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REVISED DESTROYER/CRUISER CONSTRUCTION COST MODEL DRAFT FINAL REPORT

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REVISED DESTROYER/CRUISER CONSTRUCTION COST MODEL

DRAFT FINAL REPORT

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1. INTRODUCTION

The objective of this study is to update a cost model developed for U.S. destroyer/cruiser type ships, based primarily upon actual shipyard return cost data. It provides the Navy Center for Cost Analysis (NCA) with an independent cost analysis capability for general force planning, allocation of resources, and other comparable purposes as appropriate. The model provides reproducible results that can be relied upon to validate estimates received from other sources or to form a basis for internal estimating purposes.

The original model (Reference 1) was developed between 1980 and 1981 and therefore does not incorporate several of the newer ship types that have been introduced in the fleet since that time. This version of the model updates the original model by adding return cost data and cost estimates for ship types that are more representative of the types of ships expected to be of interest to the Navy and NCA.

The primary goal of this revised model is to provide feasibility level estimates for near-future (late 1980's/early 1990's) vessels. The scope of the model is limited to shipyard costs only and does not include the acquisition of government-furnished equipment (GFE) with respect to command, control, communications, weapons systems and additional costs such as training, integrated logistics support, or Navy program support. The model is designed to use information available at the end of the feasibility or conceptual stage of design, including such items as the three-digit weight breakdown, shaft horsepower, electric generation capacity (kilowatts) and cubic number.

The shipbuilding firm of Bath Iron Works (BIW), which has a long history of building the types of vessels used in this model, assisted Gibbs & Cox, Inc. in this modelling effort. A number of experienced cost estimators were available for this effort. Their knowledge of the BIW data was invaluable in transforming shipyard costs into the required format for this model.

The U.S. Navy has subdivided the basic items associated with ship construction programs into the nine one-digit SWBS groups shown in Table 1-1. The Ship Work Breakdown Structure (SWBS) system, which keeps track of ship specifications, weights, costs, drawings, and reports, was preceded by the Bureau of Ships Consolidated Index (BSCI) system. The value of such a structure lies in its familiarity (which is built up by learning and refining through constant use), its acceptance as a standard (which is acquired through regulated adherence), and its definition (through the associated data base, which is accumulated over time).

Table 1-1. U.S. Navy Shipbuilding Subdivisions/SWBS One-Digit Group

No.	Description	Weight	Cost
1	Hull Structure	X	X
2	Propulsion Plant	X	X
3	Electric Plant	X	X
4	Command and Surveillance	X	X
5	Auxiliary Systems	X	X
6	Outfit and Furnishings	X	X
7	Armament	X	X
8	Integration/Engineering		X
9	Ship Assembly & Support Services		X

The SWBS is familiar to both the U.S. Navy and the shipbuilding industry. It provides a convenient means of categorizing the systems and components that comprise the ship, enabling resources such as weight, cost, power, etc. to be allocated against ship systems and components for accounting purposes. Two problems arise with the use of SWBS, however, which are discussed below.

Historic shipyard labor and material accounting systems differed from those outlined in the SWBS. For the original version of the model, therefore, it was necessary to modify the historical shipyard cost and labor data to permit the sorting of costs by SWBS elements. Recently, ship construction practice has involved the use of zone construction, where a zone represents a certain volume or region of the ship. Resources such as material costs or labor are reported against these zones and not against ship's systems, further complicating the ability to translate costs and labor to a SWBS format. The use of different accounting systems between the shipyards and the Navy, along with the change in internal shipyard accounting procedures, introduces problems in accurately converting costs and labor to a SWBS format. This, in turn, may result in possible inconsistency in the data and hence in the resultant cost estimating relationships.

2. COST MODEL DEVELOPMENT APPROACH

To assure a comprehensive cost model an extensive data search was conducted. Gibbs & Cox retained data provided much of the information while other information was gathered from NCA, BIW, and other relevant sources.

2.1 Cost Data

A major problem in collecting cost data from any shipyard is the requirement to translate that data into a form recognizable to the user. Cost data is recorded at a shipyard for a number of reasons, but not specifically for the purpose of accommodating the U.S. Navy's cost estimating process. In fact, the NAVSEA Ship Work Breakdown Structure (SWBS) System, which was developed in 1973 to replace the 20-year old Bureau of Ships Consolidated Index (BSCI), was proposed by the Navy for adoption by shipyards working with the Navy (References 2 and 3). That goal has never been fully attained, which has caused difficulty in the conversion of shipyard records to the Navy structure. A significant portion of the effort involved in developing the original version of this cost model concerned the conversion of BIW cost data into the SWBS based cost structure shown in Table 2-1. During the revision of the model this data conversion was further complicated by the recent changes adopted by BIW for ship construction, which will be discussed in a subsequent section.

The structure, which has been defined for the purposes of this model as a two-digit breakdown, groups ship subsystems (as defined by the SWBS three-digit breakdown) into categories that exhibit similar cost characteristics. This allocation was based on the familiarity of the BIW estimators and the Gibbs & Cox, Inc. engineers with the subsystems of interest, as justified by the BIW cost data. Each of the two-digit groups has a different relationship between material cost or labor manhours and an independent parameter of interest such as weight, ship length, shaft horsepower, etc. The 24 groups encompass Groups 100 through 900 of the SWBS system.

Table 2-1. Two-Digit Model Structure Cost

Group	Group Title	Group	Group Title
1A	Structural Envelope/Subdivisions	5A	Environmental Systems
1B	Superstructure	5B	Fluid Systems
1C	Foundations	5C	Maneuvering Systems
1D	Structural Attachments	5D	Equipment Handling Systems
2A	Propulsion Energy Systems	6A	Hull Fittings
2B	Propulsion Train Systems	6B	Non-Structural Subdivisions
2C	Propulsion Gases (Intake and and Exhaust) Systems	6C	Preservation
		6D	Ship Support
2D	Propulsion Service Systems	6E	Habitability
3A	Electrical Power Generation	7	Armament
3B	Electrical Power Distribution		
4A	Vehicle Command	8	Integration/ Engineering
4B	Weapons Command	9	Ship Assembly and Support Services

The definition of each cost group lies in the equipment content of the assigned SWBS 3-digit groups. Each cost group has been given a one- or two-word title to approximate its contents, but these titles are applicable only to this model and are not associated with any other cost structure or system. At this two-digit level, each cost group is represented by a material and a labor cost estimating relationship (CER).

During revision of the model these groups were reviewed to ensure that they remained applicable for the newer ships being incorporated in the model data base. It was determined that the model structure retained its validity and did not require any modification.

Table 2-2 lists the independent variables that were used for each cost group to relate costs and manhours to the technical characteristics of the ships. The CER's that were developed integrate the BIW data of material costs ($/ton) and labor requirements (MH/ton) into useable algorithms that can be depicted as plots of material costs ($) or labor man-hours (MH) against the appropriate independent variable that provides the best correlation. The CER's selected for use in this revised model are provided in equation and graphical form in section 3.4 for the baseline ships.

The SWBS groups that do not address actual ship systems are Group 0 (General Guidance and Administration), 8 (Integration/Engineering) and 9 (Ship Assembly and Support Services); they do, however, entail cost (Reference 3). The costs associated with Group 0 include the development of requirements to be addressed by Groups 1 through 9. Those costs are not included in the model, since they are not incurred by the shipyard as part of a basic ship construction procurement. Group 8 and 9 costs are included, since they are associated with the fabrication of the ship, and are discussed in Section 3.5. Recently the importance of these groups has increased, so that they now form a significant portion of total ship costs.

In any ship design, the spiral of development begins with the selection of a tentative payload. On ship types analyzed for this model, the combat system is considered the payload, and cannot be expected to follow explicit trend lines as other dependent subsystems do; thus, expenditures for these systems (which fall within Groups 4 and 7) are handled as separate items within the Navy system. Barring radical selections of payloads, the present day U.S. Navy does maintain a gross trend in weapon suites' weights, but their costs depend mainly upon their performance and sophistication, which are not measured as easily as weight, space, etc. This has led to the Navy providing these systems to the shipyard as Government Furnished Equipment (GFE).

TABLE 2-2. Independent Variables

COST GROUP	COST GROUP TITLE	MATERIAL	LABOR
1A	Structural Envelope/Subdivisions	WT	CN/WT
1B	Superstructure	WT	WT
1C	Foundations	WT	WT
1D	Structural Attachments	WT	WT
Total	WEIGHT GROUP 1	CN/WT	CN/WT
2A	Propulsion Energy System	WT	SHP/WT
2B	Propulsion Train System	SHP/WT	SHP
2C	Propulsion Gases System	SHP	WT
2D	Propulsion Service System	SHP	WT
Total	WEIGHT GROUP 2	SHP	SHP
3A	Elec. Power Generation	WT	WT
3B	Elec. Power Distribution	WT	WT
Total	WEIGHT GROUP 3	WT	WT
4A	Vehicle Command	400 HZ/ CONSTANT	WT
4B	Weapon Command	WT	WT
Total	WEIGHT GROUP 4	VOL	WT
5A	Environment System	WT	WT
5B	Fluid Systems	WT/VOL	WT
5C	Maneuvering System	WT	WT
5D	Handling System	WT	L
Total	WEIGHT GROUP 5	WT	WT
6A	Hull Fittings	WT	LxB
6B	Non-Struct. Subdivisions	WT/VOL	WT
6C	Preservation	LxB/WT	WT
6D	Facilities	COMPL/WT	CN
6E	Habitability	WT	COMPL
Total	WEIGHT GROUP 6	LxB/COMPL	WT
7	Armament		
Total	WEIGHT GROUP 7	CONSTANT	CONSTANT

Key: L = Length
B = Beam
D = Depth
H = Draft
CN = Cubic Number

WT = Group Weight
KW = Kilowatts
SHP = Shaft Horsepower
COMPL= Complement
VOL = Total Ship Volume
400 HZ = 400 HZ 110 KW

In several recent ship construction programs a number of components that have typically been contractor-furnished items in the past are now being designated as class standard items. This practice results in the lead shipyard ordering the specified class-standard items for all or significant numbers of ships in the class. To follow shipyards this equipment essentially becomes "GFE" as they have no role in ordering or purchasing the items.

2.2 Weight Data

When costing ships for feasibility studies, individual subsystems (and the actual equipment) may not yet be defined; instead, only the function that will require such a subsystem may be identified. Normally, the functional requirements of existing similar ships will be sufficient for this model, even if the installed subsystem providing the operational capability has changed over the years due to technology or more explicitly defined requirements.

Consequently, it was necessary to represent components and systems by some measurable parameter. Space, weight, and power requirements are generally used for this purpose due to their availability during all stages of design. Over the years, the ship engineering community has built up a data base for ship design and construction using these parameters. The data bases at Gibbs & Cox and at BIW were used for this model.

In particular, three-digit SWBS weights were sought for the eight ships in the BIW data base as well as the three ships built at other shipyards. The most detailed and accurate weights available for several ships were still in the form of the BSCI system, because all conventional destroyer/cruiser type ships prior to the FFG-7 and DD-963 were designed and built using the BSCI breakdown. An attempt was made to convert to the SWBS system; however, the revised SWBS groups could only be applied in some instances. Weight estimates range from early preliminary design estimates through detailed estimates and weight reports containing returned weights that are either calculated or actually weighed.

The result was the best conversion possible of the BSCI weight distribution among the two-digit cost groups, which has been detailed in Appendix B in terms of the corresponding three-digit SWBS titles. Appendix C details the minor discrepancies in the BSCI to SWBS conversion and explains their impact on the cost model.

2.3 Ship Data

The candidate ships for examination in this task are listed in Table 2-3. The sources referenced provided much of the data on the weights and technical features. These candidates were selected from the U.S. Navy classification of combatant ships (excluding nuclear types) within the time frame of 1955 to the present. One constraint was the availability of shipyard costs (several additional shipyards were considered, but would not make their cost data available).

Table 2-3. Cost Anaylsis Reference Points

	Commission Date	DD Weight Analysis (Ref 4)	Major Drivers (Ref 5)	MIDMIX Study (Ref 6)	Soviet Study (Ref 7)	Revised Soviet Study (Ref 8)	Other Navy Sources (Ref 9-11)
DDG 51*	1990						X
CG 51*	1986						X
CG 47	1983		X				X
DDG 993	1981					X	X
FFG 7*	1977	X	X	X	X	X	
DD 963	1975	X	X	X		X	X
FF 1052	1969	X	X	X			
FFG 4*	1967				X		
FF 1040	1964	X	X	X			
CG 26*	1964	X	X	X		X	
CG 16*	1962	X	X			X	
DDG 40	1960	X					
DDG 2	1960	X	X		X		
DD 931	1955	X	X		X		

Notes: FFG-4 represents the FFG-1 class because it is the first ship of this class that BIW built.

* Indicates ships built by BIW.

The newer ships on the list represent all gas-turbine powered ships and contain a mix of actual return cost data and some estimates. Return cost data was available for CG-51, FFG-7 and to a limited extent, CG-47. The DDG-51 data represents a contractor bid estimate for the ship as it existed at the end of contract design. Subsequent changes during detail design have modified the ship; however, weight and other parameters used in the CER's correspond to the ship as it was estimated. The DD-963 and DDG 993 data are BIW estimates developed for another study and under the assumption that typical BIW construction procedures would be used.

Some problems exist with the availability of data for these newer ships. As noted earlier, the most recent combatant ship classes have many items that are bought as class-standard equipment by the lead shipyard. For the CG-47 class, Ingalls Shipbuilding, Inc. (ISI) was the lead shipyard. Consequently, BIW did not have to purchase a number of key items for the construction of CG-51, and, therefore, did not have material costs for certain groups on that ship. In the case of the CG-47, NCA documents were reviewed to identify return costs for that ship. ISI cost reporting data was organized differently from that used in the model; however, in certain instances the groups did match at the single digit cost group level. Cost data for CG-47 was incorporated in the model, when possible.

In the original model, cost data for the FF-1052 and FF-1040 were sought from another shipyard. This shipyard would also have been a second source of DDG-2 data to confirm the BIW data. The FF-1040 data would have also helped confirm the BIW data on the FFG-4 since the ships are identical except for a change in the weapon system. The proposed second source was dropped at that time because of proprietary data concerns expressed by the shipyard. During the revision of this model it was evident that emphasis should be placed on gas-turbine powered ships as they are the most likely ships to be procured in the future.

Although built at BIW, BIW no longer had a data base for the DDG-40 class available for this study, due to the policy of destroying "old" data. The data available at BIW in terms of return cost includes the original six ships in the model (FFG-4, CG-26, CG-16, DDG-2 and DD-931) and the CG-51. Reasonable estimates based upon shipyard estimator experience and actual construction contract bid costs are also available for three other ships. Table 2.4 presents technical characteristics (and potential cost group independent variables) for these ships.

Table 2.4

CHARACTERISTICS OF SAMPLE SHIPS

PARAMETER	DDG 931	DDG 2	CG 16	CG 26	FFG 4	FFG7	DD963	DDG993	CG-47/51	DDG-51
Number Ships Built	14	23	9	9	6	51	31	4	9	1
Year Commissioned	1955-59	1960-61	1962-64	1964-67	1966-67	1977-85	1975-83	1980-81	1983-91	1990
BIW Delivery Date	11/55	8/60	7/62	11/64	4/67	11/77	-------	-------	1986	1990
Displacement, Full	3960	4500	7800	7900	3426	3605	7810	8300	9200	8292
Length Between Perpendiculars	407	420	510	524	414	408	529	529	529	466
Beam	45	47	54.9	54.8	44.2	45	55	55	55	59
Draft	14.5	15.6	19.6	19.0	15.0	14.8	19.0	21.3	23	20.7
Depth on Center Line	29.0	28.7	38.9	39.0	31.6	31.7	42	42	42	41
Cubic Number	5217	5669	10619	11031	5420	5848	12220	12220	12220	11,270
Volume	414,484	488,492	823,299	867,776	406,949	531,980	1,040,000	1,065,000	1,100,000	965,000
Complement	337	355	395	418	251	185	304	360	341	310
Power Plant	2 Geared Steam Turbines	2 Geared Steam Turbines	2 Geared Steam Turbines	2 Geared Steam Turbines	1 Geared Steam Turbine	2 Gas Steam Turbines	4 Gas Turbines	4 Gas Turbines	4 Gas Turbines	4 Gas Turbines
SHP	70,000	70,000	85,000	85,000	35,000	41,000	80,000	80,000	80,000	100,000
KW	2,400	2,400	4,600	6,600	3,000	4,000	6,000	6,000	7,500	7,500
Shafts/propellers	2/FP	2/FP	2/FP	2/FP	1/FP	1/CP	2/CP	2/CP	1/CP	2/CP
Other	4 Boilers	4 Boilers	4 Boilers	4 Boilers	2 Boilers	4 Diesel Generators	3 Gas Tur Gen	3 Gas Tur Gen	3 Gas Tur Gen	3 Gas Tur Gen
400 Hz KW	50	470	1350	1000		450	450	450	1,200	600

The characteristics of those ships not in the cost baseline, FF-1040 and DDG-40, are given in Table 2-5.

