead yard											
		AOE 6			T-AGOS 19			T-AO 187			T-AGS 45		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	4,523	3,734	(17)	584	395	(32)	1,874	2,509	34	1,390	1,184	(15)
Production Manhours	100 - 700, 900	5,080	4,271	(16)	802	588	(27)	2,277	2,932	29	1,643	1,461	(11)
Total Manhours	100 - 900	8,052	7,243	(10)	1,103	865	(22)	3,260	3,901	20	2,136	1,992	(7)
Total FY93 Material Cost $K	100 - 900	N/A	N/A	N/A	22.9	34.6	51	102.9	109.8	7	70.5	62.1	(12)

	SWBS	Lead Ship / Follow Yard		
		AOR 7*		
		Actual	Estimated	% Diff
Construction Manhours	100 - 700	2,397	2,463	3
Production Manhours	100 - 700, 900	N/A	N/A	N/A
Total Manhours	100 - 900	N/A	N/A	N/A
Total FY93 Material Cost $K	100 - 900	99.4	102.0	3

	SWBS	Follow Ships Estimated to be Lead Ship					
		AO 180*			AFS 6*		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	1,741	1,397	(20)	1,188	1,810	52
Production Manhours	100 - 700, 900	N/A	N/A	N/A	N/A	N/A	N/A
Total Manhours	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A
Total FY93 Material Cost $K	100 - 900	88.5	72.1	(19)	73.8	77.3	5

4.4 Other Ships

NCA provided CPR data for three classes of small ships for use in the model that did not fit into any of the ship types used in the model. These ships are shown in Table 4-10 and the data on these ships is provided in Section 3.4. These ships represent two types of ships, landing craft and mine warfare craft. They also represent three types of platforms: aluminum air cushion vehicle, a GRP monohull, and a wooden hulled monohull. Given this diversity, it was considered prudent to place these ships in a general category.

TABLE 4-10
OTHER SHIPS

Ship	Class	Shipyard	Cost Data Type	Year Delivere
LCAC 34	LCAC Class Landing Craft Air-Cushion	Avondale		1992
MHC 51	MHC 51 Class Minehunters Coastal	Intermarine	Leadship/Lead Yard	1993
MHC 53	MHC 51 Class Minehunter Coastal	Avondale	Leadship/Follow Yard	1994
MCM 1	MCM 1 Class Mine Counter Measures Vessels	Peterson	Leadship/Lead Yard	1987
MCM 2	MCM 1 Class Mine Counter Measures Vessels	Marinette	Leadship/Lead Yard	1989

Since there are limited numbers of ships of each group, significant differences between the ship types, and a lack of detailed weight data, development of detailed CER's was not accomplished in this model. Instead, the data is presented for each ship, so that it can provide a basis for estimating future similar ships, based on direct comparison.

4.4.1 Other Ships CER's

In this model, a number of summary relationships were evaluated and are presented in the following paragraphs. Only those relationships which made technical sense, and proved to be statistically viable, are presented. In particular, a material cost CER is not provided due to dissimilarities between the three ship types, and a statistically meaningful SWBS Group 800 labor CER is not provided due to lack of data. The lack of a meaningful SWBS Group 800 versus weight CER also prevented development of a total contract labor versus weight CER.

In order to allow a total labor cost CER to be derived, a constant for SWBS Group 800 is provided based on the data available.

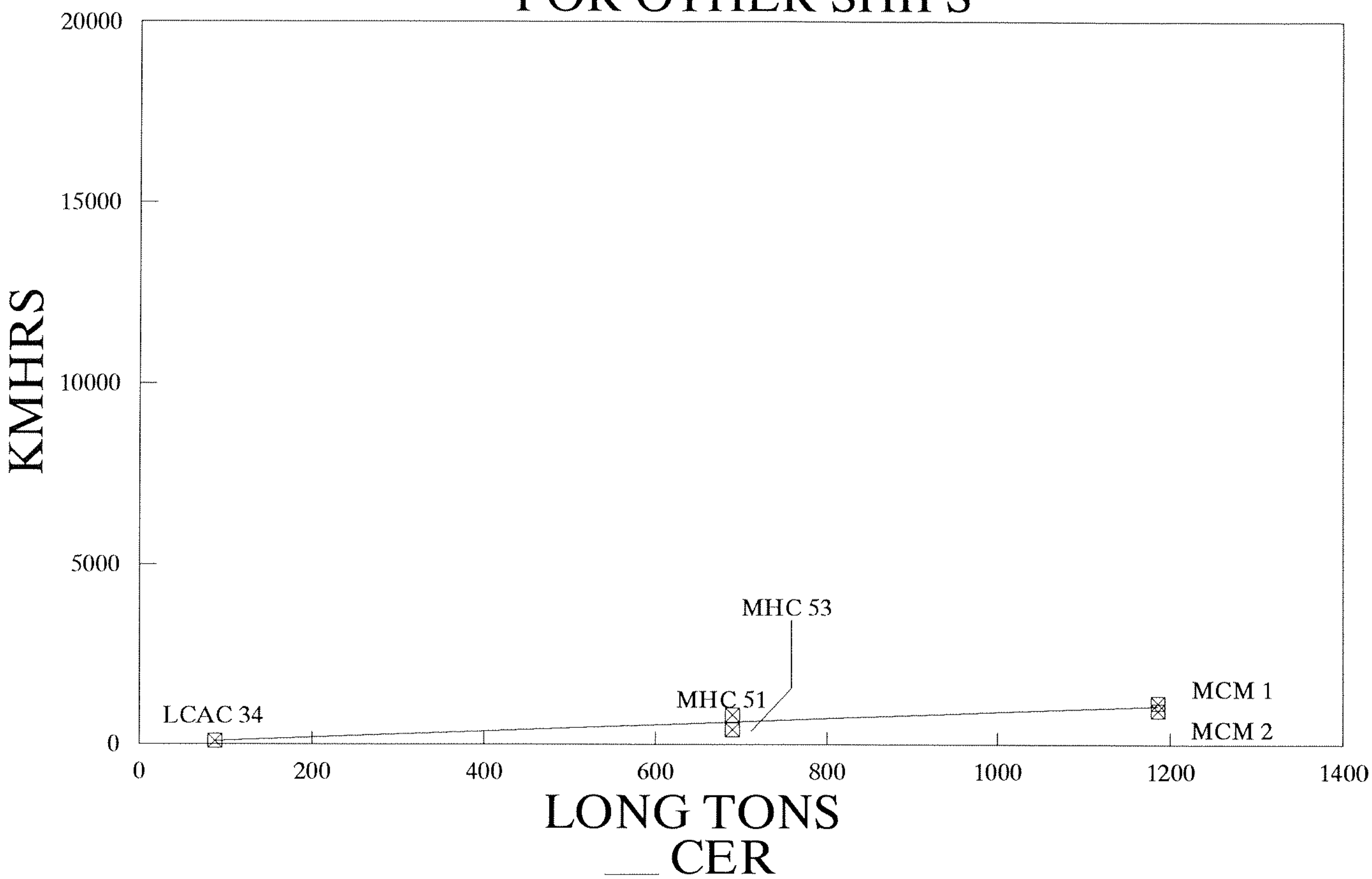
Figure 4-40 provides a labor versus weight CER for construction manhours (SWBS Groups 100-700).

The SWBS Group 100-700 CER for labor versus weight is:

$$KMHRS = 0.875\ LT + 10.7$$

The R^2 value of 0.862 indicates an good correlation. T and F are significant at 95 percent, indicating a statistically significant relationship. The CV of 26.9 percent indicates the model is a good predictor.

LABOR VS. WEIGHT IN GROUP 1-7
FOR OTHER SHIPS



CER: KMHRS = 0.875 LT + 10.7; R^2 = 0.862; T and F are significant at 95%; CV = 26.9%

Regression Output:

Constant			10.7
Std Err of Y Est			183
R Squared			0.862
No. of Observations			5
Degrees of Freedom			3
# Variables			1
X Coefficient(s)		0.875	
Std Err of Coef.		0.202	
T =	4.337	F =	18.81
CV % =		26.9	

DATA

SHIPS	LT 1-7	LAB 1-7
LCAC 34	87	87
MHC 51	690	811
MHC 53	690	417
MCM 1	1,186	1,156
MCM 2	1,186	941

Figure 4-41 provides a labor versus weight CER for production manhours (SWBS Groups 100-700 and 900).

The SWBS Groups 100-700 and 900 CER for labor versus weight is:

$$KMHRS = 1.117\ LT + 48.5$$

The R^2 value of 0.792 indicates a good correlation. T and F are significant at 90 percent, indicating a relationship of questionable significance. The CV of 33.2 percent indicates the model is a good predictor.

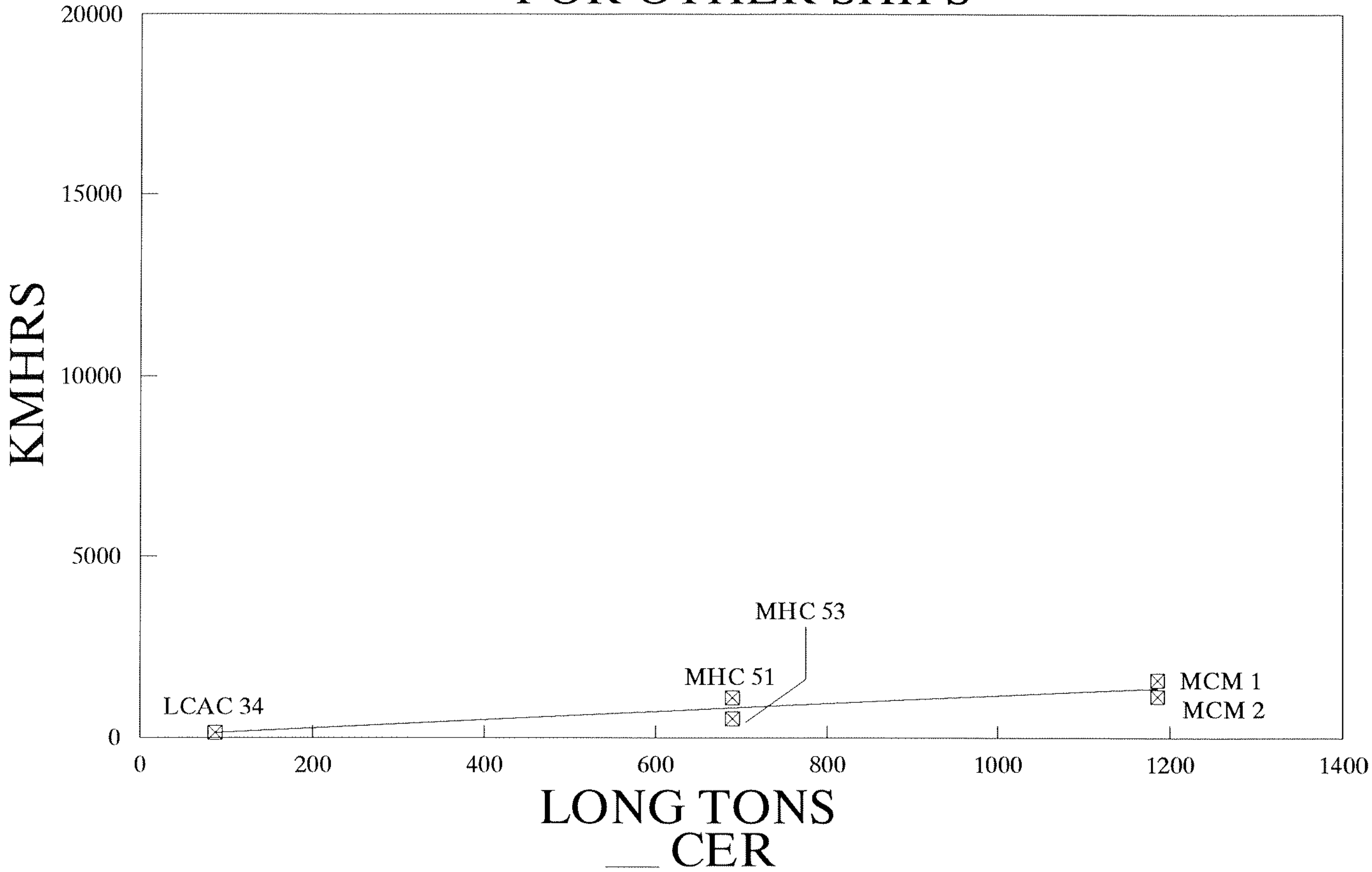
Figures 4-40 and 4-41 show that there is a relationship between weight and aggregate construction and production labor, even given the dissimilarities between the ship types. If this relationship holds, as additional data for ships of this size are added to the data base, it could be the genesis of a set of small ship CER's.

As there are only two lead ships in a lead yard data available, it is not possible to derive a statistically significant CER for SWBS Group 800 for this ship type. In addition, the lighter MHC 51 had a significantly higher Group 800 cost compared to the heavier MCM 1, as shown below. This counters historical trends shown throughout the other ship types. A similar relationship holds for SWBS Group 800 versus production manhours; however, the extent of the difference is reduced, as shown below.

Ship	Weight LT	SWBS Group 800 Labor KMHRS	Production Labor KMHRS
MHC 51	690	625.7	1110.9
MCM 1	1186	332.0	1602.0

Lacking additional data, it is recommended that a constant of 480 KMHRS be used to estimate SWBS Group 800 for ships in this size range.

LABOR VS. WEIGHT IN GROUPS 1-7,9
FOR OTHER SHIPS



CER: KMHRS = 1.117 LT + 48.5; R^2 = 0.792; T and F are significant at 90%; CV = 33.2%

Regression Output:

Constant		48.5
Std Err of Y Est		301
R Squared		0.792
No. of Observations		5
Degrees of Freedom		3
# Variables		1
X Coefficient(s)	1.117	
Std Err of Coef.	0.331	
T = 3.375	F =	11.39
CV % =	33.2	

DATA

SHIPS	LT 1-7	LAB 1-7,9
LCAC 34	87	142
MHC 51	690	1,111
MHC 53	690	537
MCM 1	1,186	1,602
MCM 2	1,186	1,140

4.4.2 Summary of CER's for Other Ships

Table 4-11 shows each CER for Other Ships with its associated statistics listed by cost group.

TABLE 4-11

OTHER SHIP CER's

COST GROUP	RELATIONSHIP	STATISTICS
SUMMARY CER's:		
100-700	Group 1-7 (KMHRS) = 0.88 (WT) + 10.7	R^2=.86; T,F at 95%; CV=27%
100-700 & 900	Group 1-7 & 9 (KMHRS) = 1.12 (WT) + 48.5	R^2=.79; T,F at 90%; CV=33%
SWBS Gr 800	Constant = 480 KMHRS	N/A

4.4.3 Comparison of Actual Versus Estimated Costs

In order to measure the effectiveness of the model, a comparison of the actual return costs versus the estimated return costs using the model was performed. For this category, the comparisons are made for labor manhours at the construction and production cost level for all ships, and at the total labor costs for the MCM 1 and MHC 53. No comparison is made for material costs since there is not a material cost CER.

Table 4-12 provides the results of the comparisons made. Both the construction and production cost comparisons show moderate to poor correlation for all ships, with the range of 24 percent underestimated to 47 percent overestimated for construction costs and a range of 26 percent underestimated to 53 percent overestimated for the production costs.

At the total cost level the range is 26 percent underestimated for the MHC 51 and 7 percent overestimated for the MCM 1. This shows the impact of the limited number of data points and the use of a constant based on these two ships for SWBS Group 800. The use of these CER's for estimating at the total cost level is questionable given the contribution of both the limited SWBS Group 800 data points and the negative trend indicated between the lighter MHC 51 and heavier MCM 1.

The relatively poor correlation between the estimated and actual return costs is due to the inherent differences between the ships within the data base. Another factor is the small magnitude of the costs, which cause the differences to be a larger percentage of the whole compared to equivalent differences in large ships. Another factor is the relatively large differences between lead and follow ships, especially for the MHC 51 where construction and production costs of the follow yard ship is one-half that of lead yard ship. This, plus the large SWBS Group 800 costs for the MHC 51 imply that the MHC 51 may be an outlier. Finally, the negative trend for SWBS Group 800, as noted, indicates that the SWBS Group 800 cost CER is questionable.

Since this category represents a limited collection of different types of ships, the relatively poor correlation between estimated and actual return costs is not surprising. In lieu of better CER's, it is advisable in estimating future ships to compare ships of this size to the most appropriate data in the data set. However, the CER's developed do show a statistically reasonable set of trends for construction and production costs and may prove to be the genesis of a set of small ship cost CER's. As more data is identified, this potential trend should be further analyzed. In the interim, use of these CER's for ships other than mine warfare craft, especially at the total contract level, should be limited.

Table 4-12

COMPARISON OF ACTUAL VS. ESTIMATED COSTS

FOR OTHER SHIPS

	SWBS	Lead Ship / Lead Yard					
		MCM 1			MHC 51		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	1,156	1,048	(9)	811	614	(24)
Production Manhours	100 - 700, 900	1,602	1,374	(14)	1,111	820	(26)
Total Manhours	100 - 900	1,737	1,853	7	1,737	1,298	(25)

	SWBS	Lead Ship / Follow Yard								
		LCAC 34			MCM 2			MHC 53		
		Actual	Estimated	% Diff	Actual	Estimated	% Diff	Actual	Estimated	% Diff
Construction Manhours	100 - 700	87	87	(1)	941	1,048	11	417	614	47
Production Manhours	100 - 700, 900	142	146	3	1,140	1,374	20	537	820	53
Total Manhours	100 - 900	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

5.0 PROCEDURE FOR ESTIMATING CONSTRUCTION COST OF A LEAD SHIP

The procedure for estimating the cost of a lead ship is fairly straightforward. In this chapter, both a manual method and a computer method is presented. Both methods follow the same procedure, which is as follows:

- Develop a set of ship's characteristics and provide physical characteristics for use in exercising the CER's. Most importantly, develop a one digit SWBS lightship weight breakdown.

- Based on the ship's characteristics, select database and CERs that most closely represent the proposed ship for estimating purposes.

- Identify any significant differences between the proposed ship's characteristics and the characteristics of the ships in the selected ship type database. Assess which SWBS groups will be impacted by these differences and whether these differences will significantly affect either the labor or material CER's being used. If no significant differences are identified, the CER's can be used. If significant differences are noted, new CER's may need to be developed using dummy variables to account for the difference. Consideration can also be given to using CER's from other ship types that may more appropriately reflect the difference. Caution should be used when using CER's from other ship types, since they are derived from separate databases and may represent different design criteria and shipyard accounting conditions.

- Estimate individual one-digit SWBS group labor manhours using the CER's for the appropriate ship type.

- Sum the one-digit SWBS group labor manhours to derive a total ship labor manhour estimate.

- Develop fully burdened manhour rates in dollars per hour for production and engineering labor using rates from recent CPR's for similar ships or other sources available to NCA. These manhour rates should be fully burdened and include direct labor, labor overhead, G&A and fee.

- Multiply production manhours (SWBS Group 100-700,900) by the production rate and engineering/integration manhours (SWBS Group 800) by the engineering rate to obtain labor dollars by SWBS groups.

- Adjust the labor rates to represent the anticipated base year of the construction contract for the proposed ship using factors presented in Reference (5).

- Sum the individual SWBS groups to obtain a total labor dollar estimate.

- Estimate total ship FY 93 material dollars using the CER for the appropriate ship type.

- Multiply the FY 93 material dollars by factors to account for G&A, fee and cost of money using percentages from recent CER's for similar ships or other sources available to NCA. (If NAVSEA provided a material cost breakdown for the proposed ship, compare the major elements of the material costs (e.g., steel rates, propulsion motor costs, generator sets, etc.) with current vendor information to check for reasonableness in the proposed estimate. If the proposed material costs are well documented, comprehensive and reasonable, consideration should be given to using this value for the material cost estimate. If the material cost estimate differs significantly from that derived using the CER, the differences must be adjudicated prior to substituting it for the CER derived estimate.)

- Adjust the material dollars to represent the anticipated base year of the construction contract for the proposed ship using factors presented in Reference (5).

- Sum the construction contract base year total labor dollars and total material dollars to develop an estimate for total lead ship construction contract costs in base year dollars for the proposed ship.

- Estimate the percentage of total cost due to change orders using NAVSEA 017's factor of 10 percent of total costs for lead ship (5 percent for follow ship) or base it on actual percentages derived from assessments of return costs of similar ships.

- Subtract the costs for change orders from the total costs to derive a value for bid cost for the ship.

5.1 Manual Approach

Table 5-1 provides a form for summarizing the ship's characteristics to be used in selecting the ship type and the independent variables for the CERs. It is not necessary to fill in all items; however, the one-digit lightship weight estimate is necessary for estimating purposes.

TABLE 5-1

SUMMARY OF SHIP'S CHARACTERISTICS

Ship:
Ship Type:
Anticipated Contract Base Year: FY
Estimator:
Date of Estimate:

LEAD SHIP CHARACTERISTICS		
LENGTH	Overall (ft)	
	At Waterline (ft)	
BEAM	Extreme (ft)	
	At Waterline (ft)	
DRAFT	Maximum Navigational (ft)	
	Limiting (ft)	
MATERIAL	Hull	
	Superstructure	
DISPLACEMENT	Light Ship (LT)	
	Full Load (LT)	
TOTAL ACCOMMODATIONS		
SHAFT HORSEPOWER (SHP)		
ENGINES	Number	
	Manufacturer	
	Type	
MAIN REDUCTION GEARS	Manufacturer	
	Type	
MAIN GENERATORS	Number	
	Type	
	KW	

Table 5-2 provides a work sheet to assist in developing the cost estimate manually. The work sheet is self-explanatory. Of note is that the work sheet is designed to be general. Thus, the factors identified for estimating labor and material burdened rates include labor overhead, G&A, fee and cost of money. Some shipyards use accounting methods that either combine some of these (such as G&A in overhead) or use terminology that is different. If these methods are used in developing a burdened cost, then the estimating work sheet should be modified to suit. The main objective is to develop a fully burdened cost for consistency sake.

TABLE 5-2

WORK SHEET FOR ESTIMATING LEAD SHIP CONSTRUCTION CONTRACT COST

Ship:		Ship Type:
Anticipated Contract Base Year: FY	Estimator:	Date of Estimate:

1. Estimate Labor Costs:

SWBS Group	Light Ship Weight (tons)	CER Used (kmhrs)	Labor (kmhrs)	Burdened Manhour Rate Used ($/mhr)	Base Year Labor $K (FY __)
100					
200					
300					
400					
500					
600					
700					
800					
900					
TOTAL					

2. Adjust labor dollars to anticipated contract base year dollars.

Base year labor dollars = Estimated base year dollars times inflation factor.

= $________K (FY ____) X ________

= $________K (FY ____)

TABLE 5-2
WORK SHEET FOR ESTIMATING LEAD SHIP CONSTRUCTION CONTRACT COST (Cont'd)

3. Estimate FY 93 material dollars:

CER used: FY 93 material dollars = ____
= $________K (FY 93)

4. Multiply by factors for G&A, fee, and cost of money to develop burdened FY 93 material dollars

Burdened FY 93 material dollars = FY 93 material dollars X G&A X fee X cost of money

= $________K (FY 93) X ________ X _____ X _____
= $________K (FY 93)

5. Adjust burdened FY 93 material dollars to anticipated contract base year dollars, using Reference (5).

Contract base year material dollars = FY 93 burdened material dollars times inflation factor.
= $________K (FY 93) X ________
= $________K (FY __)

6. Sum construction contract base year total labor and material dollars to obtain total construction contract cost estimate.

Contract base year labor dollars = $________K (FY __)
Contract base year material dollars = $________K (FY __)

Total construction contract cost estimate = $________K (FY __)

7. Estimate additional costs due to change orders.

Percent of total cost assumed for change orders = ________

Change order construction costs = $________K (FY __) X ________
= $________K (FY __)

8. Subtract the costs due to change orders from the total cost to obtain a bid cost.

Total Cost = $________K (FY __)
- Change Order Costs = $________K (FY __)

Bid Cost = $________K (FY __)

TABLE 5-2
WORK SHEET FOR ESTIMATING LEAD SHIP CONSTRUCTION CONTRACT COST (Cont'd)

9. Perform statistical analysis of estimate.

R^2 (correlation coefficient)^2:

$$R^2 = \frac{\Sigma\,(\bar{y} - \hat{y}_i)^2}{\Sigma\,(\bar{y} - y_i)^2}$$

R^2 = ________

where: $\bar{y}$ = mean y value

$\hat{y}_i$ = y estimate for x_i using CER

y_i = actual y value for x_i

T statistic:

$$T = \frac{A}{S_x} \qquad Sx = \sqrt{\frac{(Sy)^2}{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2}}$$

T = ______ Sx = _____

where:
A = x coefficient
Sx = standard error of the coefficient
Sy = standard error of the y estimate
x_i = actual x values

n = number of observations

TABLE 5-2
WORK SHEET FOR ESTIMATING LEAD SHIP CONSTRUCTION CONTRACT COST (Cont'd)

F statistic:

$$F = \frac{R^2/k}{(1-R^2)/(n-k-1)}$$

F = ______

where:

	R^2	=	(correlation coefficient)^2
	n	=	number of observations
	k	=	number of independent variables

notes: (n-k-1) = degrees of freedom

CV (coefficient of variation):

$$CV = \frac{Sy}{\bar{y}} \qquad Sy = \sqrt{\frac{\Sigma(y_i - \hat{y}_i)^2}{dof}}$$

CV = ______ Sy = ______

where:

$\bar{y}$	=	mean y value
Sy	=	standard error of y estimate
y_i	=	actual y value for x_i
$\hat{y}_i$	=	y estimate for x_i using CER
dof	=	degrees of freedom

5.2 PC Version

A cost estimate can also be developed using the PC database. Appexdix A provides a users manual that provides guidelines on the use of the model.

6.0 CONCLUSIONS

This report and supporting PC-based model present a method for estimating the lead ship construction labor and material costs for U.S. Naval Surface Combatants, Amphibious Ships and Auxiliary Ships. The model is based on a database comprised of return cost data derived from shipyard costs reported to the Navy via shipyard cost performance reports. The model categorizes costs by ship type, and by a one-digit SWBS breakdown for labor costs and total ship costs for material costs.

Cost Estimating Relationships (CER's) are presented using general ship's characteristics, such as weight, shaft horsepower, total accommodations and months in shipyard, as independent variables. The CER's are linear, single variable relationships. The CER's estimate total shipyard construction costs, including detail design and engineering. The CER's do not estimate GFE or other costs incurred by the Government. The CER's estimate labor costs in manhours and material costs in FY 93 dollars.

A total shipyard construction cost estimate is developed by adding the estimated total labor cost (derived by summing individual one-digit labor manhours multiplied by the burdened rate for each SWBS Group for the anticipated year of construction) and the estimated total material cost (derived by estimating the FY 93 material costs multiplied by an appropriate G&A and fee and escalated to the anticipated construction year). This total construction cost is then adjusted to reflect a shipyard bid cost by subtracting out an estimated cost for change order work during construction derived using a NAVSEA factor, or based on an assessment of historical trends for the ship type being considered.

A summary of the key findings, conclusions and recommendations made during the development of this model is as follows:

- Use of CPR data provides a reliable database for a large variety of ships and from the major shipyards doing Navy work. The CPR data provides labor costs in manhours and dollars, and material costs in dollars. The CPR data also provides information on the contract types, the burdens applied to the costs, and other pertinent cost information.

- CPR data is not sufficiently detailed to assign costs to the 22 cost groups used in previous models. Shipyards present costs in a variety of ways including SWBS breakdown, construction trade, zone, module, or total cost. For the model, labor costs were assigned to one digit SWBS cost groups by analysis of the CPR data, use of historical trends at the shipyard for similar ships, and by best engineering judgment. Material costs were not broken down by SWBS, since the material costs tended to be reported as a single item in the CPR's.

- Labor manhours were used in the model to reduce uncertainties caused by variable rates between shipyards, and by the need to escalate the costs to FY 93 dollars. This is also consistent with the approach used in previous models.

- Material dollars were used in the model. Actual material dollars were escalated to FY 93 dollars using Reference (5). The then-year for the escalation was determined from the contract type, with fixed price contract data escalated from a contract base year and cost type contract data escalated from the CPR report year.

- Cost data for each ship type was compared to the other data in the data set to identify any outliers requiring further analysis. Outlying data was assessed to determine if the data was complete; if its SWBS assignment was correct; if it had been correctly adjusted for inflation; and if a suitable technical reason existed for its value. In most cases, the outliers were properly adjudicated and incorporated into the model. Outliers that represented incomplete or unexplainable data were deleted, as were outliers that were significantly technically different than the other data.

- Both lead ship in a lead yard and lead ship in follow yard data were used in the model. This is consistent with previous construction models. Follow yard data are considered satisfactory for use in estimating lead ship production (SWBS Groups 100-700, and 900) labor costs. The follow yard data are not suitable for estimating engineering and integration costs (SWBS Group 800) since they do not include the non-recurring costs (such as detail design and engineering) incurred under a lead ship contract. The follow yard data were also considered questionable for estimating material costs for a lead ship for a number of reasons. These include non-recurring costs and the fact that follow ships are often provided with a different mix of equipment as GFE than a lead ship. This GFE is often purchased as class buys using a separate contract. Even if these GFE costs are assigned to the construction contract, their value may reflect savings or handling costs resulting from group buys that would not be reflected in a lead ship contract. Thus, only lead yard data are used in developing CER's for SWBS Group 800 labor costs and for material costs.

- Return cost data from previous models were used in this model when considered appropriate and when more recent CPR data was unavailable. Care was taken not to include any total estimates used in the previous models in developing CER's. In certain cases adjusted return cost data was included since it was reflective of lead ship return costs. Also, in a number of cases, estimates used in the previous models were displayed on the graphical representation of the CER. This was done for comparison, since this estimated data is based on a shipyard cost estimator's best judgement. Although not an element of the CER, these estimates improve confidence in the CER, and also help relate the historical data to the current CPR derived data. In all cases, adjusted or estimated data is identified in the model.

- Linear, non-linear, multi-variate and dummy variable analyses were considered in developing CER's for the model. Linear, single variable CER's were used in the model. Historically, construction cost models have used linear single variable CER's, and the current model continues this trend. The data supports using linear regressions as satisfactory CER's, and, given the few data points in any data set, higher order regressions may be specious and would potentially give very poor estimates outside the range of the data. In addition, the structure of the model, which divided the data by ship types and subdivided the data by SWBS group for similar ship types, obviated the need for multi-variate analyses or use of dummy variables for developing adequate CER's.

- Although a number of independent variables were used in developing CER's for the model, lightship weight was the primary independent variable used. This was based on historical trends and the satisfactory results obtained. In addition, weight is a variable that affects all SWBS groups. In developing the CER's a total ship's weight was broken down by SWBS group, as were the ship's return costs. The relation between these two assures that in aggregate, all weight and cost items are accounted for. Thus, when estimating a new ship, summing the costs by SWBS groups derived from weight based CER's assures a direct accounting for the weight items on the ship and the total costs estimated.

- In developing the CER's, data outliers were assessed to determine if they should be included in the CER. As noted earlier, incomplete, estimated, or inappropriate data was deleted from the CER's. Remaining outliers were incorporated into the CER's, or, if appropriate, used to develop a separate CER. Since a number of the outliers, such as costs for the DDG 51 or AOE 6, represent recently constructed ships, their data was considered critical for the model and was included in developing the CER's.

- The model contains summary labor CER's for SWBS Groups (100-700), SWBS Groups (100-700 and 900) and SWBS Groups (100-900). SWBS Groups (100-700) represent what has been historically referred to as the ship's construction costs in previous models. SWBS Groups (100-700 and 900) correlate roughly to the ship's production costs, as used in the CPR's. SWBS Groups (100-900) represent the total contract costs. All of these summaries, like all the CER's, represent the lead ship at completion of the ship construction program.

- A statistical assessment is made for each CER. Values for R^2 (correlation coefficient squared), T, F and CV (coefficient of variation) were analyzed for each CER.

- The model does not contain labor rates, burdening factors (overhead, G&A and fee), or GFE costs, since these are available to NCA from other sources.

- The overall model builds upon and retains many of the good features of previous models. This includes model structure, SWBS categorization, CER's based on ship's characteristics, differentiation of ship types, estimating of labor manhours and material costs, and appropriate historical data or data trends.

- This model includes all detail design and engineering costs within SWBS Group 800. This differs from previous models, which kept these costs separate. Including the detail design and engineering costs more appropriately represents CPR contract data, and assures that the total contract costs are estimated. Inclusion of this data also highlights the relative magnitude of SWBS Group 800 to the other ship's construction costs. This is most significant for surface combatants where, for example, SWBS Group 800 represents 51 percent of the total contract manhours for the DDG 51.

- The overall statistics associated with the CER's indicate that the individual CER's show good correlation between the data and the CER.

- Comparisons between the estimated total contract labor and material costs derived from the model and the actual return costs for the ships used in developing the model indicate that the model satisfactorily estimates these historical construction costs. The model will also predict future ship's costs, providing the ships do not significantly differ from ships in the database and that shipbuilding practices do not significantly change.

- The PC based database and model provide an interactive method for both exercising the model and for adding new data to the model. It also automatically estimates the costs and associated statistical data.

- Although the database for the model is extensive, it is recommended that new data be added when it is identified. Care needs to be taken in adding data to assure it is done in a consistent manner. Of particular interest is lead yard data, since the number of data points is small, and these costs determine both the SWBS Group 800 and material cost CER's.

- It is recommended that NCA consider developing the cost model to the original 22 cost group level. Although the CPR data is accurate, the loss of detail hinders analyses of costs. It is also not possible to isolate cost drivers or to be sensitive to differences between ships. Further refinement of the model should consider use of key shipyards to provide a three digit SWBS breakdown of their costs for specific recent ships, such as the DDG 51, LSD 44, AOE 6, or LHD 1. This could be reformatted into the 22 cost groups, compared against historical trends, and 22 new cost group CER's developed.

APPENDIX A

USER GUIDE TO THE PC CONSTRUCTION COST MODEL

APPENDIX A

USER GUIDE TO THE PC CONSTRUCTION COST MODEL

1.0 REQUIREMENTS AND GENERAL INFORMATION

1.1 Requirements

To use the PC Construction Cost Model, Lotus 1-2-3 Release 3.1 and the WYSIWYG application need to be installed on the hard drive. Also, due to the file size of the PC Construction Cost Model, a minimum of 3Mb of memory is recommended to avoid problems with saving the file.

1.2 Loading the Model

It is recommended that the cost model with its format file be copied to the hard drive to increase the speed of calculations performed in the model during use. Be sure that both of the following files are copied:

CSTMDL94.WK3
CSTMDL94.FM3

Start Lotus 1-2-3 Release 3.1 and add-in the WYSIWYG application. Perform a File Retrieve of CSTMDL94.WK3 from the directory. The menu system starts automatically upon loading. The Main Menu will appear as shown in Figure A-1.

Figure A-1

Main Menu

MAIN MENU

PLEASE DETERMINE WHICH TYPE OF SHIP YOU WISH TO EXPLORE

A --- Surface Combatants

B --- Amphibious Ships

C --- Auxiliary Ships

D --- Other Ships

E --- End Lotus Session (Wait until printer is finished)

X --- Exit Menu Program (Press Alt-M to restart)

TYPE THE LETTER OF YOUR CHOICE:

1.3 Setting Up the Printer

This procedure is highly recommended because it confirms that you have the right printer and port selected. If printing problems have occurred, going through this procedure should correct most problems.

The file, when loaded, defaults to Printer 2. If your computer does not have a Printer Driver 2, then the program will load with no device driver installed. To install a printer driver or change the printer driver, follow this procedure:

1) Start at the Main Menu (if the menu system has been interrupted, press Alt-M to restart the menu system).
2) Press [X] to exit the menu system.
3) Press [:], [P], [C], [P] (this moves you to the printer driver selection screen).
4) Select the printer you wish to use. (Do this by using the arrow key to cycle through the choices, then press [Enter] on your choice.)
5) Press [I] (this moves you to the printer port selection screen).
6) Select the printer port for the printer you have selected.
7) Press [Q], [L], [D], [U] (this updates the default setting to the ones you just input).
8) Press [Q], [Q], Alt-M (to restart the menu system).

1.4 Operation of the Menu System

The menu system operates by user input of letters corresponding to choices on the menu. If a key is pressed that does not correspond to a valid selection on the current menu, an error message will sound and prompt the user to check their selection and press [Enter] to try again. Occasionally, the user will also be prompted for other selected keystrokes, such as [Enter], Alt-A, Alt-B, etc. In the event that an error or other user input aborts the menu system, then restart the menu system by pressing Alt-M.

2.0 Using the Model

From the Main Menu, (Figure A-1) select the type of surface ship desired. Choices are: Surface Combatants, Auxiliary, Amphibious, or Other Ships. Other Ships include coastal minehunters, mine countermeasure vessels, and air cushion landing vehicles (LCAC). Other choices available from this menu are to End Lotus Session (file is automatically saved) and Exit the Menu Program (Alt-M restarts the menu system).

Once a ship type is selected (from the Main Menu), the Group Menus provide the options described below. There are four Group Menus -- one for each ship type. The Group Menu for Surface Combatants is shown in Figure A-2. (Due to limited data, no CER's for Groups 1-7 are available for Other Ships.)

Figure A-2

Group Menu

(for Surface Combatants)

SURFACE COMBATANTS
WHAT WOULD YOU LIKE TO DO?

A --- Input New Ship Characteristics & Weight Breakdown

B --- Calculate New Regressions (Input New Ship First)

C --- Print New Ship Data (Calculate New Regressions First)

D --- Print Original Data

E --- Price Out a New Ship

F --- View New Graphs (Calculate New Regressions First)

X --- Return to Main Menu

TYPE THE LETTER OF YOUR CHOICE:

A. Input New Ship

Note: To price out a new ship based on the original CER's described in Chapter 4 of this report, go directly to Option E - Price Out a New Ship. You do not need to input the new ship through Option A.

This section is used to input all known information for a ship to see how the addition of this ship to the data base would affect the existing CER's. To do this, you must input a SWBS Weight breakdown (in long tons), a SWBS Labor breakdown (in KMHRS), the total unburdened unescalated material cost (in $M), the Shaft Horsepower (SHP), the Complement, and the number of Months to Construct the ship.