During the original modelling effort an unsuccessful attempt was made to obtain the Master Equipment List (MEL) and Top Level Requirement (TLR) for many of these ships. The goal was to recognize differences between ships in terms of variations in installed equipment performance capability, which may imply cost differences even if weight or other basic parameters are not greatly affected. This goal was frustrated by a lack of data in the appropriate forms and the amount of effort required to properly interpret the data. It was felt that the inability to incorporate that subtlety did not detract from the accuracy of the model, since such accuracy is beyond the scope of the data base that will be available for a Class "D" cost estimate. This approach was not examined during this revision of this model.

A set of equipment description lists (Ship Subsystem Cost Drivers, Appendix D) for all existing ships that are covered by the model provide a basis for relating costs to differences in weight or performance of the analyzed ships. Relative (rather than absolute) costs for variations from normal equipment can be used to further modify group/system costs obtained from algorithms.

Existing weight analyses by BSCI or SWBS groups, such as those found in References (4-7), were reviewed for observed differences between sample ship cases. Reasons for differences were used to adjust weight algorithms and they became potential factors for fine tuning or explaining cost variations with respect to basic cost algorithms.

The basic algorithms developed can only be used to predict costs if the new ships have systems similar to those in past ships. Appendix E, Ship System Cost Drivers, contains a listing of possible variations of systems within each of the cost groups identified for this model.

Table 2-5. Characteristics of Other Ships

PARAMETER	DDG-40	FF-1052
Number Ships Built	10	46
Year Commissioned	1959-61	1969-74
BIW Delivery Date	1960	Not BIW
Displacement, Full	5709-5907	3877
Length Between Perpendiculars	490	415
Beam	52	46.8
Draft	15	15
Depth on Center Line	30.75	30.85
Cubic Number	7835	5992
Volume	(Not Available)	
Complement	373	245
Power Plant	2 Geared Steam Turbines	1 Geared Steam Turbine
SHP	85,000	35,000
KW		
Shafts/Propellers	2/FP	1/FP

These potential cost drivers were identified for the sample ships where applicable. Also included were all possible variations that could be applicable to near future ships as determined by Gibbs & Cox, Inc. The Subsystem Cost Drivers List (Appendix E) served as the foundation for the BIW analysis of cost drivers among the shipboard systems of interest. All the variations included in the table were evaluated by BIW during the original modelling effort to determine whether or not unique CER's would be required to represent a particular technical characteristic within a cost group. As expected, most of the cost factor differences were minor and well below the expected sensitivity of the model.

The cost implications of these technical features appear in the one-digit and two-digit cost algorithms, wherever sufficient cost data or estimates were available to measure the distinction. Each variation represents a difference in technology that could impact on costs and ultimately result in separate trend lines for a given cost group. The description of all trend lines/CER's appears in Section 3.4.

3. MODEL DESCRIPTION

The original (1980) version of this model was developed to provide an improved and updated method of predicting ship construction costs by NCA. During this current update of that model no attempt was made to analyze previous models. A discussion of the merits of the 1980 model compared to those earlier models was provided in the original 1980 model report. That discussion is repeated below because it provides a historical perspective.

3.1 Prior Models

Older models used by OPNAV and NAVSEA for costing ships, such as the RAND model and the NAVSHIPS model (References 12 and 13), were built around the seven weight groups of the BSCI and SWBS systems and include additional cost considerations not associated with weights (e.g., Group 8 and 9). An older Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command (Reference 14) describes the NAVSEA ship costing process and defines the basic construction costs developed in each of the older models to include labor, materials, overhead, and profit. Reference (14) also reviews the costs that these older models exclude, such as Research, Development, Test and Evaluation (RDT&E), and other costs defined in Table 3-1, the Breakdown of the Ship Construction, Navy (SCN) Estimate.

The current model and the older models develop basic construction costs only. These basic construction costs include man-hours for labor, material costs, and the shipyard's costs for design, engineering, and construction services.

Table 3-1 Breakdown of SCN Estimate

Plan Cost	Ordnance
Basic Construction/Conversion	Future Character Changes
Change Orders	Escalation Budgeted
Electronics	Escalation Earned
Propulsion Equipment	Project Managers
Hull, Mechanical, Electrical	Growth Factor
Other Costs	Total Ship Estimate

The current model uses a two-digit level breakdown, while the NAVSEA model uses three-digit SWBS groups. Historic NAVSEA model data points are based upon contractor "bids". The current model is based upon actual returned costs for eight ships, augmented by shipyard bid estimates and shipyard cost estimates for three other ships.

The independent variables used to determine costs are similar in all of these models, but are handled a little differently in various cost groups. A critique of cost models (Reference 15) explores the logic and value of selection of such parameters. It also addresses the issue of using returned costs as opposed to contractor bids.

Cost groups and parameters in the current model are based on the cost characteristics of the selected subsystems under consideration. The characteristics of the 22 cost groups (two-digit level cost model) are more specifically related to weight, volume, or power than are the more general seven cost groups (one-digit level cost model), which is one advantage of the use of cost groups below the one-digit SWBS level.

3.2 Cost Factors

Material costs include those materials purchased by the shipyard, such as steel, engines, generators, winches, pumps, lifeboats, and galley equipment. Some materials are purchased from manufacturers ready to install in the ship, while others, such as the hull steel, require considerable labor to fabricate or assemble. Materials not used for the ship itself, but necessary for the functioning of the shipyard (e.g, temporary utilities and service, contract administration, etc.), are included under groups 8 and 9.

Labor costs include the man-hours involved in the construction and assembly of raw materials and in the installation of equipment.

The two-digit level factors are the BIW weighted average of material costs or labor man-hours for the three-digit SWBS elements in that group. The one-digit level factors are weighted averages of the two-digit level data. The weights are based on final weight reports with minor modifications.

BIW has observed that their level of confidence in the cost factors is much higher at the one-digit level than at the two-digit level. In certain cases it was not possible to accurately identify appropriate cost factors for a two-digit group. In these cases the cost factors were adjusted so that the one-digit group cost factors totaled correctly. During the time period between issue of the original model and this revision, BIW noted some modifications were required to certain FFG-7 cost groups. These modifications are reflected in the model.

3.2.1 Data Adjustments

The BIW data for the seven ships for which return-costs are available provide as-built costs for representative subsystems installed on these ships. This also applies to the ships for which only bids or estimates were available. Observed differences in ship costs may reflect differences in the subsystems of the ships as a function of technology changes, inflation, or productivity differences. If inflation and productivity are backed out of the data, the remaining differences should reflect the technology level and major characteristics of the ship subsystems, providing a series of trend lines for probable new ship configurations.

The raw data obtained from BIW was adjusted for differences in time over which the data was reported, between 1955 and the present. The changes over this period of time in economics, technology and Navy requirements significantly affected the cost of ships. Technology changes and Navy requirements are of direct interest to the algorithms included as part of the model. However, the impacts of economics and the business environment were factored out to ensure that all the data was treated from the same perspective. This is significant, because the model reflects costs, not price, which may differ because of competition, projected workload and other factors.

The primary adjustment to material costs was for the effects of inflation. The raw data represents actual BIW costs accumulated against each vessel from the contract award to the delivery date. These costs were escalated from a point midway in the construction cycle to 1986 constant year dollars. This escalation is based on NAVSEA "Inflation Data Sheet" (Reference 16) values for converting then-year dollars to constant year dollars.

- 1986 Material Cost = Material Cost (Mid-point of Construction Date) x Inflation Factor

Inflation factors are provided for the ships of interest as shown in Figure 3-1.

Labor factors were adjusted for ship and workload (previously called productivity) based upon the BIW total ship labor factor curve (Figure 3-2).

- 1986 Labor Man-hours = Man-hours (Delivery Date) x Workload Factor

Figure 3-2 depicts BIW total ship man-hours per ton over time. The right hand ordinate is a measure of the workload factor. In mathematical terms the workload factor is equal to the value of total man-hours per ton for the CG-51 (490) divided by the total man-hours per ton actually incurred for each of the ships of interest. The CG-51 is the most recent ship for which BIW has return cost data and therefore was selected as the base value most representative of current labor trends. The workload curve shows variations due to: (a) ten continuous years of DD/CG/FF building, (b) ten years of the lack of such business before construction of FFG-7, (c) and recent trends for larger combatants (DDG & CG). In the original model a downward slope was projected based on BIW's estimate of an anticipated trend in the shipyard that was expected to occur because of a continuous workload. This has since been revised to depict current trends. Stability in a shipyard's workload affects total ship productivity and should be considered when costing a future ship. The CG-47 is not shown because it represents a different shipyard with its own labor factor. No labor factor was applied to the CG-47. The adjustment is intended to normalize the raw

SHIPBUILDING ESCALATION FACTOR
(BUDGET YEAR TO CONSTANT DOLLAR YEAR)

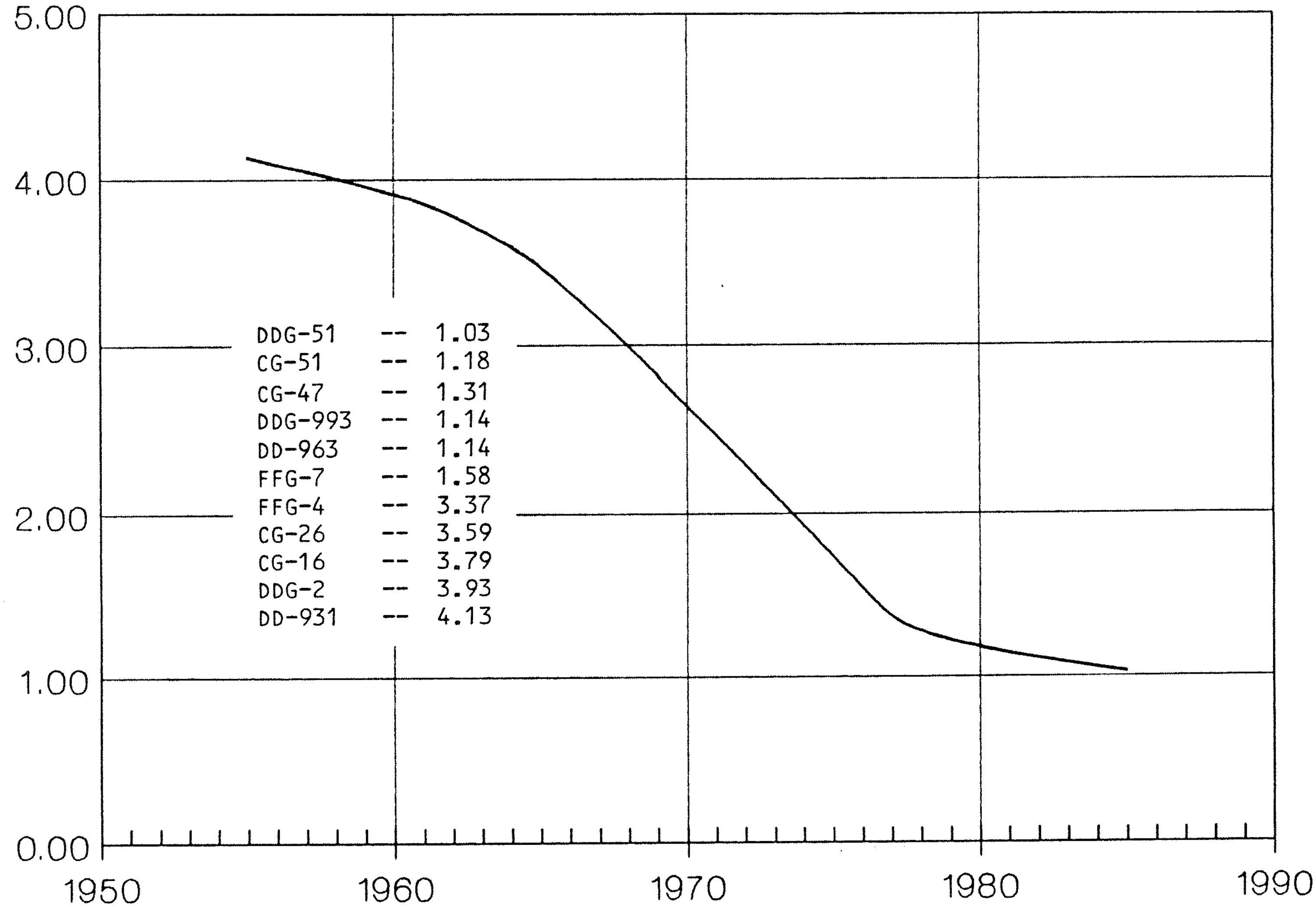


FIGURE 3-1

TOTAL SHIP LABOR FACTOR

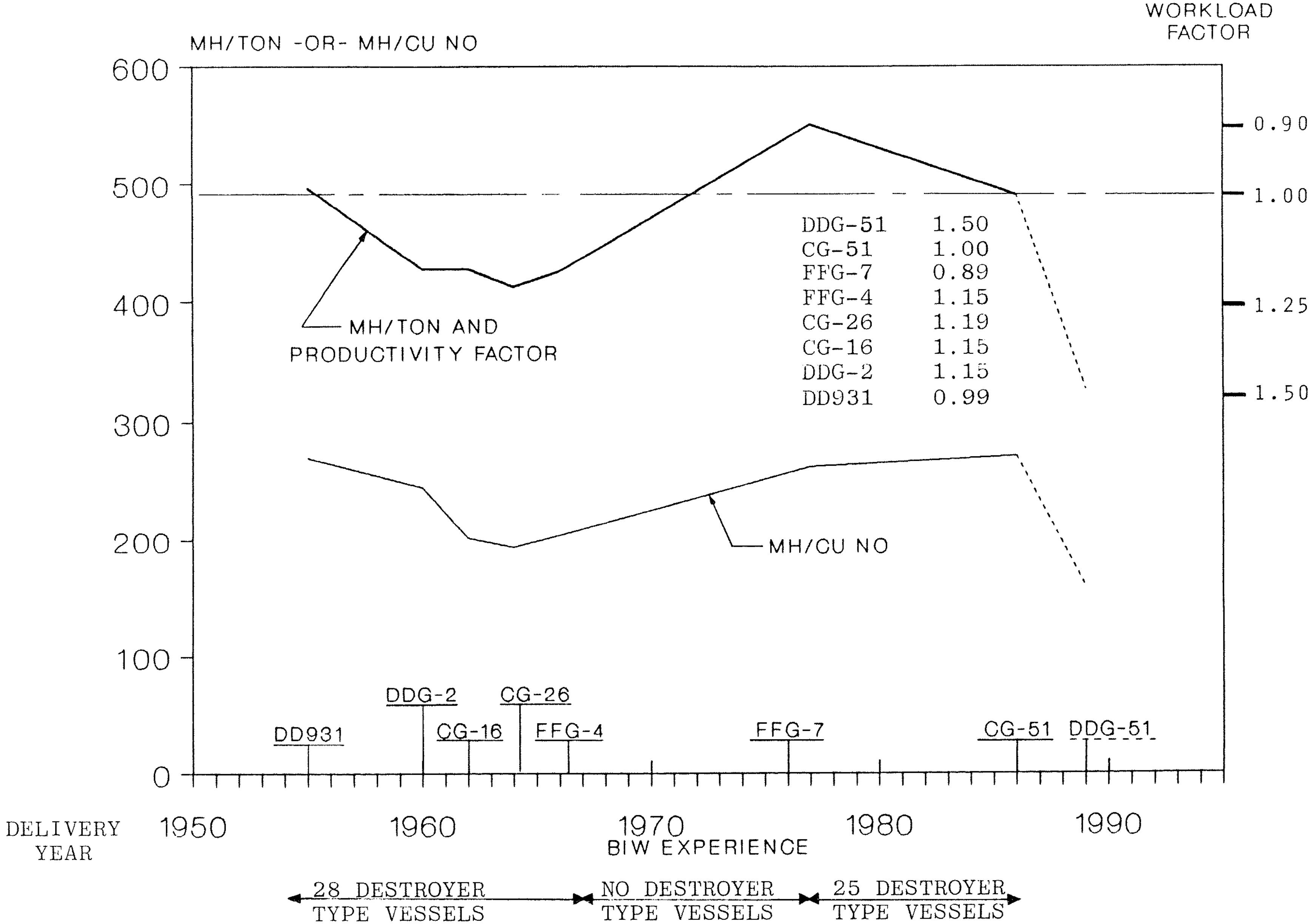


FIGURE 3-2

data for economic and workload influences in order to arrive at a set of data points that show dependency on some relatable technical trends. The resultant cost factors from the set of sample ships can then be exhibited in the form of a base algorithm or algorithms that reflect the characteristics of the installed subsystems.

Analyses of the data points entailed plotting the costs against various parameters, such as the cost group weight, ship's cubic number (length x beam x depth)/100, complement, SHP, installed electrical generation capacity in KW, etc., to determine data fit, establish trends, and define differences between ships along with the attendant causes.

Additional CER's were generated from the cost factors developed by BIW estimators to include subsystems that were not included in the basic six ships, e.g., electric drive, steel superstructures, etc. Even if only one data point off the base algorithm was available, a new algorithm proportional to the base has been derived with generally satisfactory results.

This treatment of "scattered" data is different from the approach used in other models where "outliers" are abandoned on the presumption that unique points are not representative of a trend and, therefore, should not influence the selection of a normal algorithm. The limited number of candidate ships with the subsystems of interest for this model precluded obtaining a large number of data points for each cost group, and, more specifically, for each subsystem variation within each cost group. However, based on an analysis of cost data by the BIW estimators and of ship subsystem characteristics by Gibbs & Cox, Inc., the approach taken is considered sufficiently accurate for this model, and it provides added versatility and depth as well.

3.2.2 Cost Estimating Relationships (CER's)

Cost estimating relationships (CER's) were derived by plotting sample ship cost and labor data points against meaningful parameters. Based on technical characteristics of the ships analyzed and the cost and labor data provided, conclusions (algorithms) were developed for the most meaningful and best-fit relationships. These algorithms and CER's include some based on a single data point because the technical characteristics warranted a separate relationship.

The independent variables against which cost or man-hours were plotted in each group were arrived at through experimentation and with due regard for the availability of pertinent input parameters during early stages of cost estimating. The selection was based upon the assumption that cost group weight would be the primary desired parameter unless weight provided poor data correlation, or other data e.g., SHP, provided a better fit. In the original version of the model the CER's were only investigated as linear trends. This was primarily due to the small number of sample points and the perceived uncertainty of technological direction. Both these concerns have ameliorated somewhat since that time, and it was therefore decided to evaluate nonlinear relationships in addition to the linear trend Reference (17). The CER's provide estimates of material costs and labor man-hours in 1986 dollars and 1986 adjusted man-hours if the technical features of the ship to be costed are similar to those of the sample ships.

These algorithms were developed using the least squares regression technique. The primary criteria for the predictive value of each algorithm were the coefficient of determination, r^2, and the number of data points included in that equation, as an indicator of the significance of the r^2 value. The coefficient of determination is a measure of the fit of the regression equation to the data points. An r^2 of 1.0 would indicate a perfect fit, implying that all data lie on the curve. An adjusted r^2 is provided for each CER which modifies the obtained r^2 by a factor based on the number of points used to derive the CER.

Known differences between ship examples account for many of the variations in weight/cost. The remainder of the differences are assumed to result from unknown variations, the natural dispersion of the data, and minor undefined differences in such areas as shipyard productivity and the amount of procured versus fabricated items, accommodated by the general relationship established in the algorithm. Therefore, the more knowledge of differences, the better the algorithm. Based on the foregoing, the descriptions of the cost estimating relationships in Section 3.4 include the conditions, exceptions, and variations that qualify the conclusions. These qualifications or limitations are just as important as the CER for predicting the costs of future ships, since the user of the model should understand the basis for the CER's and supporting data points, especially if the model is to be used to cost a subsystem not specifically covered by one of the trend lines.

Excursions from the baseline features, which are summarized in Appendix E, in some cases are taken care of through the use of supplementary trend lines or algorithms. Costs desired for subsystems that are not addressed by supplementary trend lines or algorithms may be estimated by the user of the model through comparisons of the "new" subsystem with those for which trend lines are available.

3.2.3 Government Furnished Equipment (GFE)

In accordance with the constraints put on this model, the basic construction costs do not include the government furnished equipment (GFE) associated with the combat system of the ship. Other hull, mechanical and electrical (HM&E) subsystems may be considered GFE on a particular ship (propulsion gas turbines on FFG-7), but that is not usually the case, so all non-combat system HM&E costs are included in this model.

Combat systems GFE is excluded for several reasons. Equipment in the combat system is extremely costly, compared to HM&E subsystems and, therefore, is usually acquired by the Navy in multi-ship lots. It is unusually high in cost per weight and volume, which distinguishes it from other equipment. Costs are unique to the various combat system equipment and are driven by the complexity of the system. Also, equipment is selected for installation on ships in a variety of combinations with regard to the ship's mission requirements and other ship characteristics. This model is restricted to the inclusion of installation costs of the combat suite that are incurred by the shipyard. Installation includes the material and labor costs for foundations, mounts, magazines and hoists, the supporting hydraulics, cables, and electrical systems and their testing. Cost groups that are most affected by GFE considerations are Group 4B and 7.

Group 4A contains other non-GFE command and communication functions associated with the ship, and is treated the same as other cost groups.

3.3 Procedure

The foregoing discussions have provided the background for use of the algorithms in estimating the basic construction costs of FF/DD/CG types of ships.

Section 3.4 contains the descriptions and graphs for the two alternative approaches that can be taken in the use of this model: one for the one-digit level SWBS groups, and the other for the two-digit level cost groups. Each approach has an associated input data requirements work table, and output worksheet (Appendix A) for arriving at the cost estimate, and the requisite algorithms to perform the analysis.

If only one-digit weight estimates, cubic number, KW, and SHP of a new ship are available, the one-digit level cost model will provide a cost estimate. One-digit estimates presume a given combination of subsystems or system configurations within each cost group. The disadvantage of this estimate is its inability to take into account unusual features of a new ship, which may be different from the features included in the baseline data from which the one-digit algorithms were derived. This flexibility is built into the two-digit level cost model. Additionally, if known technical features are identified for specific cost groups, it is possible to modify the basic cost estimate through the use of supplementary trend lines. Some of these features, such as electric-drive propulsion systems, have been examined to arrive at distinct cost differences that are identified on the appropriate algorithm plots. Other features can be taken into account if some knowledge of their differences with respect to the already identified algorithms can be determined. This would then permit interpolation between algorithms or some degree of extrapolation to determine a cost for the new features.

Many of the 22 cost groups use weight as the independent variable. This procedure assumes the availability of a three-digit weight estimate. When there is a lack of weight data for a particular cost group area, the alternative is to estimate the missing information. Appendices B and C may be used for this purpose by (1) comparing the known data for the new ship to the average data for the model baseline ships through percentage distributions, or (2) generating weight estimates from algorithms. In this manner, insight gained can be used to estimate the missing weights, thus permitting the user to enter the model with estimates of the required input for the 22 cost groups.

In this revised edition of the model, an additional parameter has been used to estimate costs. This parameter is total ship volume. Several cost groups failed to have good correlation with the other standard parameters, but demonstrated strong dependence on volume. Although total ship volume is not typically available during early stages of design, it is possible to estimate volume based on known ship characteristics and comparing these to known characteristics and volumes of other ships.

3.3.1 One Digit Level Cost Model

At the one-digit level, SWBS Groups 1 through 7 are each represented by a material CER and a labor CER. Where more than one independent variable (input parameter) is suggested as satisfactory for a group, cost values generated may be compared to validate each other. When only one algorithm or trend line is shown for a group, the equation may be applied to all destroyer type vessels. If supplementary trend lines are available, the applicable equation should be used, e.g., the steam CER versus the gas turbine CER for Group 2 material.

The procedure for estimating ship construction costs at the one-digit level is as follows:

1. Begin by determining the input parameters, estimated weights (in long tons), shaft horsepower, kilowatts, etc., as appropriate for each of the cost groups (Table A-1).

2. Select the one-digit level graph for material costs in Section 3.4 for each cost group. Determine the cost using the respective input parameter for that particular group. Record the cost on the output worksheet (Table A-2). Repeat this process for each group until all material costs are obtained, then total. In some cases, several trend lines are provided, depending on cost group variables as well as to account for various different ship configurations.

3. Repeat step 2 for man-hours of labor using the one-digit level graphs in Section 3.4.

4. Using the summary worksheet (Table A-3), multiply the man-hours by a man-hour cost/hour for the year concerned. (The cost per man-hour must be supplied by the user of the model.) If the estimate for which labor costs are being projected is desired in a form other than constant year 1986 dollars, the man-hour costs must be adjusted by a workload factor, as described in Figure 3-3 of this report.

5. If the estimate for which material costs are being projected is desired in a form other than constant year 1986 dollars, the material costs must be adjusted by an escalation factor as described in Figure 3-2 of this report.

6. Determine SWBS Group 8 and 9 man-hours and costs from Section 3.5 and make adjustments as appropriate, using the procedures described in steps 4 and 5.

7. Add the material cost to man-hour cost to obtain total basic construction cost as defined in Section 3.1.

3.3.2 Two-Digit Cost Model

This cost model consists of 22 cost groups, each of which is represented by at least one materials cost CER and a labor man-hours CER. Where supplementary trend lines are specified, the relationship most applicable to the system being costed should be used.

The procedure for estimating ship construction costs at the two-digit level is as follows:

1. Begin by determining the input parameters, estimated weights (in long tons), shaft horsepower, kilowatts, etc., as appropriate for each of the 22 cost groups (Table A-4).

2. Select the two-digit level graph for material costs in Section 3.4 for each cost group. Determine the cost using the respective input parameter for that particular group. Record the cost on the output worksheet (Table A-5). Repeat this process for each group until all material costs are obtained, then total. In some cases, several trend lines are provided, depending on cost group variables as well as to account for various different ship configurations. Note which trend line is used for each cost.

3. Repeat step 2 for man-hours of labor using the two-digit level graphs in Section 3.4.

4. Using the summary worksheet (Table A-6), multiply the man-hours by a man-hour cost/hour for the year concerned. (The cost per man-hour must be supplied by the user of the model.) If the estimate for which man-hour costs are being projected is desired in a form other than constant year 1986 dollars, the man-hours costs must be adjusted by a workload factor as described in Figure 3-2 of this report.

5. If the estimate for which material costs are being projected is desired in a form other than constant year 1986 dollars, the material costs must be adjusted by an escalation factor as described in Figure 3-1 of the report.

6. Determine SWBS Group 8 and 9 man-hours and costs from Section 3.5 and make adjustments, as appropriate, using the procedures described in steps 4 and 5.

7. Add the material cost to the man-hour cost to obtain total basic construction cost as defined in Section 3.1.

3.4 Cost Algorithms

Two means are available for estimating costs - graphs and mathematical relationships. Both full page graphs and mathematical equations are provided for each one-digit and two-digit cost group. The graphs provide a means of assessing the obtained cost estimate relative to the data points that were used to derive the cost algorithms. This approach permits the analyst to use his or her own judgement to adjust the algorithm-derived estimate as they deem appropriate, if it appears the known characteristics of the ship being estimated are more similar to a specific data point. Use of the mathematical expression provides a straightforward solution to obtaining a cost estimate, but any relational feel for the algorithm and the data used to develop it is lost by the analyst, unless he refers back to the data.

A number of enhancements over the previous edition are provided in this version of the model. These enhancements include: 1) investigation of linear and non-linear CERs, 2) provision of more than one graph and CER for certain cost groups. For those cost groups where linear and nonlinear CERs produce markedly different results, plots of both CERs are provided. If no distinction could be made between nonlinear and linear CERs, only the linear CER is shown. (A full set of alternative non-linear algorithms was evaluated for this model and is contained in Reference 17.) Also, some cost groups are also described by more than one CER. This is generally the case when total ship volume is the parameter that yields the best fit, because total ship volume may not be available. Finally, an improved product is obtained through reliance on computers for mathematical and graphing functions because of elimination of calculation and plotting errors.

The cost algorithm plots contain two types of data points, actual adjusted return costs and estimated or derived costs. The actual data points are marked by a "o" while estimated and derived points are marked by "*". Different line types are provided on the plots for those cost groups where more than one relationship is required because of the different technical characteristics of the ships being used to derive the CER (an example would be plots of a separate cost versus SHP for gas turbine ships and for steam turbine ships).

A number of cost algorithms have been derived for cost groups based on only a single data point. These algorithms always pass through that point, are always linear, and have a slope based on the slope of the principal CER of that group. The slope is adjusted up or down based on the magnitude of the point, relative to its value if it were calculated by the principal CER of that group. The limitations of this approach are understood, but given the lack of additional data and an understanding of ship systems characteristics and costs, it was deemed worthwhile.

This model only predicts costs of ships that have configurations based on proven or extrapolatable state-of-the-art technology.

The Small Waterplane Area Twin Hull (SWATH) hullform is a state-of-the-art hullform currently being applied to some naval auxiliaries and similar commercial-type vessels. It has also been investigated by the Navy for use as a surface combatant but that application is not currently being pursued. Based on previous work performed by BIW Table 3-2 has been prepared to show material costs and man-hours at the one-digit level for a 7100-ton displacement SWATH frigate. The numbers have been escalated for inflation but do not include profit and have not been adjusted for the labor

TABLE 3-2
MATERIAL COSTS AND LABOR MAN-HOURS
FOR A 7100-TON FULL LOAD DISPLACEMENT
SWATH COMBATANT

COST GROUP	WEIGHT (LT)	MATERIAL COSTS (K)[1]	LABOR MAN-HOURS[2]
1	2809	5883500	590547
2	462	31587200	79443
3	336	5964800	240384
4	178	1201800	95230
5	790	7951000	295624
6	448	3606300	432081
7	143	37900	14968
8		63974200	1328589
9		3084200	1228723
TOTALS	5166	123,290,000	4,305,589

NOTE: 1) COSTS INCLUDE ESCALATION TO CONSTANT YEAR 1986 DOLLARS

2) MAN-HOURS ARE NOT ADJUSTED FOR SHIP WORKLOAD FACTOR

Source: Reference (18)

workload factor. It was decided to provide this information in this manner rather than on the plots, because of the feasibility-level nature of the design and attendant cost estimate.

The following sections discuss each of the individual cost group algorithms, providing insight into the technical features and production history of the ships forming the data base that were used to derive the algorithms. This perspective can be useful in estimating costs of future ships.

3.4.1 Group 1 - Hull Structure (Total)

Group 1 is comprised of the following two-digit cost groups:

1A Hull Structural Envelope/Subdivisions

1B Superstructure

1C Foundations

1D Structural Attachments

The algorithms for one-digit Group 1 are discussed below.

Material Costs - Group 1 weight should be used as the independent variable to estimate the Group 1 material costs. DDG-2 was omitted from the calculation due to the high cost of using HY80 when it was built. (This increase in material costs for HY80 appears only in this vessel because it was a "new" material at the time.) The basic algorithm applies only to aluminum superstructure vessels. A separate algorithm based on the DDG-51 is provided for steel superstructure ships; however, the actual data point represents a superstructure that was 75 percent steel and 25 percent aluminum.