Option A of the Group Menu allows the user to input data for a ship which can be used for either pricing out a ship or to use the ship's data to see how it affects the existing CER's. To see how the ship's data affects the existing CER's, you must have an estimate of the ship's labor and material costs (which can be done through Option E - Price Out a New Ship). Required data input such as ship name, lightship weight, labor manhours and material costs appear as shaded cells in the worksheet. Optional data input appear as clear cells in the worksheet. Optional data are for the user's information only—they are not used in any calculations or functions of the program. When the PC Construction Cost Model is used for the first time, the program has existing data for a sample ship called "Myship." This sample ship data is provided to show the user the type of data available for input and its format (i.e., weight is entered in long tons; length, beam and draft are entered in feet, etc.). The abbreviations used in the model follow those in the Naval Vessel Register. The program will ask if previous input data should be erased or modified before prompting for new data (see

Figure A-3). The first-time user should select "modify" so he can become familiar with the type and format of data available for input by reviewing the sample ship data. The cursor will be highlighted on a cell where the new ship name should be input. (See Figure A-4, example ship name is "Myship.") Enter the ship's information in the same row, using the cursor keys to move from one field to the next. All the data fields allowed for input are shown in condensed form in Figure A-5. The shaded cells must be entered to calculate new regressions. After entering the data, return to the Group Menu by typing the designated keystrokes as noted on the screen.

Figure A-3

Erase or Modify Prompt

DO YOU WANT TO ERASE PREVIOUS SHIP DATA, OR MODIFY PREVIOUS SHIP DATA?
E --- Erase Previous Ship Data
M --- Modify Previous Ship Data
X --- Return to Group Menu
TYPE THE LETTER OF YOUR CHOICE:

Figure A-4

Partial Input Screen

New Ship Input Section
SURFACE COMBATANTS

SURFACE COMBATANTS

		LIGHTSHIP WEIGHT (LONG TONS)					
SHIPS	BUILDER	1	2	3	4	5	6
* MYSHIP	AVONDALE	5,400.0	600.0	400.0	250.0	1,100.0	700.0

^

* --- SYMBOLIZES A SHIP THAT WASN'T COMPLETED AT THE TIME OF THE REPORT

ONCE FINISHED PRESS ALT-A

Figure A-5

Full Input Screen

New Ship Input Section

SURFACE COMBATANTS		SURFACE COMBATANTS							SURFACE COMBATANTS				SURFACE COMBATANTS			
		LIGHTSHIP WEIGHT (LONG TONS)							LABOR (KMHRS)				LABOR (KMHRS)			
SHIPS	BUILDER	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
*MYSHIP	AVONDALE	5,400.0	600.0	400.0	250.0	1,100.0	700.0	300.0	1,707.000	192.000	782.000	197.000	1,203.000	1,158.000	97.000	10,851.000
^																

* --- SYMBOLIZES A SHIP THAT WASN'T COMPLETED AT THE TIME OF THE REPORT

SHADED CELLS ARE REQUIRED FOR CALCULATE NEW REGRESSIONS

ONCE FINISHED PRESS ALT-A

SURFACE COMBATANTS					SURFACE COMBATANTS					SURFACE COMBATANTS						SURFAC
LABOR (KMHRS)						MATERIAL $M				SHIP CHARACTERISTICS						SHIP CH
					CONTRACT					LENGTH		BEAM		DRAFT		
9	SUM 1-7	PROD	TOTAL	SUM 1-9	AWARD	BGT YR	BY $M	FY93	FACTOR	OVERALL	LWL	EXTREME	BWL	MAXNAV	LIMIT	HULL
2,358.000	5,336.000	7,694.000	18,876.000	18,545.000	06/91	1993	305.712	305.712	1.0000	300.0	250.0	40.0	38.0	25.0	20.0	ST
	^ CALC	^ CALC		^ CALC	^ 'MM/YY	^ YYYY		^ CALC	^ ENTER FACTOR AS +AY## WHERE ## IS THE BUDGET YEAR EX: 1991 --> +AY91							Λ HULL AND S MATERIALS INPUTTED A AL - ALUMI ST - STEEL ETC...

E COMBATANTS					SURFACE COMBATANTS						SURFACE COMBATANTS				
IARACTERISTICS								SHIP CHARACTERISTICS			SHIP CHARACTERISTICS				
	DISPLACEMENT			TOTAL	START	DELIVERY	MONTHS	ENGINES		REDUCT. GEAR	GENERATORS			NO. OF	TOTAL
SS	LIGHT	FULL	COMPLEMENT	ACCOM	CONST.	DATE	IN YARD	NUMBER	TYPE	TYPE	NUMBER	TYPE	TOT KW	SCREWS	SHP
ST	8,750	9,000	50	75	10/13/91	12/25/93	26.4	8 GT		DBL	20 GT		200,000	4	80,000
SUPERSTRUCTURE SHOULD BE AS: INUM -					'MM/DD/YY Λ M1/D1/Y1	'MM/DD/YY Λ M2/D2/Y2	Λ FOLLOW FORMULA BELOW V								

[(((# of days in M1) - D1) / (# of days in M1))
+ (# of months between (M1+1) , Y1 & M2 , Y2)
+ (D2 / (# of days in M2))]
Example:
04/15/85 06/06/87
[((30-15) / 30) + (25) + (6 / 30)] = 25.7

B. Calculate New Regressions

NOTE: Option A (Input a New Ship) must be fully completed before this option is run.

This section is used to process the data input in Section A into two sets of graphs. One set (Original Regressions) uses the original CER's from this report and shows where the new ship lies on the existing model CER. The other set (New Regressions) recalculates the CER with new ship included and shows where the new ship lies with the new CER.

Option B of the Group Menu allows the user to recalculate regressions using data input through Option A. Before calculating new regressions, the program asks the user to verify that a new ship has been input (see Figure A-6). After verification, this option calculates new regressions using the new ship and updates all the graphs to include the new ship. At this point the user is informed that Lotus 1-2-3 needs to initialize the graphs to be updated (see Figure A-7). This consists, in part, of displaying each graph to be updated in its previous form. The user needs to press [Enter] after each graph appears until the View Graphs with New Data Point Included Using Original Regression Menu appears (see Figure A-8). When this menu appears, each graph has been initialized and updated. (The user is now at Option F -- View New Graphs.)

Figure A-6

Verify Input Prompt

```
HAVE YOU INPUT A NEW SHIP? (Y/N)
TYPE (N) TO RETURN TO THE PREVIOUS MENU
WITHOUT CALCULATING NEW REGRESSIONS
```

Figure A-7

Graph Update Warning

IMPORTANT: IN ORDER TO UPDATE THE GRAPHS, LOTUS MUST FIRST INITIALIZE EACH GRAPH. THIS INITIALIZATION CONSISTS IN PART OF DISPLAYING AN INCORRECT GRAPH ON THE SCREEN. CONSEQUENTLY, A SERIES OF INCORRECT GRAPHS MUST BE DISPLAYED. PLEASE DISREGARD THESE GRAPHS AND PRESS "ENTER" REPEATEDLY UNTIL THE MENU APPEARS, WHERE YOU WILL BE ABLE TO VIEW ALL OF THE CORRECT, UPDATED GRAPHS.

ONCE READY TO CONTINUE, PRESS ANY KEY

Figure A-8

View Graph Menu

VIEW GRAPHS WITH NEW DATA POINT INCLUDED
USING ORIGINAL REGRESSION
PLEASE CHOOSE A GRAPH TO BE VIEWED

A	---	Group 1 CER	M	---	Material Cost CER
B	---	Group 2 CER	N	---	Groups 8, 9, 1-7, 1-7&9, 1-9, & Material Cost CERs
C	---	Group 3 CER			
D	---	Group 4 CER			
E	---	Group 5 CER	O	---	Groups 2, 6, 8, & 9 non-CERs
F	---	Group 6 CER			
G	---	Group 7 CER	P	---	All Graphs CERs & non-CERs
H	---	Group 8 CER			
I	---	Group 9 CER	Q	---	Continue to Next View Menu
J	---	Group 1-7 CER			
K	---	Group 1-9 CER	X	---	Return to Previous Menu
L	---	Group 1-7,9 CER			

TYPE THE LETTER OF YOUR CHOICE:

C. Print New Ship Data

NOTE: Option B (Calculate New Regressions) must be completed before this option is run.

Option C of the Group Menu allows the user to print the line graphs with either the new or original regressions, bar graphs, and data bases, including the new ship. Because there are two options for printing line graphs with the new ship, the program asks the user which option is desired (See Figure A-9). Printing with the original regression shows where the new ship data point falls on the existing model CERs. Printing with new regressions shows where the new ship data point fits if the CERs are recalculated using the new ship data point as if it were a return cost. This option then goes to the Print Line Graph Menu (Figure A-10) to allow printing of line graphs, and then to the Print Bar Graph Menu (Figure A-11) to allow printing of bar graphs. At this point, the user may return to the previous menu (Figure A-9) to select printing with original or new regressions or continue to the Print Data Base Menu (Figure A-12). The weight, labor cost, and material cost and ship characteristic data bases can be printed from this menu. Other options available from the Print Data base Menu are to return to the previous menu or return to the Group Menu.

1) Other Ships
The print routine for Other Ships is different from that for Surface Combatants, Auxiliary and Amphibious Ships in that the line and bar graphs menus are combined into one menu: the Print Other Graphs Menu.

Figure A-9

Print Option Prompt

PRINT WITH (O)RIGINAL OR (N)EW REGRESSIONS ? (O/N) TYPE (X) TO RETURN TO THE PREVIOUS MENU

Figure A-10

Print Line Graphs Menu

SURFACE COMBATANTS
PRINT LINE GRAPHS
PLEASE CHOOSE A GRAPH TO BE PRINTED

A	---	Group 1 CER	M	---	Material Cost CER
B	---	Group 2 CER	N	---	Groups 8, 9, 1-7, 1-7&9, 1-9, & Material Cost CERs
C	---	Group 3 CER			
D	---	Group 4 CER			
E	---	Group 5 CER	O	---	Groups 2, 6, 8, & 9 non-CERs
F	---	Group 6 CER			
G	---	Group 7 CER	P	---	All Graphs CERs & non-CERs
H	---	Group 8 CER			
I	---	Group 9 CER	Q	---	Continue to Next View Menu
J	---	Group 1-7 CER			
K	---	Group 1-9 CER	X	---	Return to Previous Menu
L	---	Group 1-7,9 CER			

TYPE THE LETTER OF YOUR CHOICE:

Figure A-11

Print Bar Graphs Menu

SURFACE COMBATANTS
PRINT BAR GRAPHS
PLEASE CHOOSE A GRAPH TO BE PRINTED

A	---	Group 1 CER	K	---	Group 1-7&9
B	---	Group 2 & MHRS/SHP	L	---	Group 1-9
C	---	Group 3	M	---	Material Cost
D	---	Group 4	N	---	Groups 8,9, 1-7, 1-7&9,
E	---	Group 5		---	1-9, & Material Cost
F	---	Group 6 & MHRS/Accom	O		All Graphs
G	---	Group 7	Q	---	Continue to Next
H	---	Group 8 & 1-7,9/8			Print Menu
I	---	Group 9 & MHRS/Month	X	---	Return to Previous
J	---	Group 1-7			Print Menu

TYPE THE LETTER OF YOUR CHOICE:

Figure A-12

Print Data Bases Menu

SURFACE COMBATANTS
PRINT DATA BASES
PLEASE CHOOSE A DATA BASE TO BE PRINTED

A --- Weight Data base

B --- Labor Data base

C --- Material Data base

D --- Characteristic Data base

Q --- Return to Group Menu

X --- Return to Previous Print Menu

TYPE THE LETTER OF YOUR CHOICE:

D. Print Original Data

Option D of the Group Menu prints the original model line graphs with statistics, the original bar graphs, and the original data bases.

This option starts with the Print Line Graphs Menu (as shown in Figure A-10). From this menu, the user can print line graphs or continue to the Print Bar Graphs Menu (as shown in Figure A-11). From this menu, the user can print Bar Graphs, return to the previous menu, or advance to the Print Data bases Menu (as shown in Figure A-12). From the Print Data bases Menu, the user can print desired data bases, return to the previous menu, or return to the Group Menu.

1) Other Ships

The print routine for Other Ships is different from that for Surface Combatants, Auxiliary and Amphibious ships in that the line and bar graphs menus are combined into one menu: the Print Other Graphs Menu.

E. Price Out a New Ship

Note: Option A (Input a New Ship) from the Group Menu must be completed before running Parts A or B, but is not necessary for Parts C or D.

Option E of the Group Menu allows the user to estimate labor manhours by SWBS group and total material costs for a new ship (Parts A ad B use the weights provided by the user in section A (Input New Ship); Parts C and D use the weights provided by the user in Part C of this section (Input Weights for a

New Estimate). Upon entering this option, the Price Out a New Ship Menu (Figure A-13) appears, from which all the following parts are accessed.

Part A - View Cost Estimate for New Ship

This part allows the user to view a screen (Figure A-14) that shows labor and material estimates based on the new ship weights input in Section A (Input a New Ship), then returns to the Price Out a New Ship Menu.

Part B - Print Cost Estimate for New Ship

This part prints the screen that was shown in Part A (View Cost Estimate for New Ship) then returns to the Price Out a New Ship Menu.

Figure A-13

Price Out a New Ship Menu

SURFACE COMBATANTS
PRICE OUT A NEW SHIP

WHAT WOULD YOU LIKE TO DO?

A --- View Cost Estimates for New Ship (Must Input New Ship First)

B --- Print Cost Estimates for New Ship (Must Input New Ship First)

C --- Input Weights for a New Estimate

D --- Print New Estimate

X --- Return to Group Menu

TYPE THE LETTER OF YOUR CHOICE:

Figure A-14

Labor and Material Cost Estimate

SWBS GRP	WEIGHTS	CER PRESS ANY KEY TO RETURN			LABOR KMHRS	MAT $K
1	4000	KMHRS=	0.285 WT +	145.7	1287	
2	1000	KMHRS=	0.281 WT +	34.8	316	
3	500	KMHRS=	2.892 WT +	-349.0	1097	
4	600	KMHRS=	0.442 WT +	106.4	372	
5	1100	KMHRS=	1.150 WT +	-56.8	1208	
6	750	KMHRS=	2.323 WT +	-416.4	1326	
7	400	KMHRS=	0.209 WT +	15.8	100	
1-7	8350	KMHRS=	0.635 WT +	109.4	5413	
8		KMHRS=	1.267 WT +	-239.2	10,344	
9		KMHRS=	0.258 WT +	104.6	2255	
1-7&9		KMHRS=	0.853 WT +	326.6	7447	
1-9		KMHRS=	2.120 WT +	87.4	17,791	
		MAT $K=	41.563 WT +	-47,913.4		299,139

Part C - Input Weights for a New Estimate

This part starts by warning (Figure A-15) that these weights will not carry over to any other part of the program [i.e., it will not change data input under Option A (Input a New Ship); this is done to protect any data you may have entered under Option A from being overwritten]. The program moves to a worksheet (Figure A-16) similar to that in Part A. Here, the user is required to input a one-digit SWBS weight breakdown, which the program will use to estimate SWBS breakdown of labor KMHRS and total material costs for the new ship. This screen can also be used for "what if" scenario testing. For example, the user could change all or parts of the weight breakdown (without affecting data input through Option A) to see instantly how the changes affect estimates for labor and material costs of the ship. Then the program returns to the Price Out a New Ship Menu.

Part D - Print New Estimate

This part again reminds the user that the weights that are printed out are not used elsewhere in the data base. It then prints the screen from Part C where the weights were modified. It returns to the Price Out a New Ship Menu after printing.

Part X - Return to Group Menu

Figure A-15

Weights Warning

NOTE: WEIGHTS MODIFIED IN THIS PORTION OF THE PROGRAM WILL NOT CARRY OVER TO ANY OTHER PORTION OF THE PROGRAM; IN ORDER TO CHANGE WEIGHTS IN ANY OTHER PORTION OF THE PROGRAM, YOU MUST DO SO THROUGH THE "INPUT NEW SHIP CHARACTERISTICS AND WEIGHT BREAKDOWN" OPTION.
PRESS ENTER TO CONTINUE

Figure A-16

Labor and Material Cost Estimate
(Based on Modified Weights)

SWBS GRP	WEIGHTS	CER			LABOR KMHRS	MAT $K
	MODIFY SHADED AREA ONLY! PRESS [ALT-W] TO RETURN					
1	3250	KMHRS=	0.285 WT +	145.7	1073	
2	750	KMHRS=	0.281 WT +	34.8	245	
3	500	KMHRS=	2.892 WT +	-349.0	1097	
4	600	KMHRS=	0.442 WT +	106.4	372	
5	750	KMHRS=	1.150 WT +	-56.8	806	
6	300	KMHRS=	2.323 WT +	-416.4	281	
7	500	KMHRS=	0.209 WT +	15.8	120	
1-7	6650	KMHRS=	0.635 WT +	109.4	4333	
8		KMHRS=	1.267 WT +	-239.2	8189	
9		KMHRS=	0.258 WT +	104.6	1817	
1-7&9		KMHRS=	0.853 WT +	326.6	5997	
1-9		KMHRS=	2.120 WT +	87.4	14,186	
		MAT $K=	41.563 WT +	-47,913.4		228,482

F. View New Graphs

Note: Option B (Calculate New Regressions) must be run before viewing new graphs. At the conclusion of running Option B, the program automatically places the user at the View New Graphs Menu.

Option F of Group Menu allows the user to view all of the graphs with the new ship, whether they are line or bar, new or original regressions. Option F starts with the View Graphs with New Data Point Included Using Original Regressions Menu (as shown in Figure A-17). Any of the graphs using original regressions may be viewed from this menu. The user may then choose to return to the Group Menu or advance to the View Graphs with New Data Point Included with New Regression Menu (Figure A-18). From this menu any of the graphs with new regressions can be viewed. After viewing, the user must decide to return to the previous menu or advance to the View Bar Graphs with New Data Point Menu (Figure A-19). From this menu any bar graph may be viewed. After viewing, the user must decide to return to the previous menu or return to the Group Menu.

1) Other Ships

The View Graph routine for Other Ships is different from that for Surface Combatants, Auxiliary and Amphibious Ships. For Other Ships, the View Other Line Graph Menu combines the View Graphs Using Original regressions with the View Graphs Using New Regressions.

Figure A-17

View Graphs

Using Original Regression Menu

VIEW GRAPHS WITH NEW DATA POINT INCLUDED
USING ORIGINAL REGRESSION
PLEASE CHOOSE A GRAPH TO BE VIEWED

A	---	Group 1 CER	M	---	Material Cost CER
B	---	Group 2 CER	N	---	Groups 8, 9, 1-7, 1-7&9, 1-9, & Material Cost CERs
C	---	Group 3 CER			
D	---	Group 4 CER			
E	---	Group 5 CER	O	---	Groups 2, 6, 8, & 9 non-CERs
F	---	Group 6 CER			
G	---	Group 7 CER	P	---	All Graphs CERs & non-CERs
H	---	Group 8 CER			
I	---	Group 9 CER	Q	---	Continue to Next View Menu
J	---	Group 1-7 CER			
K	---	Group 1-9 CER	X	---	Return to Previous Menu
L	---	Group 1-7,9 CER			

TYPE THE LETTER OF YOUR CHOICE:

Figure A-18

View Graphs

With New Regression Menu

VIEW GRAPHS WITH NEW DATA POINT INCLUDED
WITH NEW REGRESSION
PLEASE CHOOSE A GRAPH TO BE VIEWED

A	---	Group 1 CER	M	---	Material Cost CER
B	---	Group 2 CER	N	---	Groups 8, 9, 1-7, 1-7&9, 1-9, & Material Cost CERs
C	---	Group 3 CER			
D	---	Group 4 CER			
E	---	Group 5 CER	O	---	Groups 2, 6, 8, & 9 non-CERs
F	---	Group 6 CER			
G	---	Group 7 CER	P	---	All Graphs CERs & non-CERs
H	---	Group 8 CER			
I	---	Group 9 CER	Q	---	Continue to Next View Menu
J	---	Group 1-7 CER			
K	---	Group 1-9 CER	X	---	Return to Previous Menu
L	---	Group 1-7,9 CER			

TYPE THE LETTER OF YOUR CHOICE:

Figure A-19

View Bar Graphs
with
New Data Point Menu

VIEW BAR GRAPHS WITH NEW DATA POINT

PLEASE CHOOSE A GRAPH TO BE VIEWED

A	---	Group 1 CER	J	---	Group 1-7
B	---	Group 2 & MHRS/SHP	K	---	Group 1-7&9
C	---	Group 3	L	---	Group 1-9
D	---	Group 4	M	---	Material Cost
E	---	Group 5	N	---	Groups 8, 9, 1-7, 1-7&9, 1-9, & Material Cost
F	---	Group 6 & MHRS/Accom			
G	---	Group 7	O	---	All Graphs
H	---	Group 8 & 1-7,9/8	Q		Return to Group Menu
I	---	Group 9 & MHRS/Month	X	---	Return to Previous
				---	View Menu

TYPE THE LETTER OF YOUR CHOICE:

3.0 Sample Ship Program Execution

This sample will run through an entire process of costing out a new ship, from the input of the new ship to the printing of results. The program uses a hypothetical surface combatant as an example ship to demonstrate execution of the model.

Once the program has been loaded, the Main Menu appears on the screen. Since the program is running on this computer for the first time, the printer set up routine is followed. [X] is pressed, and the CMD indicator at the bottom of the screen disappears. [:], [P], [C], [P] are then pressed to bring up the printer choices. Using the arrow keys to check all selections, the HP Laserjet III no cartridge is selected by pressing its number, [1]. [I] is pressed, and the interface choices come up on the screen. Again, using the arrow keys to check all selections, the Parallel 1 is selected by pressing its number, [1]. [Q], [L], [D], [U] are then pressed to update the defaults. Once the computer finishes processing, [Q], [Q], Alt-M will exit print settings and restart the menu system. [A] is then pressed to proceed to the surface combatant Group Menu. (The Group Menu is the "home base" from which all operations originate. There are four Group Menus, one for each ship type.)

A. From the Main Menu (Figure A-1), press [A] to access the surface combatant Group Menu (Figure A-2). The first process is to input new ship data. [A] is pressed to start the ship input process. A screen appears (Figure A-3) to ask if the user wants to erase the previously input ship or modify the data. In this example, the user should modify the previous data so [M] is pressed. A data input screen appears (Figure A-4 is a partial screen, Figure A-5 is a whole screen), showing the example data for "Myship." (Note the directions at the lower-half of the screen, which tells the user to press [Alt-A] after finishing all data input.) The user can change (or input) lightship weight data, labor and material cost data, and ship characteristic data, using cursor keys to move between fields. Note that some cells are labeled as CALC (calculation) such as SUM 1-7, 1-7&9,

1-9, and are not input (they are automatically calculated). Some cells have special input instructions below, such as contract award date and factor. Some have formulas, such as months in shipyard. Once all the new ship data is input, [Alt-A] is pressed to return to the Group Menu.

B. Once the new ship data is input regressions can be calculated and graphs updated. [B] is pressed from the Group Menu (Figure A-2) to start this process. A verification screen appears (Figure A-6), asking the user to verify that new ship data has been input. [Y] is then pressed. The computer performs some calculations, then warns the user that Lotus 1-2-3 needs to initialize the graphs to be updated. The warning (Figure A-7) informs the user that [Enter] is to be pressed every time a graph appears on the screen until the View Graphs with New Data Point Included Using Original Regression Menu appears (Figure A-8). [N] is pressed to view the summary plots and [Enter] to advance through them. [Q] is then pressed to continue to the next View Menu, View Graphs with New Data Point Included using New Regression. Again, [N] is pressed to view the summary graphs and [Enter] to advance through them. [Q] is then pressed to continue to the next View Menu, View Bar Graphs with New Data Point. [N] is pressed to view the summary graphs and [Enter] to advance through them. [Q] is then pressed to return to the Group menu.

C. Once the new ship has been processed in the data base, printouts can be generated in the following manner. [C] is pressed from the Group Menu (Figure A-2) to Print New Ship Data. A screen appears (Figure A-9), asking the user which set of regressions are to be used ("O" for original, "N" for new). [O] is pressed for the original regressions. The screen moves to the Print Line Graphs Menu (Figure A-10). [P] is pressed to print all the graphs with original regressions. [Q] is pressed to continue to the Print Bar Graphs Menu. [X] is pressed to return to the screen that asks which regressions are to be used ("O" for original, "N" for new). This time, [N] is pressed for new regressions. The screen moves to the Print Line Graphs Menu. [P] is pressed to print all the graphs, noting that this time they are the new regressions. [Q] is pressed to continue to the Print Bar Graphs Menu (Figure A-11). [O] is pressed to print all the bar graphs. [Q] is pressed to continue to the Print Data bases Menu (Figure A-12). To print all data bases (weight, labor, materials and ship characteristics for the Group, [A], [B], [C], and [D] are pressed. [Q] is then pressed to return to the Group Menu.

D. To print extra sets of the original model CERs and bar graphs, the following procedure is followed. From the Group Menu (Figure A-12) [D] is pressed to advance to the Print Line Graphs Menu (Figure A-10). [P] is pressed to print all the original CER's. [Q] is pressed to continue to the Print Bar Graphs Menu (Figure A-11). [O] is pressed to print all the original bar graphs. [Q] is pressed to continue to the Print Data base Menu (Figure A-12). To reprint all data bases for the group, [A], [B], [C], and [D] are pressed. [Q] is then pressed to return to the Group Menu.

E. To produce a new ship estimate, the following procedure is followed. [E] is pressed from the Group Menu to advance to the Price Out a New Ship Menu (Figure A-13). [A] is pressed to view the estimates based on the weights input earlier in Section A. Any key is pressed to return to the Price Out a New Ship Menu. [B] is pressed to produce a printout. [C] is pressed to modify weights for a new estimate. This allows the user to do "what if" scenario testing. A warning screen (Figure A-15) flashes to tell the user that any weight changes made here will not change the data input in Section A. [Enter] is pressed to continue to the worksheet area. The cursor keys and [Enter] are used to input data into a cell. Once the data is input and the estimate checked, [Alt-W] is pressed to return to the Price Out New Ship Menu. [D] is pressed to produce a printout. Again the warning screen flashes and [Enter] is pressed to continue. The screen returns to the Price Out New Ship Menu. [X] is pressed to return to the Group Menu when finished.

Upon completion [X] is pressed from the Group Menu to return to the Main Menu and [E] is pressed to save the file and exit Lotus. If the user does not wish to save the file, [X] is pressed to exit the menu system and [/][Q] is pressed to quit Lotus without saving the file.

Appendix B
Two-Digit SWBS Distribution

The basic two-digit structure has been somewhat modified to take into account special systems costs and areas where the cost estimators data would not fit into the two-digit structure. These are outlined below.

SWBS 197 - Welding

This is apportioned between 1A, 1B, 1C, and 1D by the same percentage that the two-digit weight is of the total Group 1 weight.

SWBS 252 - Propulsion Control System

This is estimated separately from Group 2D because of the variety of automation systems that may be found on auxiliaries and amphibious vessels.

SWBS 475 - Degaussing

Degaussing is estimated separately from the rest of Group 4A because it is not found on all auxiliaries and its cost factor is different than that for the rest of Group 4A.

SWBS 639 - Radiation Shielding

This is not found in large quantitites on all auxilairies and has a higher cost factor. It is estimated as a function of weight.

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 1A

SWBS NO.	DESCRIPTION	WEIGHT
111	SHELL PLATING, SURF. SHIP AND SUBMARINE PRESS. HULL	
113	INNER BOTTOM	
114	SHELL APPENDAGES	
115	STANCHIONS	
116	LONGIT. FRAMING, SURF. SHIP AND SUBMARINE PRESS. HULL	
117	TRANSV. FRAMING, SURF. SHIP AND SUBMARINE PRESS. HULL	
121	LONGITUDINAL STRUCTURAL BULKHEADS	
122	TRANSVERSE STRUCTURAL BULKHEADS	
123	TRUNKS AND ENCLOSURES	
124	BULKHEADS IN TORPEDO PROTECTION SYSTEM	
131	MAIN DECK	
132	2ND DECK	
133	3RD DECK	
134	4TH DECK	
135	5TH DECK AND DECKS BELOW	
136	01 HULL DECK	
137	02 HULL DECK	
141	1ST PLATFORM	
142	2ND PLATFORM	
143	3RD PLATFORM	
144	4TH PLATFORM	
145	5TH PLATFORM	
149	FLATS	
166	SPONSONS	
197	WELDING (1A PERCENTAGE OF 197)	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 1B

SWBS NO.	DESCRIPTION	WEIGHT
151	DECKHOUSE STRUCTURE TO FIRST LEVEL	
152	1ST DECKHOUSE LEVEL	
153	2ND DECKHOUSE LEVEL	
154	3RD DECKHOUSE LEVEL	
155	4TH DECKHOUSE LEVEL	
156	5TH DECKHOUSE LEVEL	
157	6TH DECKHOUSE LEVEL	
158	7TH DECKHOUSE LEVEL	
159	8TH DECKHOUSE LEVEL AND ABOVE	
164	BALLISTIC PLATING	
197	WELDING (1B PERCENTAGE OF 197)	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 1C

SWBS NO.	DESCRIPTION	WEIGHT
182	PROPULSION PLANT FOUNDATIONS	
183	ELECTRIC PLANT FOUNDATIONS	
184	COMMAND AND SURVEILLANCE FOUNDATIONS	
185	AUXILIARY SYSTEMS FOUNDATIONS	
186	OUTFIT AND FURNISHINGS FOUNDATIONS	
187	ARMAMENT FOUNDATIONS	
189	COMBAT SYSTEM ALIGNMENT	
197	WELDING (IC PERCENTAGE OF 197)	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 1D

SWBS NO.	DESCRIPTION	WEIGHT
161	STRUCTURAL CASTINGS, FORGINGS, AND EQUIV. WELDMENTS	
162	STACKS AND MACKS (COMBINED STACK AND MAST)	
163	SEA CHESTS	
165	SONAR DOMES	
167	HULL STRUCTURAL CLOSURES	
168	DECKHOUSE STRUCTURAL CLOSURES	
169	SPECIAL PURPOSE CLOSURES AND STRUCTURES	
171	MASTS, TOWERS, TETRAPODS	
172	KINGPOSTS AND SUPPORT FRAMES	
179	SERVICE PLATFORMS	
197	WELDING (1D PERCENTAGE OF 197)	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 2A

SWBS NO.	DESCRIPTION	WEIGHT
221	PROPULSION BOILERS	
222	GAS GENERATORS	
223	MAIN PROPULSION BATTERIES	
224	MAIN PROPULSION FUEL CELLS	
231	PROPULSION STEAM TURBINES	
232	PROPULSION STEAM ENGINES	
233	PROPULSION INTERNAL COMBUSTION ENGINES	
234	PROPULSION GAS TURBINES	
235	ELECTRIC PROPULSION	
236	SELF-CONTAINED PROPULSION SYSTEMS	
237	AUXILIARY PROPULSION DEVICES	
241	PROPULSION REDUCTION GEARS	
242	PROPULSION CLUTCHES AND COUPLINGS	
253	MAIN STEAM PIPING SYSTEM	
254	CONDENSERS AND AIR EJECTORS	
255	FEED AND CONDENSATE SYSTEM	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 2B

SWBS NO.	DESCRIPTION	WEIGHT
243	PROPULSION SHAFTING	
244	PROPULSION SHAFT BEARINGS	
245	PROPULSORS	
246	PROPULSOR SHROUDS AND DUCTS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 2C

SWBS NO.	DESCRIPTION	WEIGHT
251	COMBUSTION AIR SYSTEM	
259	UPTAKES (INNER CASING)	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 2D

SWBS NO.	DESCRIPTION	WEIGHT
256	CIRCULATING AND COOLING SEA WATER SYSTEM	
258	H.P. STEAM DRAIN SYSTEM	
261	FUEL SERVICE SYSTEM	
262	MAIN PROPULSION LUBE OIL SYSTEM	
264	LUBE OIL FILL, TRANSFER, AND PURIFICATION	
252	PROPULSION CONTROL SYSTEM	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 3A

SWBS NO.	DESCRIPTION	WEIGHT
311	SHIP SERVICE POWER GENERATION	
312	EMERGENCY GENERATORS	
314	POWER CONVERSION EQUIPMENT	
342	DIESEL SUPPORT SYSTEMS	
343	TURBINE SUPPORT SYSTEMS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 3B

SWBS NO.	DESCRIPTION	WEIGHT
313	BATTERIES AND SERVICE FACILITIES	
321	SHIP SERVICE POWER CABLE	
322	EMERGENCY POWER CABLE SYSTEM	
323	CASUALTY POWER CABLE SYSTEM	
324	SWITCHGEAR AND PANELS	
331	LIGHTING DISTRIBUTION	
332	LIGHTING FIXTURES	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 4A

SWBS NO.	DESCRIPTION	WEIGHT
421	NON-ELECTRICAL/ELECTRONIC NAVIGATION AIDS	
422	ELECTRICAL NAVIGATION AIDS (INCL NAVIG. LIGHTS)	
423	ELECTRONIC NAVIGATION SYSTEMS, RADIO	
424	ELECTRONIC NAVIGATION SYSTEMS, ACOUSTICAL	
426	ELECTRICAL NAVIGATION SYSTEMS	
427	INERTIAL NAVIGATION SYSTEMS	
428	NAVIGATION CONTROL MONITORING	
431	SWITCHBOARDS FOR I.C. SYSTEMS	
432	TELEPHONE SYSTEMS	
433	ANNOUNCING SYSTEMS	
434	ENTERTAINMENT AND TRAINING SYSTEMS	
435	VOICE TUBES AND MESSAGE PASSING SYSTEMS	
436	ALARM, SAFETY, AND WARNING SYSTEMS	
437	INDICATING, ORDER, AND METERING SYSTEMS	
438	INTEGRATED CONTROL SYSTEMS	
443	VISUAL AND AUDIBLE SYSTEMS	
473	TORPEDO DECOYS	
474	DECOYS (OTHER)	
476	MINE COUNTERMEASURES	
491	ELECTRONIC TEST, CHECKOUT, AND MONITORING EQUIPMENT	
492	FLIGHT CONTROL AND INSTRUMENT LANDING SYSTEMS	
493	NON COMBAT DATA PROCESSING SYSTEMS	
494	METEOROLOGICAL SYSTEMS	
495	SPECIAL PURPOSE INTELLIGENCE SYSTEMS	
475	DEGAUSSING	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 4B

SWBS NO.	DESCRIPTION	WEIGHT
411	DATA DISPLAY GROUP	
412	DATA PROCESSING GROUP	
413	DIGITAL DATA SWITCHBOARDS	
414	INTERFACE EQUIPMENT	
415	DIGITAL DATA COMMUNICATIONS	
417	COMMAND AND CONTROL ANALOG SWITCHBOARDS	
441	RADIO SYSTEMS	
442	UNDERWATER SYSTEMS	
444	TELEMETRY SYSTEMS	
445	TTY AND FACSIMILE SYSTEMS	
446	SECURITY EQUIPMENT SYSTEMS	
451	SURFACE SEARCH RADAR	
452	AIR SEARCH RADAR (2D)	
453	AIR SEARCH RADAR (3D)	
454	AIRCRAFT CONTROL APPROACH RADAR	
455	IDENTIFICATION SYSTEMS (IFF)	
456	MULTIPLE MODE RADAR	
459	SPACE VEHICLE ELECTRONIC TRACKING	
461	ACTIVE SONAR	
462	PASSIVE SONAR	
463	MULTIPLE MODE SONAR	
464	CLASSIFICATION SONAR	
465	BATHYTHERMOGRAPH	
471	ACTIVE ECM (INCL COMBINATION ACTIVE/PASSIVE)	
472	PASSIVE ECM	
481	GUN FIRE CONTROL SYSTEMS	
482	MISSILE FIRE CONTROL SYSTEMS	
483	UNDERWATER FIRE CONTROL SYSTEMS	
484	INTEGRATED FIRE CONTROL SYSTEMS	
489	WEAPON SYSTEMS SWITCHBOARDS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 5A

SWBS NO.	DESCRIPTION	WEIGHT
511	COMPARTMENT HEATING SYSTEM	
512	VENTILATION SYSTEM	
513	MACHINERY SPACE VENTILATION SYSTEM	
514	AIR CONDITIONING SYSTEM	
517	AUXILIARY BOILERS AND OTHER HEAT SOURCES	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 5B

SWBS NO.	DESCRIPTION	WEIGHT
521	FIREMAIN AND FLUSHING (SEA WATER) SYSTEM	
522	SPRINKLER SYSTEM	
523	WASHDOWN SYSTEM	
524	AUXILIARY SEA WATER SYSTEM	
526	SCUPPERS AND DECK DRAINS	
557	FIREMAIN ACTUATED SERVICES - OTHER	
528	PLUMBING DRAINAGE	
529	DRAINAGE AND BALLASTING SYSTEM	
531	DISTILLING PLANT	
532	COOLING WATER	
533	POTABLE WATER	
534	AUX. STEAM AND DRAINS WITHIN MACHINERY BOX	
535	AUX. STEAM AND DRAINS OUTSIDE MACHINERY BOX	
536	AUXILIARY FRESH WATER COOLING	
541	SHIP FUEL AND FUEL COMPENSATING SYSTEM	
542	AVIATION AND GENERAL PURPOSE FUELS	
543	AVIATION AND GENERAL PURPOSE LUBRICATING OIL	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 5B (Continued)

SWBS NO.	DESCRIPTION	WEIGHT
544	LIQUID CARGO	
545	TANK HEATING	
549	SPECIAL FUEL AND LUBRICANTS, HANDLING AND STOWAGE	
551	COMPRESSED AIR SYSTEMS	
552	COMPRESSED GASES	
553	O_2N_2 SYSTEM	
554	LP BLOW	
555	FIRE EXTINGUISHING SYSTEMS	
556	HYDRAULIC FLUID SYSTEM	
557	LIQUID GASES, CARGO	
558	SPECIAL PIPING SYSTEMS	
565	TRIM AND HEEL SYSTEMS (SURFACE SHIPS)	
593	ENVIRONMENTAL POLLUTION CONTROL SYSTEMS	
594	SUBMARINE RESCUE, SALVAGE, AND SURVIVAL SYSTEMS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 5C

SWBS NO.	DESCRIPTION	WEIGHT
561	STEERING AND DIVING CONTROL SYSTEMS	
562	RUDDER	
565	TRIM AND HEEL SYSTEMS	
568	MANEUVERING SYSTEMS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 5D