CER:	$ = 2,910 WT - 109,803
Variable:	Group 1 Weight
Application:	Aluminum Superstructure Vessels, all steel hulls
Adjusted r^2:	0.8311, 9 points

CER:	$ = 1,894 WT - 714,845
Variable:	Group 1 Weight
Application:	Steel Superstructure Vessels, all steel hulls
Adjusted r^2:	N/A

Labor Factor: Either the Group 1 weight or the ship's cubic number can be used to estimate the total Group 1 man-hours. Weight appears to provide better correlation with cost than does the cubic number; however, both provide acceptable results. Two algorithms are provided for each plot, one (covering the majority of points) for aluminum superstructures, and one for steel superstructures. The impact of somewhat different procurement/construction practices for Group 1D structural attachments does not appear to substantively affect the data.

For Aluminum superstructures

CER	MH = 241.6 WT + 42,263
Variable:	Group 1 Weight
Application:	Aluminum Superstructure Vessels, all steel hulls
Adjusted r^2:	.9919, 9 points

OR

CER:	MH = 74 CN - 98,162 Variable:
Cubic Number	
Application:	Aluminum Superstructure Vessels, all steel hulls
Adjusted r^2:	.9568, 10 points

AND for steel/aluminum superstructures

CER:	MH = 306.7 WT + 53,655
Variable:	Group 1 Weight
Application:	Steel/Alum Superstructure Vessels, all steel hulls
Adjusted r^2:	N/A

OR

CER:	MH = 84 CN - 98,162
Variable:	Cubic Number
Application:	Steel/Alum Superstructure Vessels, all steel hulls
Adjusted r^2:	N/A

See Figures 3-3, 3-4, 3-5 for plots of data points.

HULL STRUCTURE (TOTAL)
GROUP 1
MATERIALS COST

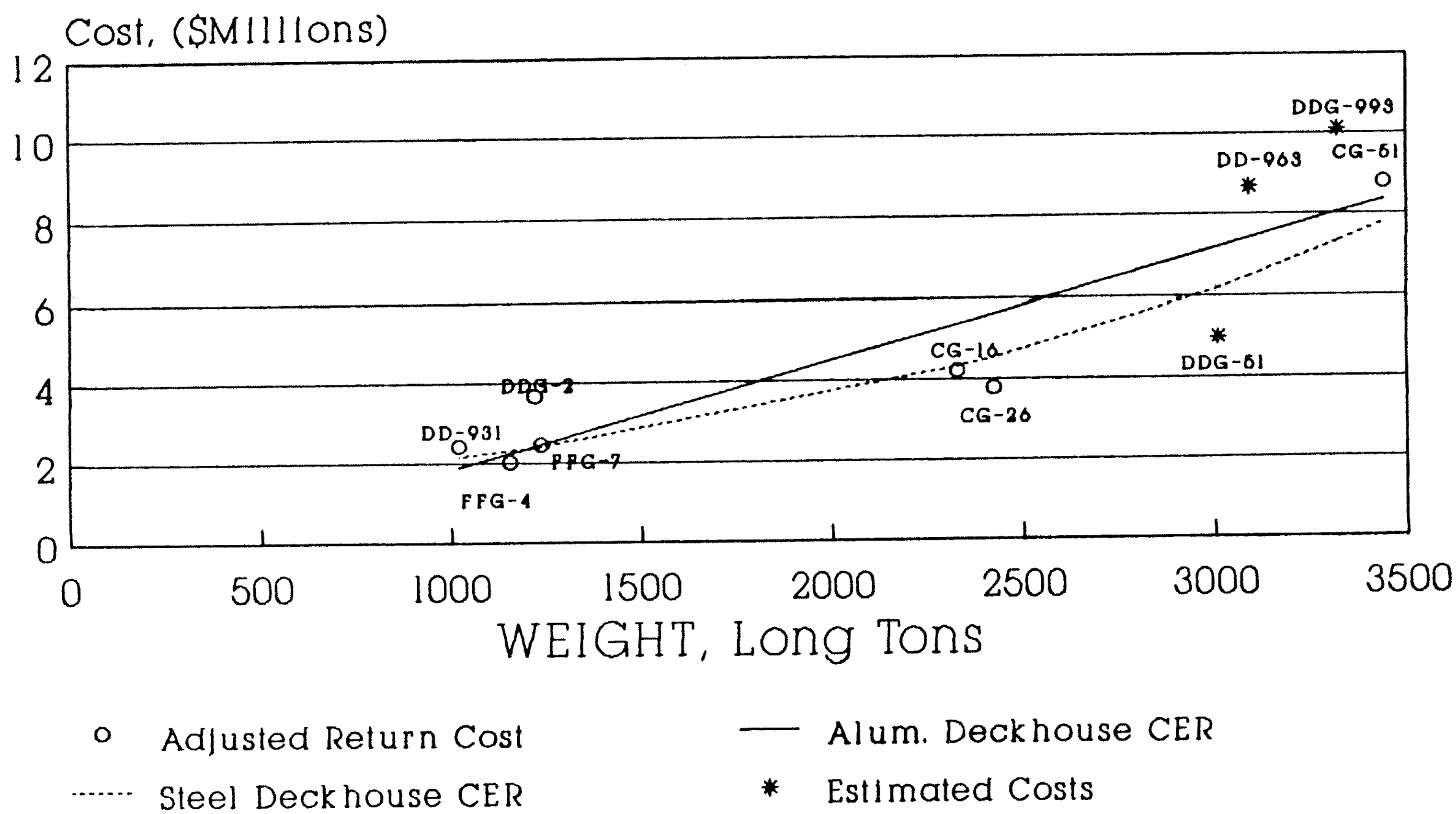


FIGURE 3-3

HULL STRUCTURE (TOTAL)
GROUP 1
LABOR

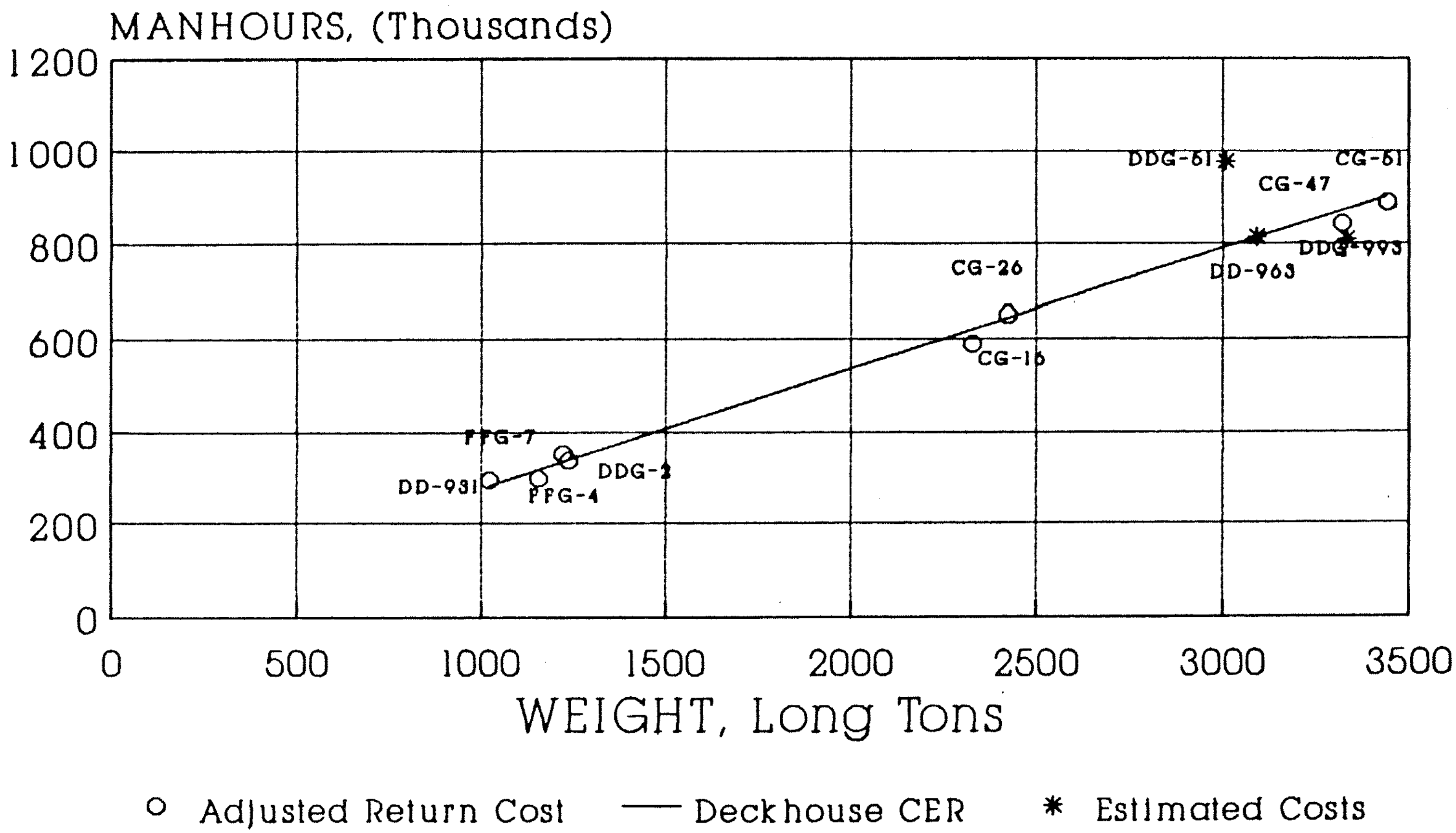


FIGURE 3-4

HULL STRUCTURE (TOTAL)
GROUP 1
LABOR

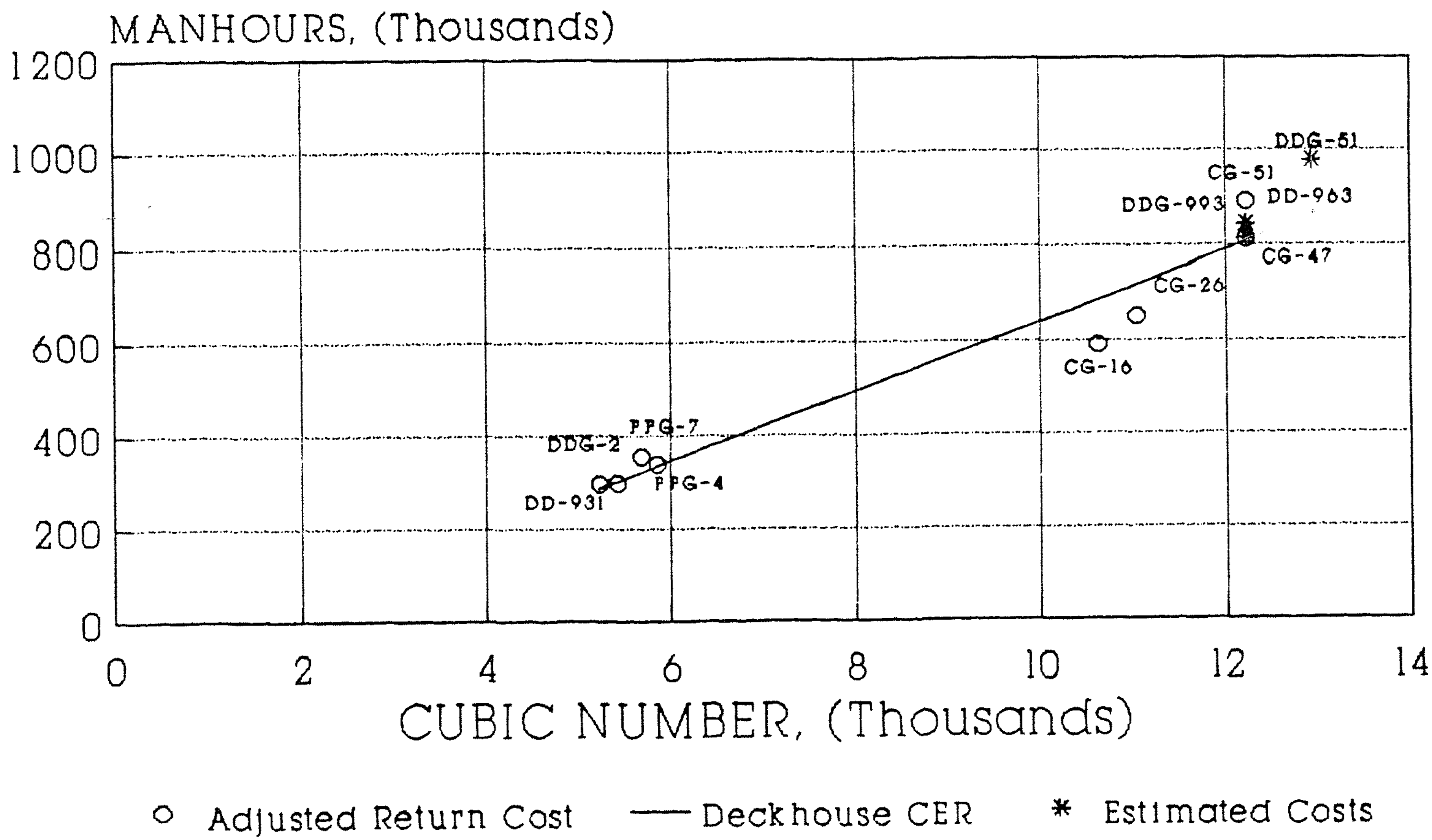


FIGURE 3-5

Group 1A - Structural Envelope/Subdivisions

This group includes the shell plating, framing, structural bulkheads and decks.

MATERIAL FACTOR: Group 1A weight should be used as the independent variable to estimate costs. For the ships being studied, the only major outlier is CG 47. However, this number was obtained from another shipyard and was not included in the algorithm since the reason for the difference could not be determined. Otherwise, there were close correlations between the various ships, which seemed to be independent of the type of steel used (HY 80, HTS, or MS), although HY 80 does show an indication of being slightly more expensive.

CER:	$ = 1,455 WT - 339,800
Variable:	Group 1A Weight
Application:	HTS, MS, HY80 hull
Adjusted r^2:	.8962, 9 points

LABOR FACTOR: Either cubic number or the cost group weight can be used to estimate the Group 1A man-hours regardless of the type of hull steel used.

CER:	MH = 40.6 CN - 83,791
Variable:	Cubic Number
Application:	HTS, MS, HY80 hulls
Adjusted r^2:	.9348, 11 points

OR

CER:	MH = 202 WT + 41,981
Variable:	Group 1A Weight
Application:	HTS, MS, HY80 hulls
Adjusted r^2:	.8924, 11 points

See Figures 3-6 through 3-8 for graphs of data points.

Group 1B - Superstructure

This group includes the deckhouse structure, helicopter hangars, etc., but does not include masts, stacks and macks.

MATERIAL FACTOR: Superstructure cost is estimated as a function of Group 1B weight with one algorithm for aluminum superstructures and another for steel. The steel costs were estimated by BIW for the DDG-51 superstructures, as they stood at the end of contract design, in which 25 percent of the superstructure would still be aluminum. The Group 1B weight for an all steel superstructure can be estimated as approximately twice the weight of an equivalent volume aluminum superstructure. Although a straight weight ratio of steel to aluminum is 3 to 1, for structural systems of equivalent strength (plating and framing), the weight ratio is typically 2 to 1.

HULL STRUCTURAL ENVELOPE/SUBDIVISIONS
GROUP 1A
MATERIALS COST

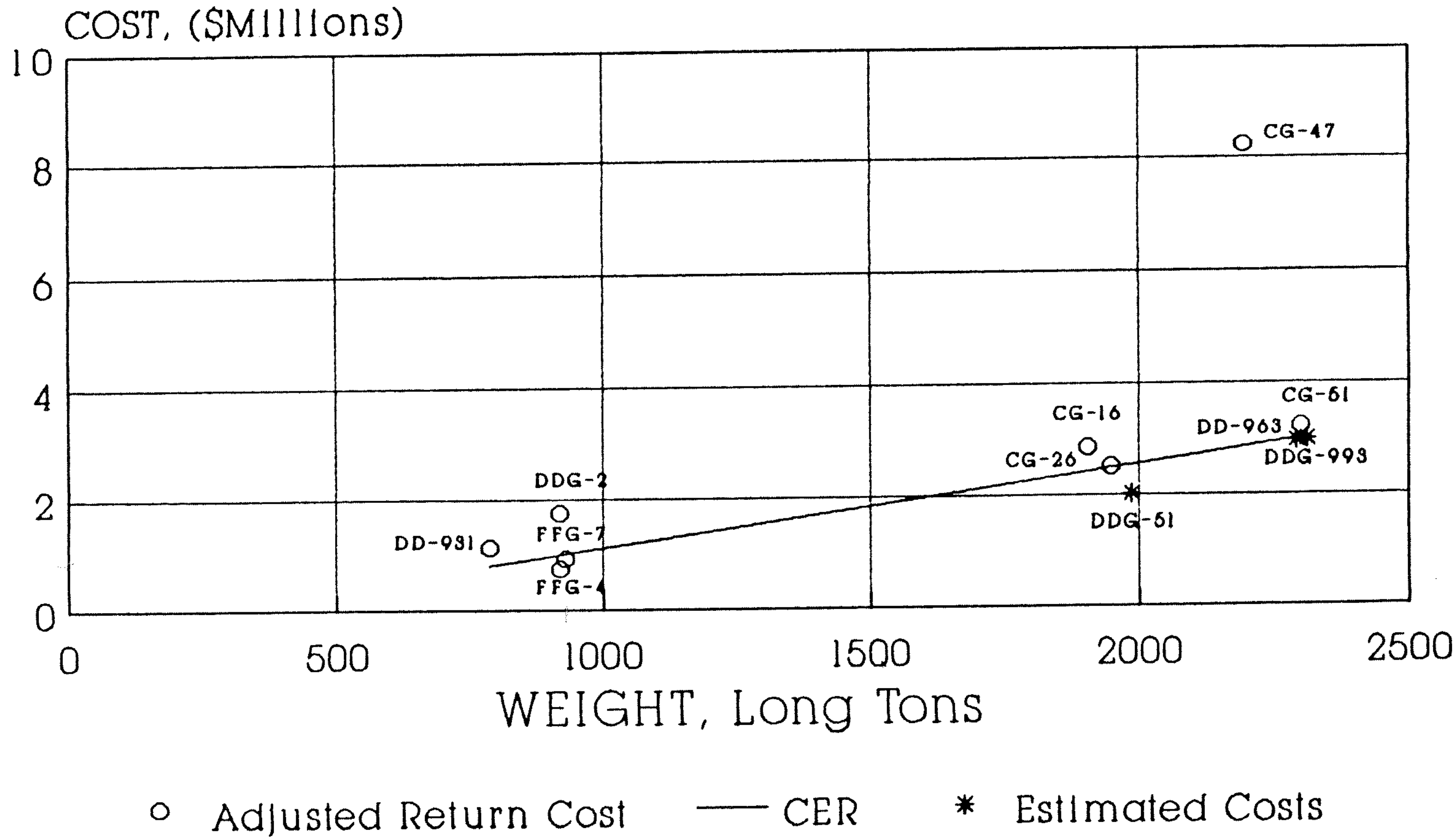


FIGURE 3-6

HULL STRUCTURAL ENVELOPE/SUBDIVISIONS
GROUP 1A
LABOR

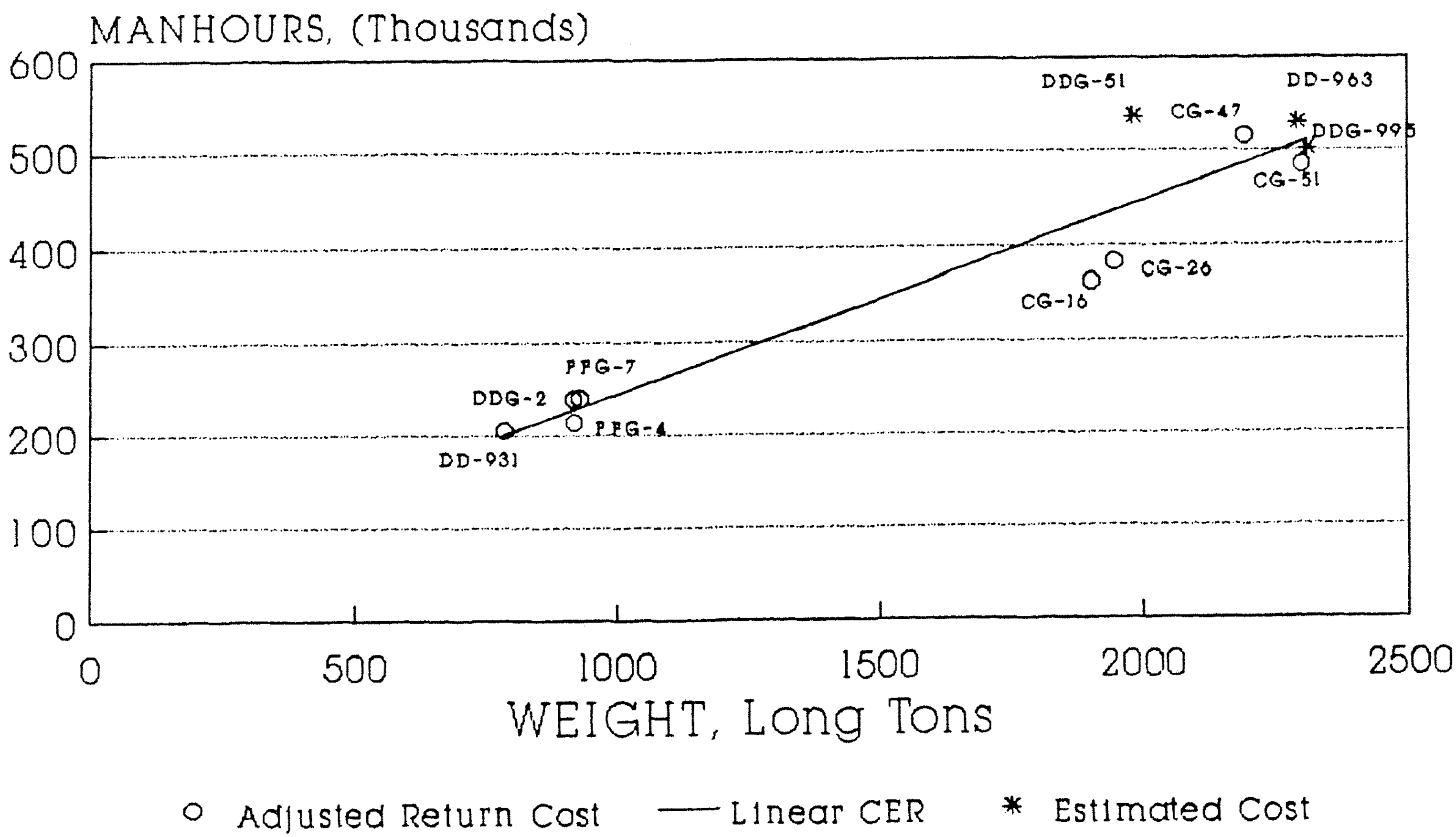


FIGURE 3-7

HULL STRUCTURAL ENVELOPE/SUBDIVISIONS
GROUP 1A
LABOR

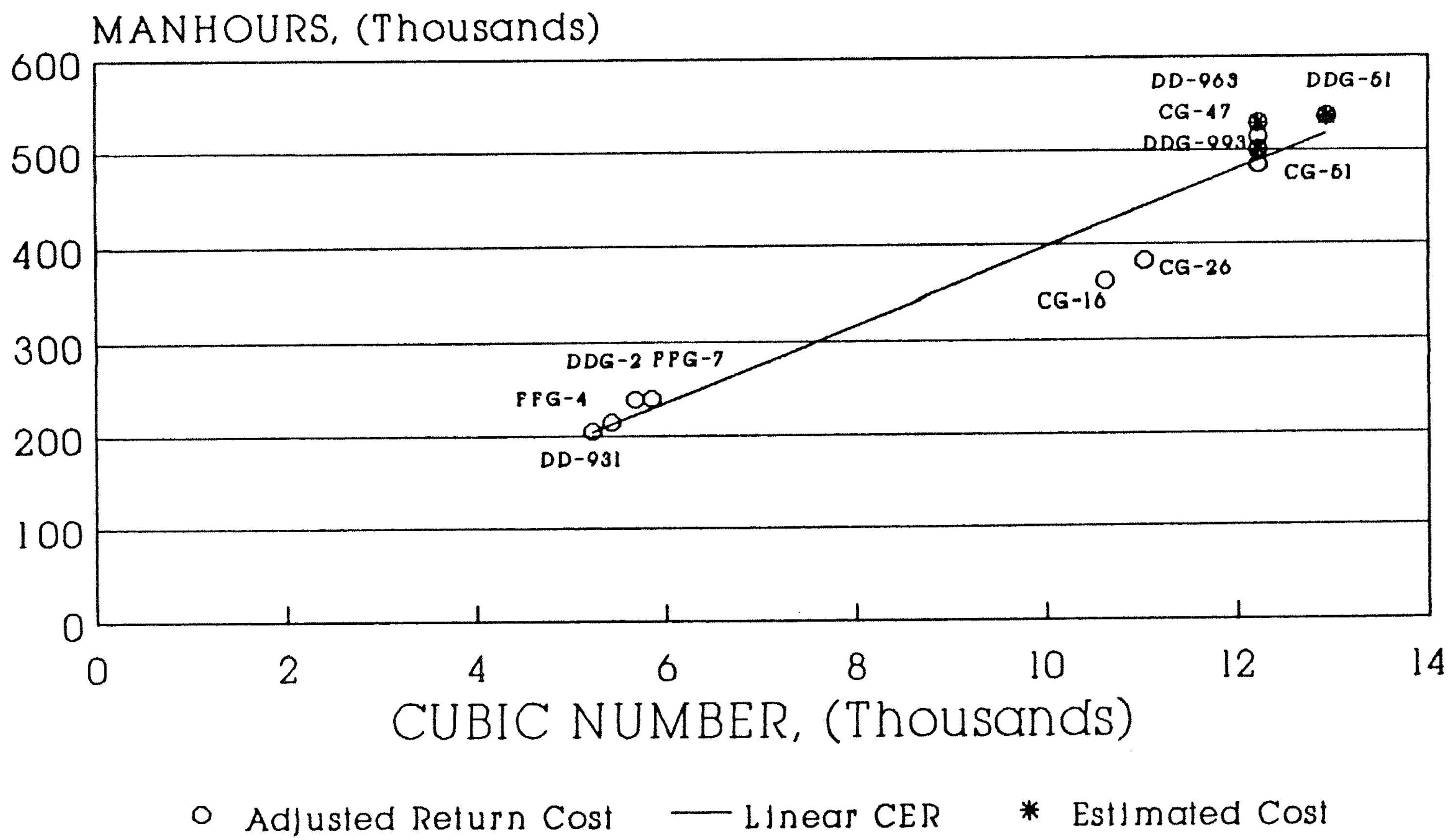


FIGURE 3-8

The inclusion of helicopter hangars does not seem to be a major determinant in the cost when plotted against weight. The CG-47 is the only outlier but represents a different shipyard and was not included in the algorithm.

CER:	\$ = 4,778.5 WT + 44,000
Variable:	Group 1B Weight
Application:	Aluminum Superstructures
Adjusted r^2:	.9797,9 points

CER:	\$ = 3,560 WT + 33,000
Variable:	Group 1B Weight
Application:	Steel Superstructures
Adjusted r^2:	N/A

LABOR FACTOR: Group 1B man-hours are also estimated as a function of the superstructure weight. The algorithm for steel superstructures was estimated for an all-steel equivalent superstructure on the DDG-51. DD-931 is a major outlier for labor because it was the first aluminum superstructure constructed by BIW, and several problems associated with this "first" caused the labor figures to be high. One consideration in the extrapolation of labor figures with the aluminum algorithm is that a number of the ships for which data is plotted were constructed before the advent of machine cutting (plasma burning) for aluminum. The addition of several ships built with this technology does not appear to have significantly changed the man-hour per ton relationships for ships such as CG-51 and CG-47.

CER:	MH = 449 WT + 1,000
Variable:	Group 1B Weight
Application:	Aluminum Superstructures

CER:	MH = 300 WT
Variable:	Group 1B Weight
Applicable:	Steel Superstructures

See Figures 3-9 and 3-10 for graphs of data points.

Group 1C - Foundations

This group includes the foundations for propulsion plant machinery, auxiliaries and other equipment.

MATERIAL FACTOR: The material costs for foundations are a function of the type of propulsion plant and whether the foundations are shock hardened or not. The data for two cases: steam plant, non-shock hardened, and gas turbine plant, shock hardened, are represented here. The scatter of the steam plant foundations is due to an evolutionary change in design criteria from the 50's through the 60's with regard to underwater shock, inconsistencies in the classification of the foundation shock levels, and in the classification of foundation weights. In most 1950 and 1960 vintage vessels, the ship's main propulsion machinery is hard mounted with only limited attention given to foundation design. Also shafting, most auxiliaries, and piping systems were designed to carry only limited static equivalent shock loads. Later vessels were designed with more attention given to high shock and self noise limitation as seen in the gas turbine, shock-hardened ships. The higher material cost is not caused by the actual material content, but is because a portion of the foundation is bought already fabricated as a unit along with the gas turbine itself. This unit or bedplate contains a shock mounting system for the prime mover;