SWBS NO.	DESCRIPTION	WEIGHT
571	REPLENISHMENT-AT-SEA SYSTEMS	
572	SHIP STORES AND EQUIPMENT HANDLING SYSTEMS	
573	CARGO HANDLING SYSTEMS	
770	CARGO MUNITIONS	
772	CARGO MUNITIONS HANDLING	
773	CARGO MUNITIONS STOWAGE	
574	VERTICAL REPLENISHMENT SYSTEMS	
581	ANCHOR HANDLING AND STOWAGE SYSTEMS	
582	MOORING AND TOWING SYSTEMS	
583	BOATS, BOAT HANDLING AND STOWAGE SYSTEMS	
584	MECHANICALLY OPERATED DOOR, GATE, RAMP, TURNTABLE SYSTEM	
585	ELEVATING AND RETRACTING GEAR	
588	AIRCRAFT HANDLING, SERVICING AND STOWAGE	
589	MISCELLANEOUS MECHANICAL HANDLING SYSTEMS	
592	SWIMMER AND DIVER SUPPORT AND PROTECTION SYSTEMS	
595	TOWING, LAUNCHING AND HANDLING FOR UNDERWATER SYSTEMS	
596	HANDLING SYSTEMS FOR DIVER AND SUBMERSIBLE VEHICLES	
597	SALVAGE SUPPORT SYSTEMS	

APPENDIX B

TWO-DIGIT SWBS BREAKDOWN

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 6A

SWBS NO.	DESCRIPTION	WEIGHT
605	RODENT AND VERMIN PROOFING	
611	HULL FITTINGS	
612	RAILS, STANCHIONS, AND LIFELINES	
613	RIGGING AND CANVAS	
625	AIRPORTS, FIXED PORTLIGHTS, AND WINDOWS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 6B

SWBS NO.	DESCRIPTION	WEIGHT
621	NON-STRUCTURAL BULKHEADS	
622	FLOOR PLATES AND GRATINGS	
623	LADDERS	
624	NON-STRUCTURAL CLOSURES	
637	SHEATHING	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 6C

SWBS NO.	DESCRIPTION	WEIGHT
602	HULL DESIGNATING AND MARKING	
603	DRAFT MARKS	
604	LOCKS, KEYS, AND TAGS	
631	PAINTING	
632	ZINC COATING	
633	CATHODIC PROTECTION	
634	DECK COVERING	
635	HULL INSULATION	
636	HULL DAMPING	
639	RADIATION SHIELDING	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 6D

SWBS NO.	DESCRIPTION	WEIGHT
654	UTILITY SPACES	
655	LAUNDRY SPACES	
656	TRASH DISPOSAL SPACES	
664	DAMAGE CONTROL STATIONS	
665	WORKSHOPS, LABS, TEST AREAS (INCLUDING PORTABLE TOOLS, EQUIPMENT)	
671	LOCKERS AND SPECIAL STOWAGE	
672	STOREROOMS AND ISSUE ROOMS	
673	CARGO STOWAGE	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 6E

SWBS NO.	DESCRIPTION	WEIGHT
638	REFRIGERATED SPACES	
641	OFFICER BERTHING AND MESSING SPACES	
642	NONCOMMISSIONED OFFICER BERTHING AND MESSING SPACES	
643	ENLISTED PERSONNEL BERTHING AND MESSING SPACES	
644	SANITARY SPACES AND FIXTURES	
645	LEISURE AND COMMUNITY SPACES	
651	COMMISSARY SPACES	
652	MEDICAL SPACES	
653	DENTAL SPACES	
661	OFFICES	
662	MACHINERY CONTROL CENTERS FURNISHINGS	
663	ELECTRONICS CONTROL CENTERS FURNISHINGS	

APPENDIX B
TWO-DIGIT SWBS DISTRIBUTION

COST GROUP: 7

SWBS NO.	DESCRIPTION	WEIGHT
701	GENERAL ARRANGEMENT - WEAPONRY SYSTEMS	
711	GUNS	
712	AMMUNITION HANDLING	
713	AMMUNITION STOWAGE	
721	LAUNCHING DEVICES (MISSILES AND ROCKETS)	
722	MISSILE, ROCKET, AND GUIDANCE CAPSULE HANDLING SYSTEM	
723	MISSILE AND ROCKET STOWAGE	
724	MISSILE HYDRAULICS	
725	MISSILE GAS	
726	MISSILE COMPENSATING	
727	MISSILE LAUNCHER CONTROL	
728	MISSILE HEATING, COOLING, TEMPERATURE CONTROL	
729	MISSILE MONITORING, TEST AND ALIGNMENT	
731	MINE LAUNCHING DEVICES	
732	MINE HANDLING	
733	MINE STOWAGE	
741	DEPTH CHARGE LAUNCHING DEVICES	
742	DEPTH CHARGE HANDLING	
743	DEPTH CHARGE STOWAGE	
751	TORPEDO TUBES	
752	TORPEDO HANDLING	
753	TORPEDO STOWAGE	
754	SUBMARINE TORPEDO EJECTION	
761	SMALL ARMS AND PYROTECHNIC LAUNCHING DEVICES	
762	SMALL ARMS AND PYROTECHNIC HANDLING	
763	SMALL ARMS AND PYROTECHNIC STOWAGE	
782	AIRCRAFT RELATED WEAPONS HANDLING	
783	AIRCRAFT RELATED WEAPONS STOWAGE	
792	SPECIAL WEAPONS HANDLING	
793	SPECIAL WEAPONS STOWAGE	
797	MISCELLANEOUS ORDNANCE SPACES	

APPENDIX C

ANALYSIS OF RELATIONSHIPS ATTEMPTED, BUT NOT SELECTED FOR THE MODEL

APPENDIX C

ANALYSIS OF RELATIONSHIPS ATTEMPTED, BUT NOT SELECTED FOR THE MODEL

1.0 RELATIONSHIPS ATTEMPTED

Linear, non-linear and multi-variate analyses were considered in developing the CER's for this model. Regression analyses were conducted to determine the statistical adequacy of all attempted CER's. In addition, the quality of the CER's were judged based on best engineering judgement regarding their potential for being an indicator of shipyard expenditure. Using the multi-variate analysis program provided by NCA (Lotus file PERMJK.WK3), CER's of the form

$$Ax + By + C = \text{Construction Costs (Labor Group 100-700 KMHRS)}$$

were analyzed for statistical significance. Dummy variable analysis was also attempted (i.e., AEGIS versus Non-AEGIS ships). Some of the variables tested included:

Lightship Weight	Generator Type
Labor in Group 900	Generator KW
AEGIS vs. Non-AEGIS	Total Accommodations
Superstructure Material	Shaft Horsepower
Months in Shipyard	

This multi-variate analysis was conducted for all ship types—surface combatants, amphibious ships, auxiliary ships, and other ships. A sample of the results from the multi-variate analysis for surface combatants is provided in Table C-1 below.

TABLE C-1

RESULTS OF THE MULTI-VARIATE ANALYSIS FOR SURFACE COMBATANTS

X	Y	R^2	CV%	No. of Obs.
LightShip Weight	Labor Group 900	0.81	25	12
LightShip Weight	Superstructure (St, Al)	0.86	22	12
Generator KW	Superstructure (St, Al)	0.82	24	12
Months in Shipyard	Shaft Horsepower	0.67	33	12
Shaft Horsepower	Total Accommodations	0.67	33	12
Shaft Horsepower	Generator Type (Die, GT, SSGT)	0.83	24	12

As illustrated from the results in Table C-1, most of the relationships generated by the analysis program are coincidental and are not expected to be useful CER's. For example, a combination of shaft horsepower and total accommodations are not expected to yield a good estimate of construction costs for a new ship. Thus, linear regressions were primarily used for the CER's in this model, as expected, based on previous experience and the data trends. In addition, dividing the database between ship types, and then subdividing the labor costs by SWBS elements, appear to have obviated the need for multi-variate or dummy variable analysis.

APPENDIX D

THE DATA BASE

SURFACE COMBATANTS
LIGHTSHIP WEIGHT (LONG TONS)

06/03/94

	SHIPS	BUILDER	1	2	3	4	5	6	7	SUM 1-7
	DD 931	BIW	1,020.0	840.0	123.0	88.0	302.0	206.0	256.0	2,835.0
	DDG 2	BIW	1,218.0	831.0	123.0	178.0	374.0	271.0	258.0	3,253.0
	CG 16	BIW	2,325.2	878.0	211.2	338.5	540.3	356.2	367.0	5,016.4
	CG 26	BIW	2,421.7	878.0	226.0	351.4	570.3	425.4	315.0	5,187.8
	FFG 7	BIW	1,235.0	267.0	195.0	116.0	447.0	314.0	93.0	2,667.0
	FFG 9	TODD LA	1,235.0	267.0	195.0	116.0	447.0	314.0	93.0	2,667.0
	FFG 10	TODD SEATTLE	1,235.0	267.0	195.0	116.0	447.0	314.0	93.0	2,667.0
	DD 963	INGALLS	3,104.7	759.5	284.8	353.9	718.3	454.6	151.8	5,827.8
	CG 47	INGALLS	3,333.0	665.0	379.0	381.0	884.0	590.0	355.0	6,587.0
	CG 51	BIW	3,442.0	670.0	376.0	396.0	932.0	582.0	346.0	6,744.0
	DDG 51	BIW	3,124.0	804.0	374.0	400.0	961.0	617.0	317.0	6,597.0
87.9%	DDG 52	INGALLS	3,124.0	804.0	374.0	400.0	961.0	617.0	317.0	6,597.0

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

SURFACE COMBATANTS
LABOR (KMHRS)

06/03/94

	SHIPS	1	2	3	4	5	6	7
	DD 931	295.700	200.200	117.100	77.200	319.300	287.000	97.000
	DDG 2	352.700	229.400	121.000	133.900	367.000	313.200	74.600
	CG 16	588.700	252.300	227.600	195.100	572.200	446.300	174.200
	CG 26	650.200	255.400	230.900	214.700	558.000	508.700	120.900
	FFG 7	418.668	98.815	201.941	95.858	376.284	391.316	28.092
	FFG 9	459.420	141.360	176.700	141.360	459.420	353.400	35.340
	FFG 10	538.569	124.285	207.142	248.570	600.712	331.427	20.714
	DD 963	1,104.763	261.307	586.481	207.377	706.367	462.257	69.814
	CG 47	790.721	181.109	757.149	206.646	849.093	751.094	72.400
	CG 51	872.770	120.127	426.384	323.894	686.031	733.936	70.073
	DDG 51	1,710.303	403.670	824.950	391.590	1,537.160	1,598.567	114.759
87.9%	DDG 52	928.473	212.660	889.052	242.646	997.014	881.942	85.013

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

SURFACE COMBATANTS
LABOR (KMHRS)

06/03/94

SHIPS	8	9	SUM 1–7	PROD	TOTAL	SUM 1–9
DD 931	Not Avail.	875.000	1,393.500	2,268.500	N/A	N/A
DDG 2	Not Avail.	910.000	1,591.800	2,501.800	N/A	N/A
CG 16	Not Avail.	1,085.000	2,456.400	3,541.400	N/A	N/A
CG 26	Not Avail.	1,155.000	2,538.800	3,693.800	N/A	N/A
FFG 7	3,141.361	965.665	1,610.974	2,576.639	5,718.000	5,718.000
FFG 9	558.000	775.000	1,767.000	2,542.000	3,100.000	3,100.000
FFG 10	601.380	668.200	2,071.419	2,739.619	3,341.000	3,340.999
DD 963	268.213	1,585.935	3,398.366	4,984.301	5,252.514	5,252.514
CG 47	8,430.460	1,702.142	3,608.212	5,310.354	13,740.814	13,740.814
CG 51	4,017.273	2,663.954	3,233.215	5,897.169	9,914.442	9,914.442
DDG 51	8,121.800	1,143.798	6,581.000	7,724.798	15,846.598	15,846.598
87.9% DDG 52	802.800	1,723.246	4,236.800	5,960.046	6,762.846	6,762.846

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

NOTE: Group 8 labor costs reported for FFG 7 and DDG 51 include G&C detail design costs.
Group 8 labor costs for CG 47 includes an estimate of 3871 kmhrs for detail design.
This estimate was made because CG 47 is not a complete ship design; it is a modification of the DD 963 class. It was estimated that 27% of the CG 47 represents a new design.
The 3871 kmhrs represents an equivalent total new ship detail design for CG 47.
Group 9 costs for DD 931, DDG 2, CG 16 and CG 26 are estimated based on months in yard.

SURFACE COMBATANTS
MATERIAL $M

06/03/94

SHIPS	CONTRACT AWARD	BGT YR	BY	FY93	FACTOR	COST SOURCE	SOURCE DATE	CONTRACT TYPE
DD 931	12/52	1986	31.763	40.292	0.7883	CG/DDG CCM	08/81	
DDG 2	03/57	1986	37.111	47.077	0.7883	CG/DDG CCM	08/81	
CG 16	11/58	1986	43.011	54.562	0.7883	CG/DDG CCM	08/81	
CG 26	05/61	1986	35.927	45.575	0.7883	CG/DDG CCM	08/81	
FFG 7	10/73	1977	31.584	81.152	0.3892	Navsea 017/Rev C/D CCM	8/92&8/81	
FFG 9	02/76	1975	21.452	68.955	0.3111	Navsea 017 data sheet	05/15/87	
FFG 10	02/76	1975	20.888	67.142	0.3111	Navsea 017 data sheet	05/15/87	
DD 963	06/70	1970	72.370	392.037	0.1846	Navsea 017 data sheet	02/22/80	Tot. Pkg. Proc.
CG 47	09/78	1984	187.185	252.373	0.7417	CPR	08/27/84	CPFF
CG 51	05/82	1988	60.970	73.114	0.8339	CPR	07/25/88	CPAF
DDG 51	04/85	1985	153.255	199.837	0.7669	CPR	01/27/92	FPIF
87.9% DDG 52	05/87	1987	118.370	146.208	0.8096	CPR	08/21/92	FPI

% -- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

SURFACE COMBATANTS
SHIP CHARACTERISTICS

06/03/94

	SHIPS	LENGTH OVERALL	LENGTH LWL	BEAM EXTREME	BEAM BWL	DRAFT MAXNAV	DRAFT LIMIT	HULL	SS	DISPLACEMENT LIGHT	DISPLACEMENT FULL	COMPLEMENT	TOTAL ACCOM	AEGIS? (A=yes)
	DD 931		407.0		44.3			ST	AL		4,139	337	357	N
	DDG 2		420.0		39.5			ST	AL		4,588	355	375	N
	CG 16		510.0		53.5			ST	AL	5,912	7,590	395	445	N
	CG 26		524.0		54.0			ST	AL	6,667	7,960	418	610	N
	FFG 7	445.0	408.0	47.0	47.0	25.0	16.0	ST	AL	2,667	3,624	206	215	N
	FFG 9	445.0	408.0	47.0	47.0	25.0	16.0	ST	AL	2,667	3,815	206	215	N
	FFG 10	445.0	408.0	47.0	47.0	25.0	16.0	ST	AL	2,667	3,763	206	215	N
	DD 963	563.0	529.0	55.0	55.0	32.0	23.0	ST	AL	5,827	8,928	329	353	N
	CG 47	567.0	529.0	55.0	55.0	33.0	23.0	ST	AL	6,587	9,962	358	374	A
	CG 51	567.0	529.0	55.0	55.0	32.0	23.0	ST	AL	6,744	9,590	358	360	A
	DDG 51	504.0	466.0	66.0	59.0	32.0	22.0	ST	ST	6,597	8,344	341	341	A
87.9%	DDG 52	504.0	466.0	66.0	59.0	32.0	22.0	ST	ST	6,597	8,344	341	341	A

	SHIPS	START CONST.	DELIV.	MO. IN SHPYD	ENGINES NO.	ENGINES TYPE	REDUCT GEAR TYPE	GENERATORS NO	GENERATORS TYPE	GENERATORS TOTAL KW	NO. OF SCREWS	TOTAL SHP
	DD 931	10/27/53	11/4/55	25.0	2	ST		4	SSTG	1,350	2	70,000
	DDG 2	06/16/58	08/31/60	26.0	2	ST		4	SSTG	1,350	2	70,000
	CG 16	12/59		31.0	2	ST	DLT	4	SSTG	2,700	2	85,500
	CG 26	02/62	11/64	33.0	2	ST	DLT	4	SSTG	4,050	2	85,850
	FFG 7	06/12/75	12/17/77	30.1	2	GT	DLT	4	DIE	4,000	1	40,000
	FFG 9	07/13/77	02/28/80	31.5	2	GT	DLT	4	DIE	4,000	1	40,000
	FFG 10	04/29/77	05/15/80	36.5	2	GT	DLT	4	DIE	4,000	1	40,000
	DD 963	06/05/72	08/12/75	38.2	4	GT	DLT	3	GT	6,000	2	80,000
	CG 47	07/25/79	12/13/82	40.6	4	GT	DLT	3	GT	7,500	2	80,000
	CG 51	11/03/83	06/22/87	43.6	4	GT	DLT	3	GT	7,500	2	80,000
	DDG 51	09/06/87	04/21/91	43.5	4	GT	DLT	4	GT	7,500	2	92,000
87.9%	DDG 52	05/11/89	10/19/92	41.3	4	GT	DLT	4	GT	7,500	2	92,000

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

Source: Naval Vessel Register; where NVR was blank or listed a zero, the Program Office was called; where information was unavailable from NVR and the Program Office, Janes' was used.

06/03/94

AMPHIBIOUS WARFARE SHIPS
LIGHTSHIP WEIGHT (LONG TONS)

SHIPS	BUILDER	1	2	3	4	5	6	7	SUM 1–7
LST 1182	NASSCO	2,707.0	348.0	136.0	77.0	750.0	379.0	71.0	4,468.0
LSD 41	LOCKHEED	6,627.0	985.0	435.0	141.0	1,796.0	1,134.0	47.0	11,165.0
LSD 44	AVONDALE	6,627.0	985.0	435.0	141.0	1,796.0	1,134.0	47.0	11,165.0
AD 41	NASSCO	7,333.0	498.0	453.0	72.0	2,157.0	2,698.0	101.0	13,312.0
LHD 1	INGALLS	16,614.0	1,360.0	1,082.0	521.0	4,622.0	3,043.0	312.0	27,554.0

% ––– INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

NOTE: AD 41 has an additional margin of 227 long tons.

AMPHIBIOUS WARFARE SHIPS
LABOR (KMHRS)

06/03/94

SHIPS	1	2	3	4	5	6	7
LST 1182	454.800	103.000	57.200	45.100	415.500	146.700	7.000
LSD 41	1,215.300	239.100	310.100	125.400	896.800	288.400	4.400
LSD 44	1,281.792	286.838	374.446	155.405	1,048.541	365.714	6.137
AD 41	1,280.500	178.800	351.000	75.300	1,639.900	908.500	17.700
LHD 1	2,773.083	114.500	1,777.359	277.884	2,213.905	2,097.231	84.487

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

AMPHIBIOUS WARFARE SHIPS
LABOR (KMHRS)

06/03/94

SHIPS	8	9	SUM 1-7	PROD	TOTAL	SUM 1-9
LST 1182	2,000.000	750.000	1,229.300	1,979.300	3,979.300	3,979.300
LSD 41	2,019.800	1,268.200	3,079.500	4,347.700	6,367.500	6,367.500
LSD 44	2,096.750	857.155	3,518.873	4,376.028	6,472.779	6,472.778
AD 41	2,000.000	750.000	4,451.700	5,201.700	7,201.700	7,201.700
LHD 1	6,688.444	3,634.150	9,338.449	12,972.599	19,661.043	19,661.043

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

06/03/94

AMPHIBIOUS WARFARE SHIPS
MATERIAL $M

SHIPS	CONTRACT AWARD	BGT YR	BY	FY93	FACTOR	COST SOURCE	SOURCE DATE	CONTRACT TYPE
LST 1182	07/66	1980	25.862	49.936	0.5179	Auxiliary CCM	09/01/88	
LSD 41	02/81	1985	164.447	214.431	0.7669	CPR	08/04/85	CPFF w/ ceiling
LSD 44	11/83	1984	69.040	93.083	0.7417	CPR + NCA Report	03/31/89	FPI
AD 41	12/75	1980	72.372	139.741	0.5179	Auxiliary CCM	09/01/88	FPI
LHD 1	02/84	1982	397.317	601.449	0.6606	CPR	03/18/91	

% -- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

AMPHIBIOUS WARFARE SHIPS
SHIP CHARACTERISTICS

06/03/94

SHIPS	LENGTH OVERALL	LENGTH LWL	BEAM EXTREME	BEAM BWL	DRAFT MAXNAV	DRAFT LIMIT	HULL	SS	DISPLACEMENT LIGHT	DISPLACEMENT FULL	COMPLE-MENT	TOTAL ACCOM
LST 1182	522.0	500.0	70.0	70.0	19.0	19.0	ST	ST	4,468	8,677	257	650
LSD 41	610.0	580.0	84.0	84.0	21.0	21.0	ST	ST	11,165	16,469	340	852
LSD 44	610.0	580.0	84.0	84.0	20.0	21.0	ST	ST	11,165	15,984	340	849
AD 41	642.0	620.0	85.0	67.0	22.5	27.0	ST	ST	13,312	20,423	1,595	1,681
LHD 1	844.0	778.0	110.0	106.0	27.0	28.0	ST	ST	27,554	40,674	1,873	3,150

SHIPS	START CONST.	DELIV.	MO. IN SHPYD	ENGINES NO.	ENGINES TYPE	REDUCT GEAR TYPE	GENERATORS NO	GENERATORS TYPE	GENERATORS TOTAL KW	NO. OF SCREWS	TOTAL SHP
LST 1182	12/16/67	11/22/69	23.2	6	DIE	SGL	3	DIE	2,250	2	16,000
LSD 41	04/06/81	01/08/85	45.1	4	DIE		4	DIE	5,200	2	33,000
LSD 44	11/18/85	02/24/89	39.2	4	DIE		4	DIE	5,200	2	33,000
AD 41	01/10/77	05/31/80	40.6	1	STT	DBL	4,1	STT,DIE	11,000	1	20,000
LHD 1	07/09/84	05/05/89	57.9	2	STT				14,600	2	70,000

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

Source: Naval Vessel Register; where NVR was blank or listed a zero, the Program Office was called; where information was unavailable from NVR and Program Office, Jane's was used.

AUXILIARY SHIPS
LIGHTSHIP WEIGHT (LONG TONS)

06/03/94

	SHIPS	BUILDER	1	2	3	4	5	6	7	SUM 1-7
	TAGOS 19	McDermot MC	1,692.0	55.0	157.0	65.0	384.0	248.0	1.0	2,602.0
	AO 180	NASSCO	5,572.0	646.0	267.0	48.0	1,145.0	558.0	16.0	8,252.0
	AFS 6	NASSCO	5,287.0	770.0	155.0	78.0	1,428.0	1,234.0	86.0	9,038.0
	AOR 7	NASSCO	8,183.0	971.0	323.0	102.0	2,060.0	1,063.0	42.0	12,744.0
	TAO 187	AVONDALE	9,365.0	1,122.0	405.0	105.0	1,764.0	1,142.0	20.0	13,923.0
	TAO 191	PENN/TAMPA	9,365.0	1,122.0	405.0	105.0	1,764.0	1,142.0	20.0	13,923.0
90.0%	AOE 6	NASSCO	12,630.0	977.0	914.0	192.0	2,661.0	1,388.0	802.0	19,564.0
79.6%	TAGS 45	AVONDALE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,750.0

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

AUXILIARY SHIPS
LABOR (KMHRS)

06/03/94

	SHIPS	1	2	3	4	5	6	7
	TAGOS 19	194.233	14.412	82.003	24.465	167.766	100.851	0.000
	AO 180	627.500	121.300	169.600	74.200	463.400	281.900	3.200
	AFS 6	457.600	111.700	61.200	40.900	352.600	157.000	6.900
	AOR 7	963.500	180.700	143.600	72.700	717.200	314.400	5.000
	TAO 187	780.652	88.930	93.666	48.953	492.159	368.072	1.996
	TAO 191	717.100	47.800	60.100	38.400	375.800	219.300	0.000
90.0%	AOE 6	1,172.100	145.700	505.300	180.900	1,517.100	1,001.800	0.000
79.6%	TAGS 45	595.250	25.593	174.758	52.201	294.322	247.405	0.000

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

AUXILIARY SHIPS
LABOR (KMHRS)

06/03/94

	SHIPS	8	9	SUM 1-7	PROD	TOTAL	SUM 1-9
	TAGOS 19	300.768	218.552	583.730	802.282	1,103.050	1,103.050
	AO 180	2,000.000	750.000	1,741.100	2,491.100	4,491.100	4,491.100
	AFS 6	2,000.000	750.000	1,187.900	1,937.900	3,937.900	3,937.900
	AOR 7	2,000.000	750.000	2,397.100	3,147.100	5,147.100	5,147.100
	TAO 187	982.870	402.291	1,874.428	2,276.719	3,259.589	3,259.589
	TAO 191	325.800	567.700	1,458.500	2,026.200	2,352.000	2,352.000
90.0%	AOE 6	2,971.700	557.100	4,522.900	5,080.000	8,051.700	8,051.700
79.6%	TAGS 45	492.618	253.909	1,389.529	1,643.438	2,136.056	2,136.056

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

06/03/94

AUXILIARY SHIPS
MATERIAL $M

	SHIPS	CONTRACT AWARD	BGT YR	BY	FY93	FACTOR	COST SOURCE	SOURCE DATE	CONTRACT TYPE
	TAGOS 19	10/86	1987	18.510	22.863	0.8096	CPR	06/30/92	FPIF
	AO 180	04/78	1980	45.846	88.523	0.5179	Auxiliary CCM	09/01/88	
	AFS 6		1980	38.227	73.811	0.5179	Auxiliary CCM	09/01/88	
	AOR 7	12/72	1980	51.488	99.417	0.5179	Auxiliary CCM	09/01/88	
	TAO 187	11/82	1982	67.968	102.888	0.6606	CPR	12/31/87	FPI
	TAO 191	05/85	1984	71.013	95.744	0.7417	CPR	04/30/87	FPI
90.0%	AOE 6	01/87	1987	199.900	246.912	0.8096	CPR	07/12/92	FPI
79.6%	TAGS 45	04/90	1990	63.685	70.471	0.9037	CPR	06/30/92	FPI

% -- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

AUXILIARY SHIPS
SHIP CHARACTERISTICS

06/03/94

%	SHIPS	LENGTH OVERALL	LENGTH LWL	BEAM EXTREME	BEAM BWL	DRAFT MAXNAV	DRAFT LIMIT	HULL	SS	DISPLACEMENT LIGHT	DISPLACEMENT FULL	COMPLEMENT	TOTAL ACCOM
	TAGOS 19	235.0	232.0	94.0	94.0	25.0	25.0	ST	ST	2,602	3,384	34	
	AO 180	700.0	661.0	88.0	86.0	33.0	35.0	ST	ST	8,252	27,276	135	200
	AFS 6	581.0	530.0	79.0	79.0	24.0	28.0	ST	ST	9,038	17,079	428	501
	AOR 7	658.0	640.0	96.0	96.0	35.0	37.0	ST	ST	12,744	40,053	454	457
	TAO 187	678.0	677.0	97.0	97.0	35.0		ST	ST	13,923	47,382	116	
	TAO 191	678.0	677.0	97.0	97.0	35.0	35.0	ST	ST	13,923	47,382	116	
90.0%	AOE 6	754.0	730.0	107.0	107.0	38.0	41.0	ST	ST	19,564	49,484	567	667
79.6%	TAGS 45	442.0	429.0	69.0		21.0		ST	ST	6,750	12,208	95	

%	SHIPS	START CONST.	DELIV.	MO. IN SHPYD	ENGINES NO.	ENGINES TYPE	REDUCT GEAR TYPE	GENERATORS NO	GENERATORS TYPE	GENERATORS TOTAL KW	NO. OF SCREWS	TOTAL SHP
	TAGOS 19	09/16/87	08/13/91	46.9	2	DIE-EL		4	DIE	4,070	2	1,600
	AO 180	12/19/79	08/27/82	33.3	2	TUR-RED	DBL	3	TUR	7,500	2	24,000
	AFS 6	~7/67	05/24/69	22.3	1	TUR	DBL	3	STT	4,500	1	22,000
	AOR 7	10/06/73	10/14/76	36.3	2	TUR	DBL	4	STT	8,000	2	32,000
	TAO 187	04/11/84	12/19/86	31.3	2	DIE				10,000	2	30,000
	TAO 191	10/14/85	04/27/92	78.5	2	DIE				10,000	2	30,000
90.0%	AOE 6	06/22/88	07/01/93	60.3	4	GT				12,500	2	100,000
79.6%	TAGS 45	01/16/91	06/11/93	28.8	2	DIE-EL			DIE	12,900	2	7,400

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

Source: Naval Vessel Register; where NVR was blank or listed a zero, the Program Office was called; where information was unavailable from NVR and Program Office, Jane's was used.

OTHER SHIPS
LIGHTSHIP WEIGHT (LONG TONS)

06/03/94

	SHIPS	BUILDER	1	2	3	4	5	6	7	SUM 1-7
	LCAC 34	AVONDALE GP								87.0
97.8%	MHC 51	INTERMARINE	350.0	30.0	38.0	72.0	113.0	81.0	6.0	690.0
55.0%	MHC 53	AVONDALE GP	350.0	30.0	38.0	72.0	113.0	81.0	6.0	690.0
	MCM 1	PETERSON								1,186.0
83.7%	MCM 2	MARINETTE								1,186.0

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

06/03/94

OTHER SHIPS
LABOR (KMHRS)

	SHIPS	1	2	3	4	5	6	7
	LCAC 34							
97.8%	MHC 51	333.082	27.218	135.352	39.341	197.629	75.691	2.212
55.0%	MHC 53	268.600	13.100	30.000	19.400	56.800	28.000	0.800
	MCM 1							
83.7%	MCM 2	249.789	77.172	80.518	86.022	281.347	161.468	4.421

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

OTHER SHIPS
LABOR (KMHRS)

06/03/94

SHIPS	8	9	SUM 1-7	PROD	TOTAL	SUM 1-9
LCAC 34	76.700	54.400	87.300	141.700	218.400	218.400
97.8% MHC 51	625.665	300.412	810.525	1,110.937	1,736.602	1,736.602
55.0% MHC 53	374.600	120.200	416.700	536.900	911.500	911.500
MCM 1	332.000	446.000	1,156.000	1,602.000	1,934.000	1,934.000
83.7% MCM 2	584.344	199.664	940.737	1,140.401	1,724.745	1,724.745

% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

06/03/94

OTHER SHIPS
MATERIAL $M

	SHIPS	CONTRACT AWARD	BGT YR	BY	FY93	FACTOR	COST SOURCE	SOURCE DATE	CONTRACT TYPE
	LCAC 34	12/88	1988	7.144	8.567	0.8339	CPR	06/30/92	FPI
97.8%	MHC 51	05/87	1987	86.991	107.449	0.8096	CPR	12/31/92	FPI(F)
55.0%	MHC 53	10/89	1988	65.557	78.615	0.8339	CPR	06/30/92	FPI(F)
	MCM 1	06/82	1988	66.046	79.201	0.8339	CPR	02/28/88	CPIF
83.7%	MCM 2	05/83	1988	36.076	43.262	0.8339	CPR	11/09/88	CPI w/cap

% -- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

OTHER SHIPS
SHIP CHARACTERISTICS

06/03/94

	SHIPS	LENGTH OVERALL	LENGTH LWL	BEAM EXTREME	BEAM BWL	DRAFT MAXNAV	DRAFT LIMIT	HULL	SS	DISPLACEMENT LIGHT	DISPLACEMENT FULL	COMPLE-MENT	TOTAL ACCOM
	LCAC 34	81.0		43.0		2.9				87		5	24
97.8%	MHC 51	188.0	185.0	38.0	36.0	10.0	10.0	COMP.		500		51	51
55.0%	MHC 53	188.0	185.0	38.0	36.0	10.0	10.0	COMP.		500		51	51
	MCM 1	224.0	217.0	39.0	38.0	12.0	13.0	WOOD		1,186	1,260	81	81
83.7%	MCM 2	224.0	217.0	39.0	38.0	12.0	13.0	WOOD		1,186	1,281	81	81

	SHIPS	START CONST.	DELIV.	MO. IN SHPYD	ENGINES NO.	ENGINES TYPE	REDUCT GEAR TYPE	GENERATORS NO	GENERATORS TYPE	GENERATORS TOTAL KW	NO. OF SCREWS	TOTAL SHP
	LCAC 34	10/27/89	05/31/92	31.1	4	GT				120	2	16,000
97.8%	MHC 51	05/16/88	04/23/93	59.2	2	DIE				900	2	1,600
55.0%	MHC 53	05/06/91	03/30/94	34.8	2	DIE				900	2	1,600
	MCM 1	12/13/82	08/28/87	57.5	2	DIE					2	2,400
83.7%	MCM 2	10/24/83	09/08/89	70.5	2	DIE					2	2,400

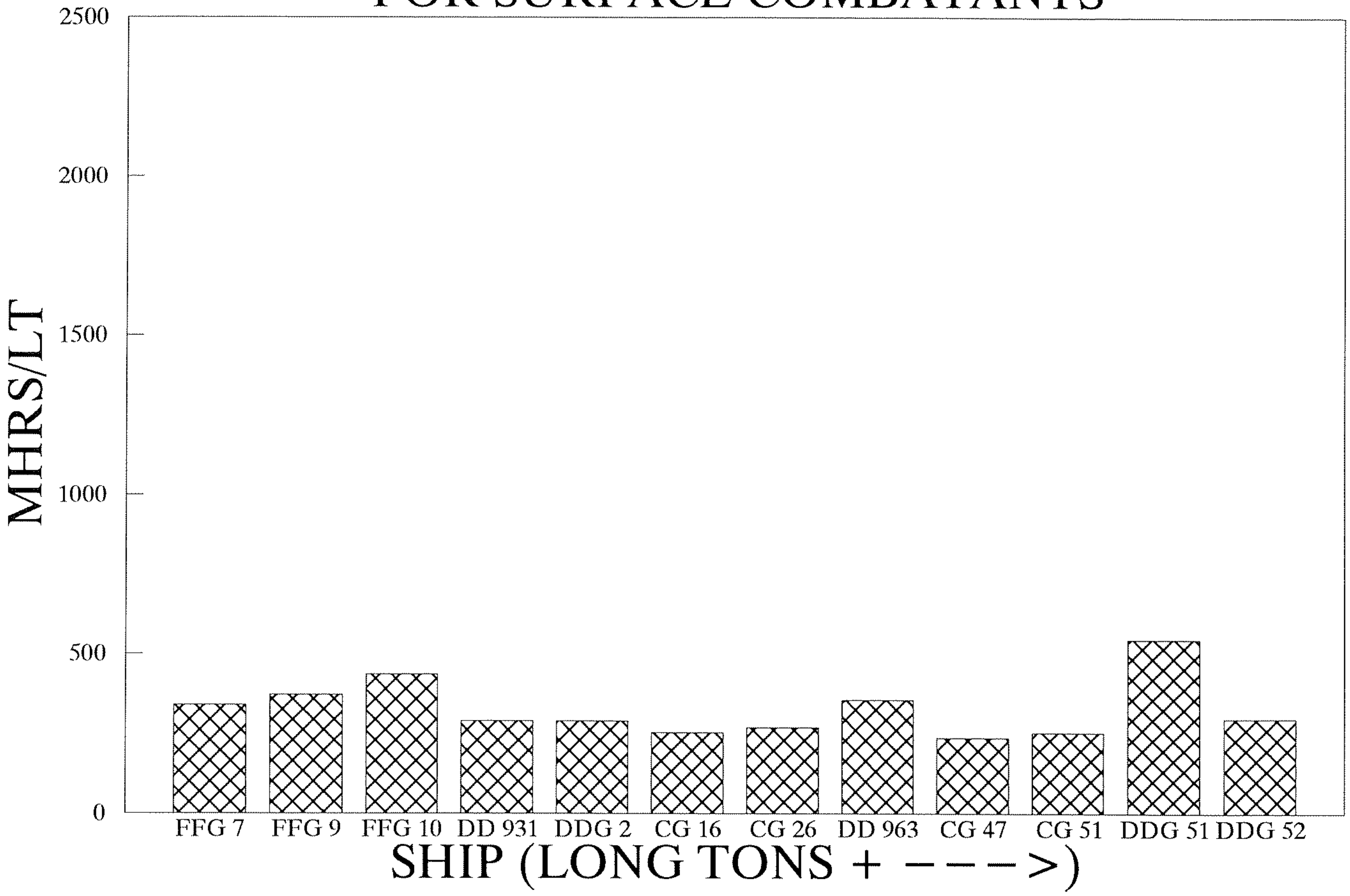
% --- INDICATES PERCENT COMPLETE IF SHIP WAS INCOMPLETE AT TIME OF REPORT

Source: Naval Vessel Register; where NVR was blank or listed a zero, the Program Office was called; where information was unavailable from NVR and Program Office, Jane's was used.

APPENDIX E

BAR GRAPH COMPARISON BY SHIP TYPE

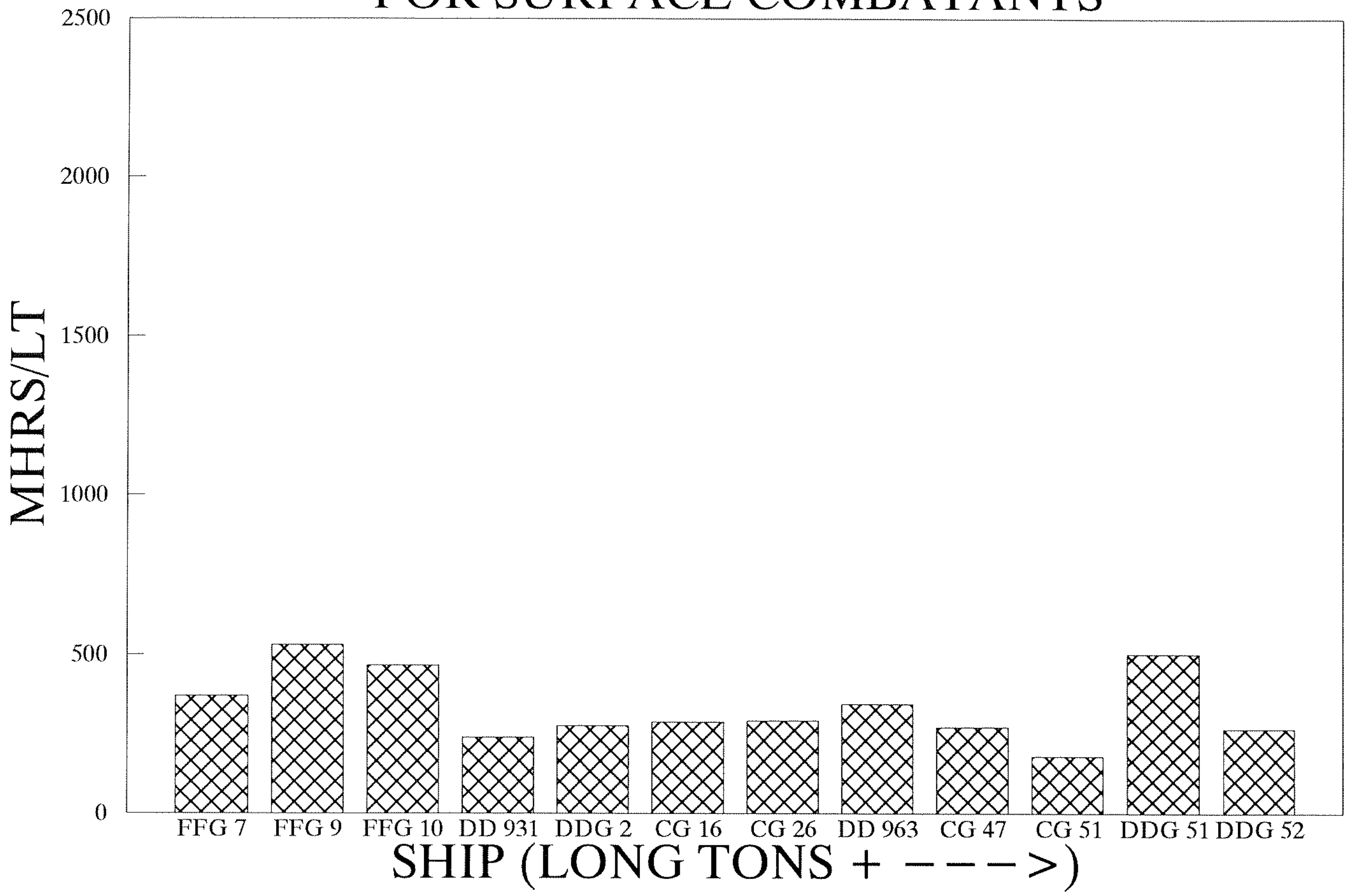
LABOR MHRS PER LT IN GROUP 1
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	339
FFG 9	372
FFG 10	436
DD 931	290
DDG 2	290
CG 16	253
CG 26	268
DD 963	356
CG 47	237
CG 51	254
DDG 51	547
DDG 52	297

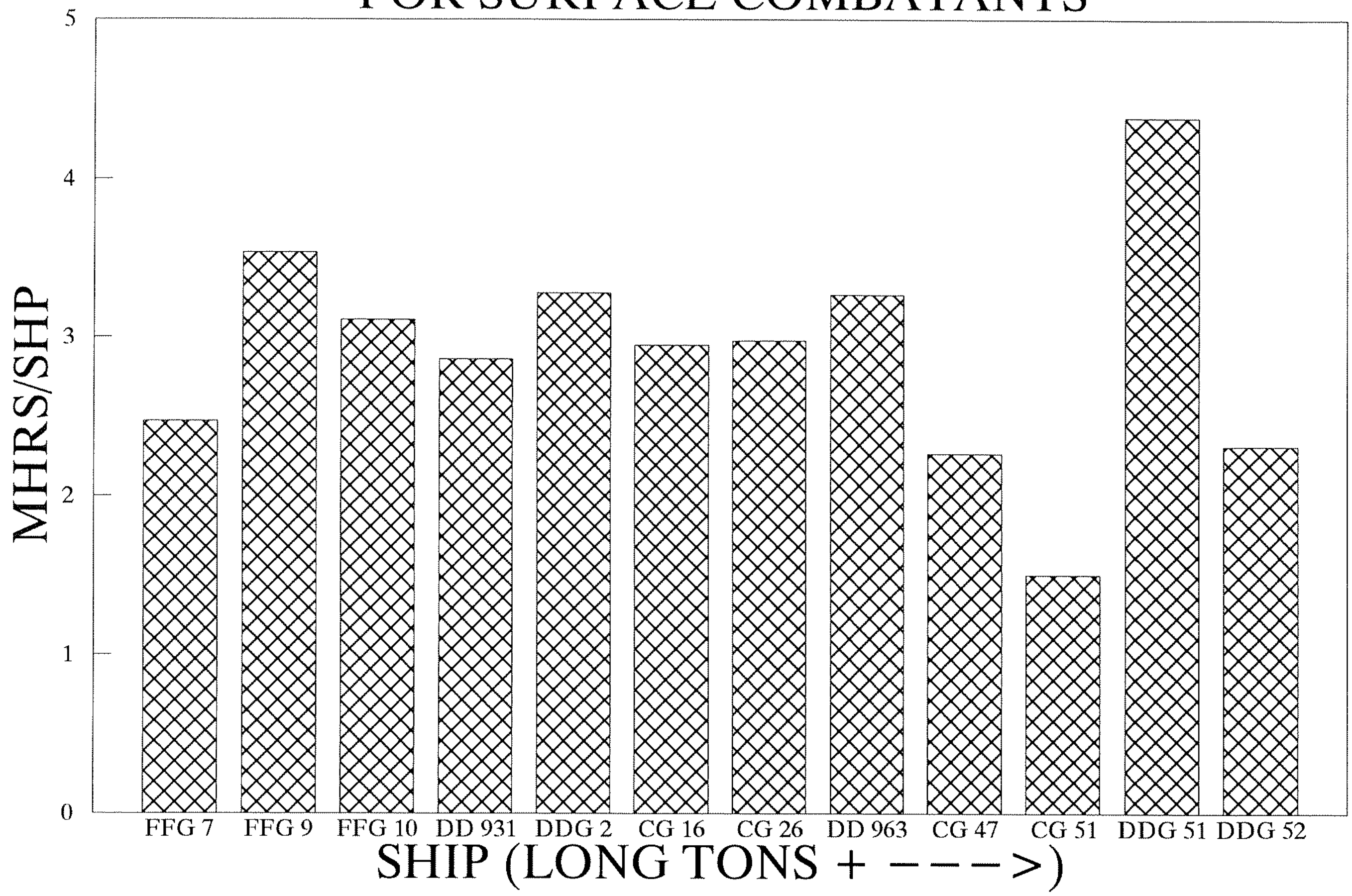
LABOR MHRS PER LT IN GROUP 2
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	370
FFG 9	529
FFG 10	465
DD 931	238
DDG 2	276
CG 16	287
CG 26	291
DD 963	344
CG 47	272
CG 51	179
DDG 51	502
DDG 52	265

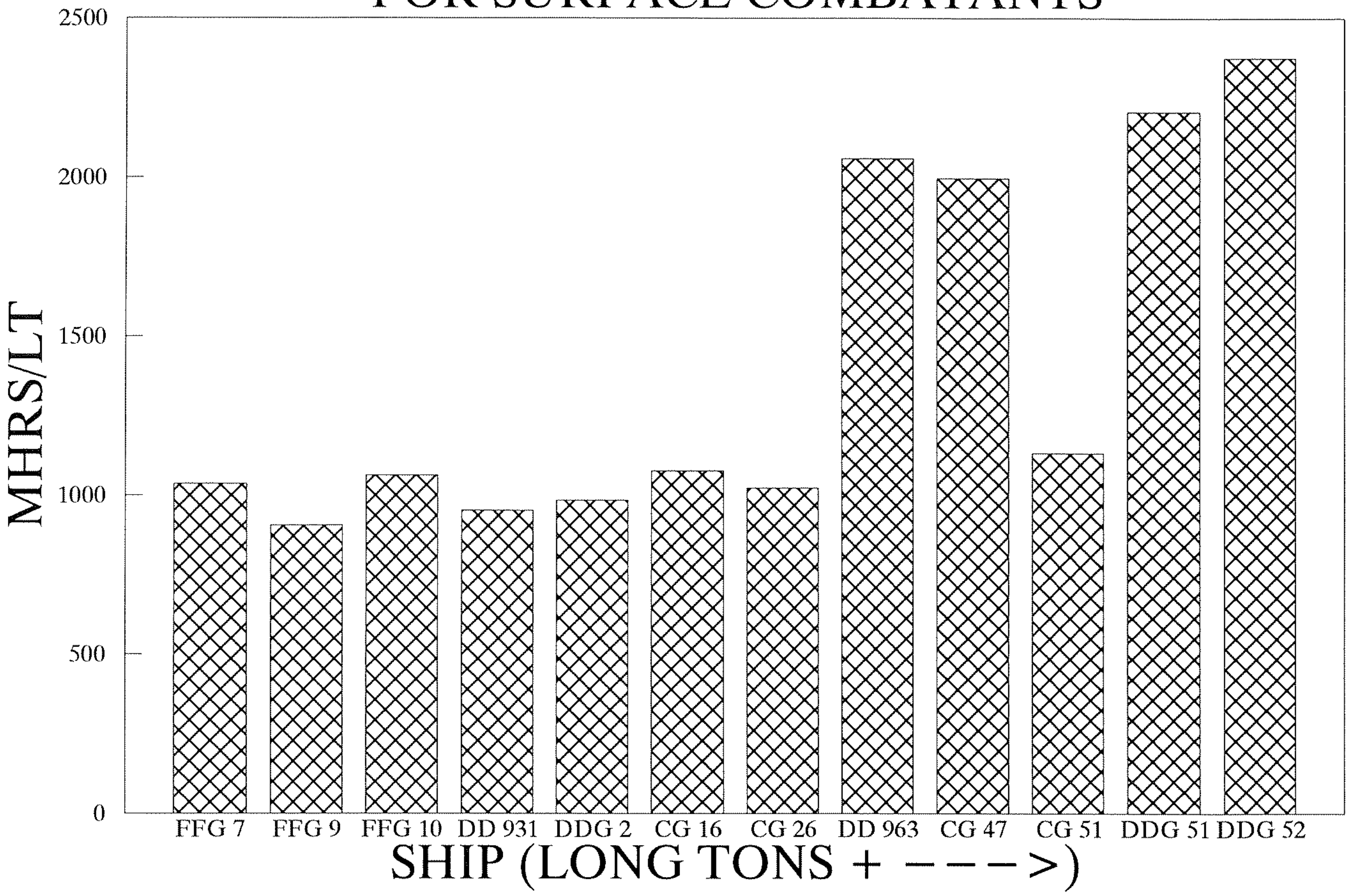
LABOR MHRS PER SHP IN GROUP 2
FOR SURFACE COMBATANTS



DATA

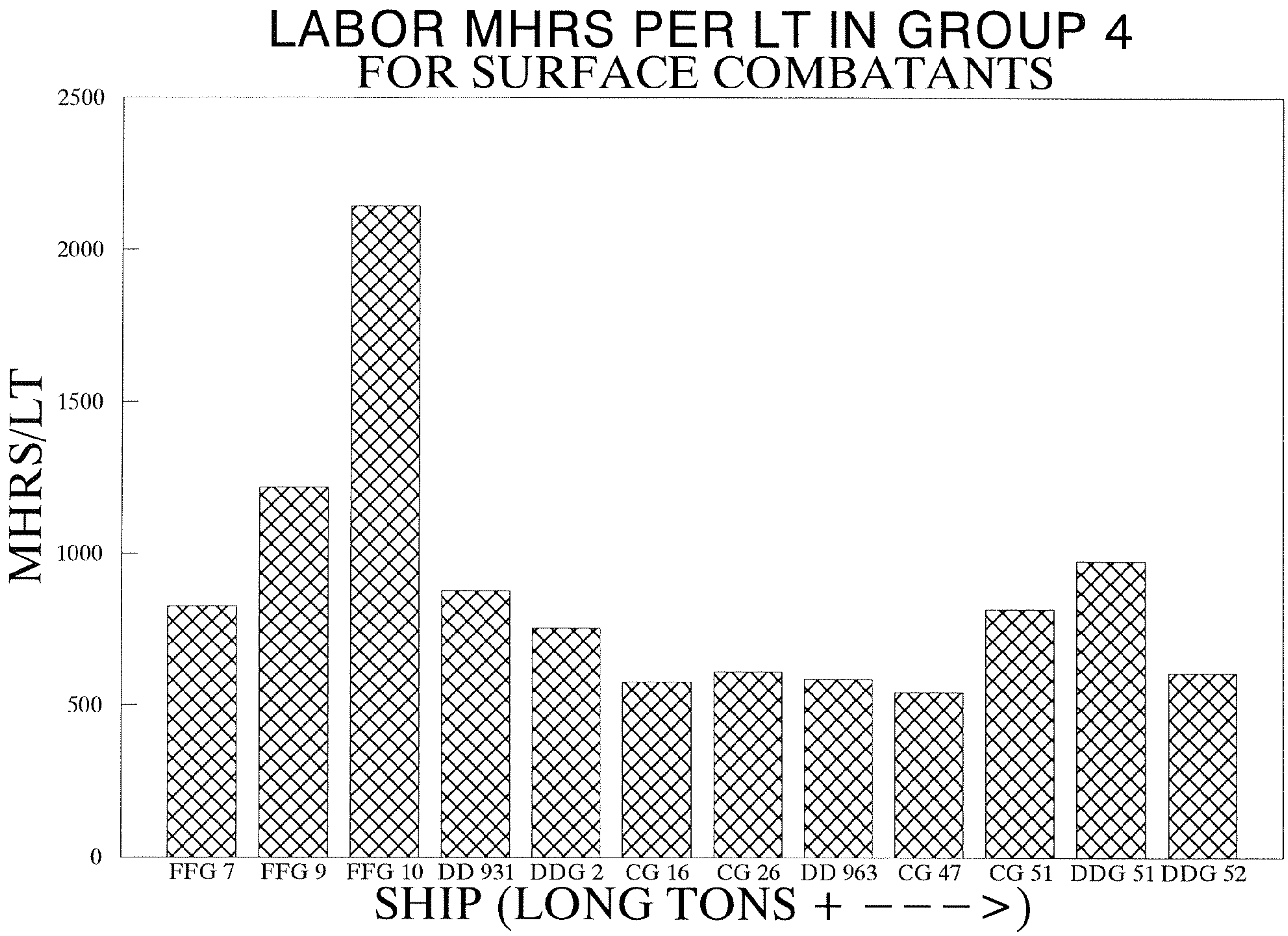
SHIPS	MHRS/SHP
FFG 7	2.5
FFG 9	3.5
FFG 10	3.1
DD 931	2.9
DDG 2	3.3
CG 16	3.0
CG 26	3.0
DD 963	3.3
CG 47	2.3
CG 51	1.5
DDG 51	4.4
DDG 52	2.3

LABOR MHRS PER LT IN GROUP 3
FOR SURFACE COMBATANTS



DATA

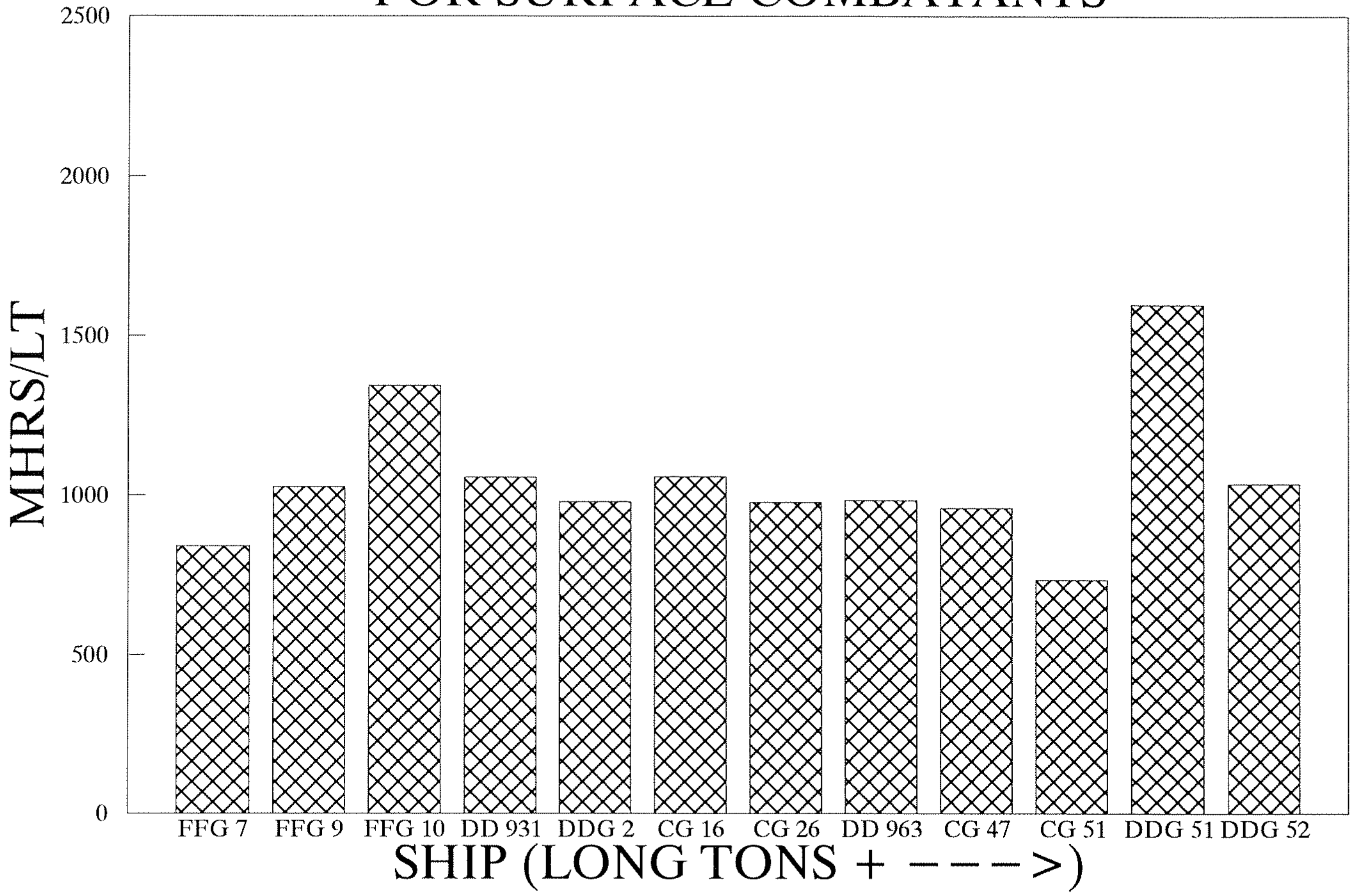
SHIP	MHRS/LT
FFG 7	1,036
FFG 9	906
FFG 10	1,062
DD 931	952
DDG 2	984
CG 16	1,078
CG 26	1,022
DD 963	2,059
CG 47	1,998
CG 51	1,134
DDG 51	2,206
DDG 52	2,377



DATA

SHIP	MHRS/LT
FFG 7	826
FFG 9	1,219
FFG 10	2,143
DD 931	877
DDG 2	752
CG 16	576
CG 26	611
DD 963	586
CG 47	542
CG 51	818
DDG 51	979
DDG 52	607

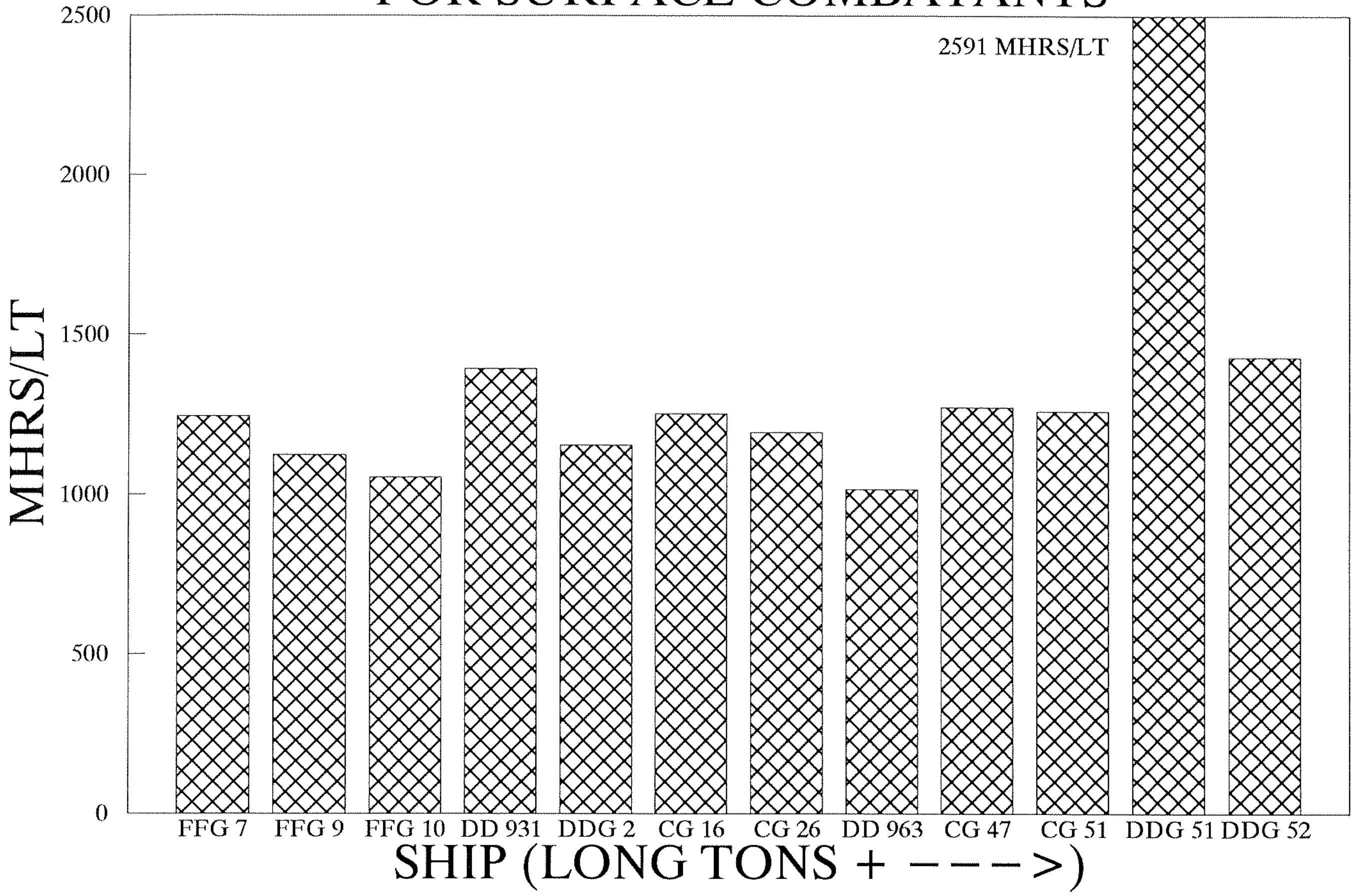
LABOR MHRS PER LT IN GROUP 5
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	842
FFG 9	1,028
FFG 10	1,344
DD 931	1,057
DDG 2	981
CG 16	1,059
CG 26	978
DD 963	983
CG 47	961
CG 51	736
DDG 51	1,600
DDG 52	1,037

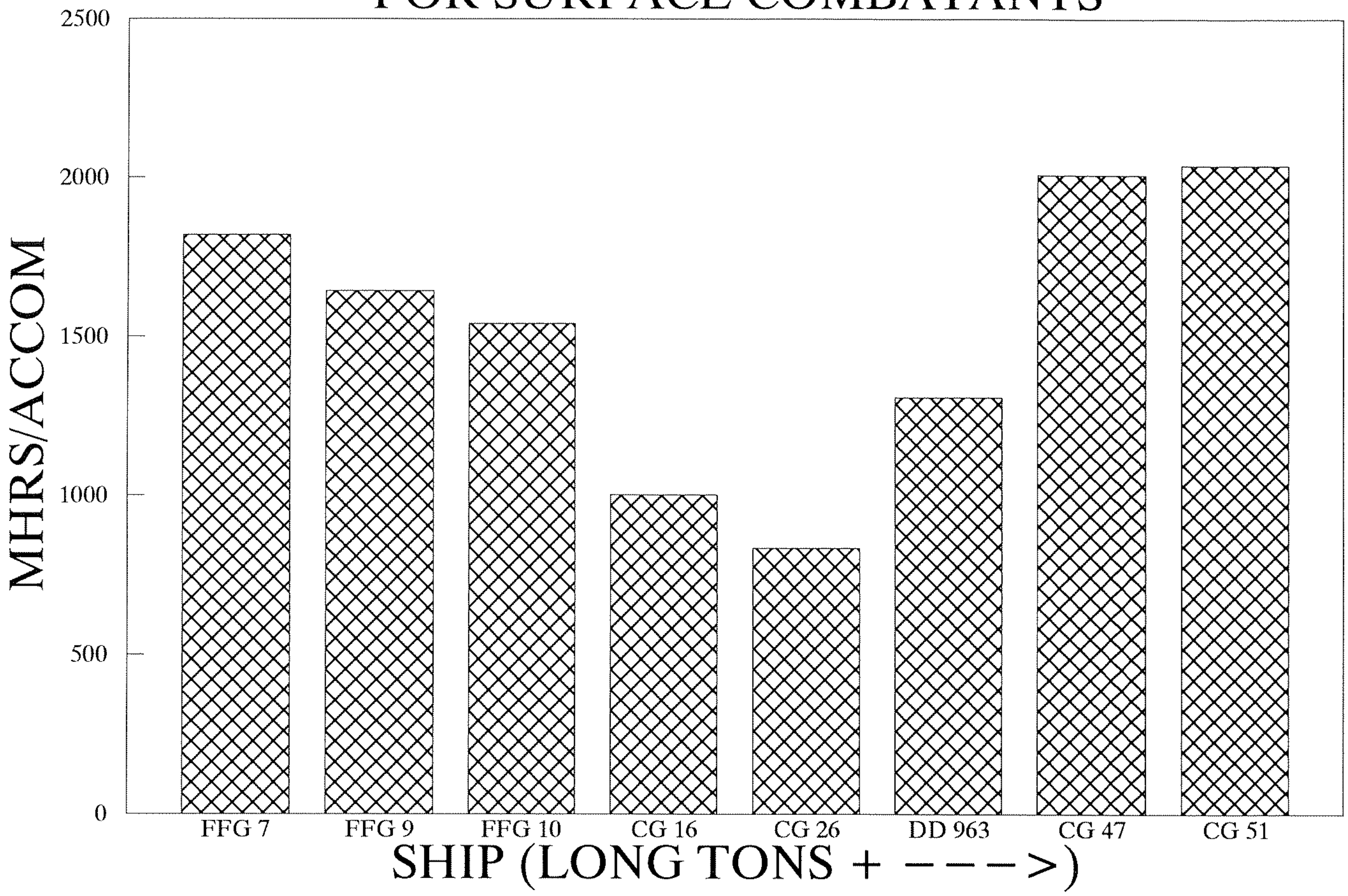
LABOR MHRS PER LT IN GROUP 6
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	1,246
FFG 9	1,125
FFG 10	1,056
DD 931	1,393
DDG 2	1,156
CG 16	1,253
CG 26	1,196
DD 963	1,017
CG 47	1,273
CG 51	1,261
DDG 51	2,591
DDG 52	1,429

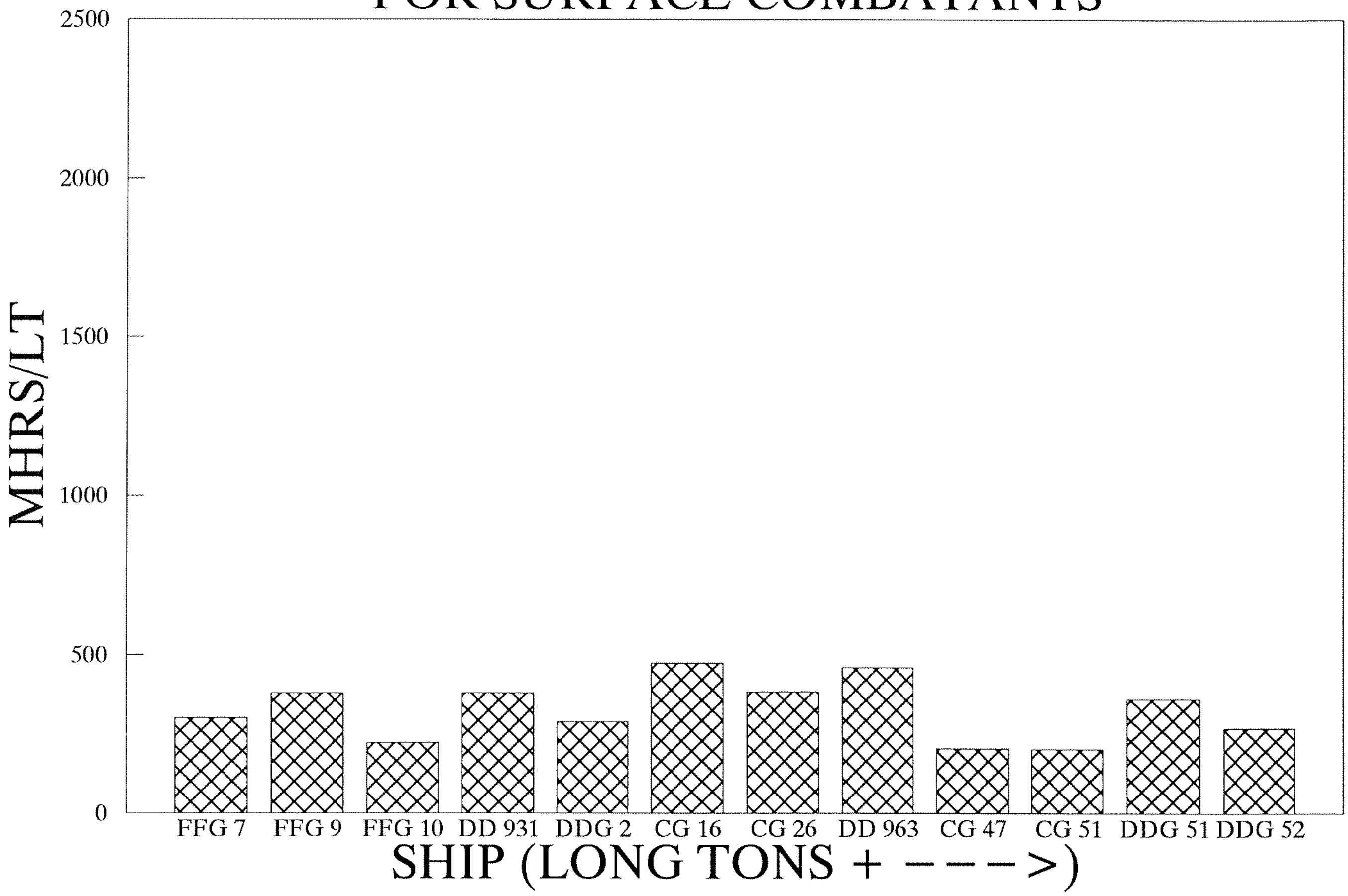
LABOR MHRS PER ACCOMODATION IN GRP 6 FOR SURFACE COMBATANTS



DATA

SHIPS	MHRS/ACCOM
FFG 7	1,820
FFG 9	1,644
FFG 10	1,542
CG 16	1,003
CG 26	834
DD 963	1,310
CG 47	2,008
CG 51	2,039

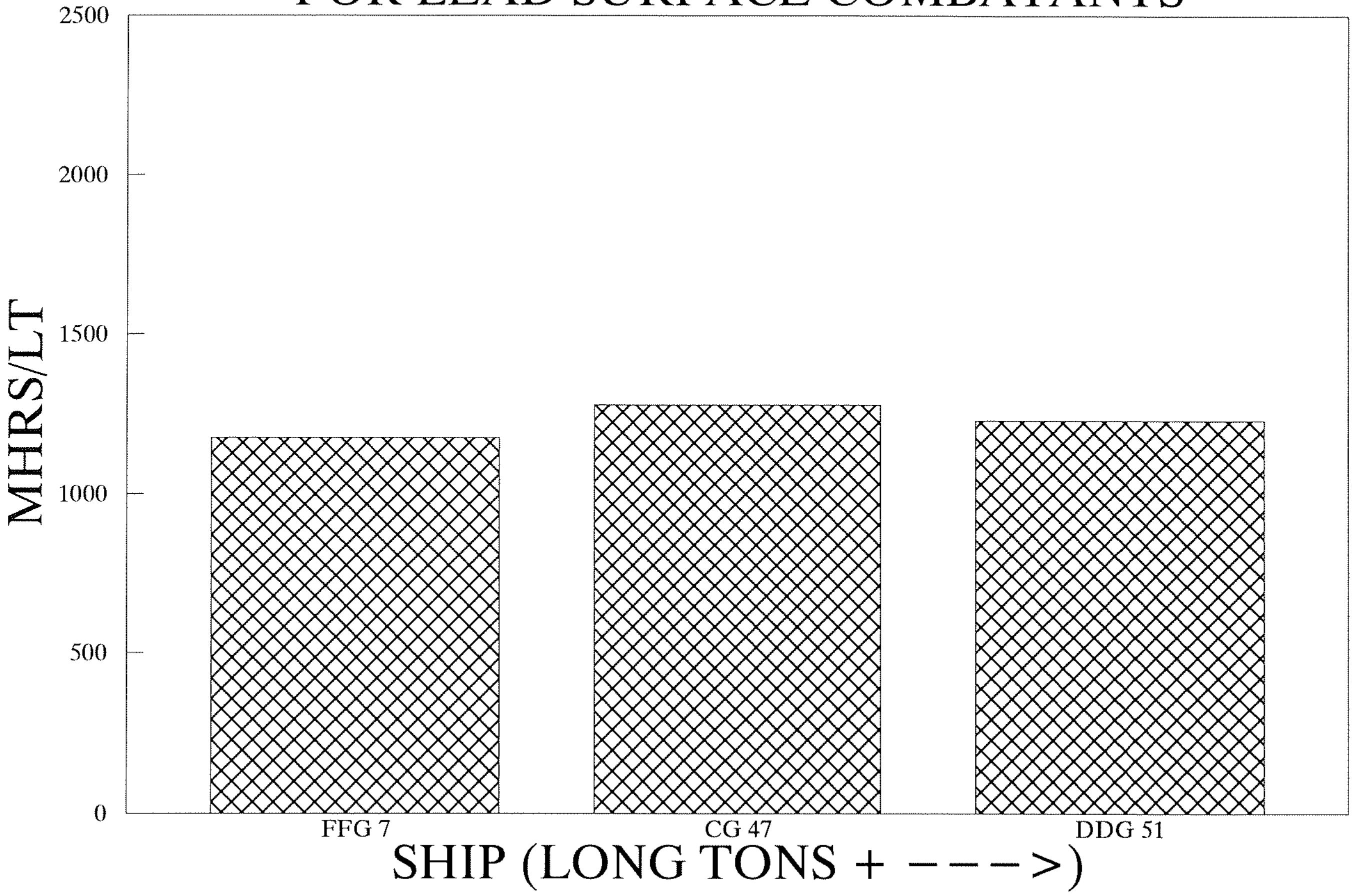
LABOR MHRS PER LT IN GROUP 7
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	302
FFG 9	380
FFG 10	223
DD 931	379
DDG 2	289
CG 16	475
CG 26	384
DD 963	460
CG 47	204
CG 51	203
DDG 51	362
DDG 52	268

LABOR MHRS PER LT IN GROUP 8
FOR LEAD SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	1,178
CG 47	1,280
DDG 51	1,231