SUPERSTRUCTURE
GROUP 1B
MATERIALS COST

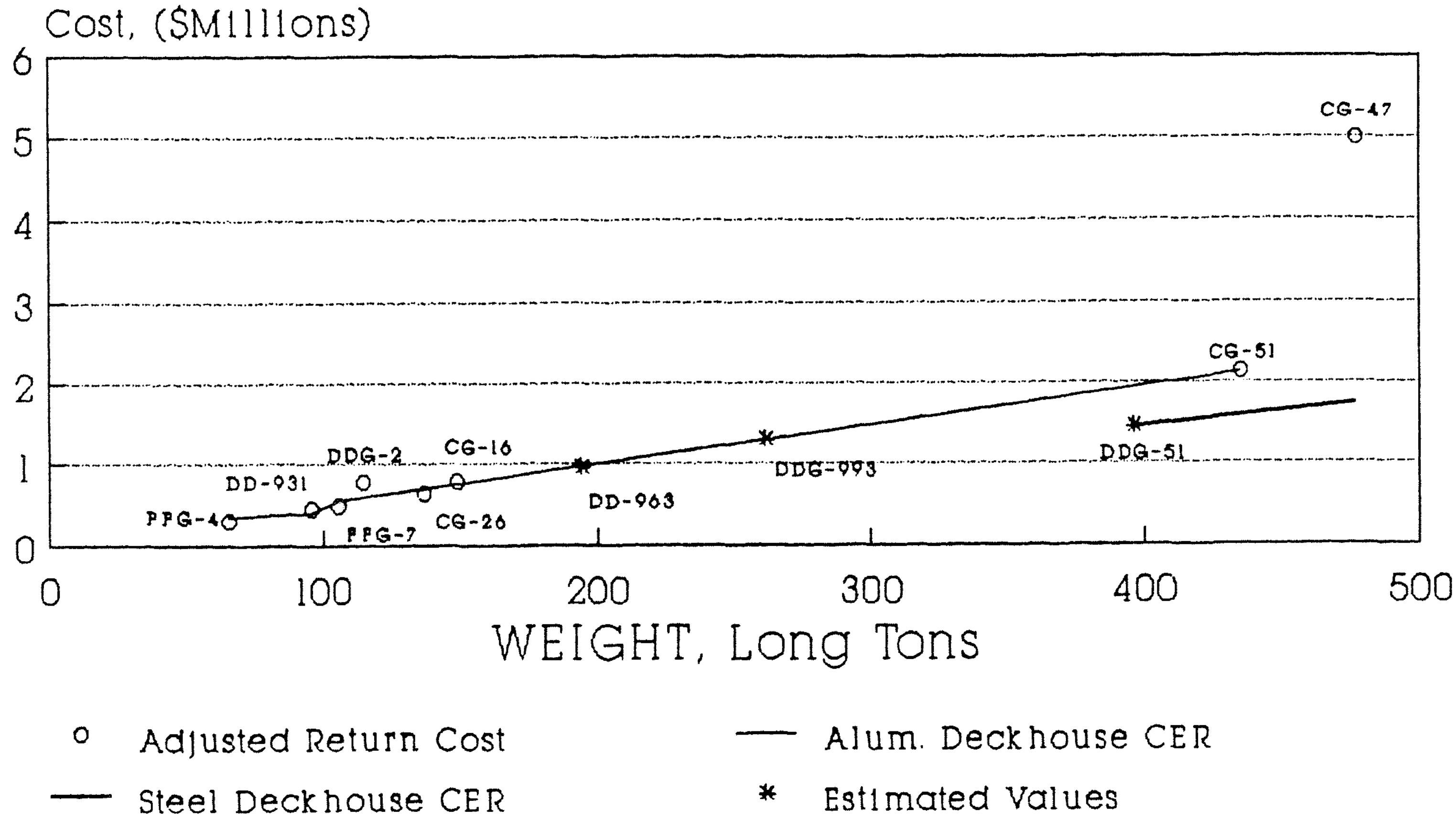
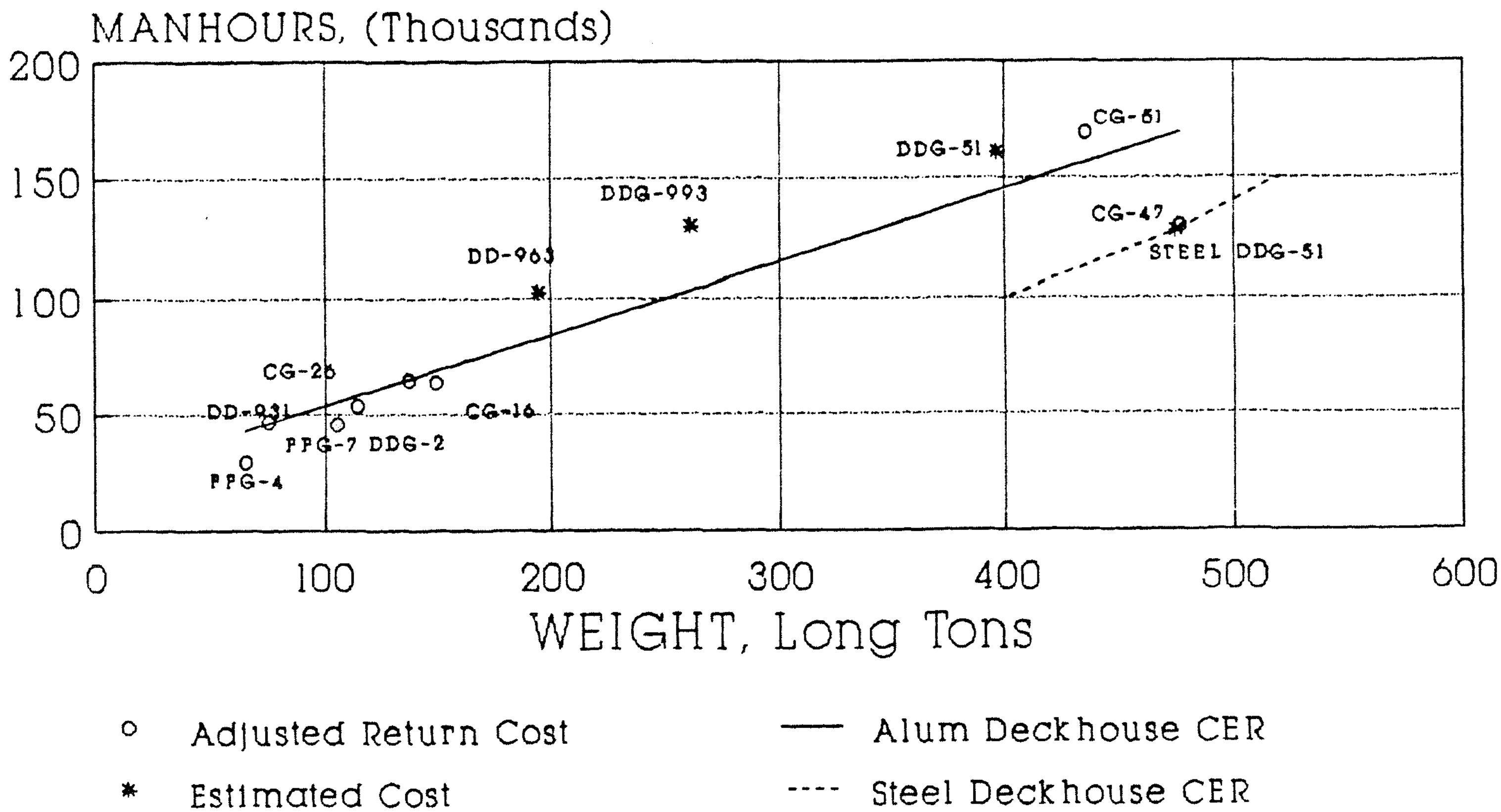


FIGURE 3-9

SUPERSTRUCTURE
GROUP 1B
LABOR



Steel Algorithm based on equivalent all steel deckhouse for DDG-51

FIGURE 3-10

thus, some of the increased shock requirements are reflected in the materials costs.

CER:	\$ = 2,553 WT - 80,000
Variable:	Group 1C Weight
Application:	Gas Turbine Plant
Adjusted r^2:	.9869, 4 points

CER:	\$ = 1,336 WT + 15,000
Variable:	Group 1C Weight
Application:	Steam Plant
Adjusted r^2:	.49, 5 points

LABOR FACTOR: The man-hours for Group 1C are also a function of the plant and foundation type. The gas turbine foundation algorithm has a shallower slope than the steam plant algorithm because the simpler configuration of the gas turbine plant provides for fewer foundations, and the gas turbine foundation is often bought, not fabricated by the shipyard. It should be noted that the gas turbine ships which may be equivalent in size to the steam ships will have a much greater total weight of foundations, a function of shock requirements.

CER:	MH = 982 WT - 66,400
Variable:	Group 1C Weight
Application:	Steam Plant
Adjusted r^2:	.917, 5 points

OR

CER:	$MH = 1.6 (WT)^{2.115}$
Variable:	Group 1C Weight
Application:	Steam Plant
Adjusted r^2:	.917, 5 points

CER:	MH = 458 WT - 22,000
Variable:	Group 1C Weight
Application:	Gas Turbine Plant
Adjusted r^2:	.8049, 5 points

OR

CER:	$MH = 77 (WT)^{1.275}$
Variable:	Group 1C Weight
Application:	Gas Turbine Plant
Adjusted r^2:	.929, 5 points

See Figures 3-11 and 3-12 for graphs of data points.

Group 1D - Structural Attachments

This group includes structural castings, forgings, doors, hatches, sonar dome, masts and towers.

MATERIAL FACTOR: The individual plots for these groups are misleading in that the CG-16, CG-26 have low material factors and high labor factors because many of the structural attachments were constructed by the yard instead of buying the item, which was the usual practice. These ships previously represented the high end of the band, but were not included in the current algorithm, because new data is available. The DDG-51 was also eliminated because it reflects an estimate that may be optimistically low. The projected algorithm of cost versus weight should yield acceptable costs for the larger destroyer with all types of structural attachments.

CER:	$ = 12,351 WT - 54,600
Variable:	Group 1D Weight
Application:	Structural Attachments
Adjusted r^2:	.9245, 7 points

OR

CER:	$\$ = 14,500 (WT)^{0.962}$
Variable:	Group 1D Weight
Application:	Structural Attachments
Adjusted r^2:	.957, 7 points

FOUNDATIONS
GROUP 1C
MATERIALS COST

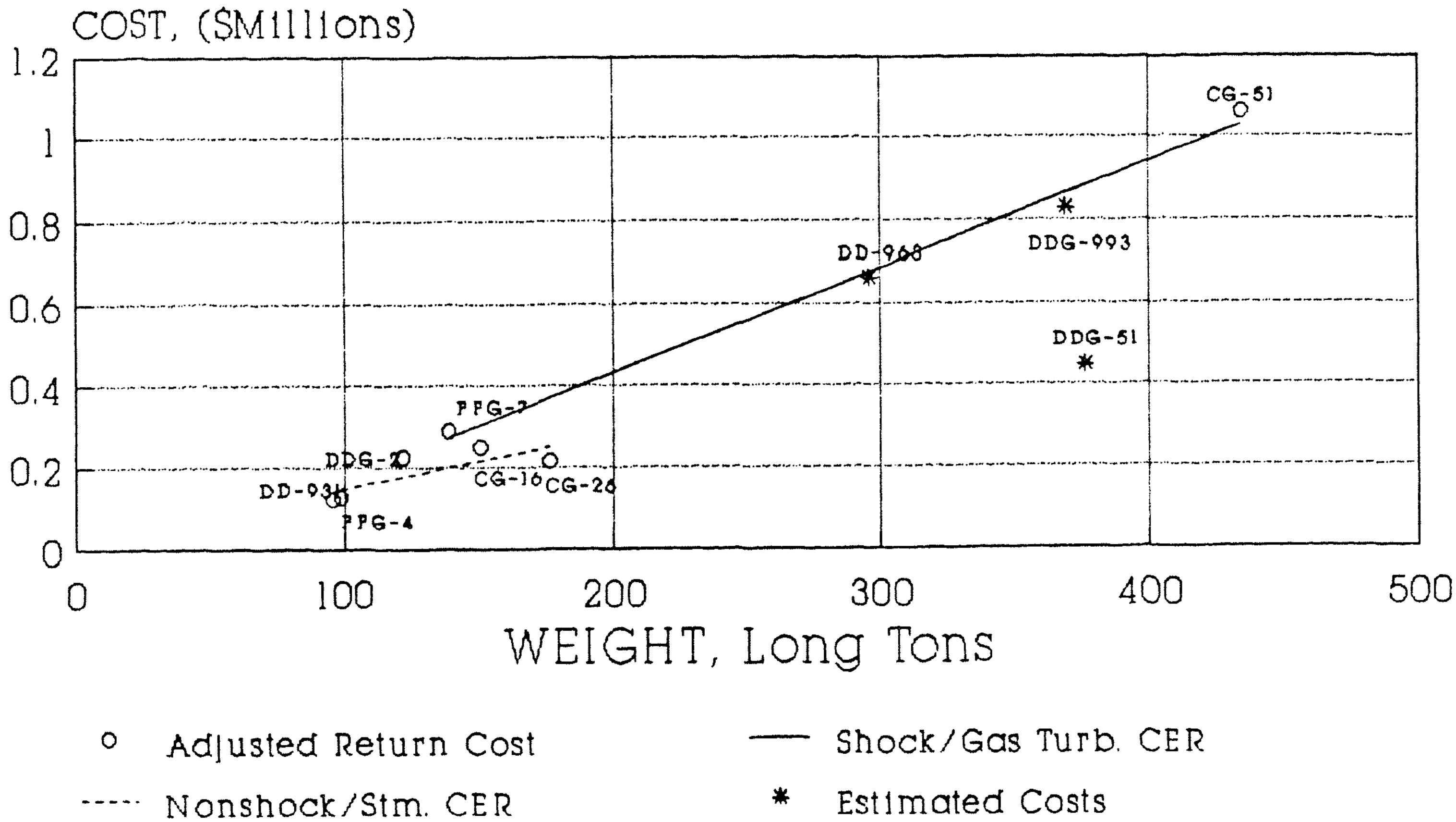


FIGURE 3-11

FOUNDATIONS
GROUP 1C
LABOR

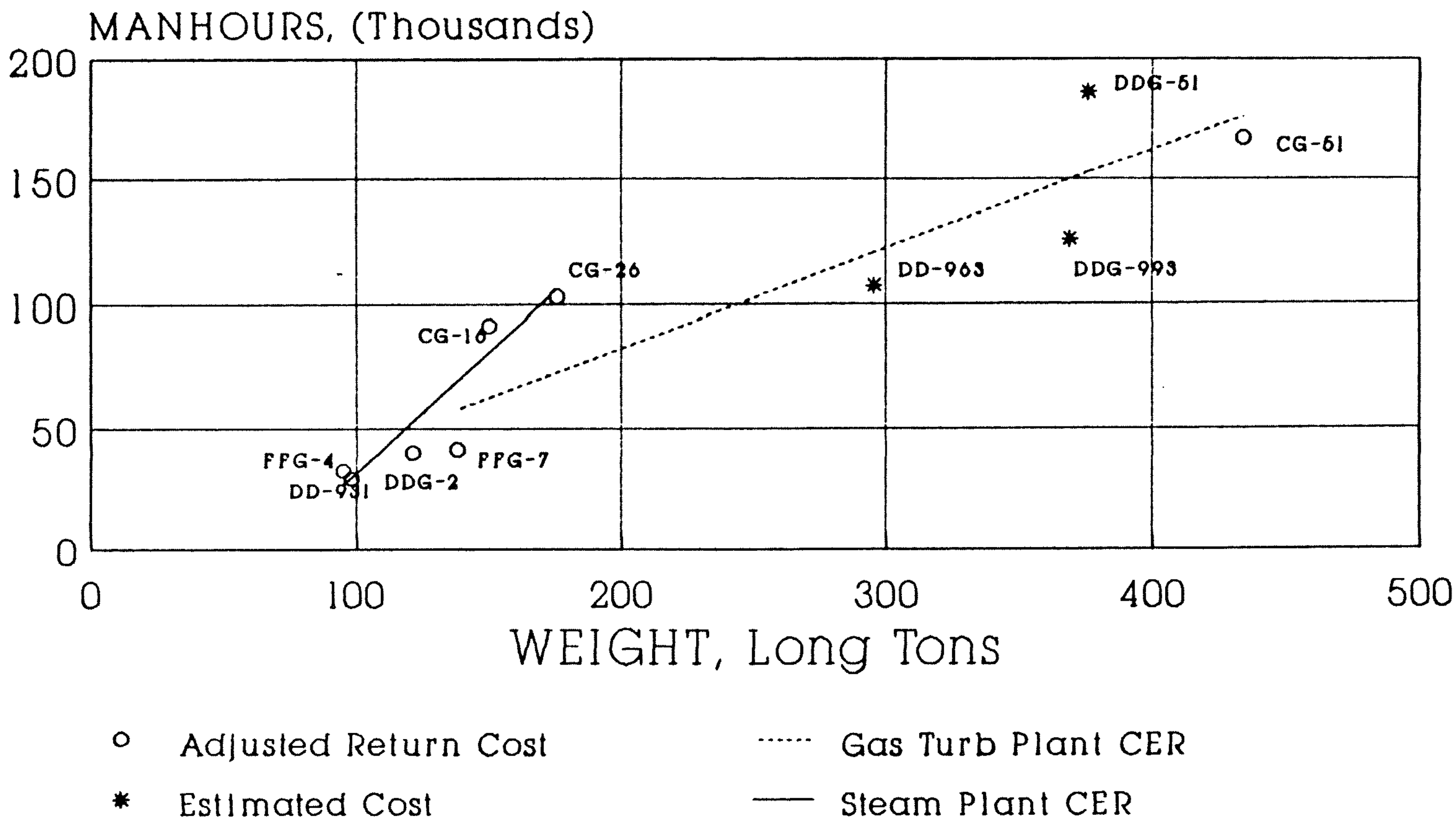


FIGURE 3-12

LABOR FACTOR: As with the material algorithm, the labor algorithm did not include data for the early vessels, CG-16 and CG-26, or for the DDG 51 for the reasons noted above.

CER: MH = 249 WT + 3,700
Variable: Group 1D Weight
Application: Structural Attachments
Adjusted r2: .8445, 8 points

OR

CER: MH = 226 (WT) 1.04
Variable: Group 1D Weight
Application: Structural Attachments
Adjusted r2: .922, 8 points

See Figures 3-13 and 14 for graphs of data points.

STRUCTURAL ATTACHMENTS
GROUP 1D
MATERIALS COST

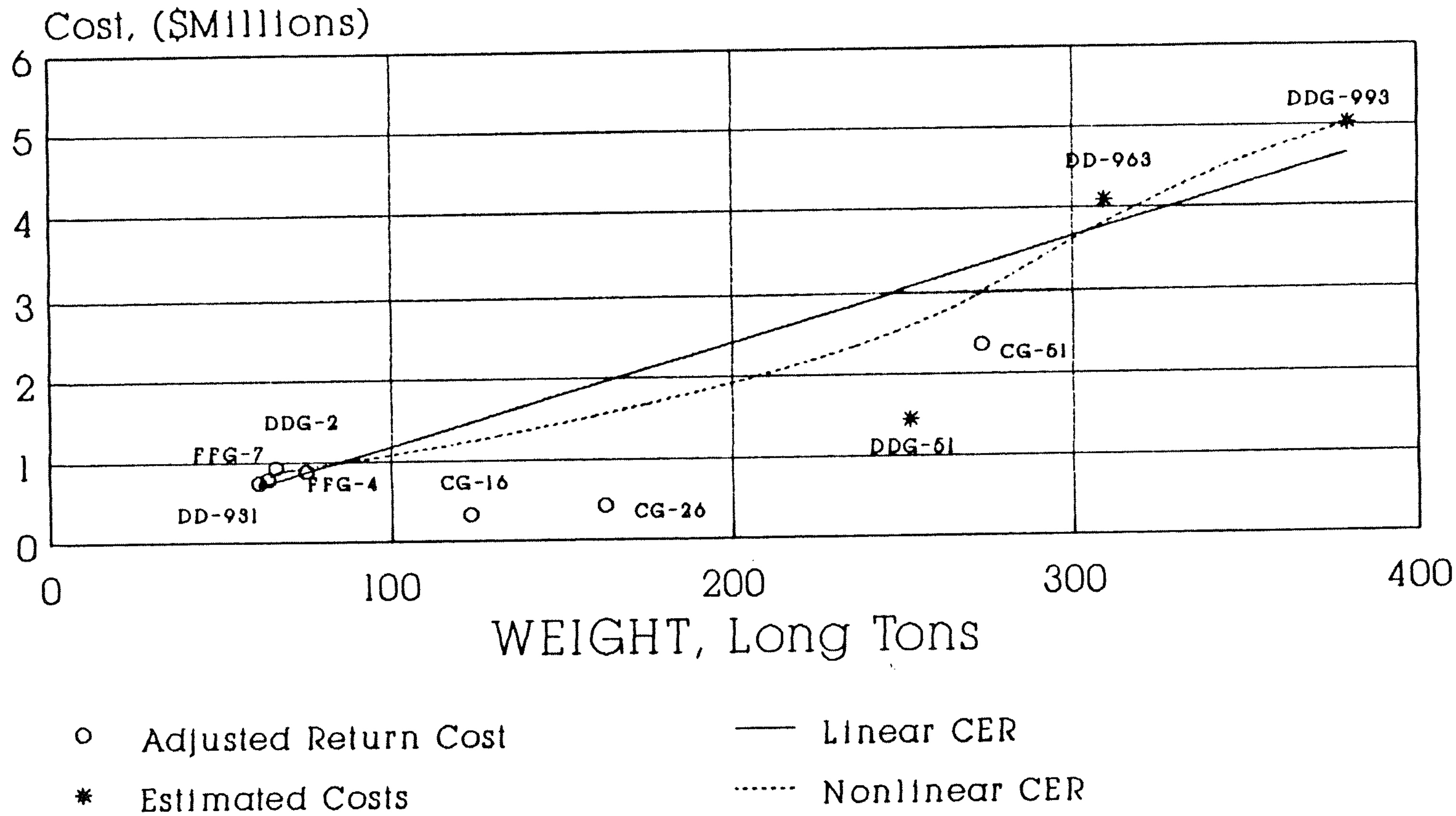
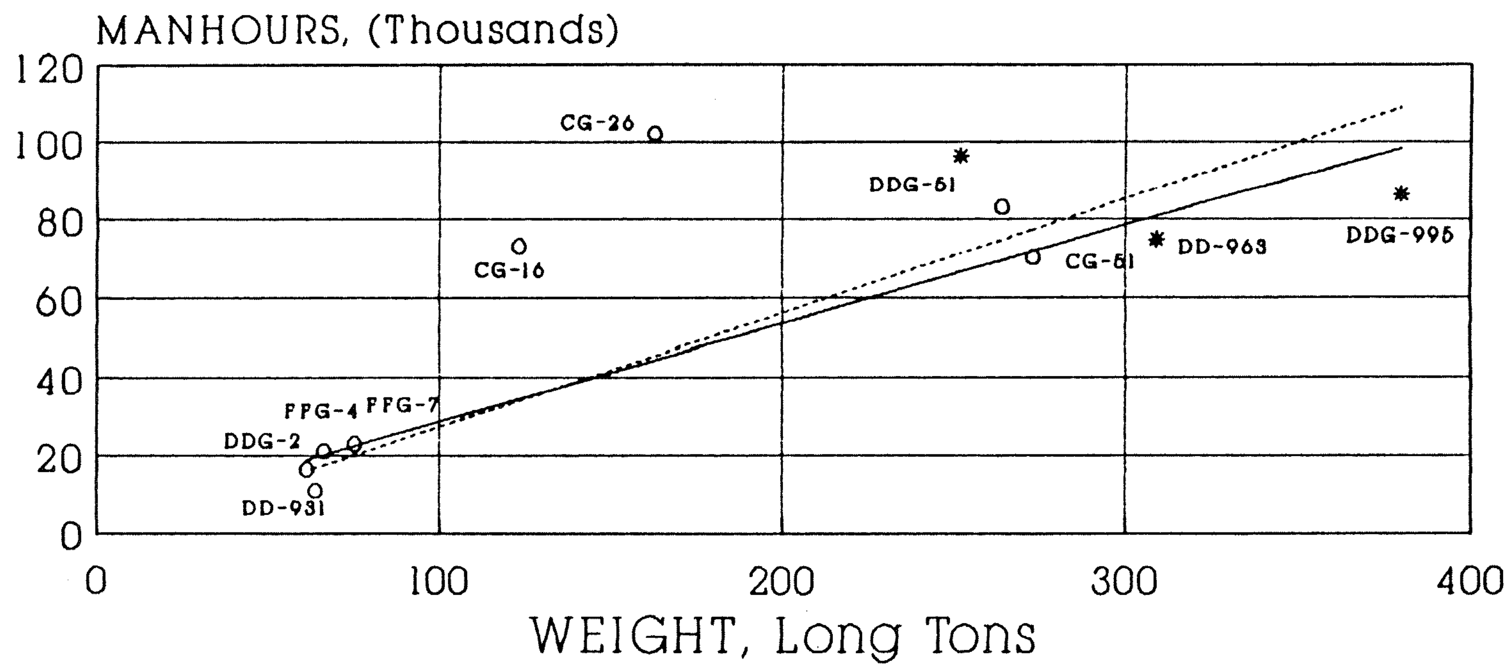


FIGURE 3-13

STRUCTURAL ATTACHMENTS
GROUP 1D
LABOR



o Adjusted Return Cost —— Linear CER

* Estimated Costs .... Nonlinear CER

CG-16 and CG-26 reflect different
procurement policy

FIGURE 3-14

3.4.2 Group 2 - Propulsion Plant

Group 2 is comprised of the following two-digit cost groups:

2A - Propulsion Energy Systems
2B - Propulsion Train Systems
2C - Propulsion Gases Systems
2D - Propulsion Service Systems

The algorithms for the one-digit Group 2 cost group are discussed as follows:

MATERIAL COSTS: The bulk of costs of a propulsion plant can be related to the choice of propulsion plant type and the number of shafts. These costs are influenced by the endurance, cruising speed, maximum sustained speed desired, length of shafting and propulsor type (fixed pitch versus controllable pitch). The cost differences between propulsion plant types are shown in the graph of shaft horsepower (SHP) versus cost. The differences in numbers of shafts have been normalized by the data in this version of the model. Factors that tend to drive the cost of the gas turbines above that of steam plants include auxiliary propulsion systems, controllable pitch propellers, and automated controls. The electric propulsion curve has an even higher cost associated with the motors and power conversion equipment as compared to the relatively low cost associated with geared plants. The CG-26 was dropped out of the data because it was a modification of the CG-16 so it is not truly a "lead" ship as the others are. The DD-963 and DDG-993 were also not included in the algorithm as they represent very rough estimates. The CG-51 was included but does not represent total Group 2 costs because of difficulty in obtaining costs of certain class common items.

CER: $ = 275 SHP - 1,744,350
Variable: Shaft Horsepower
Application: Steam, 1 or 2 shafts
Adjusted r^2: .8805, 4 points

CER: $ = 240.7 SHP + 10,803,000
Variable: Shaft Horsepower
Application: Geared Gas Turbine, 1 or 2 shafts
Adjusted r^2: .5719, 4 points

CER: $ = 441.7 SHP + 19,823,000
Variable: Shaft Horsepower
Application: Electric Drive, CODAG
Adjusted r^2: NA, 1 point

LABOR COSTS: Man-hours versus shaft horsepower (SHP) correlates very well for the steam propulsion ships. The gas turbine propulsion system also correlated fairly well; however, a slightly higher correlation coefficient was obtained when labor was plotted against Group 2 weight. That correlation was not selected because no relationship was available for electric plants.

CER: MH = 3.05 SHP - 2,600
Variable: Shaft Horsepower
Application: Steam
Adjusted r^2: .9597, 4 points

CER: MH = 1.60 SHP + 24,000
Variable: Shaft Horsepower
Application: Geared Gas Turbine
Adjusted r^2: .6087, 4 points

CER: MH = 2.13 SHP + 32,250
Variable: Shaft Horsepower
Application: Electric CODAG
Adjusted r^2: NA, 1 point

See Figures 3-15 through 3-17 for graphs of data points.

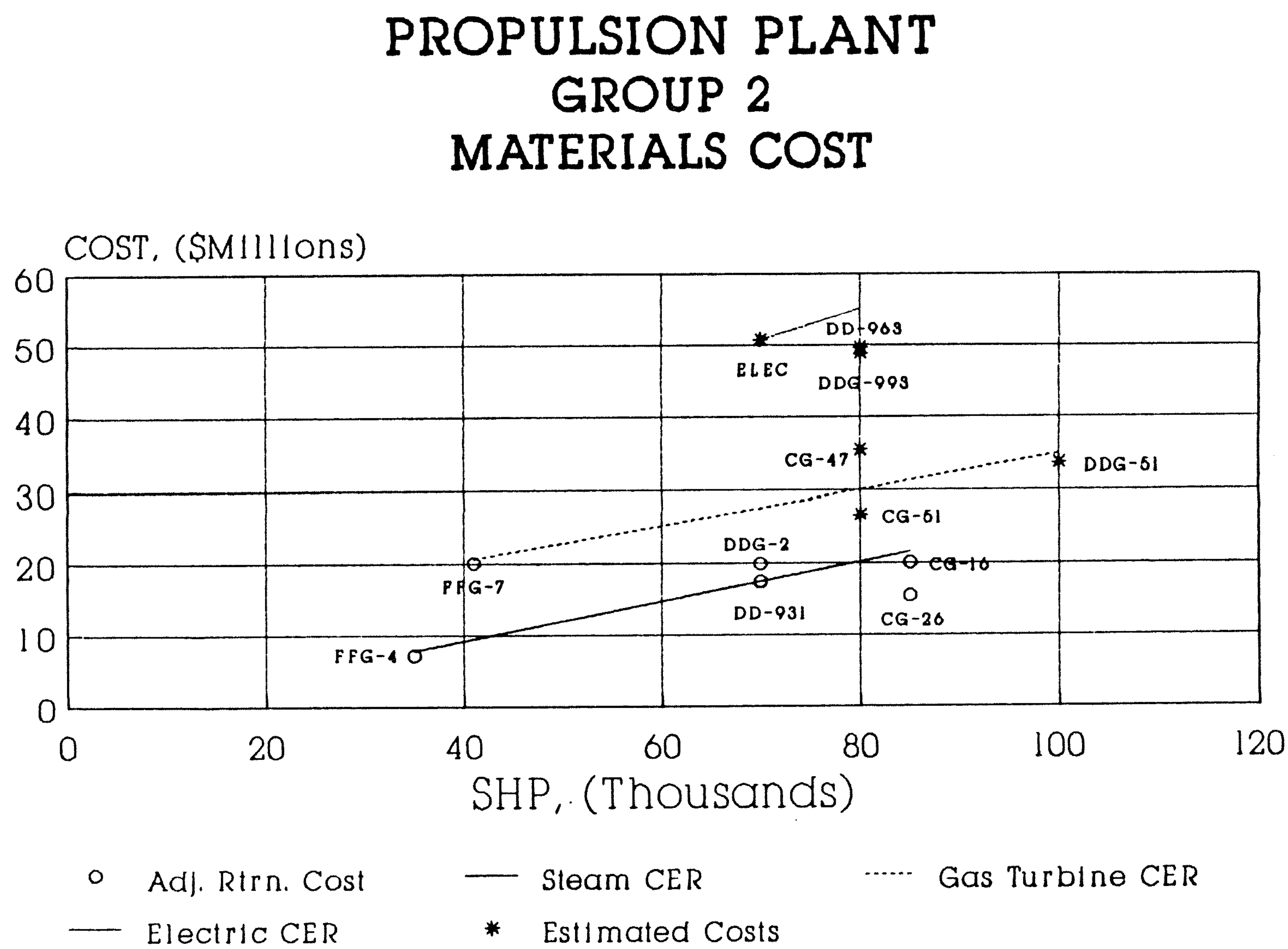

PROPULSION PLANT
GROUP 2
MATERIALS COST
COST, ($Millions)
60
50
40
30
20
10
0
0
20
40
60
80
100
120
SHP, (Thousands)
DD-963
ELEC
DDG-993
CG-47
DDG-51
CG-61
DDG-2
CG-16
FFG-7
DD-931
CG-26
FFG-4
Adj. Rtrn. Cost
Steam CER
Gas Turbine CER
Electric CER
Estimated Costs