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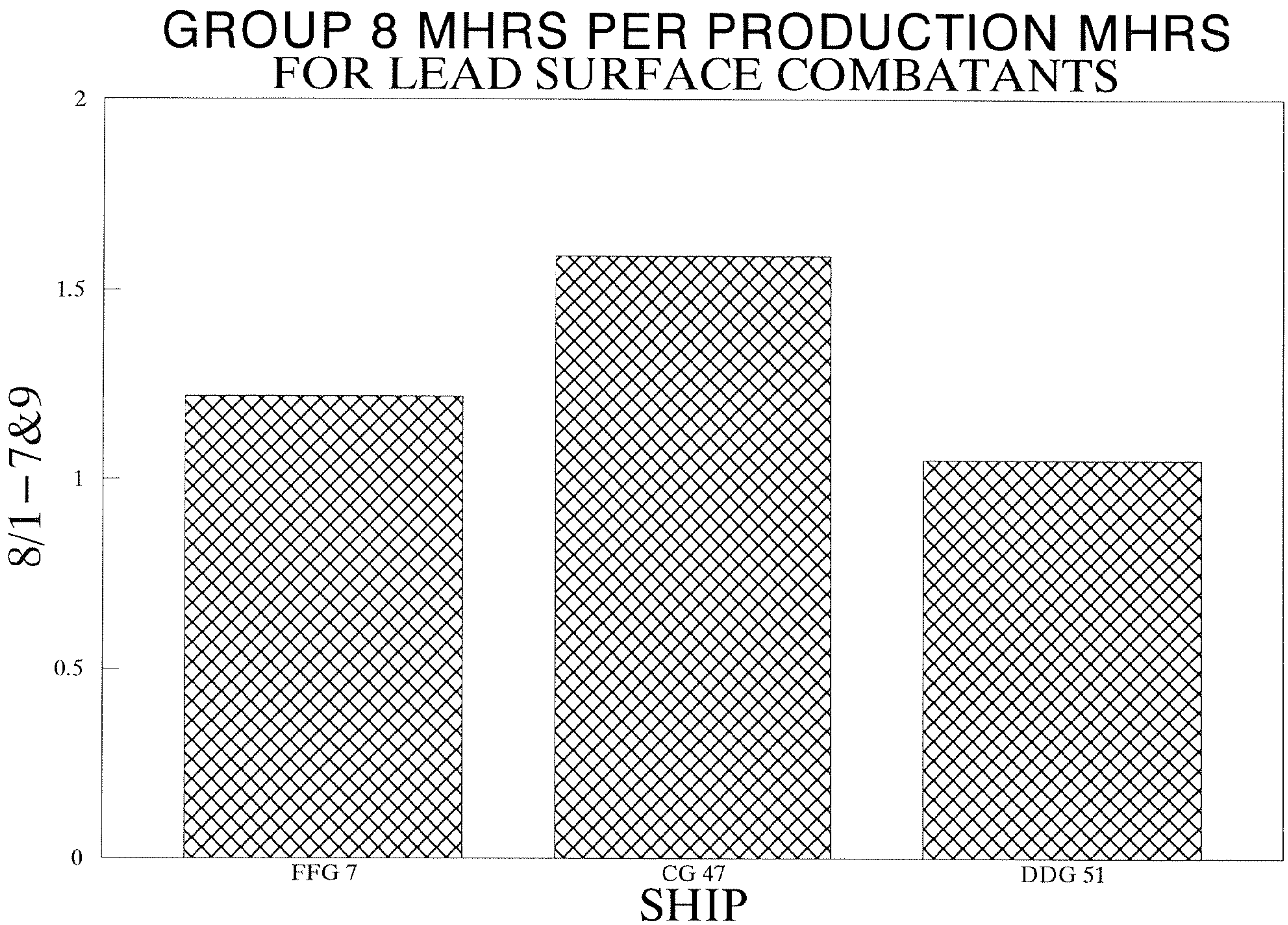
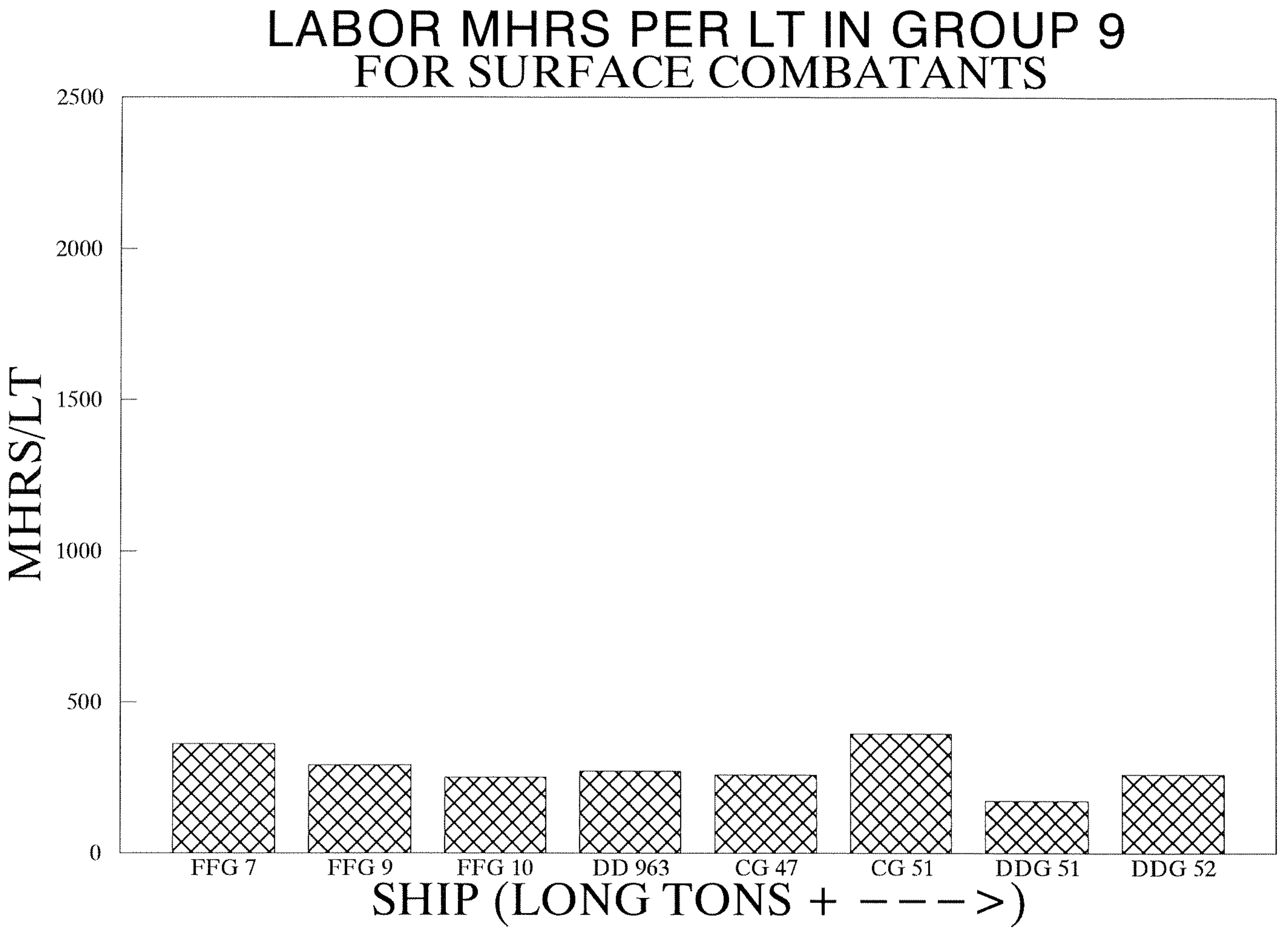


DATA

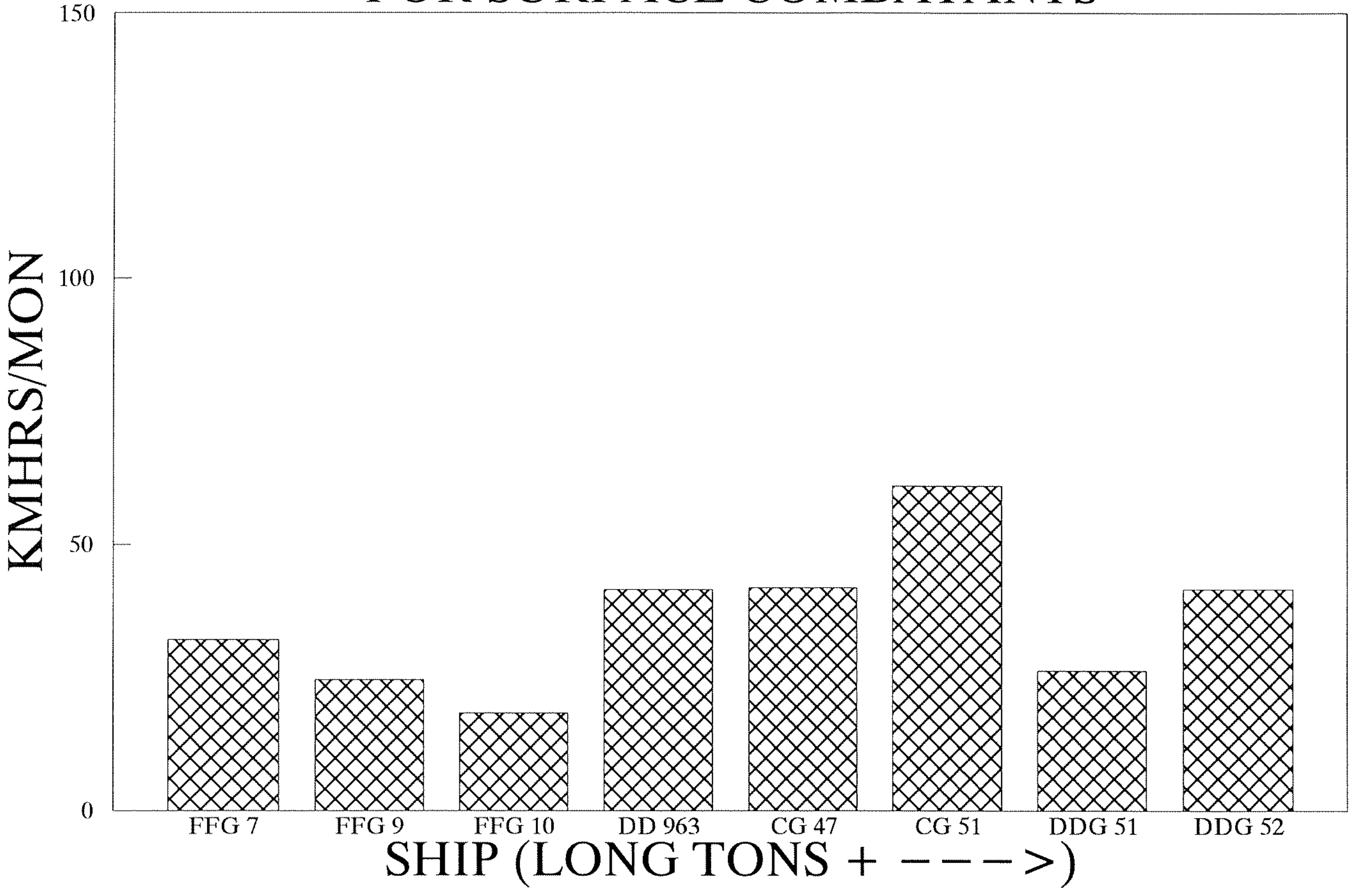
SHIPS	8/1-7&9
FFG 7	1.219
CG 47	1.588
DDG 51	1.051



DATA

SHIP	MHRS/LT
FFG 7	362
FFG 9	291
FFG 10	251
DD 963	272
CG 47	258
CG 51	395
DDG 51	173
DDG 52	261

LABOR MHRS PER MONTHS IN SHIPYARD IN GROUP 9 FOR SURFACE COMBATANTS

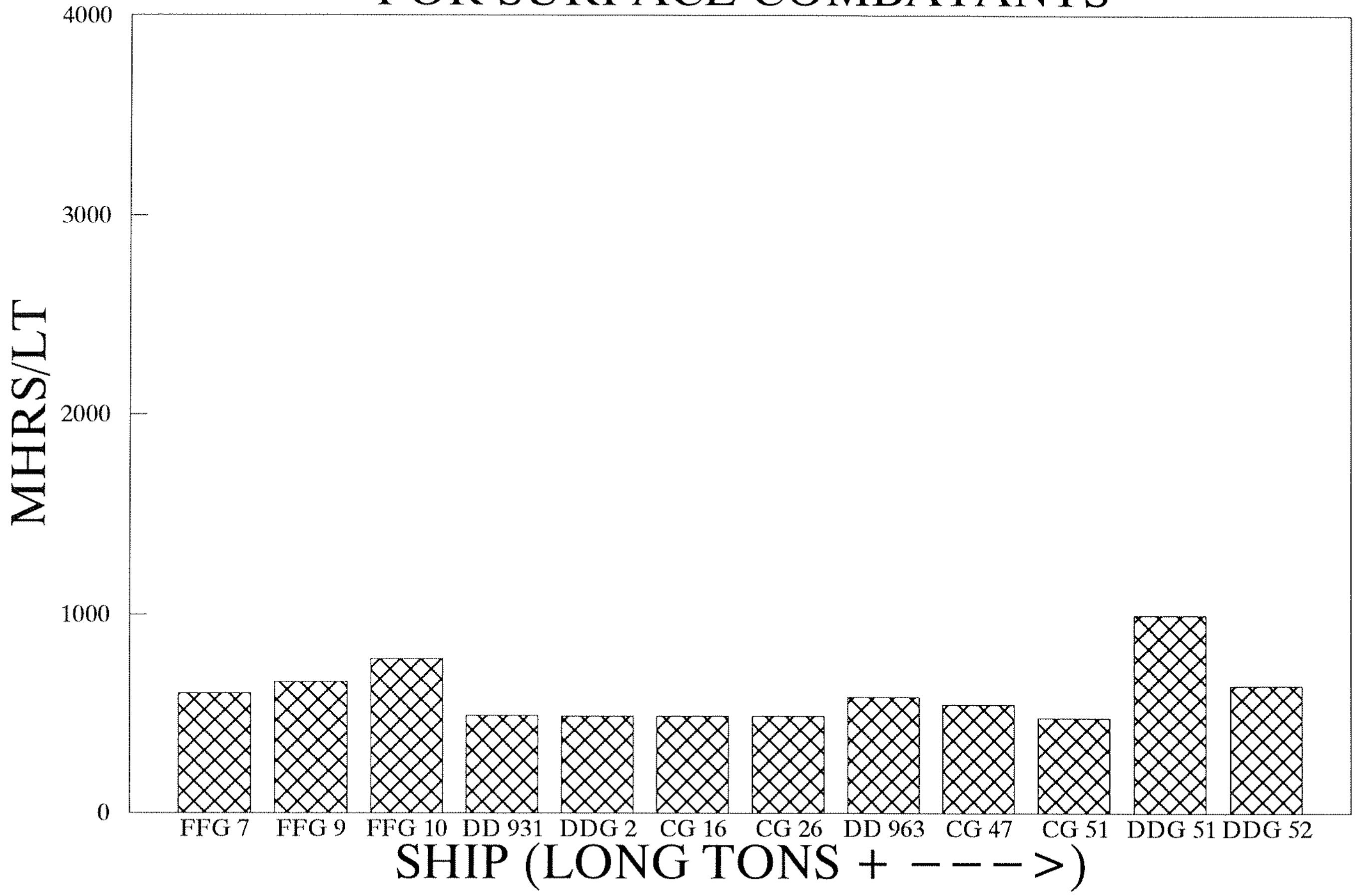


NOTE: FFG 7, 9, and 10 data was not available from NCA; data was taken from Jane's.

DATA

SHIP	KMHRS/MON
FFG 7	32.1
FFG 9	24.6
FFG 10	18.3
DD 963	41.5
CG 47	41.9
CG 51	61.1
DDG 51	26.3
DDG 52	41.7

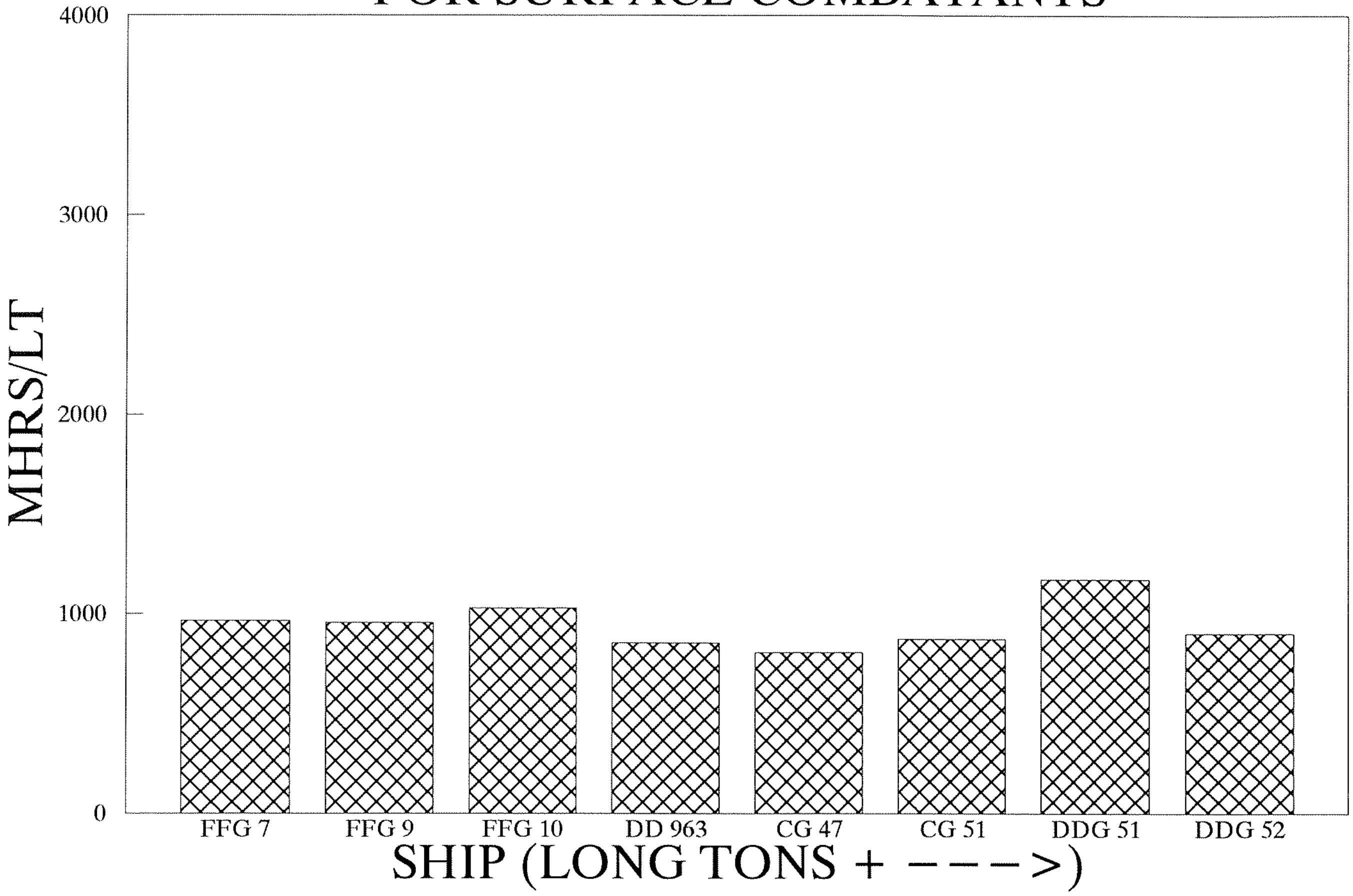
LABOR MHRS PER LT IN GROUP 1–7 FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	604
FFG 9	663
FFG 10	777
DD 931	492
DDG 2	489
CG 16	490
CG 26	489
DD 963	583
CG 47	548
CG 51	479
DDG 51	998
DDG 52	642

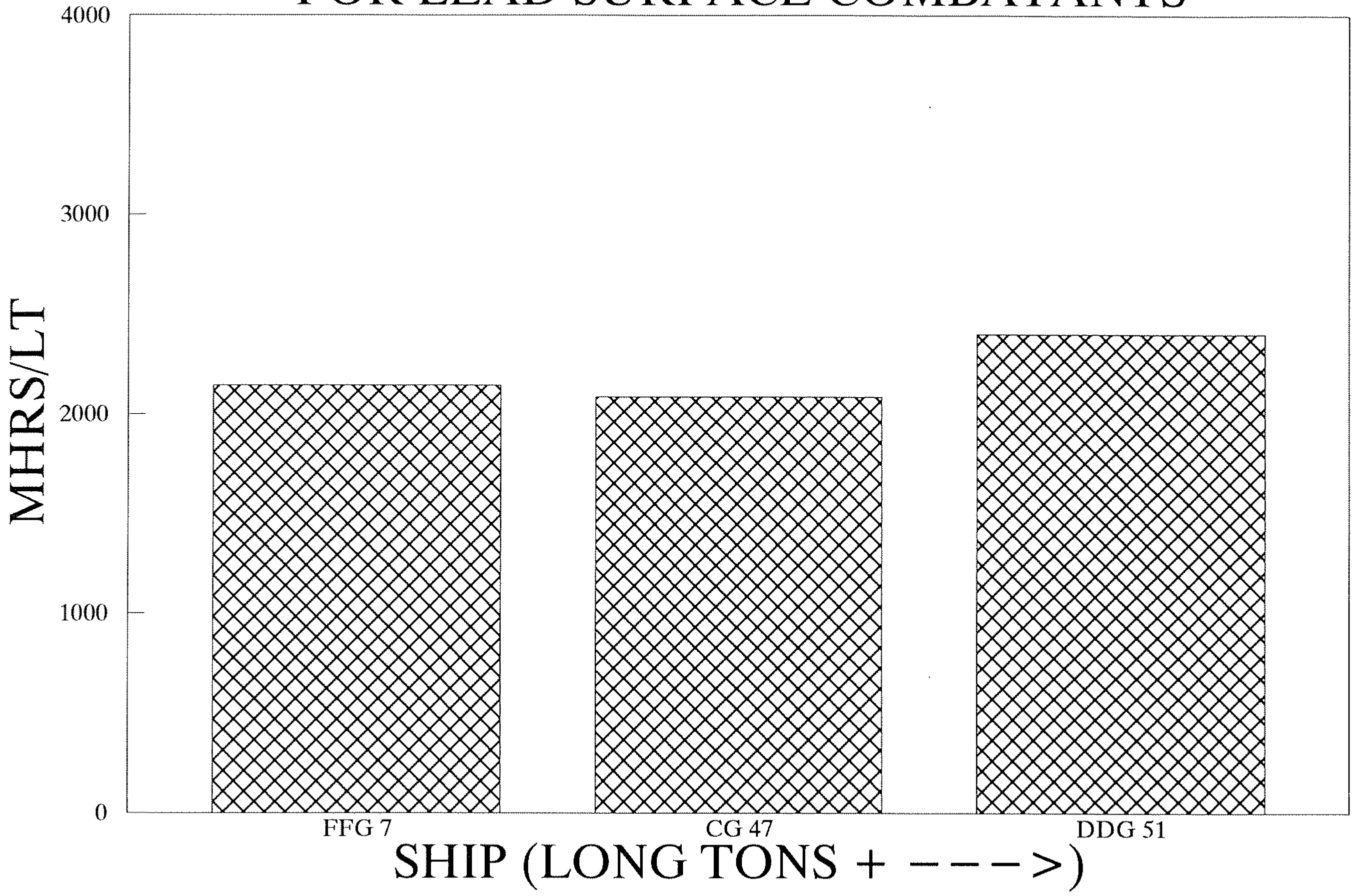
LABOR MHRS PER LT IN GROUP 1–7,9
FOR SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	966
FFG 9	953
FFG 10	1,027
DD 963	855
CG 47	806
CG 51	874
DDG 51	1,171
DDG 52	903

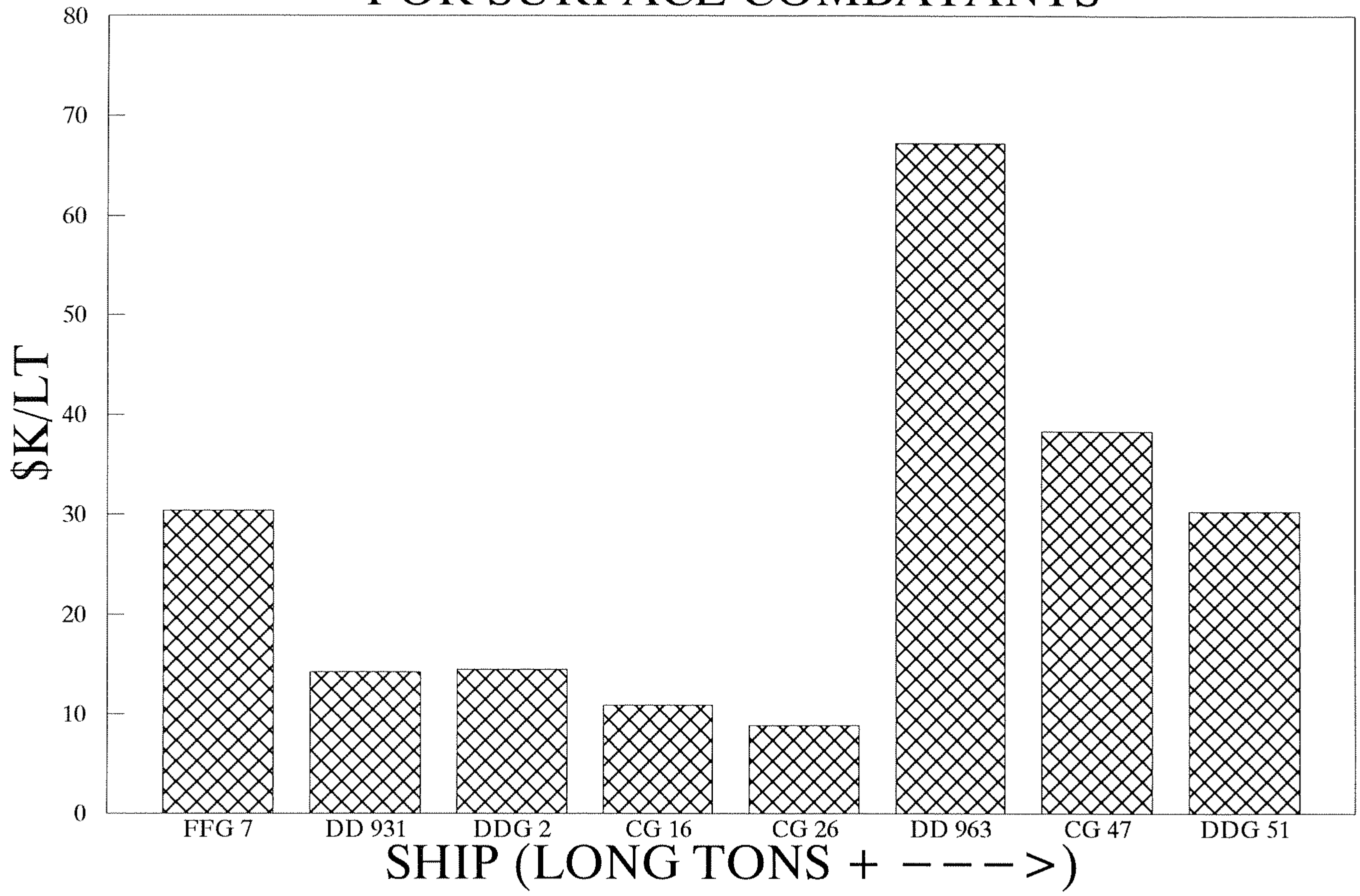
LABOR MHRS PER LT IN GROUP 1–9
FOR LEAD SURFACE COMBATANTS



DATA

SHIP	MHRS/LT
FFG 7	2,144
CG 47	2,086
DDG 51	2,402

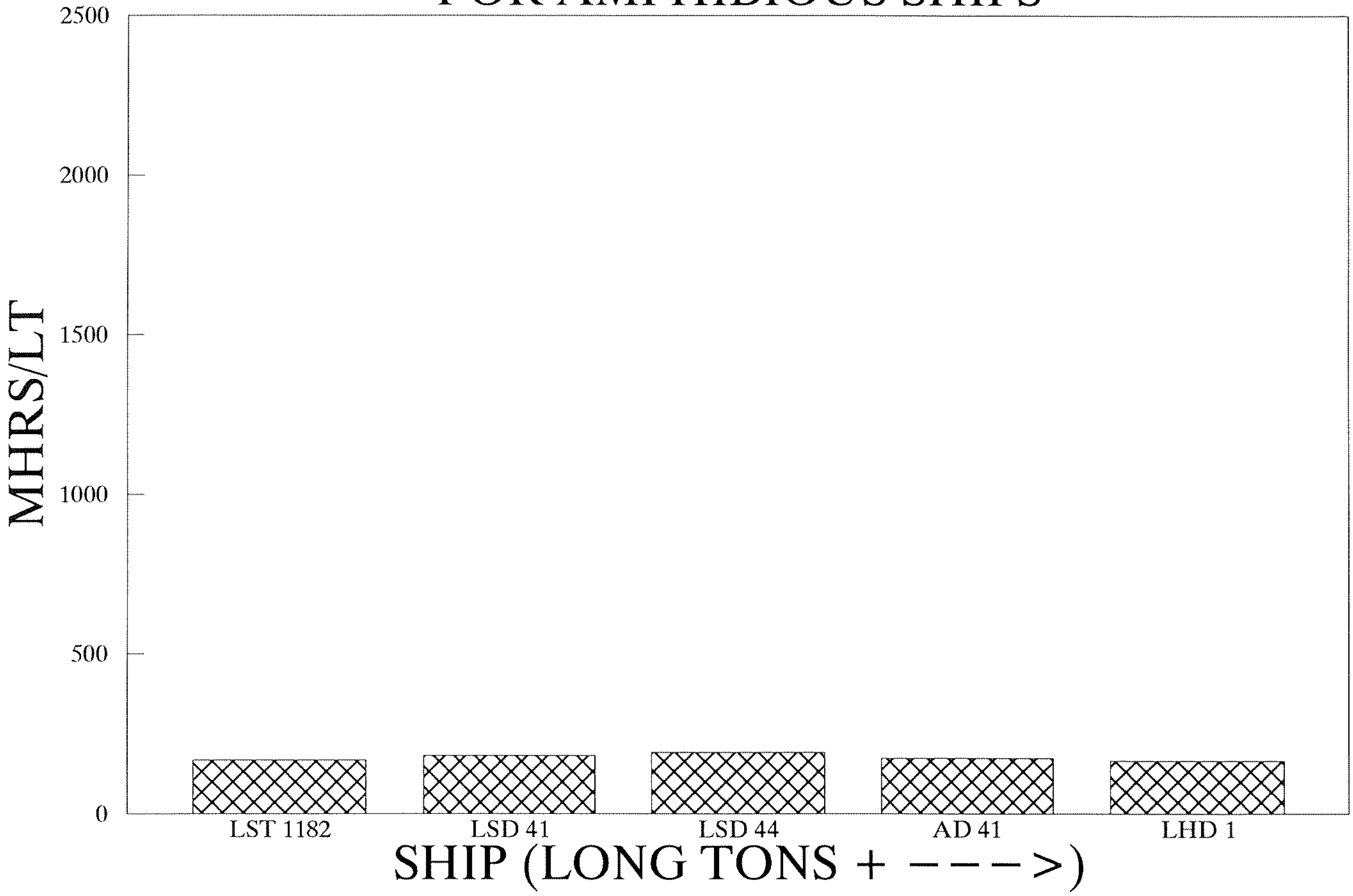
TOTAL MATERIAL COST PER LIGHTSHIP WEIGHT FOR SURFACE COMBATANTS



DATA

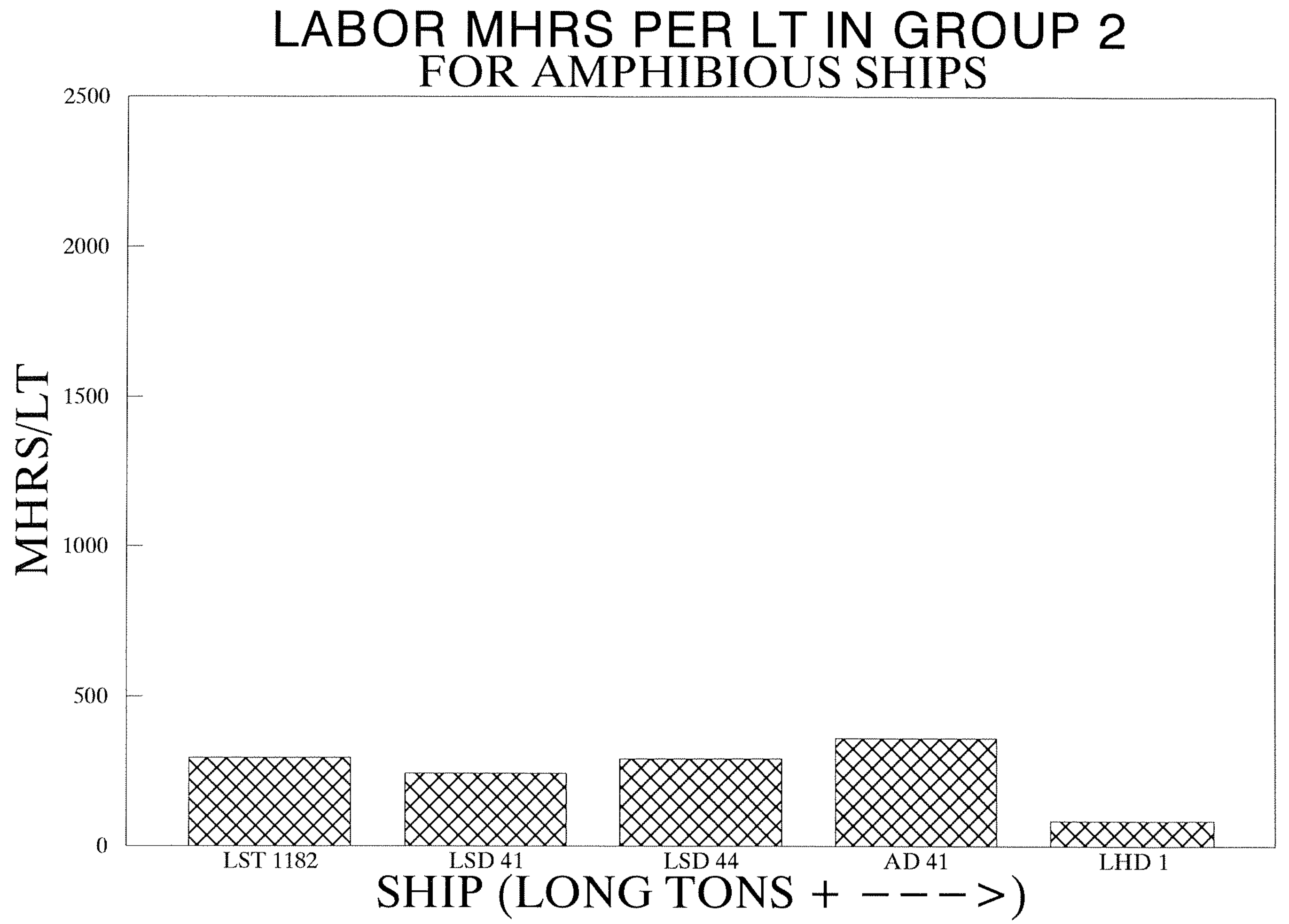
SHIP	$K/LT
FFG 7	30
DD 931	14
DDG 2	14
CG 16	11
CG 26	9
DD 963	67
CG 47	38
DDG 51	30

LABOR MHRS PER LT IN GROUP 1
FOR AMPHIBIOUS SHIPS



DATA

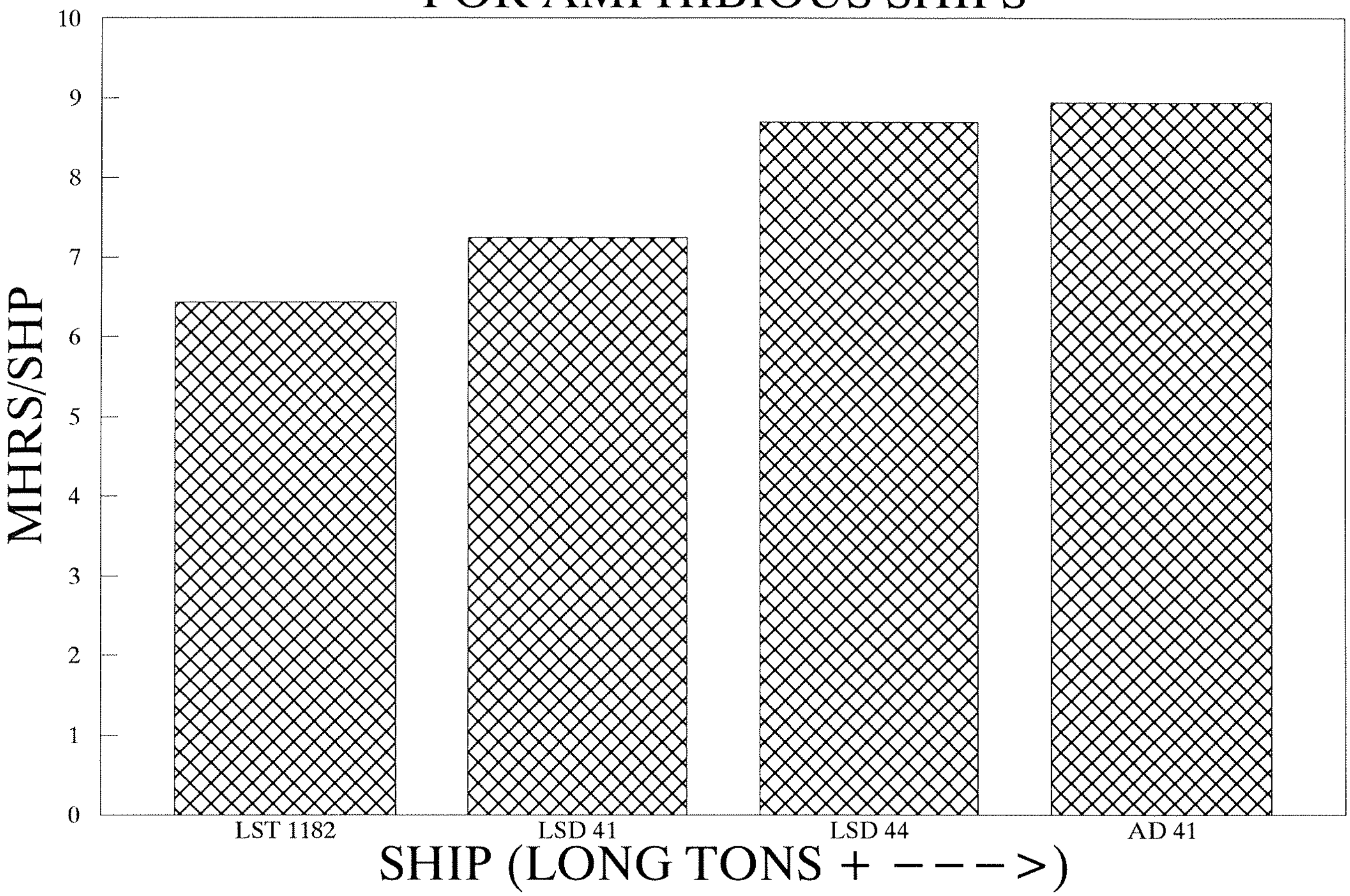
SHIP	MHRS/LT
LST 1182	168
LSD 41	183
LSD 44	193
AD 41	175
LHD 1	167



DATA

SHIP	MHRS/LT
LST 1182	296
LSD 41	243
LSD 44	291
AD 41	359
LHD 1	84

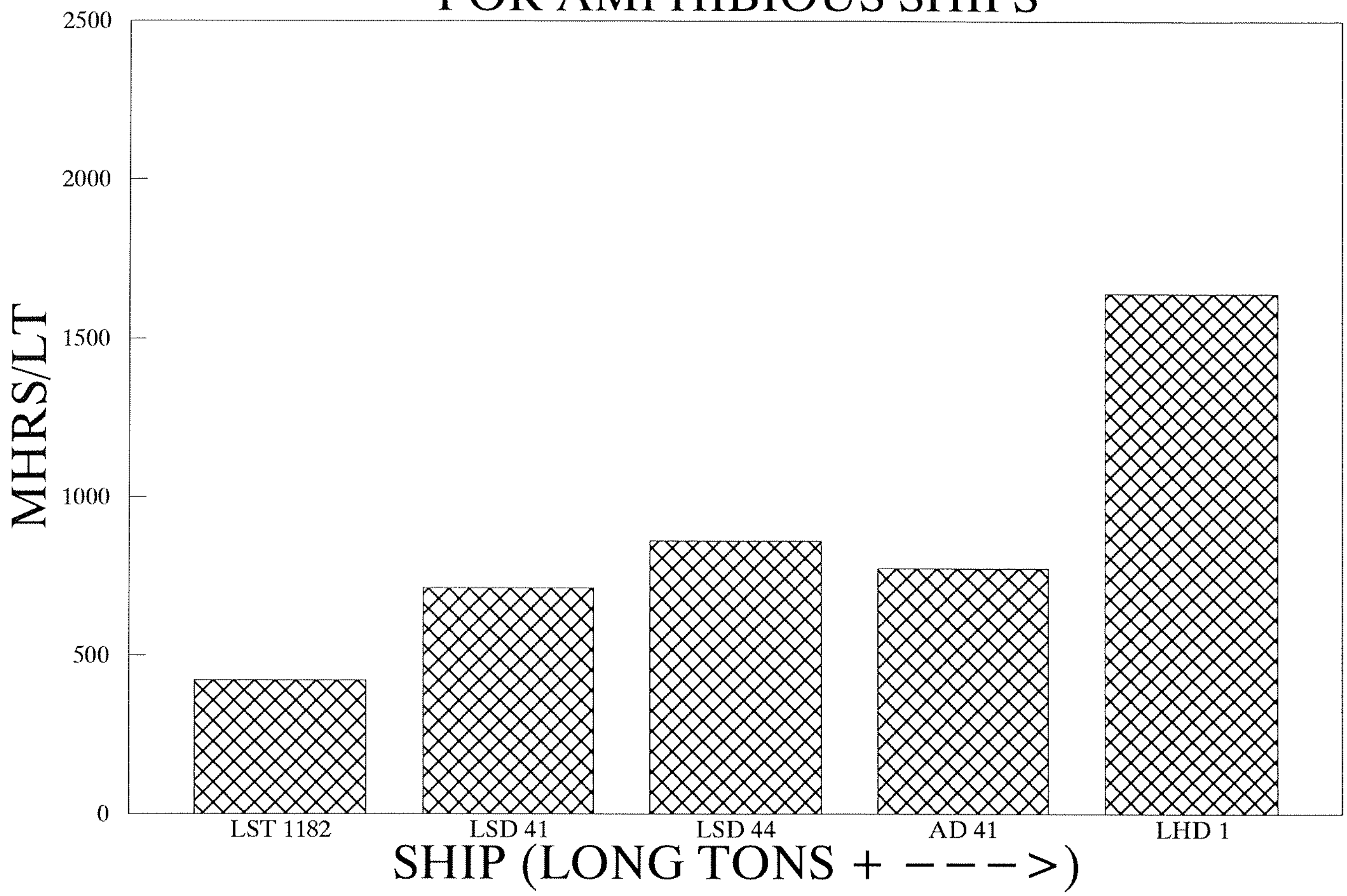
LABOR MHRS VS. SHAFT HORSEPOWER IN GRP 2 FOR AMPHIBIOUS SHIPS



DATA

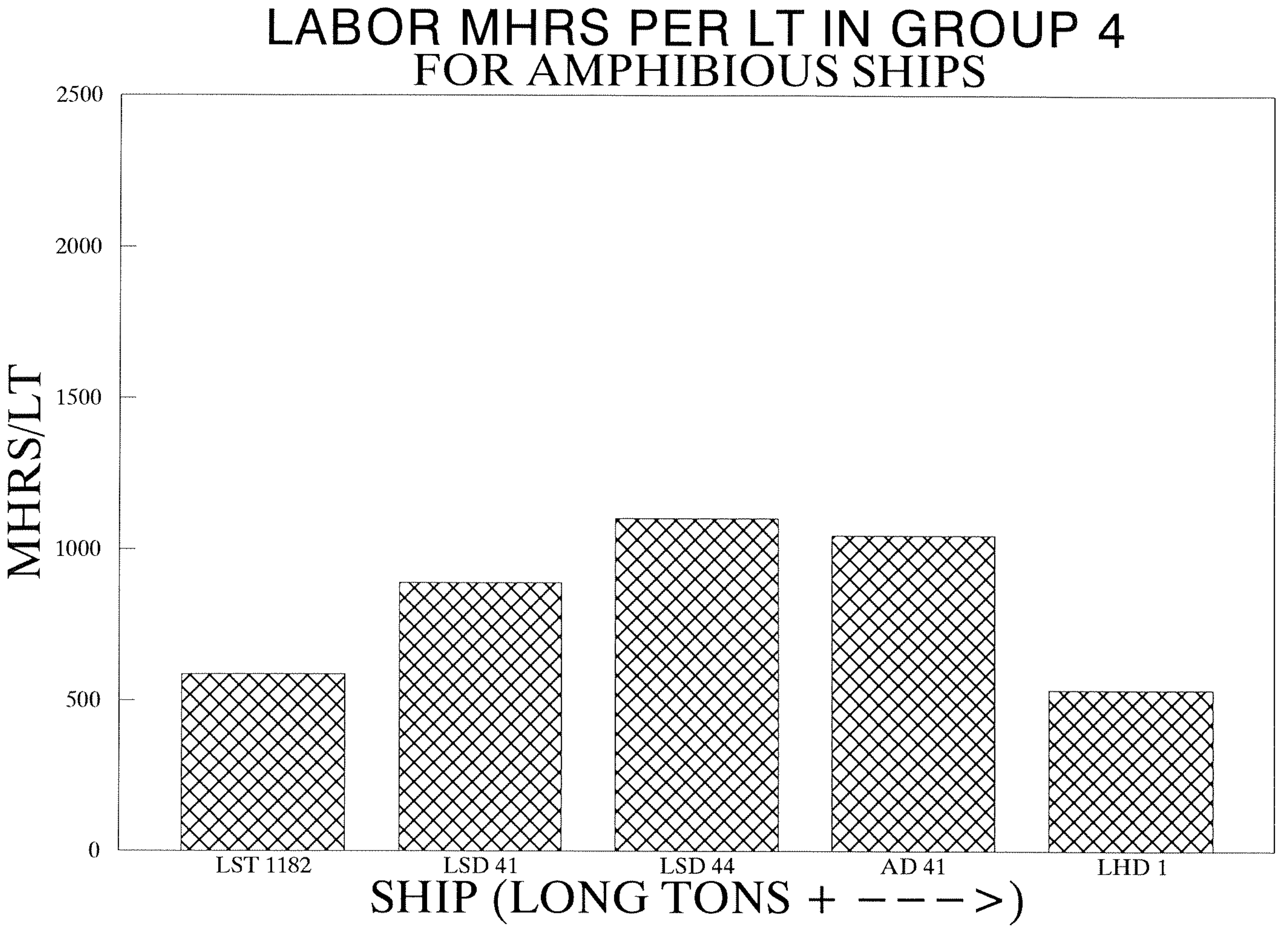
SHIPS	MHRS/SHP
LST 1182	6.4
LSD 41	7.2
LSD 44	8.7
AD 41	8.9

LABOR MHRS PER LT IN GROUP 3
FOR AMPHIBIOUS SHIPS



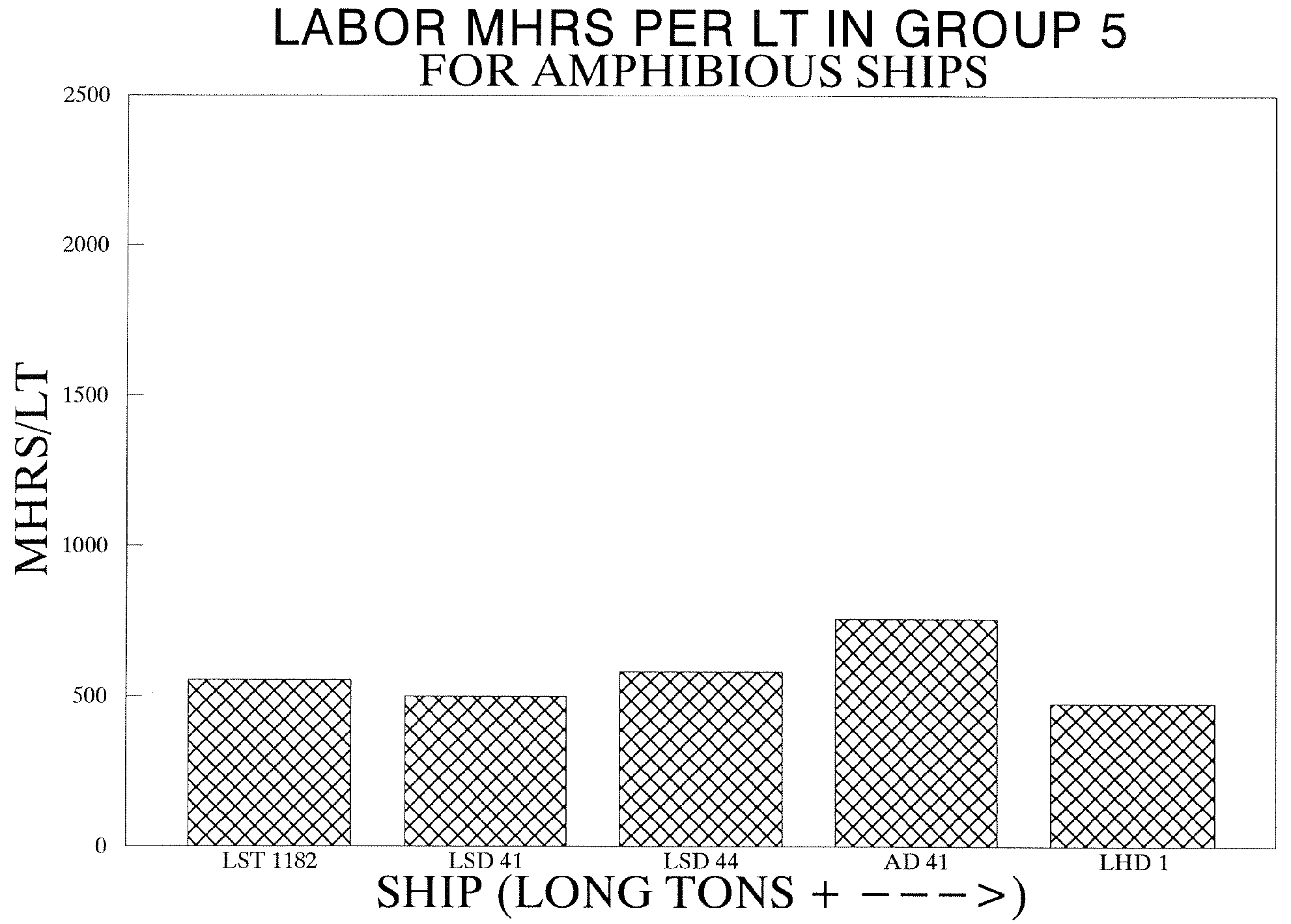
DATA

SHIP	MHRS/LT
LST 1182	421
LSD 41	713
LSD 44	861
AD 41	775
LHD 1	1,643



DATA

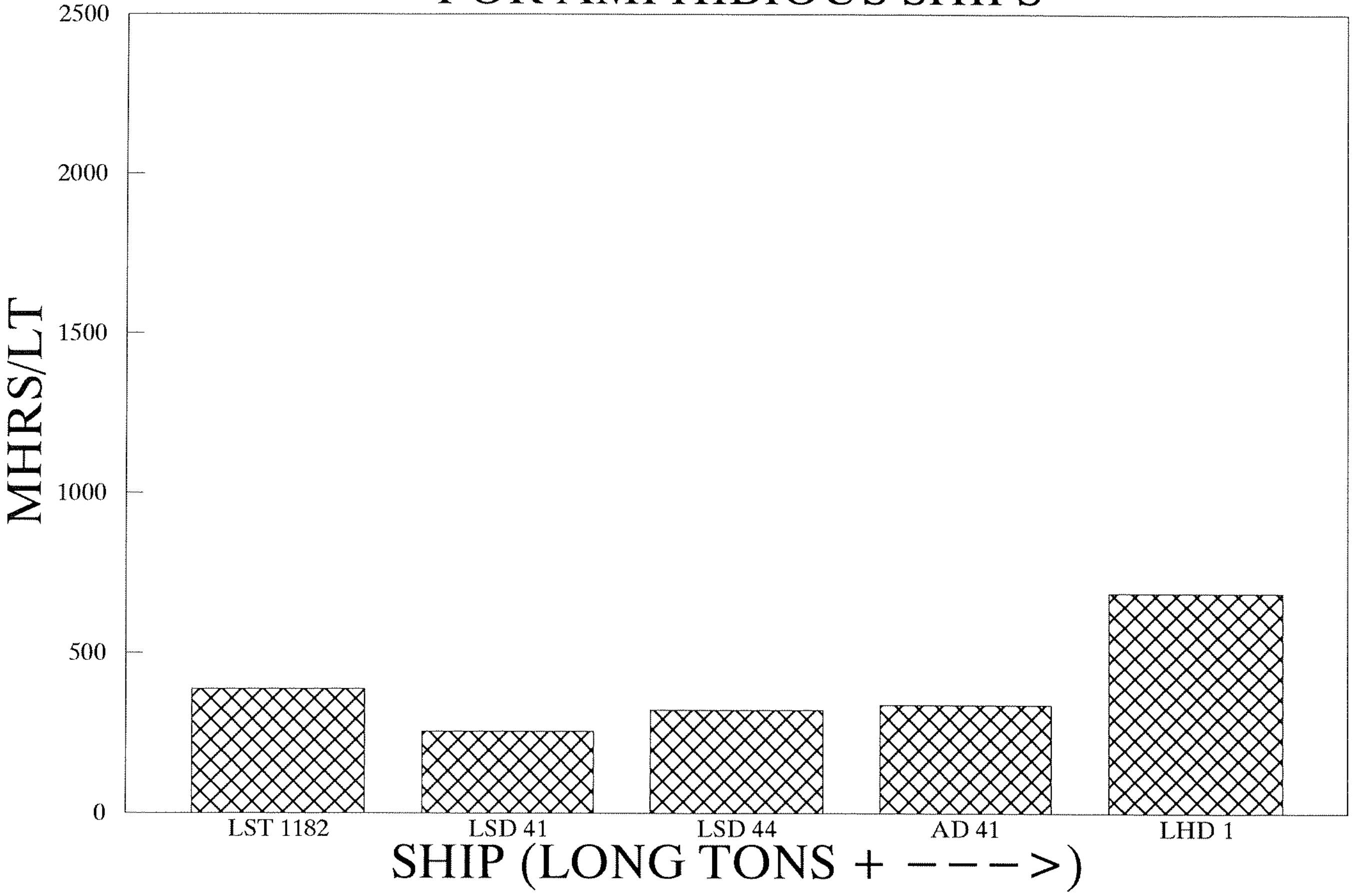
SHIP	MHRS/LT
LST 1182	586
LSD 41	889
LSD 44	1,102
AD 41	1,046
LHD 1	533



DATA

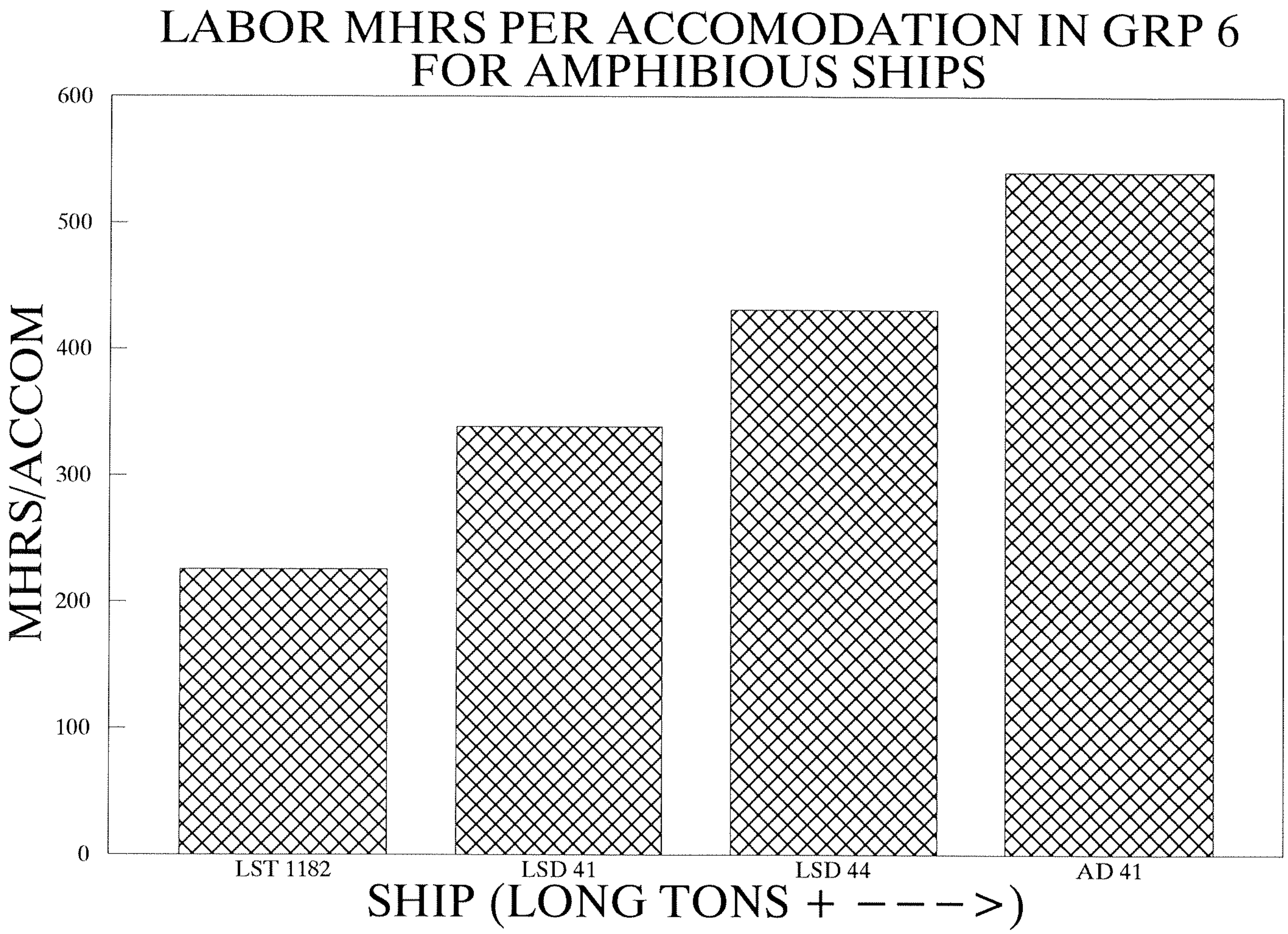
SHIP	MHRS/LT
LST 1182	554
LSD 41	499
LSD 44	584
AD 41	760
LHD 1	479

LABOR MHRS PER LT IN GROUP 6
FOR AMPHIBIOUS SHIPS



DATA

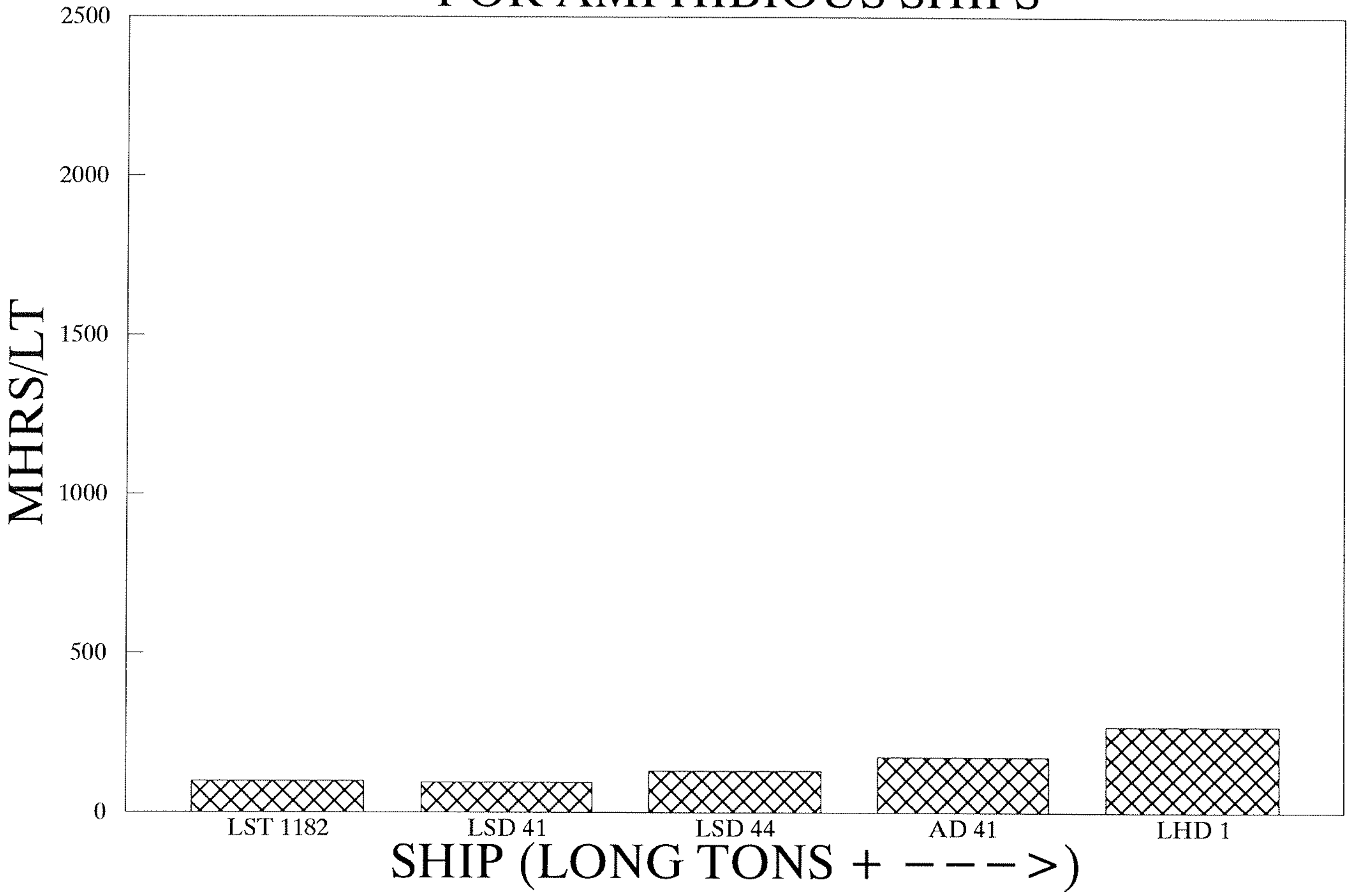
SHIP	MHRS/LT
LST 1182	387
LSD 41	254
LSD 44	322
AD 41	337
LHD 1	689



DATA

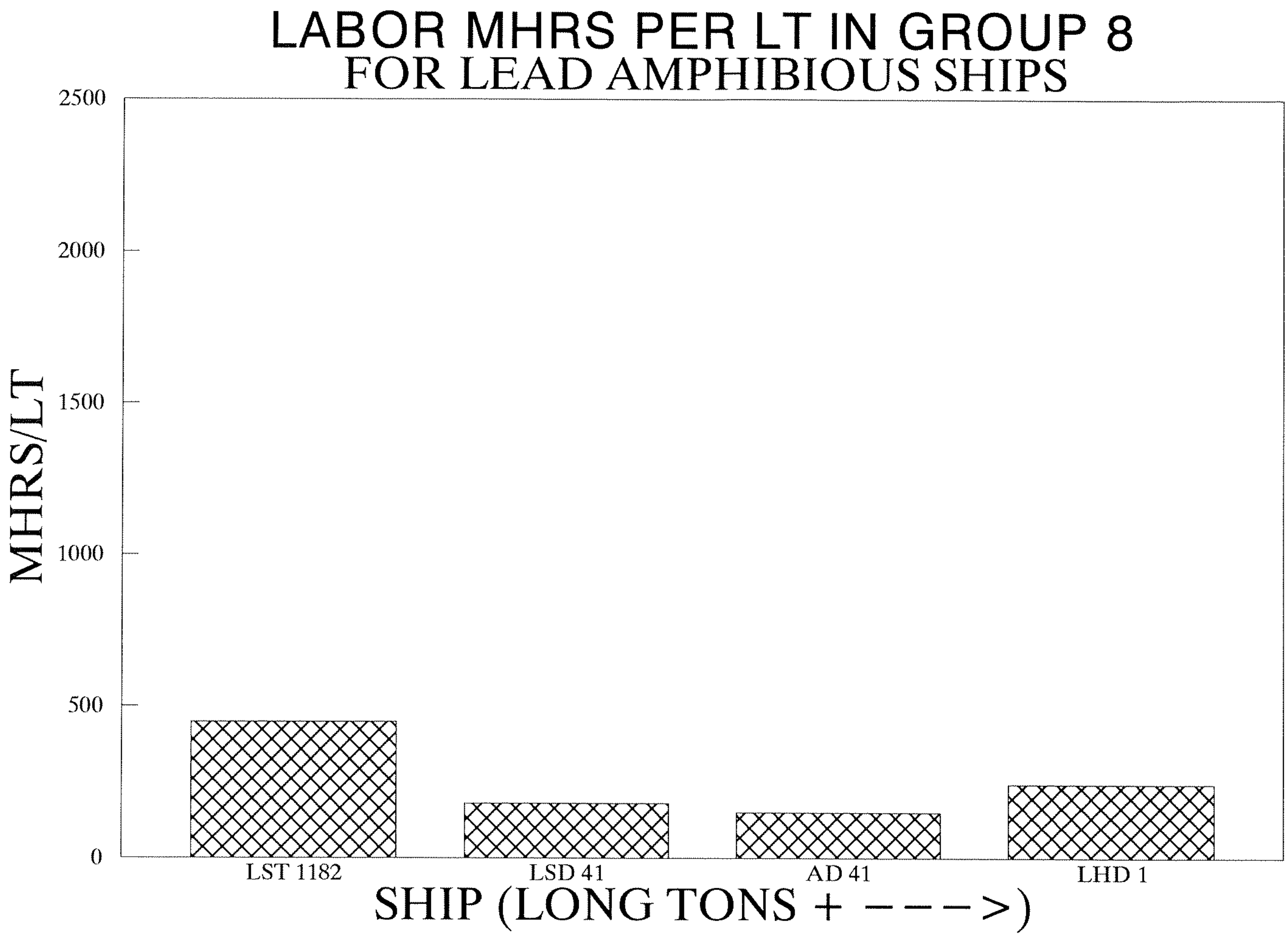
SHIPS	MHRS/ACC
LST 1182	226
LSD 41	338
LSD 44	431
AD 41	540

LABOR MHRS PER LT IN GROUP 7
FOR AMPHIBIOUS SHIPS



DATA

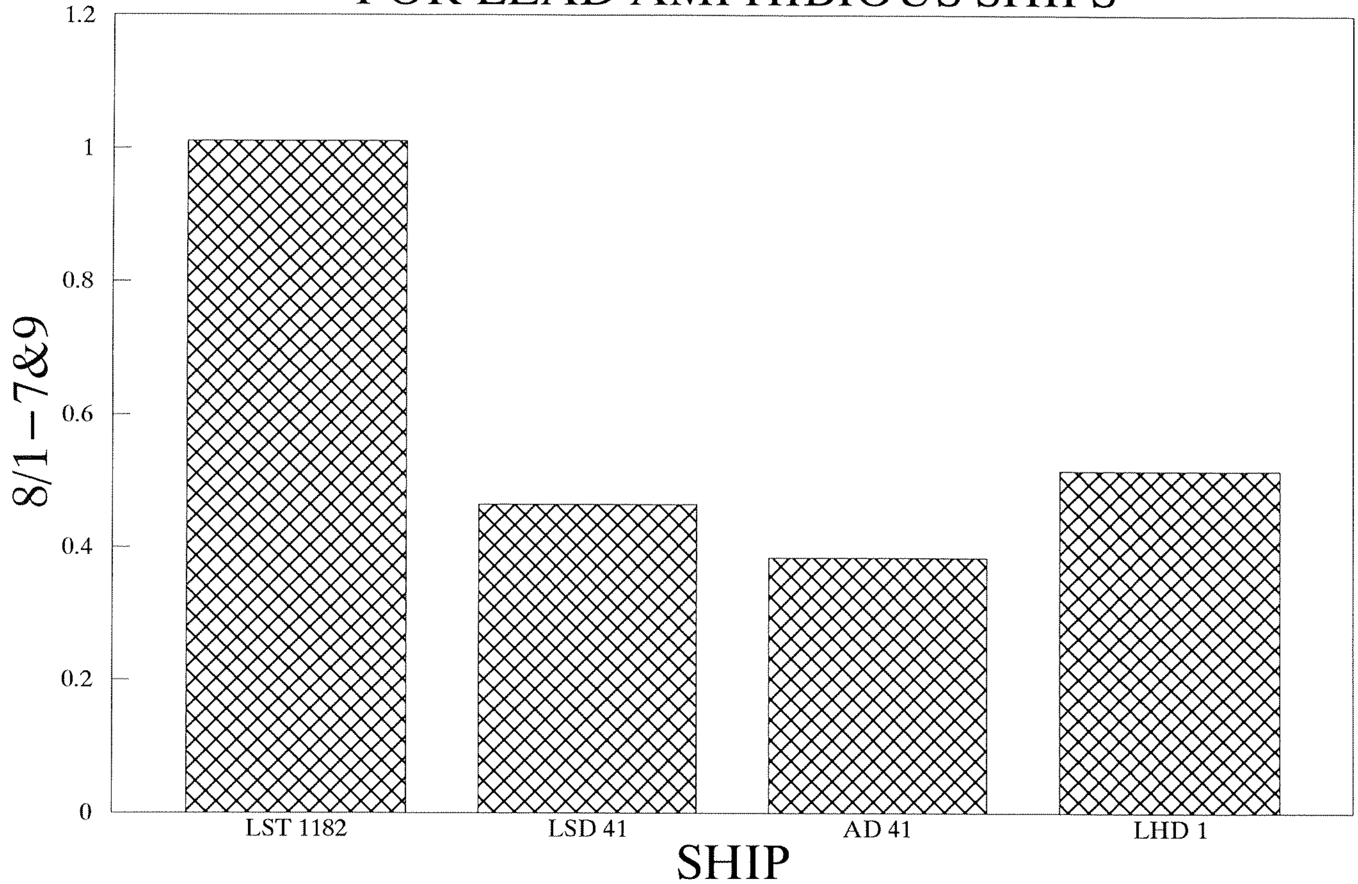
SHIP	MHRS/LT
LST 1182	99
LSD 41	94
LSD 44	131
AD 41	175
LHD 1	271



DATA

SHIP	MHRS/LT
LST 1182	448
LSD 41	181
AD 41	150
LHD 1	243

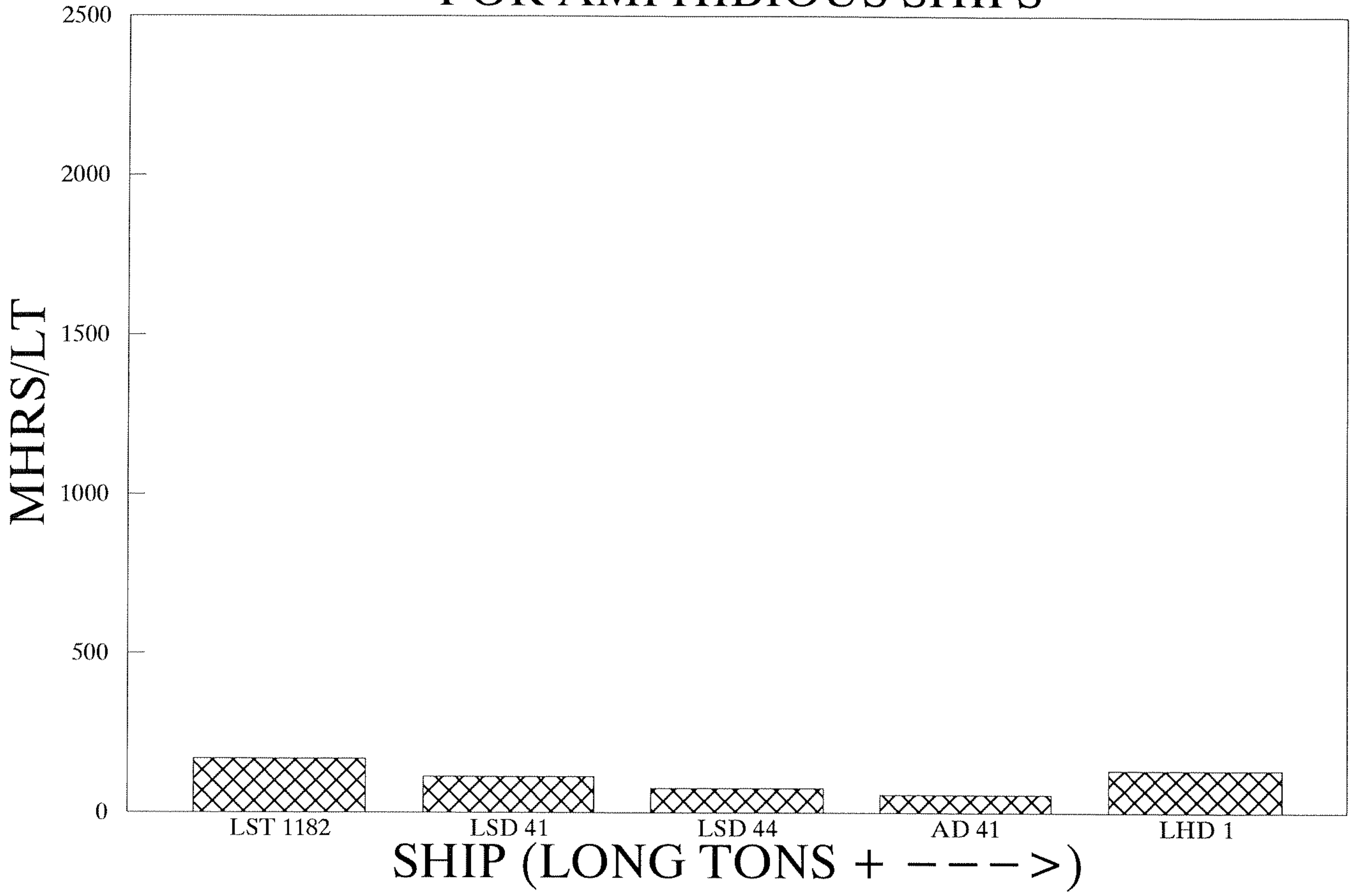
GROUP 8 MHRS PER PRODUCTION MHRS
FOR LEAD AMPHIBIOUS SHIPS



DATA

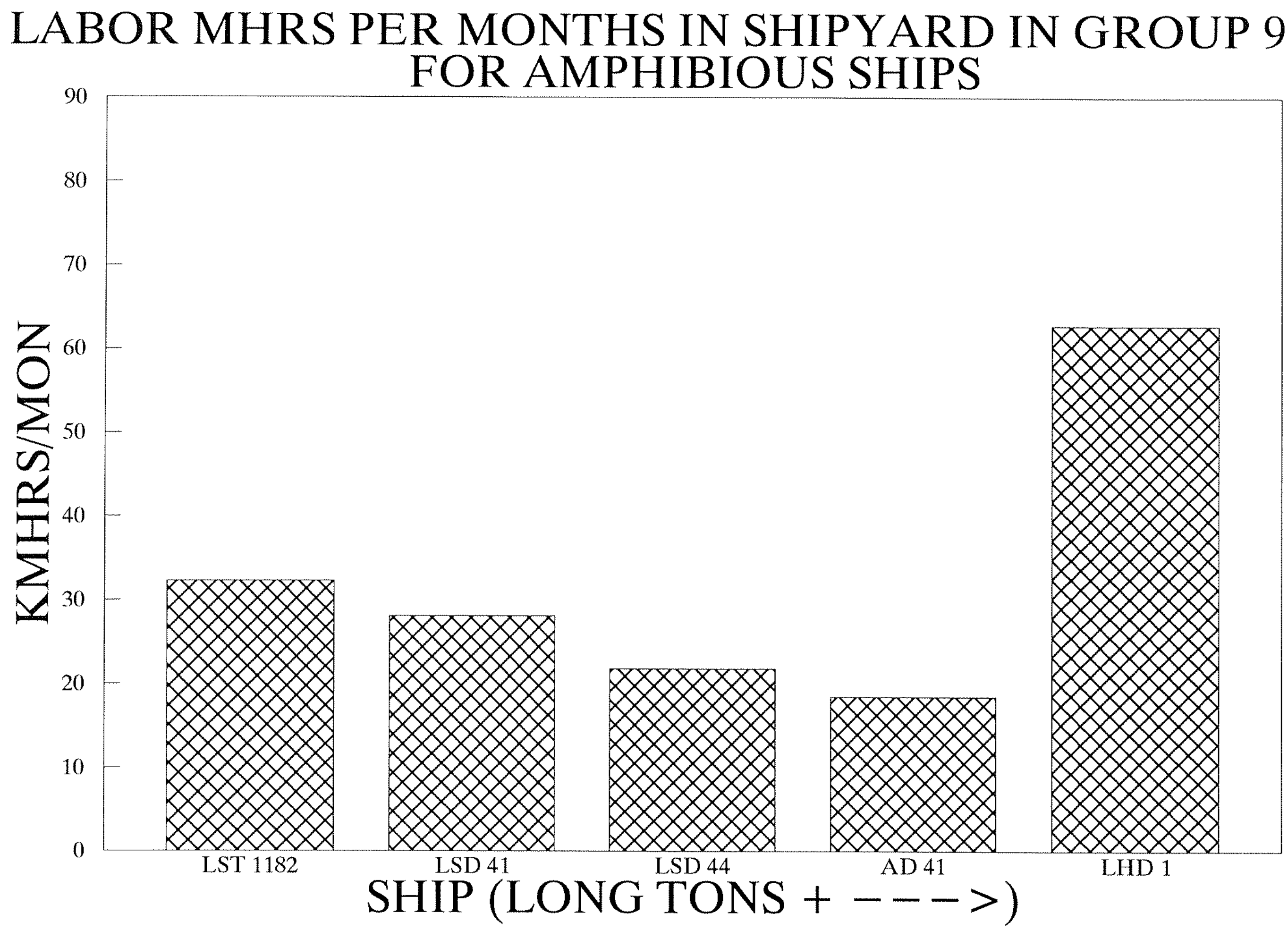
SHIPS	8/1–7&9
LST 1182	1.010
LSD 41	0.465
AD 41	0.384
LHD 1	0.516

LABOR MHRS PER LT IN GROUP 9
FOR AMPHIBIOUS SHIPS



DATA

SHIP	MHRS/LT
LST 1182	168
LSD 41	114
LSD 44	77
AD 41	56
LHD 1	132

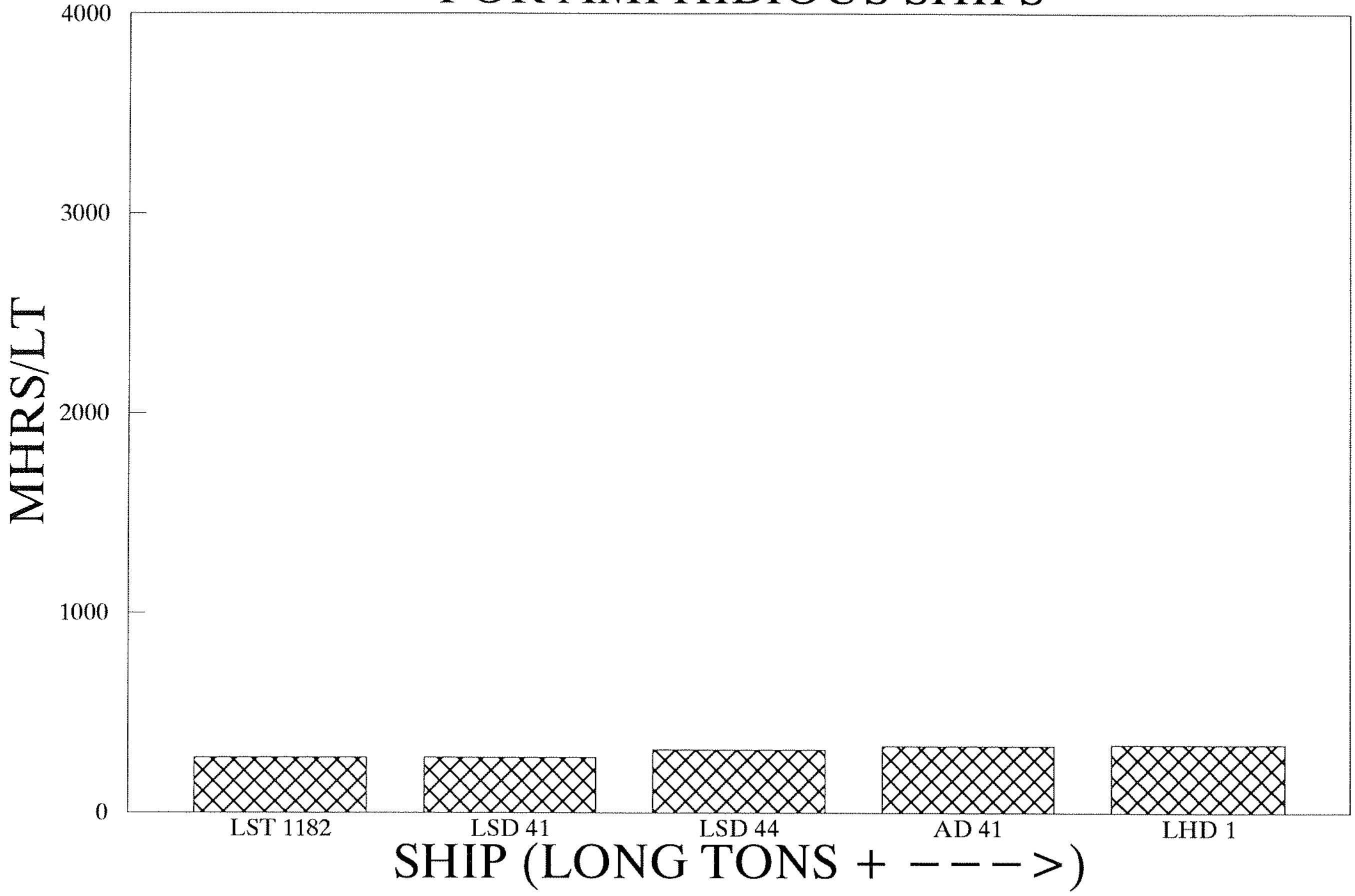


NOTE: Months in shipyard data for LST 1182 and AD 41 was not available from NCA; data was taken from Jane's.

DATA

SHIP	MHRS/MO
LST 1182	32
LSD 41	28
LSD 44	22
AD 41	18
LHD 1	63

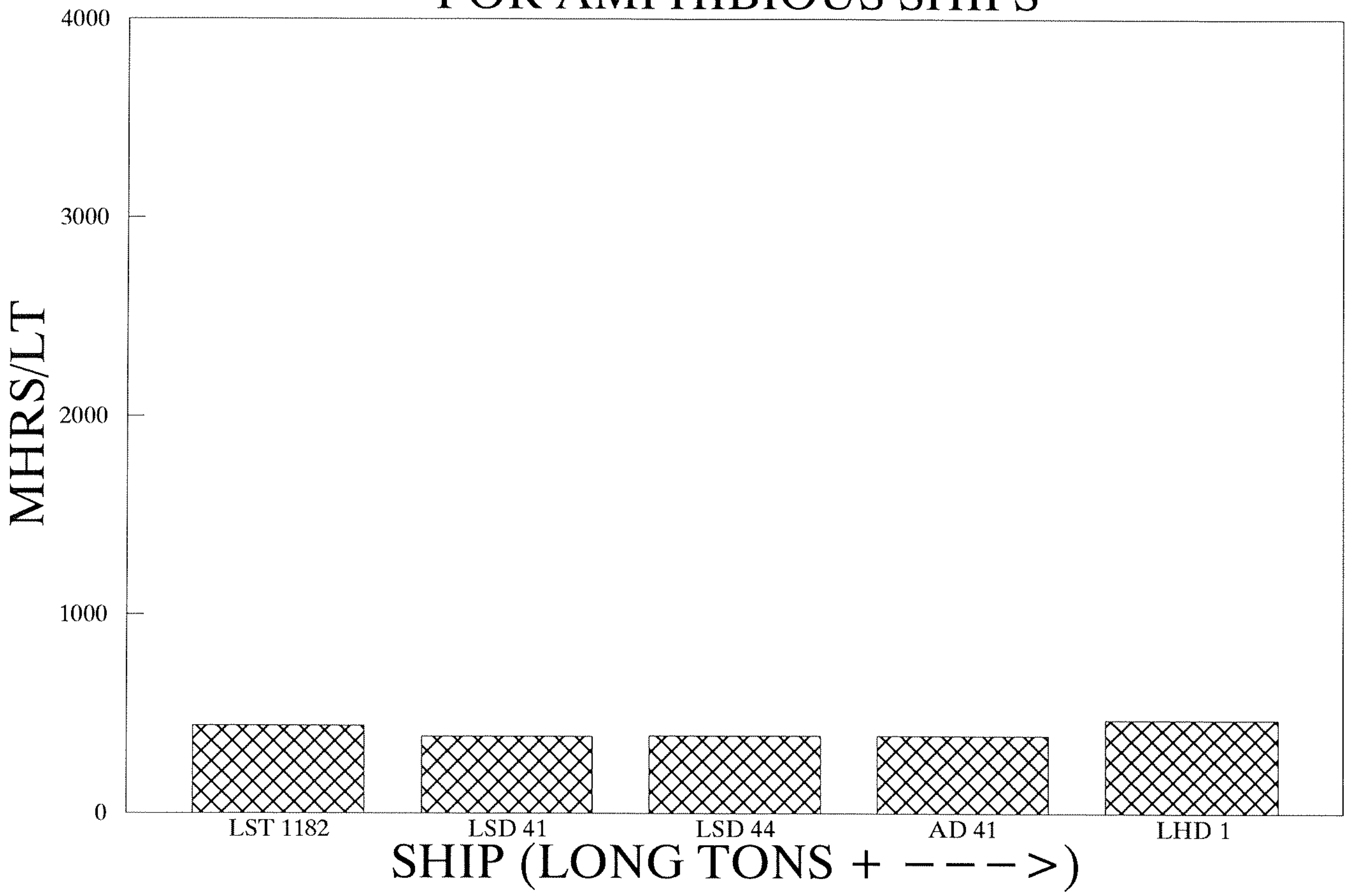
LABOR MHRS PER LT IN GROUP 1–7
FOR AMPHIBIOUS SHIPS



DATA

SHIP	MHRS/LT
LST 1182	275
LSD 41	276
LSD 44	315
AD 41	334
LHD 1	339

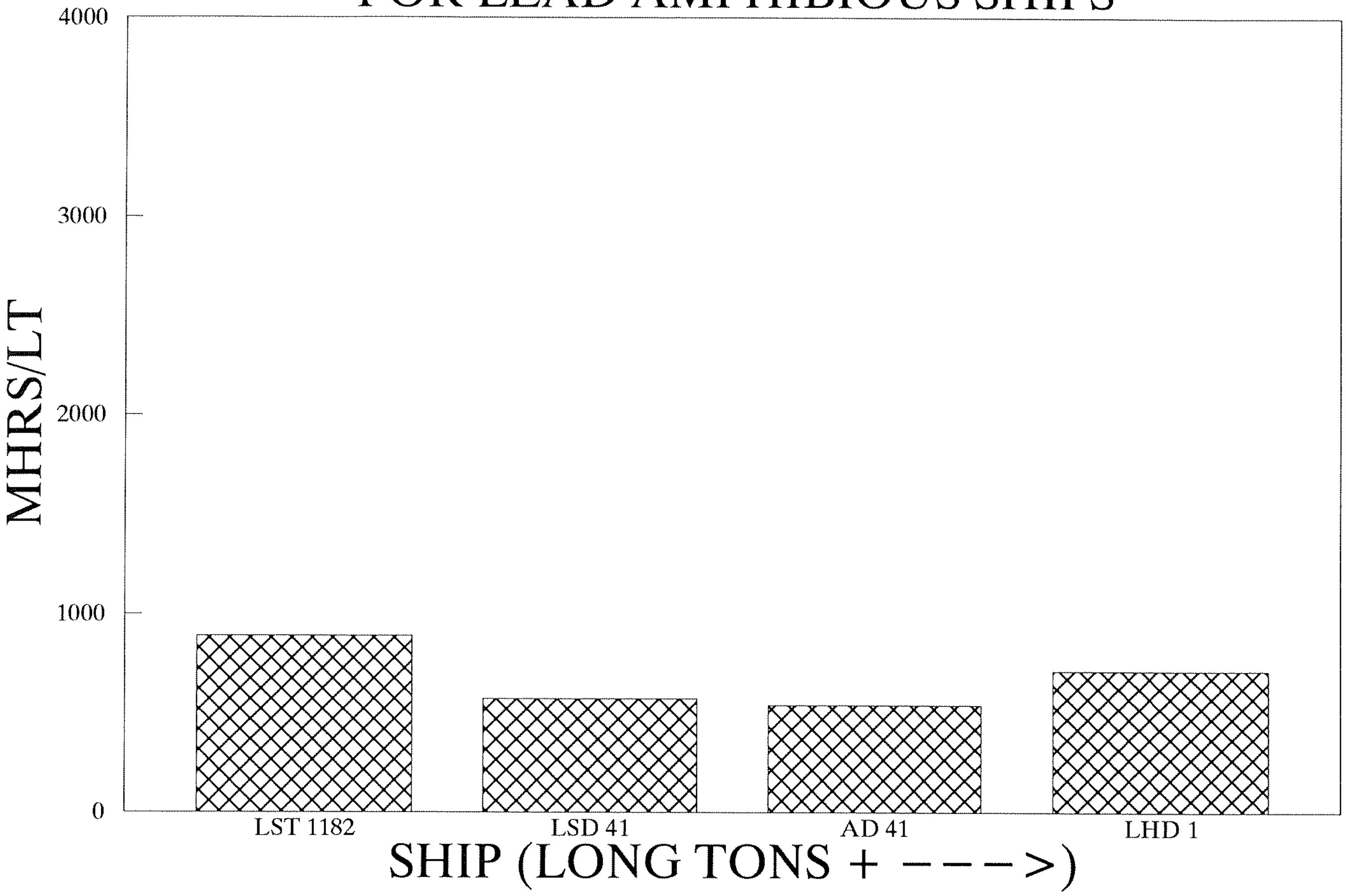
LABOR MHRS PER LT IN GROUP 1-7,9
FOR AMPHIBIOUS SHIPS



DATA

SHIP	MHRS/LT
LST 1182	443
LSD 41	389
LSD 44	392
AD 41	391
LHD 1	471

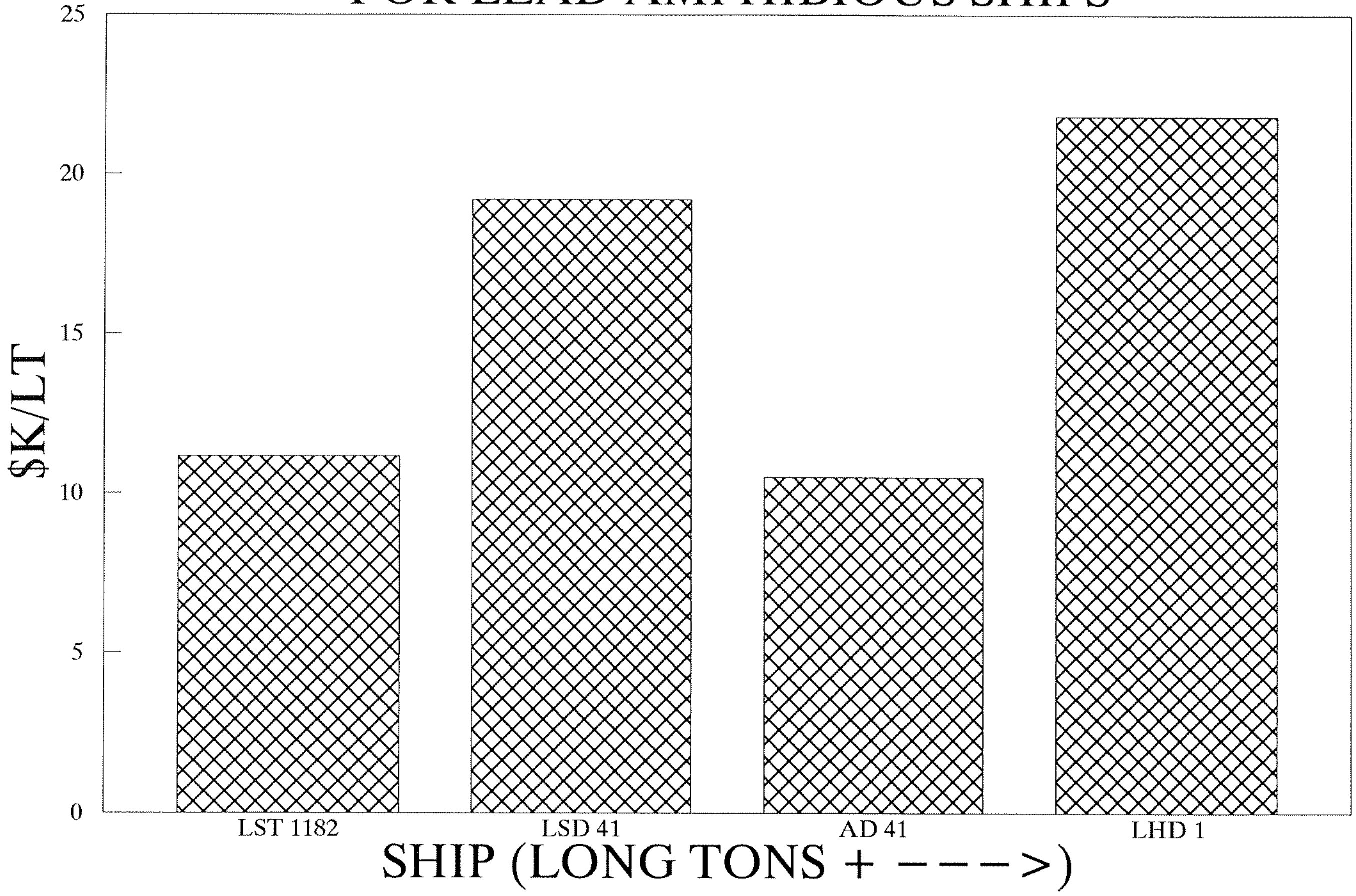
LABOR MHRS PER LT IN GROUP 1-9
FOR LEAD AMPHIBIOUS SHIPS



DATA

SHIP	MHRS/LT
LST 1182	891
LSD 41	570
AD 41	541
LHD 1	714

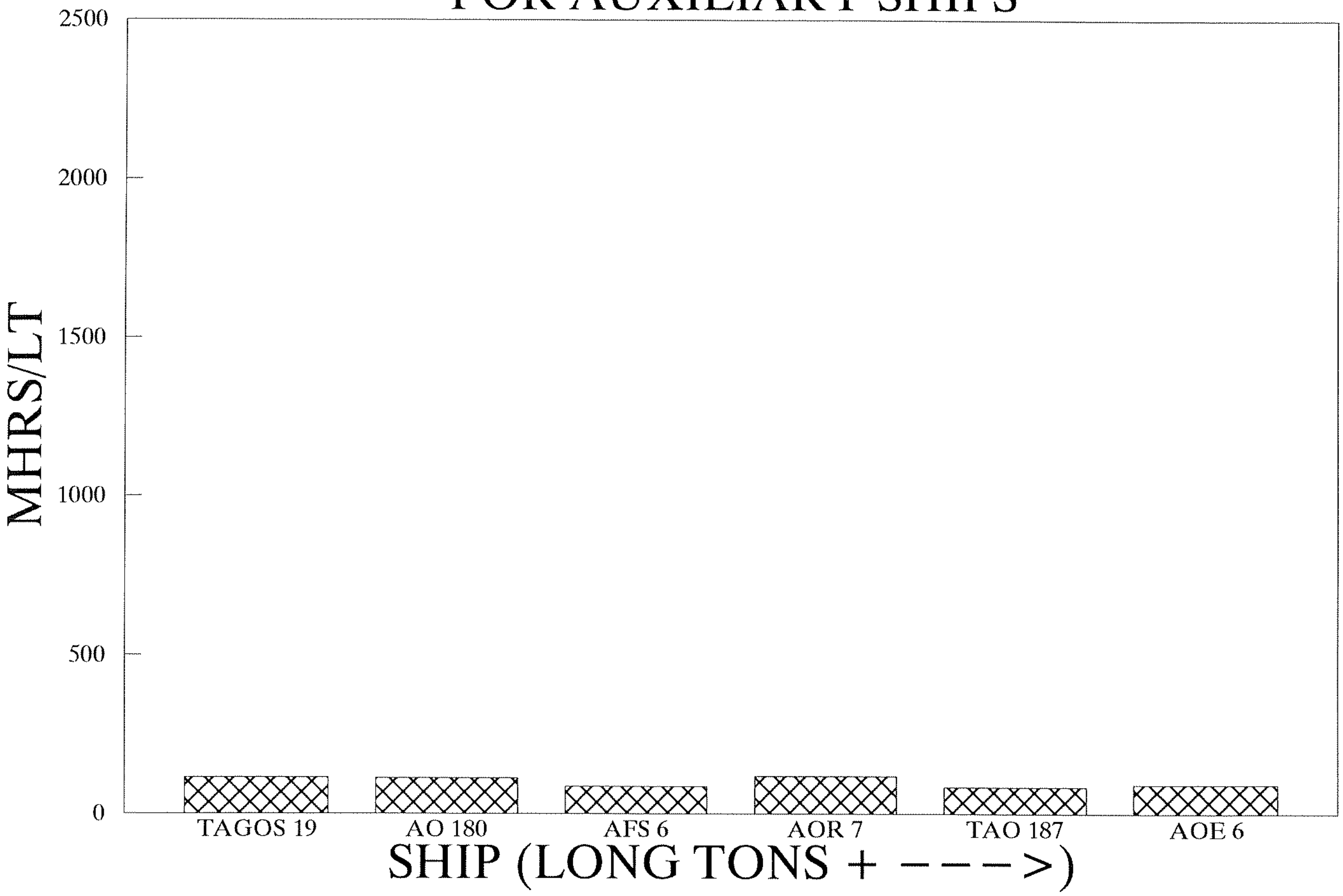
TOTAL MATERIAL COST PER LIGHTSHIP WEIGHT FOR LEAD AMPHIBIOUS SHIPS



DATA

SHIP	$K/LT
LST 1182	11.2
LSD 41	19.2
AD 41	10.5
LHD 1	21.8

LABOR MHRS PER LT IN GROUP 1
FOR AUXILIARY SHIPS



NOTE: TAGS 45 weight data was not available for this group.

DATA

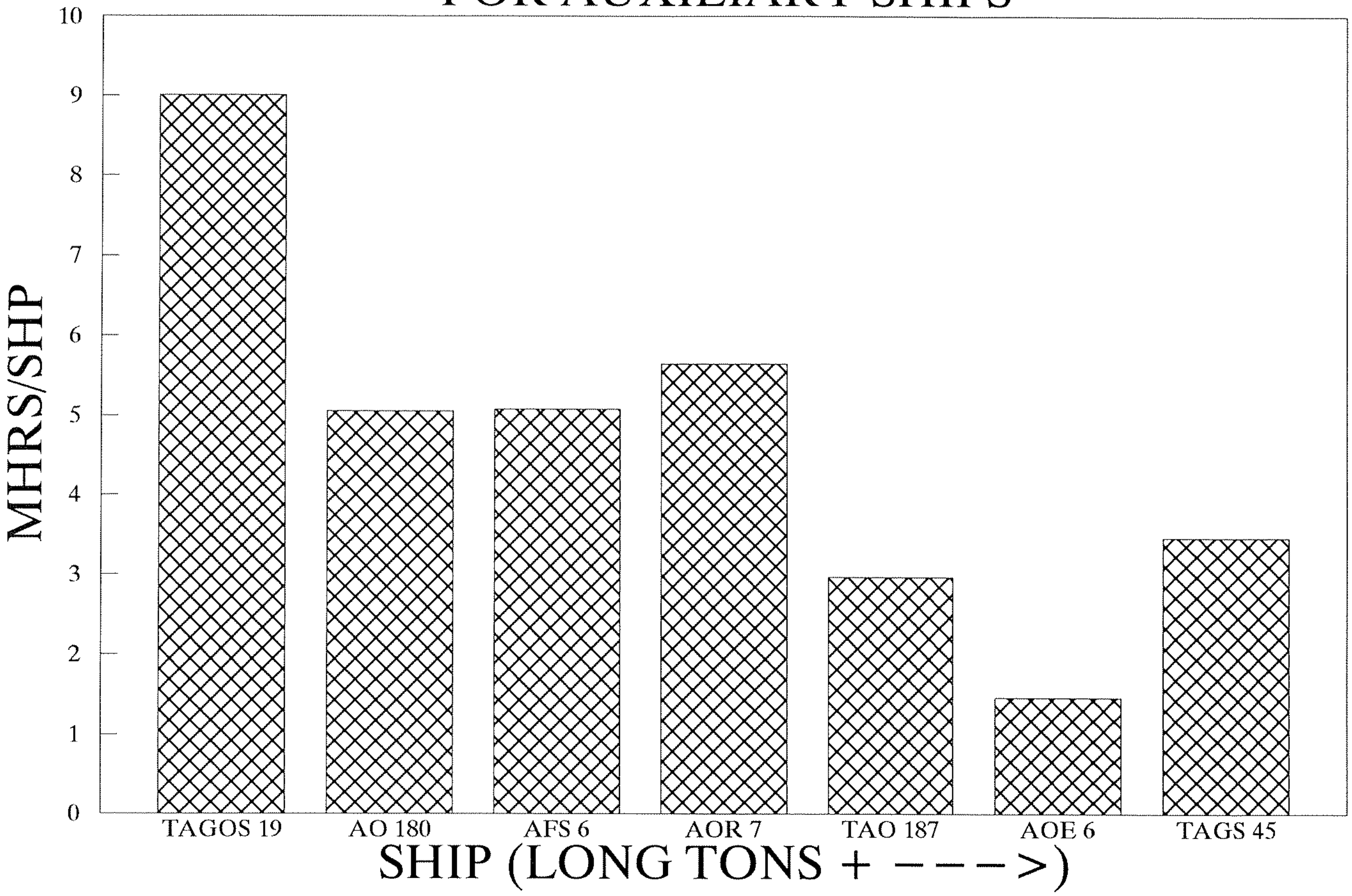
SHIP	MHRS/LT
TAGOS 19	115
AO 180	113
AFS 6	87
AOR 7	118
TAO 187	83
AOE 6	93

NOTE: TAGS 45 weight data was not available for this group.

DATA

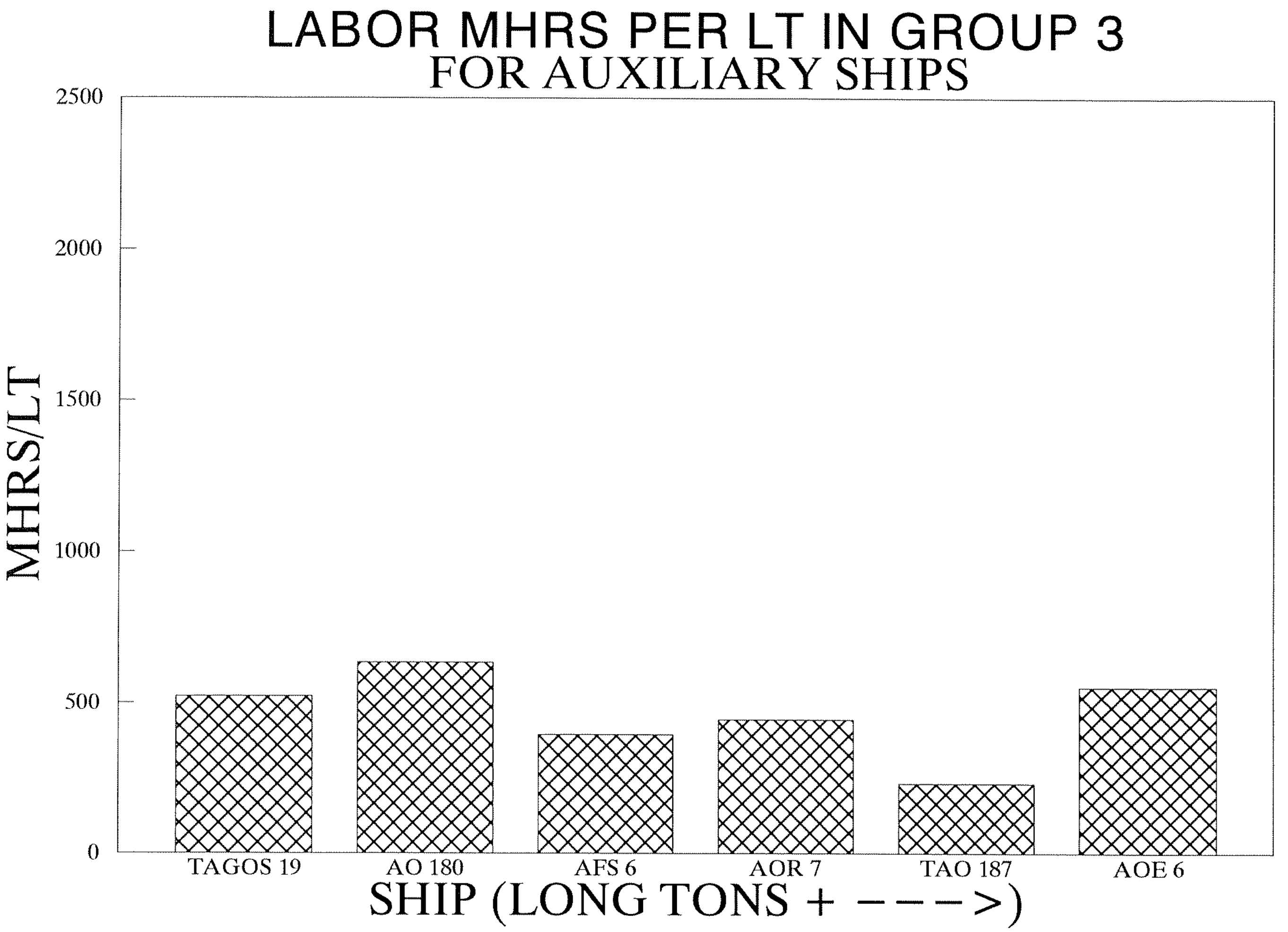
SHIP	MHRS/LT
TAGOS 19	262
AO 180	188
AFS 6	145
AOR 7	186
TAO 187	79
AOE 6	149

LABOR MHRS PER SHAFT HORSEPOWER IN GRP 2 FOR AUXILIARY SHIPS



DATA

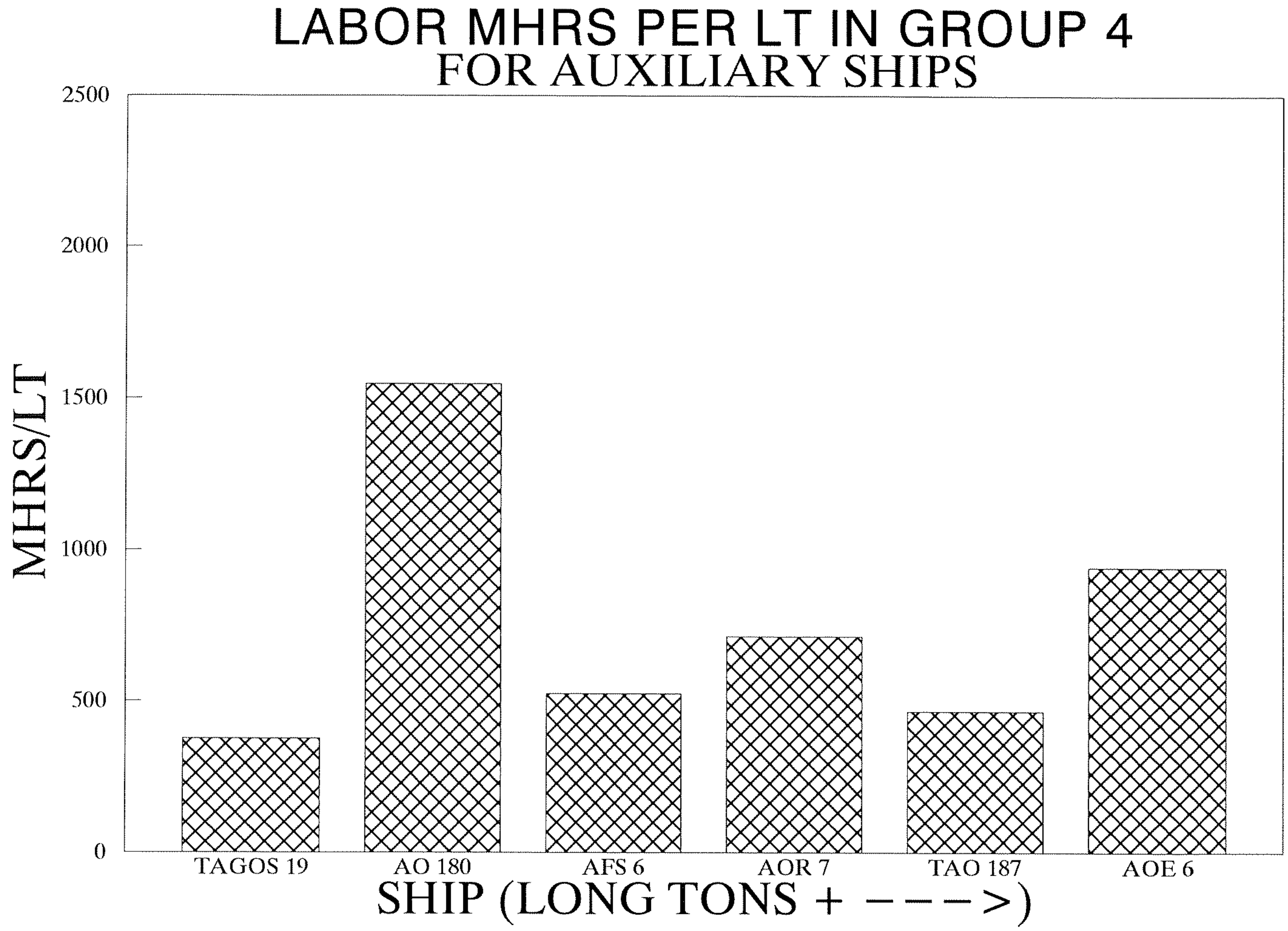
SHIPS	MHRS/SHP
TAGOS 19	9.0
AO 180	5.1
AFS 6	5.1
AOR 7	5.6
TAO 187	3.0
AOE 6	1.5
TAGS 45	3.5



NOTE: TAGS 45 weight data was not available for this group.

DATA

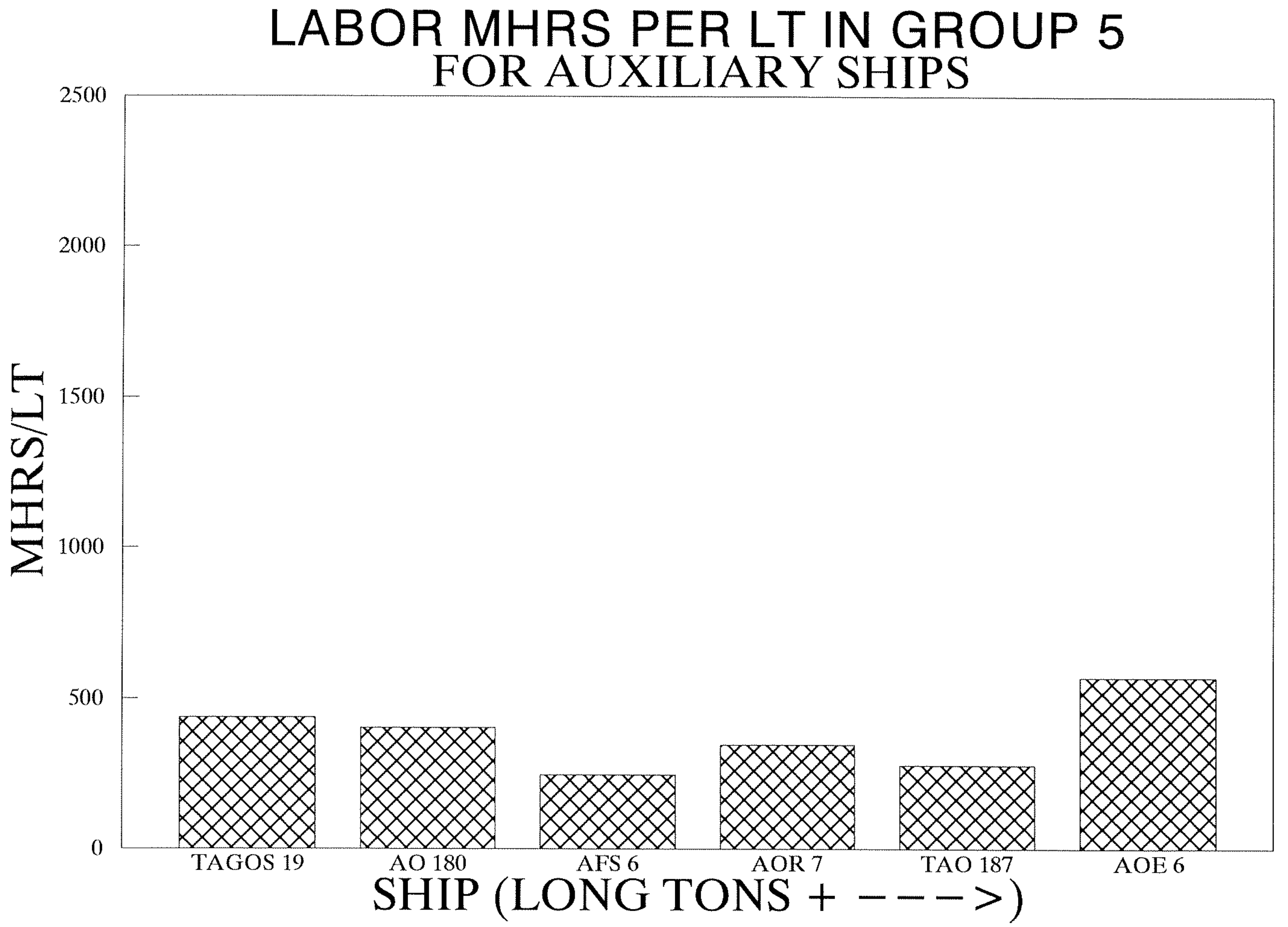
SHIP	MHRS/LT
TAGOS 19	522
AO 180	635
AFS 6	395
AOR 7	445
TAO 187	231
AOE 6	553



NOTE: TAGS 45 weight data was not available for this group.

DATA

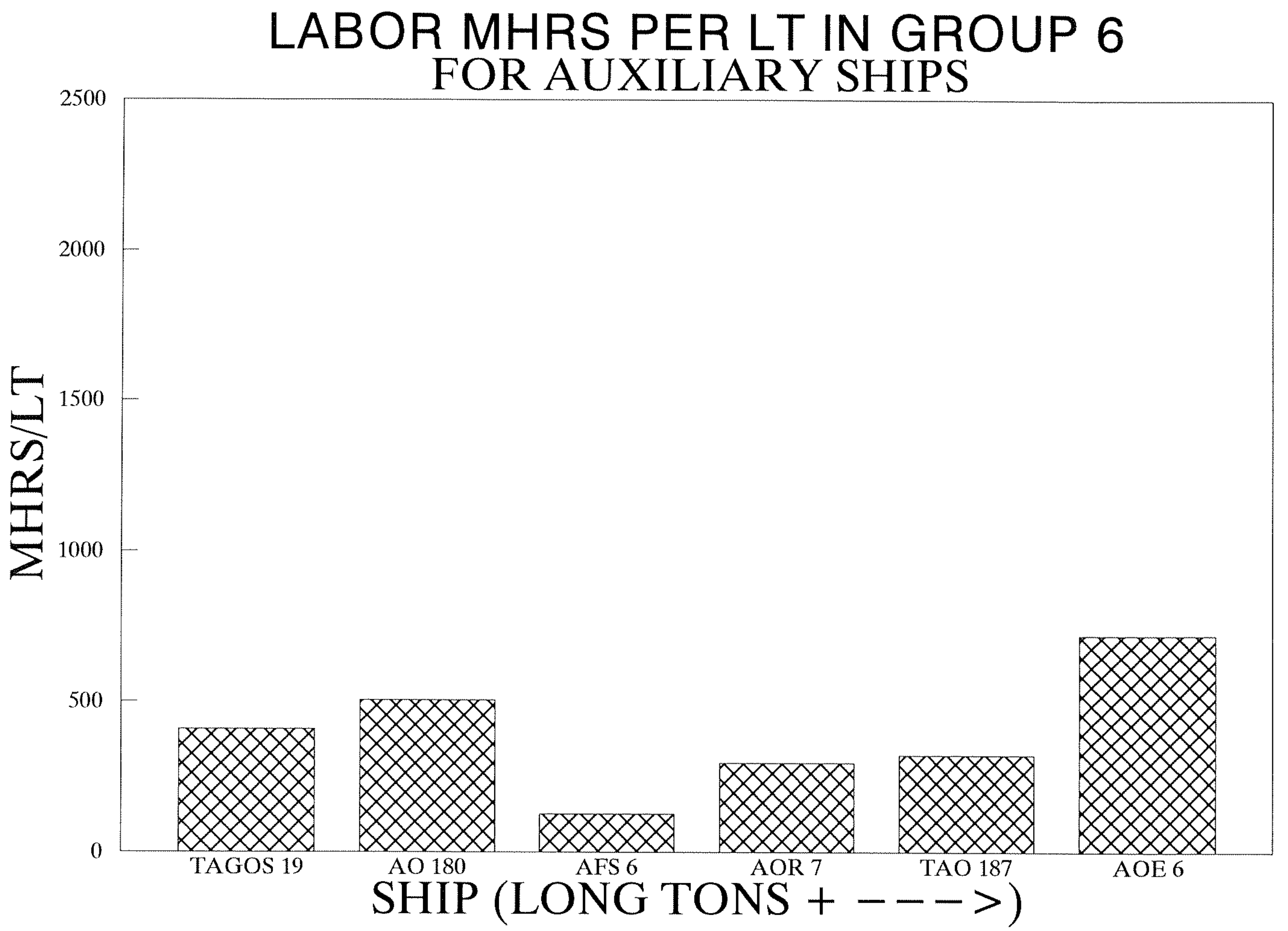
SHIP	MHRS/LT
TAGOS 19	376
AO 180	1,546
AFS 6	524
AOR 7	713
TAO 187	466
AOE 6	942



NOTE: TAGS 45 weight data was not available for this group.

DATA

SHIP	MHRS/LT
TAGOS 19	437
AO 180	405
AFS 6	247
AOR 7	348
TAO 187	279
AOE 6	570

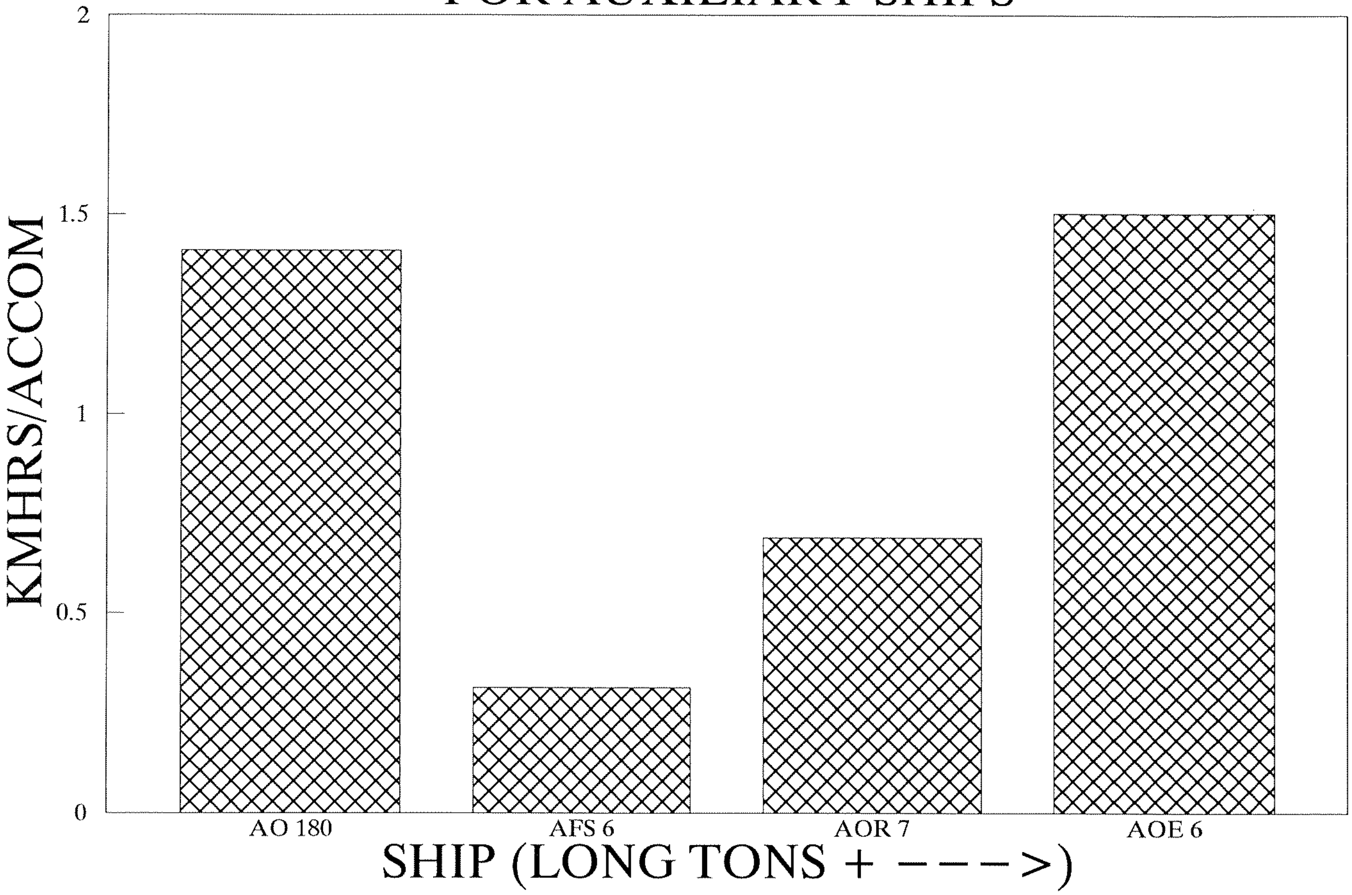


NOTE: TAGS 45 weight data was not available for this group.

DATA

SHIP	MHRS/LT
TAGOS 19	407
AO 180	505
AFS 6	127
AOR 7	296
TAO 187	322
AOE 6	722

LABOR MHRS PER ACCOMODATION IN GROUP 6 FOR AUXILIARY SHIPS

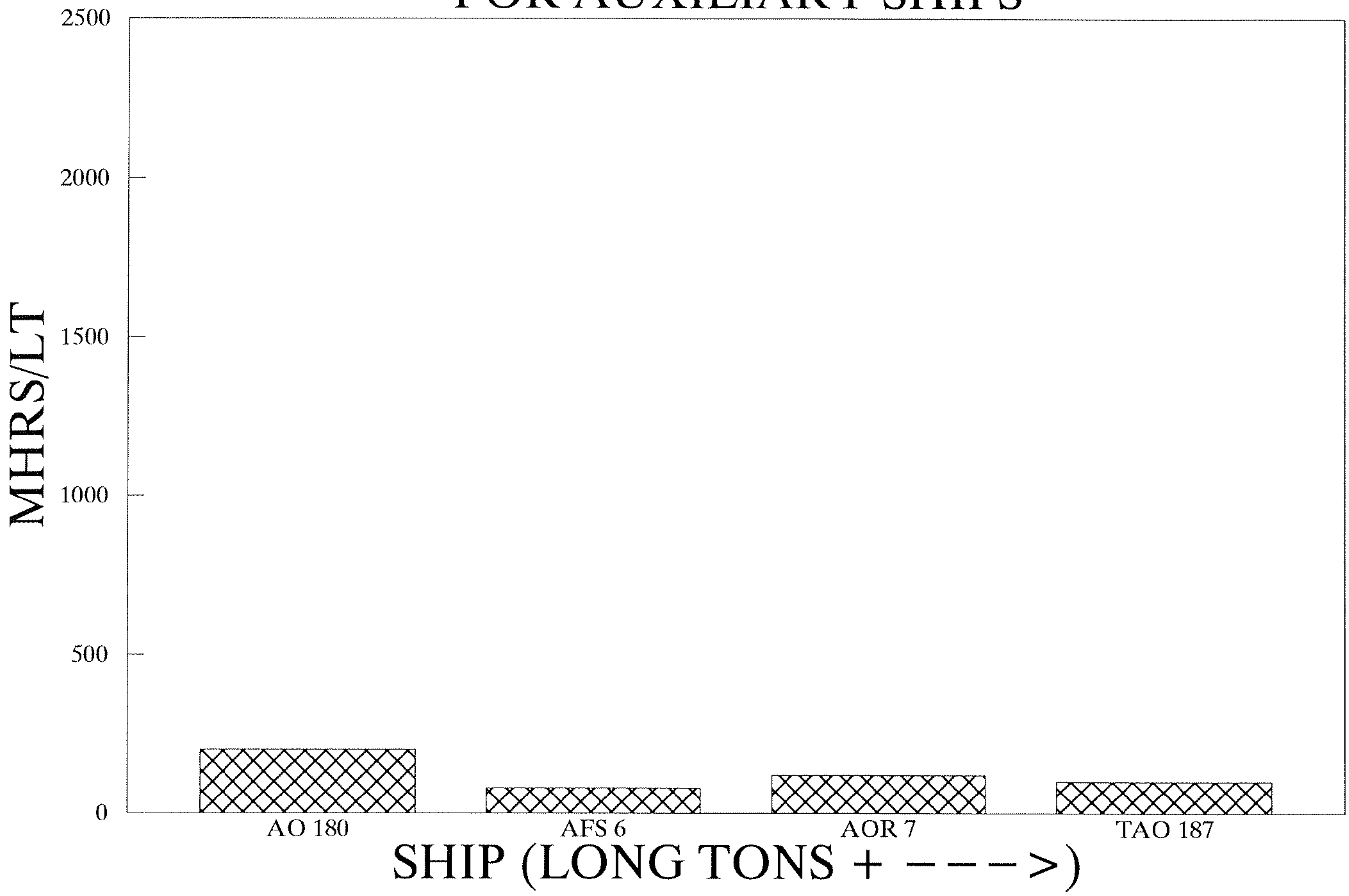


NOTE: Total accomodations were not available for T-Ships.

DATA

SHIPS	KMHRS/ACC
AO 180	1.41
AFS 6	0.31
AOR 7	0.69
AOE 6	1.50

LABOR MHRS PER LT IN GROUP 7
FOR AUXILIARY SHIPS

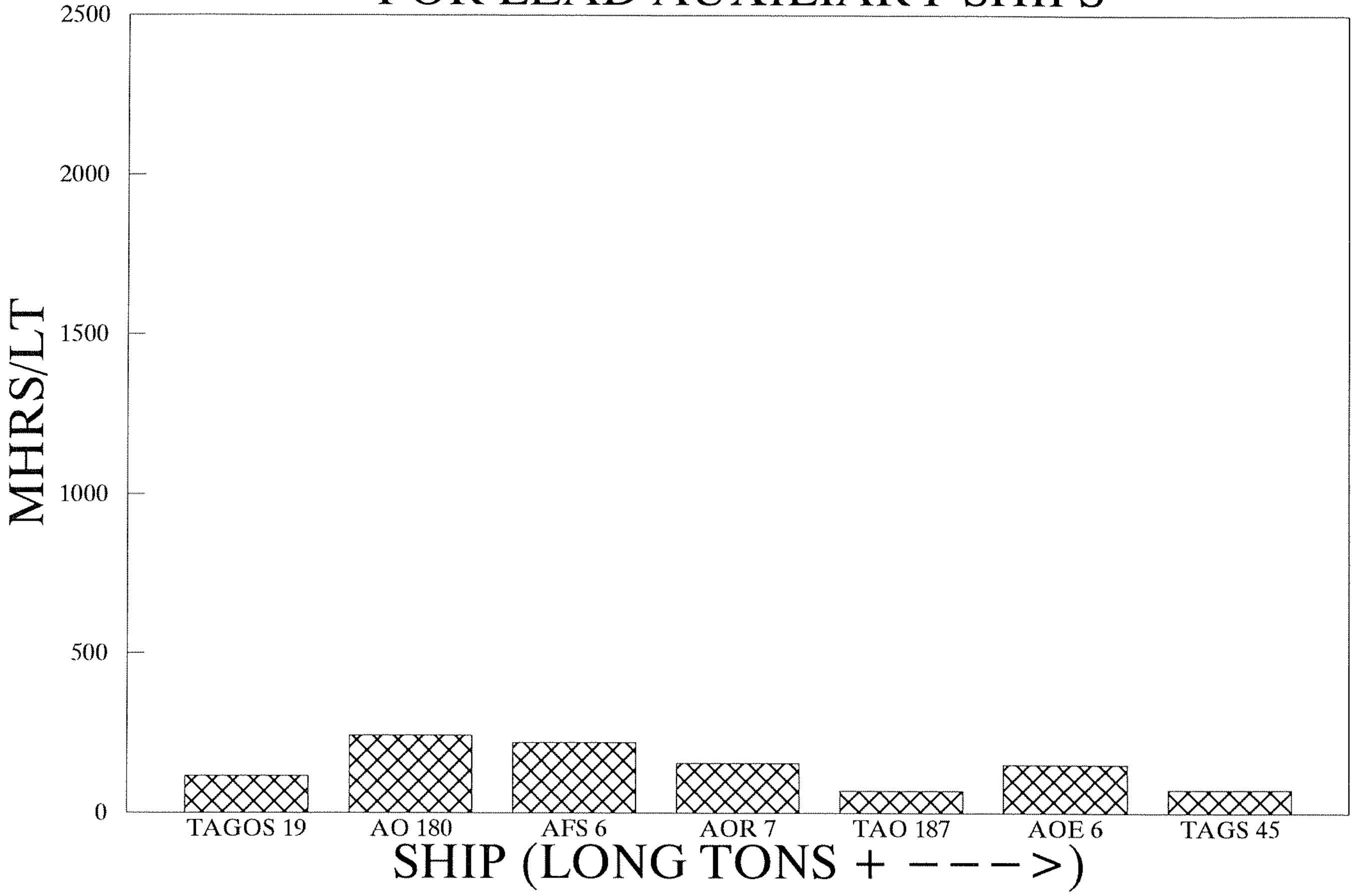


NOTE: TAGS 45 weight data was not available for this group; AOE 6, TAGOS 19 & TAO 191 labor data was not available for this group.

DATA

SHIP	MHRS/LT
AO 180	200
AFS 6	80
AOR 7	119
TAO 187	100

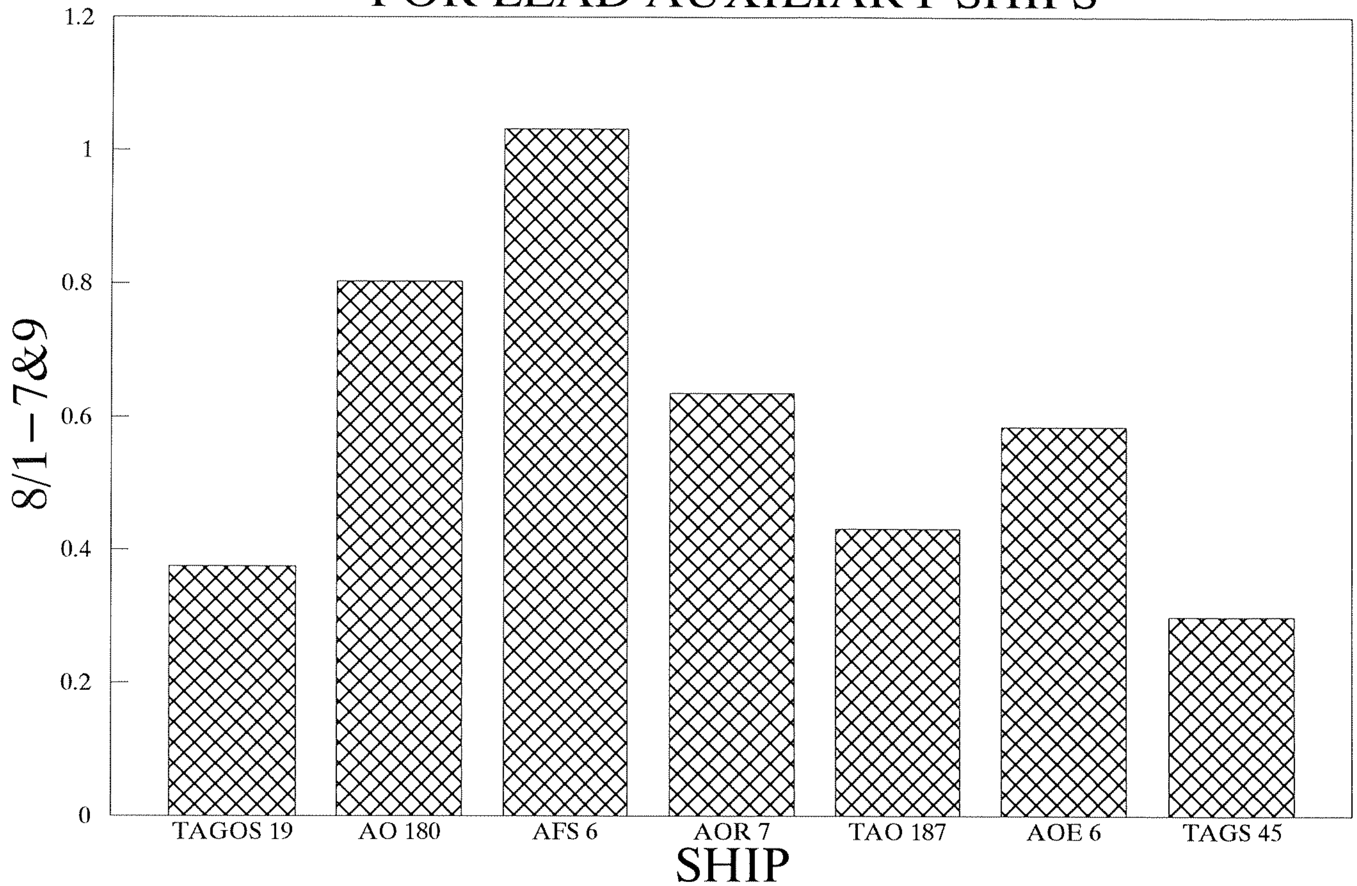
LABOR MHRS PER LT IN GROUP 8
FOR LEAD AUXILIARY SHIPS



DATA

SHIP	MHRS/LT
TAGOS 19	116
AO 180	242
AFS 6	221
AOR 7	157
TAO 187	71
AOE 6	152
TAGS 45	73

GROUP 8 MHRS PER PRODUCTION MHRS
FOR LEAD AUXILIARY SHIPS



DATA

SHIPS	8/1-7&9
TAGOS 19	0.375
AO 180	0.803
AFS 6	1.032
AOR 7	0.636
TAO 187	0.432
AOE 6	0.585
TAGS 45	0.300

DATA

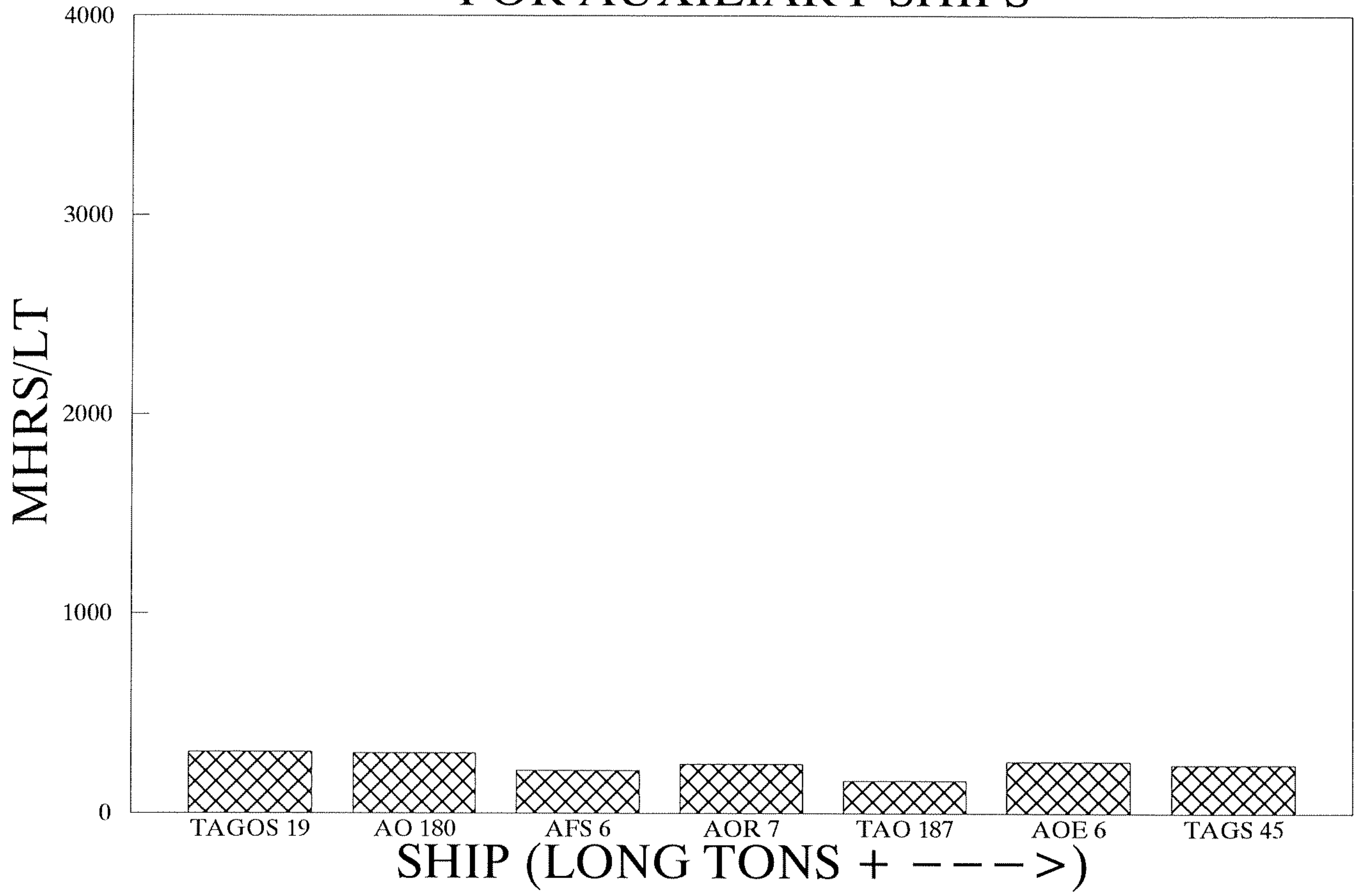
SHIP	MHRS/LT
TAGOS 19	84
AO 180	91
AFS 6	83
AOR 7	59
TAO 187	29
AOE 6	28
TAGS 45	38

LABOR MHRS PER LT IN GROUP 1−7
FOR AUXILIARY SHIPS

DATA

SHIP	MHRS/LT
TAGOS 19	224
AO 180	211
AFS 6	131
AOR 7	188
TAO 187	135
AOE 6	231
TAGS 45	206

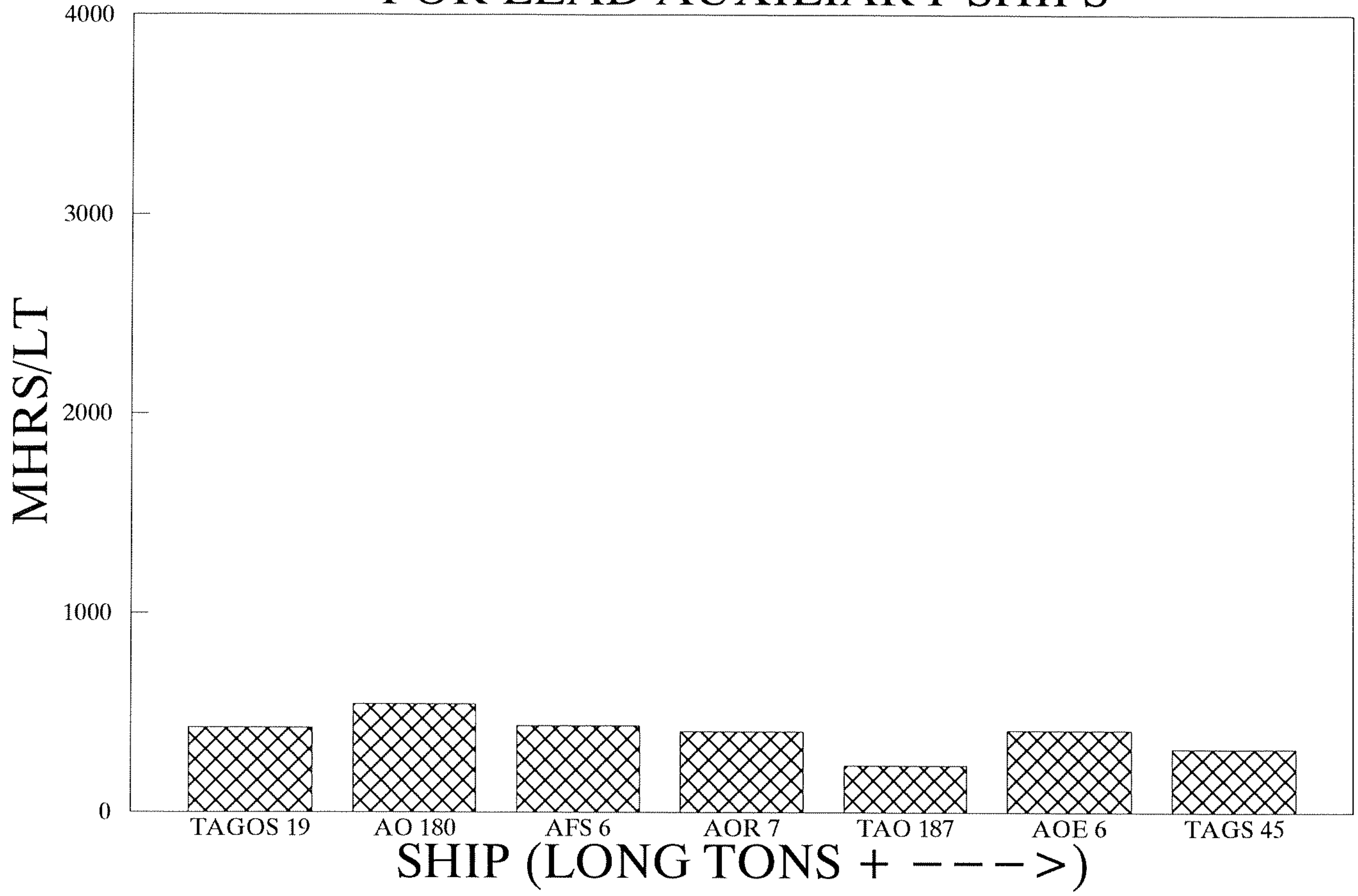
LABOR MHRS PER LT IN GROUP 1–7,9
FOR AUXILIARY SHIPS



DATA

SHIP	MHRS/LT
TAGOS 19	308
AO 180	302
AFS 6	214
AOR 7	247
TAO 187	164
AOE 6	260
TAGS 45	243

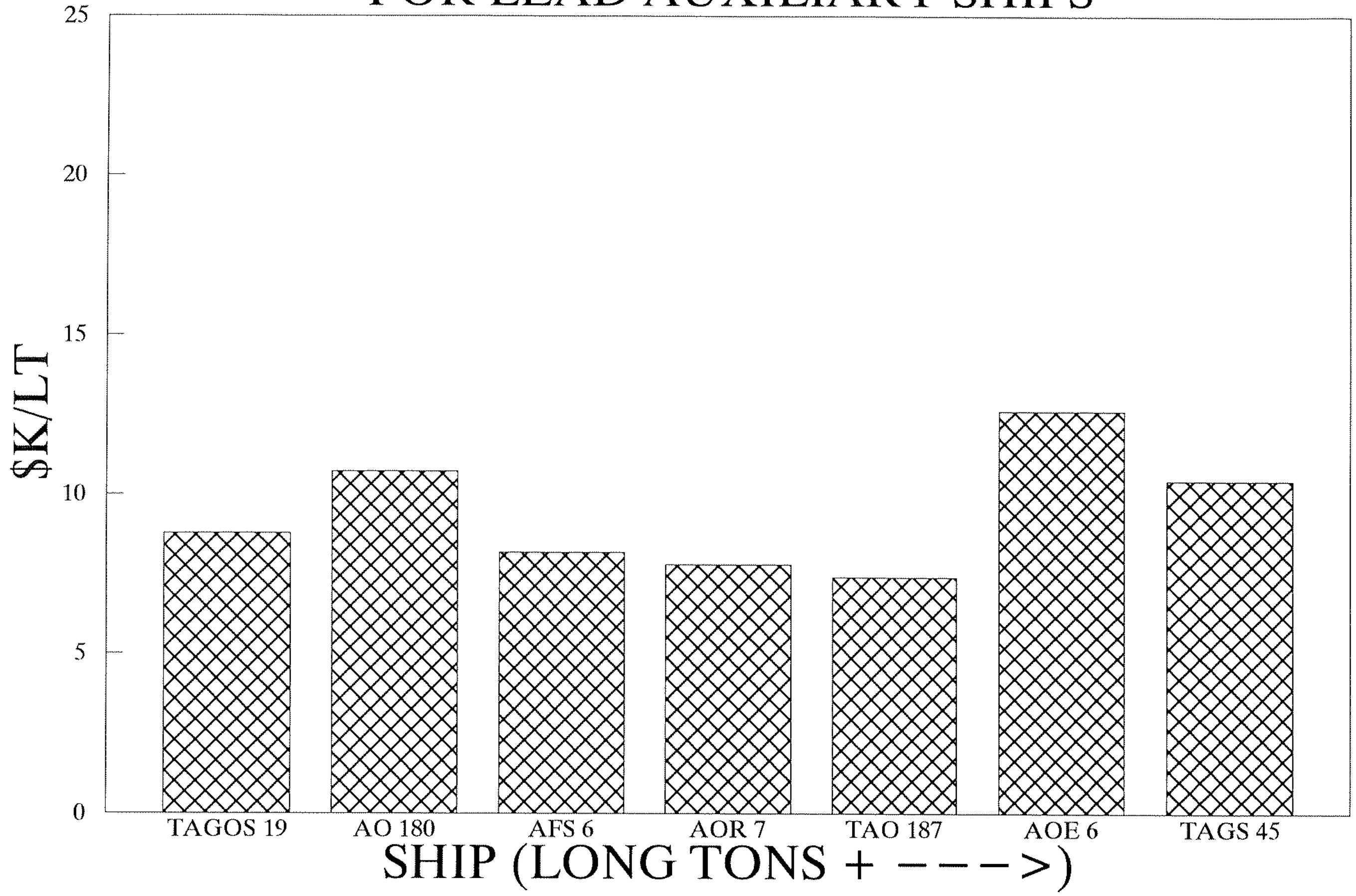
LABOR MHRS PER LT IN GROUP 1–9
FOR LEAD AUXILIARY SHIPS



DATA

SHIP	MHRS/LT
TAGOS 19	424
AO 180	544
AFS 6	436
AOR 7	404
TAO 187	234
AOE 6	412
TAGS 45	316

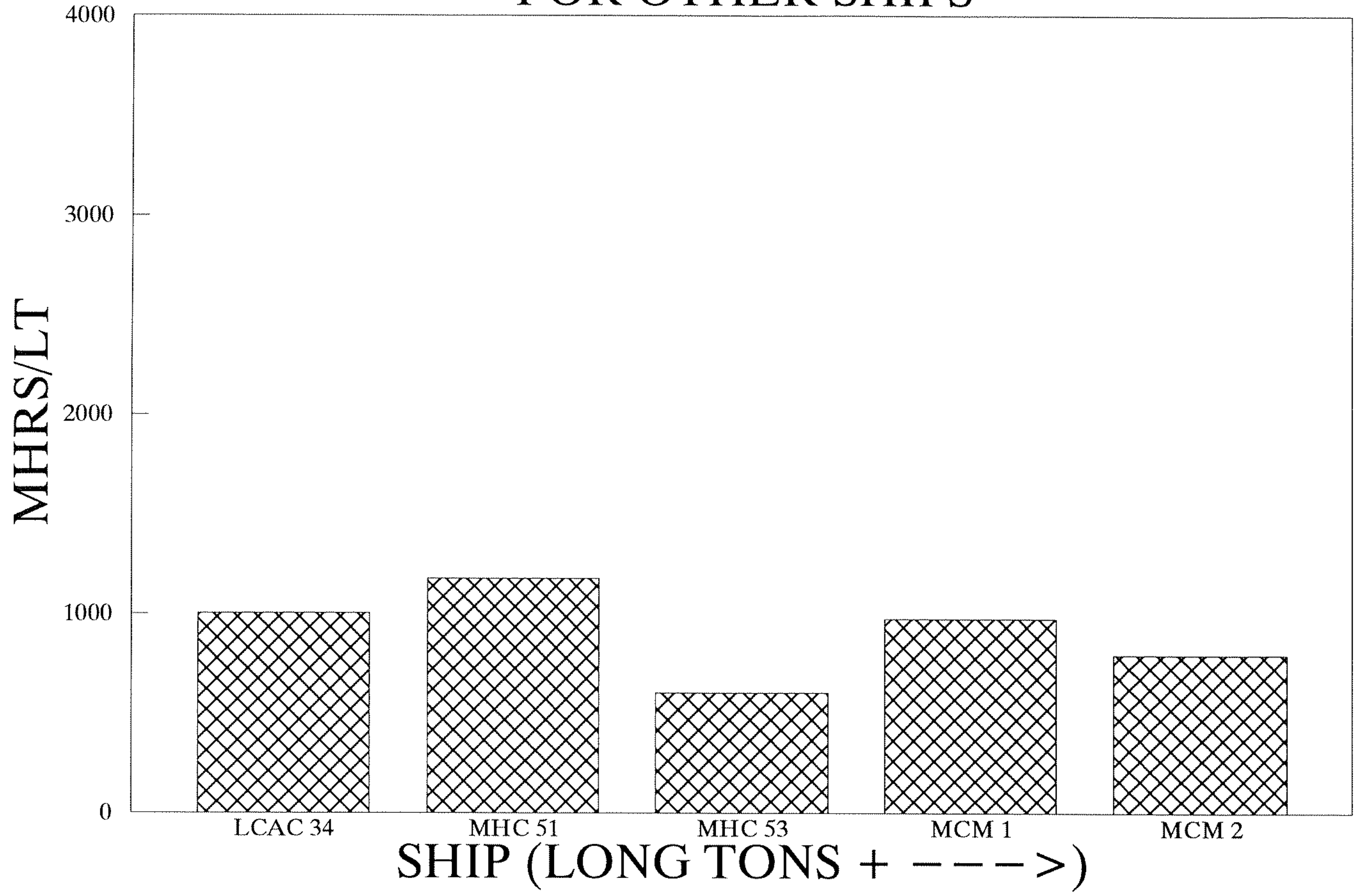
TOTAL MATERIAL COST PER LIGHTSHIP WEIGHT FOR LEAD AUXILIARY SHIPS



DATA

SHIP	$K/LT
TAGOS 19	8.8
AO 180	10.7
AFS 6	8.2
AOR 7	7.8
TAO 187	7.4
AOE 6	12.6
TAGS 45	10.4

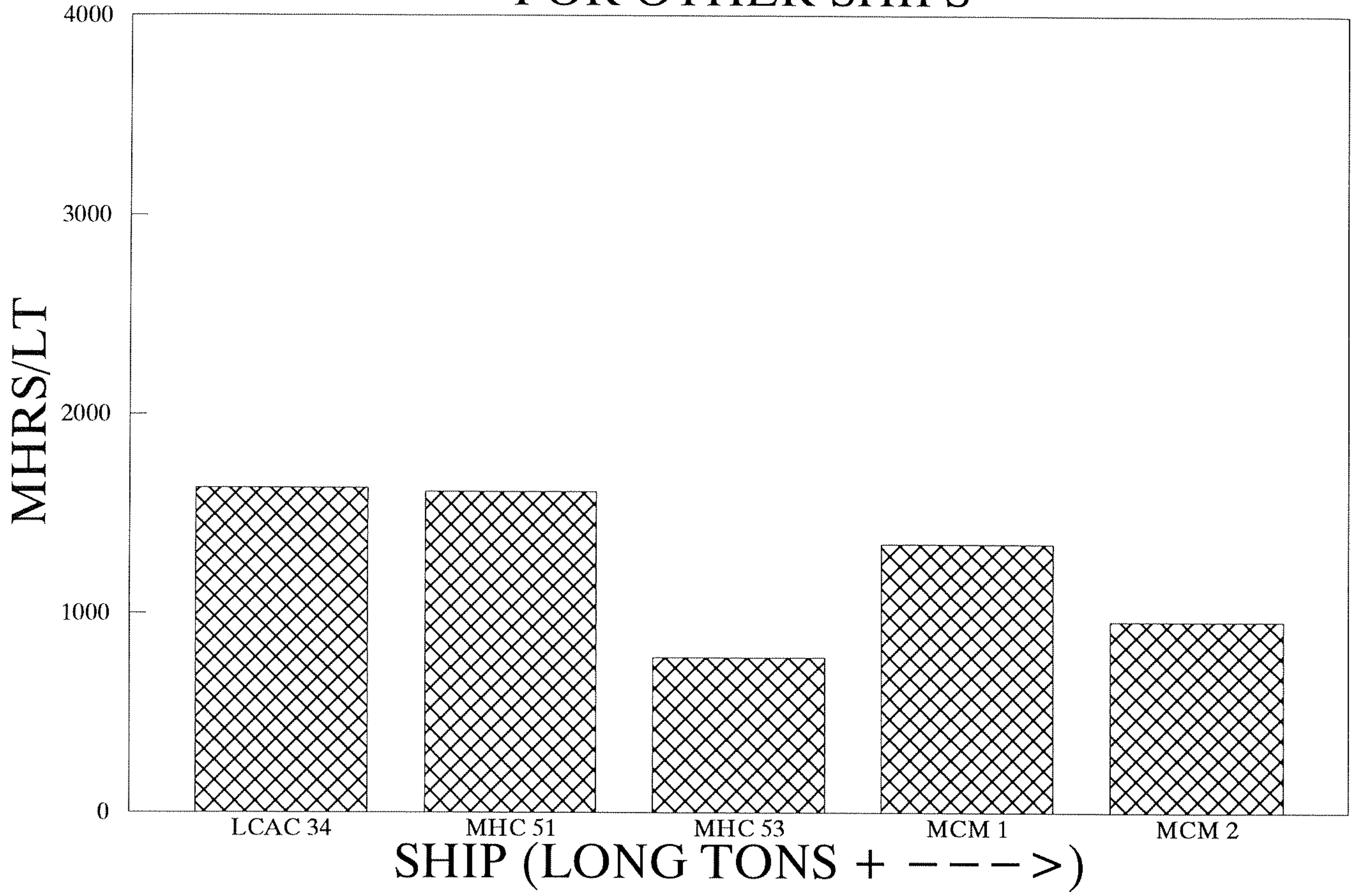
LABOR MHRS PER LT IN GROUP 1–7
FOR OTHER SHIPS



DATA

SHIP	MHRS/LT
LCAC 34	1,003
MHC 51	1,175
MHC 53	604
MCM 1	975
MCM 2	793

LABOR MHRS PER LT IN GROUP 1–7,9
FOR OTHER SHIPS



DATA

SHIPS	MHRS/LT
LCAC 34	1,629
MHC 51	1,610
MHC 53	778
MCM 1	1,351
MCM 2	962