FIGURE 3-15

PROPULSION PLANT
GROUP 2
LABOR

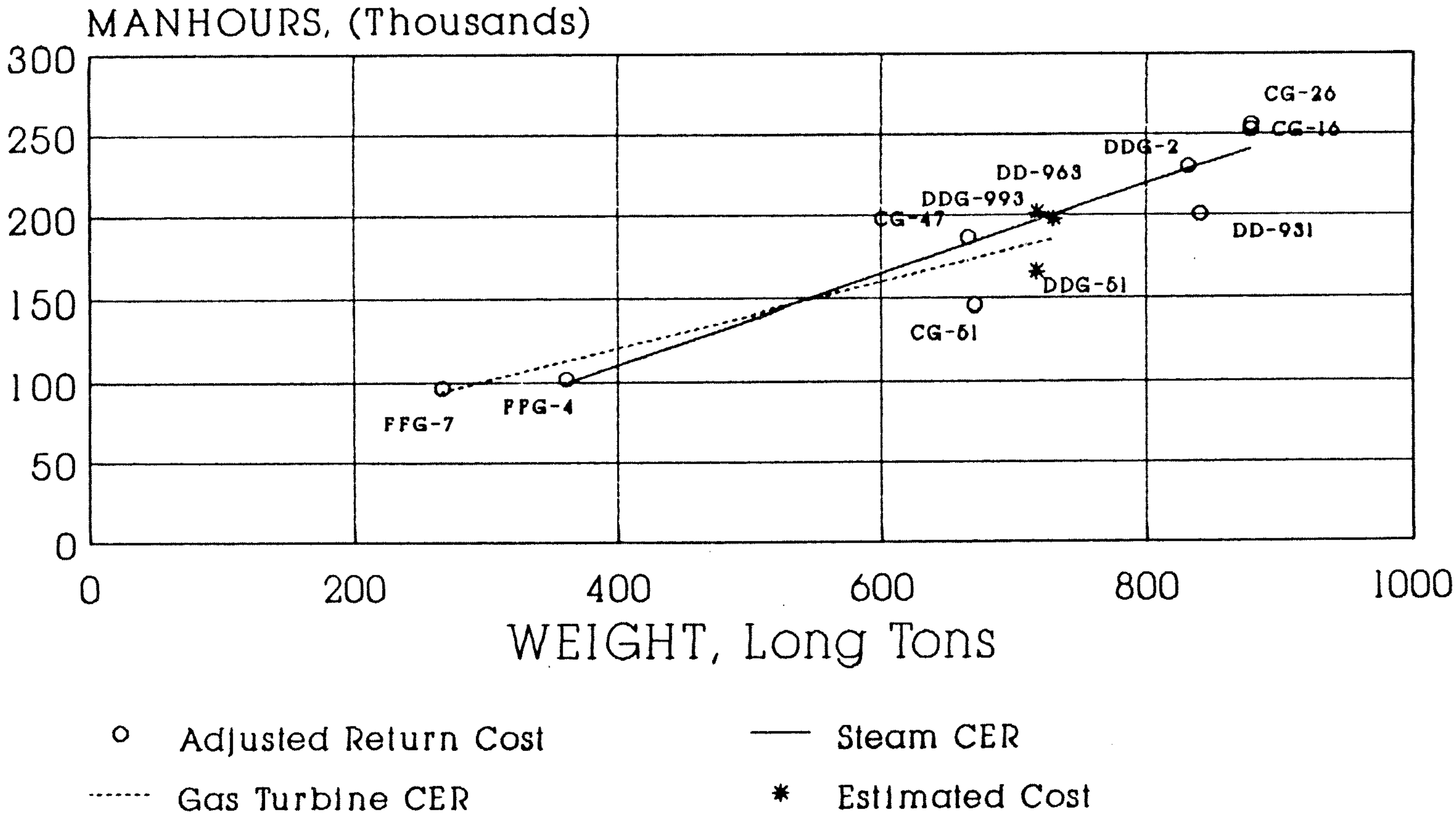


FIGURE 3-16

PROPULSION PLANT
GROUP 2
LABOR

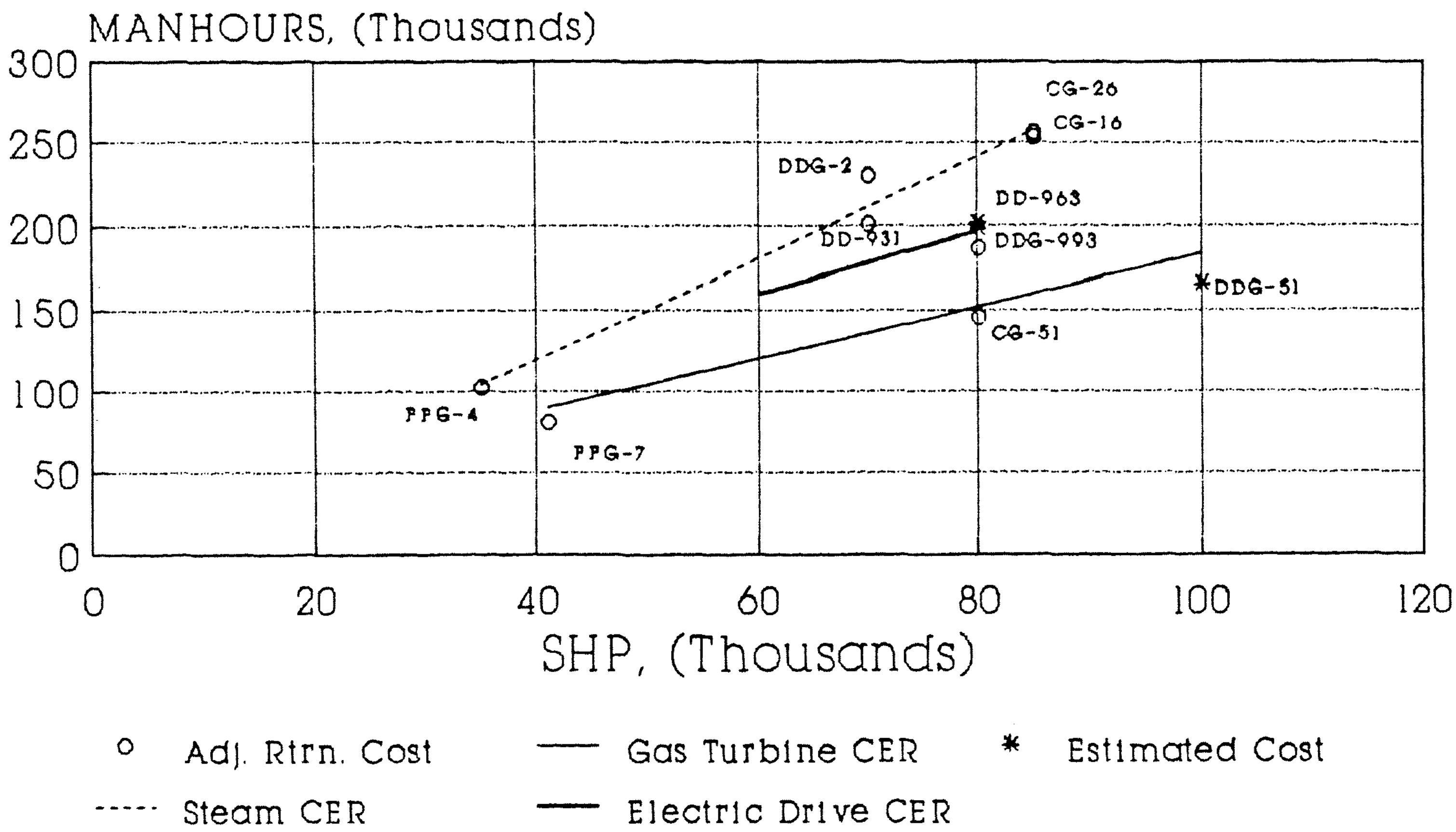


FIGURE 3-17

Group 2A - Propulsion Energy Systems

This group includes propulsion boilers, turbines, reduction gears feed and condensate system, auxiliary propulsion devices, electric drive components, etc.

MATERIAL COSTS: The propulsion energy system costs depend upon the type, size and number of propulsion systems. Differences between plants are shown in the graph. For this group weight provided better correlation than SHP. The DD-963, DDG-993 data points appear to be outliers since they should correlate with the CG-51, DDG-51 points, being essentially the same system. The feasibility level estimate for the DD-963 and DDG-993 could reflect inaccuracies resulting in this anomaly since the estimates were based on an FFG-7 algorithm and did not take into account economics that could be realized by designing the system for the larger number of prime movers. Again, the CG-26 was dropped out of the steam algorithms because it was not a lead ship design.

The electric propulsion plant as estimated for a CODAG version of DDGX is included as a point of reference for new technologies.

CER:	$ = 64,000 WT + 4,602,000
Variable:	Group 2A Weight
Application:	Geared Gas Turbine
Adjusted r^2:	.9735, 3 points

CER:	$ = 25,200 WT + 565,000
Variable:	Group 2A Weight
Application:	Steam
Adjusted r^2:	.8857, 4 points

CER:	$ = 70,000 WT + 4,981,222
Variable:	Group 2A Weight
Application:	Electric CODAG
Adjusted r^2:	NA, 1 point

LABOR FACTOR: Weight was also selected for labor as a means of correlating man-hours to ship characteristics. SHP can also be used but it does not provide as good a relationship for gas turbines. For an electric plant, which is different from that used in 2A material costs, an algorithm is provided to predict labor costs as a function of SHP. No graph is provided.

CER:	MH = 154 WT - 2650
Variable:	Group 2A Weight
Application:	Geared Gas Turbine
Adjusted r^2:	.7567, 5 points

CER:	MH = 191 WT + 9,660
Variable:	Group 2A Weight
Application:	Steam
Adjusted r^2:	.686,4 points

CER:	MH = 0.54 SHP + 9,177
Variable:	Shaft Horsepower
Application:	Electric Gas Turbine

See Figures 3-18 through 3-21 for graphs of data points.

Group 2B - Propulsion Train Systems

This group includes shafting, shaft bearings, propulsors, etc. For electric drive use the fixed propeller algorithms.

MATERIAL COSTS: In the original version of the model SHP was selected as the independent variable because of concern over configuration differences between single and twin shaft drive trains that would influence costs and not show up in relationships with weight. Revised data indicate that when the data is categorized by either controllable pitch propellers or fixed pitch propellers, the impact of shaft number is less significant. The data suggests a

PROPULSION ENERGY SYSTEMS
GROUP 2A
MATERIALS COST

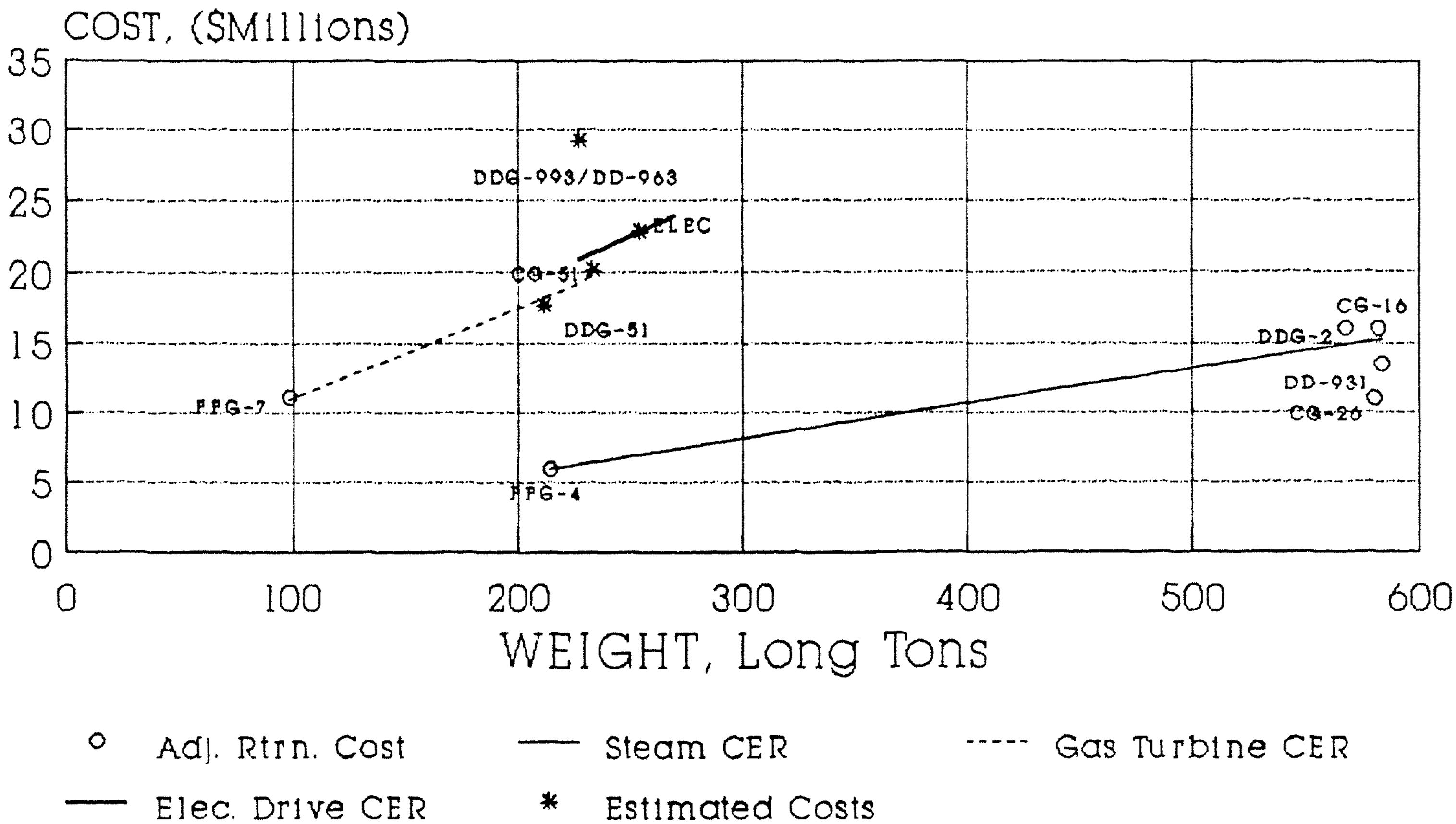


FIGURE 3-18

PROPULSION ENERGY SYSTEMS
GROUP 2A
MATERIALS COST

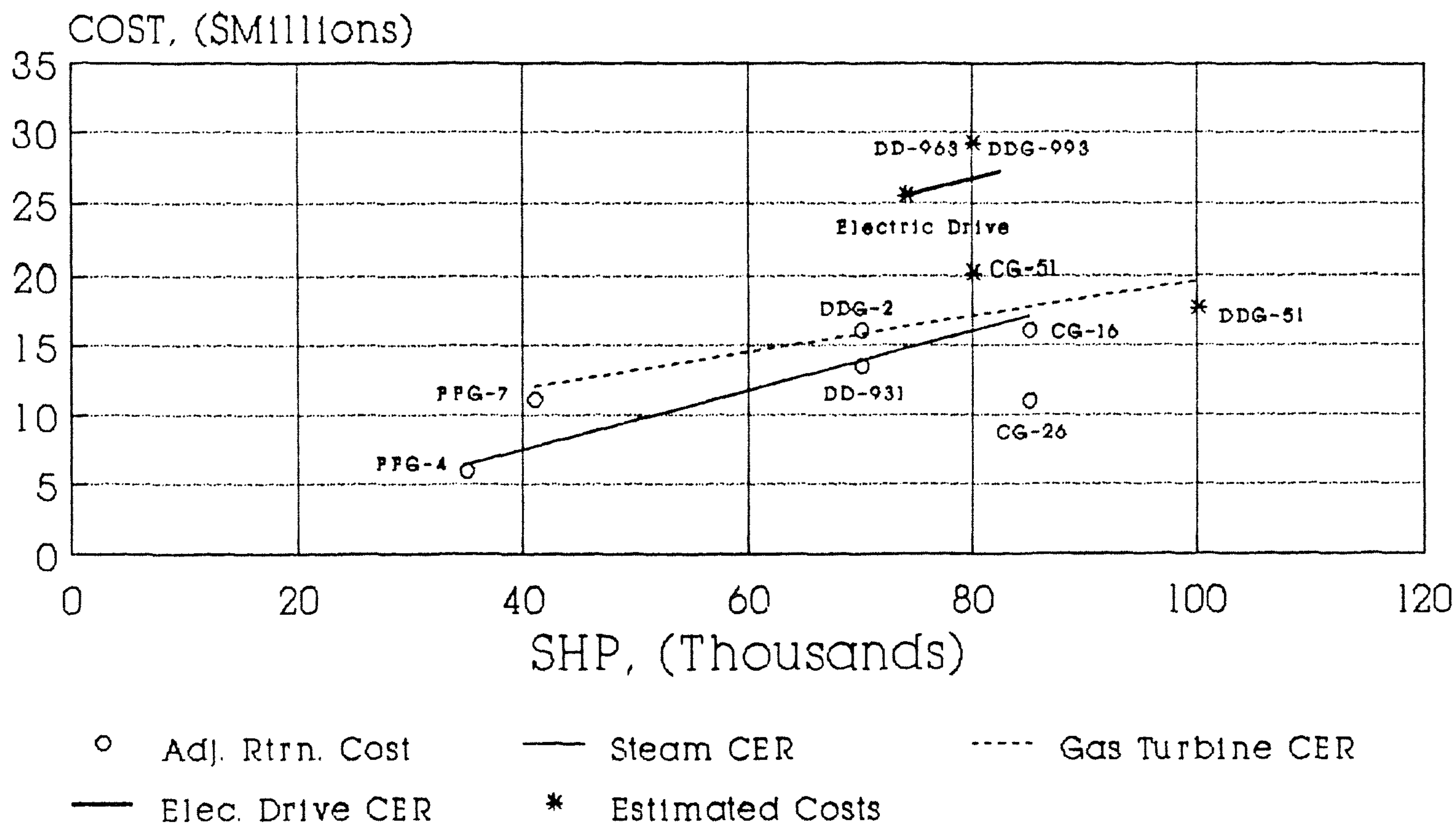


FIGURE 3-19

PROPULSION ENERGY SYSTEMS
GROUP 2A
LABOR

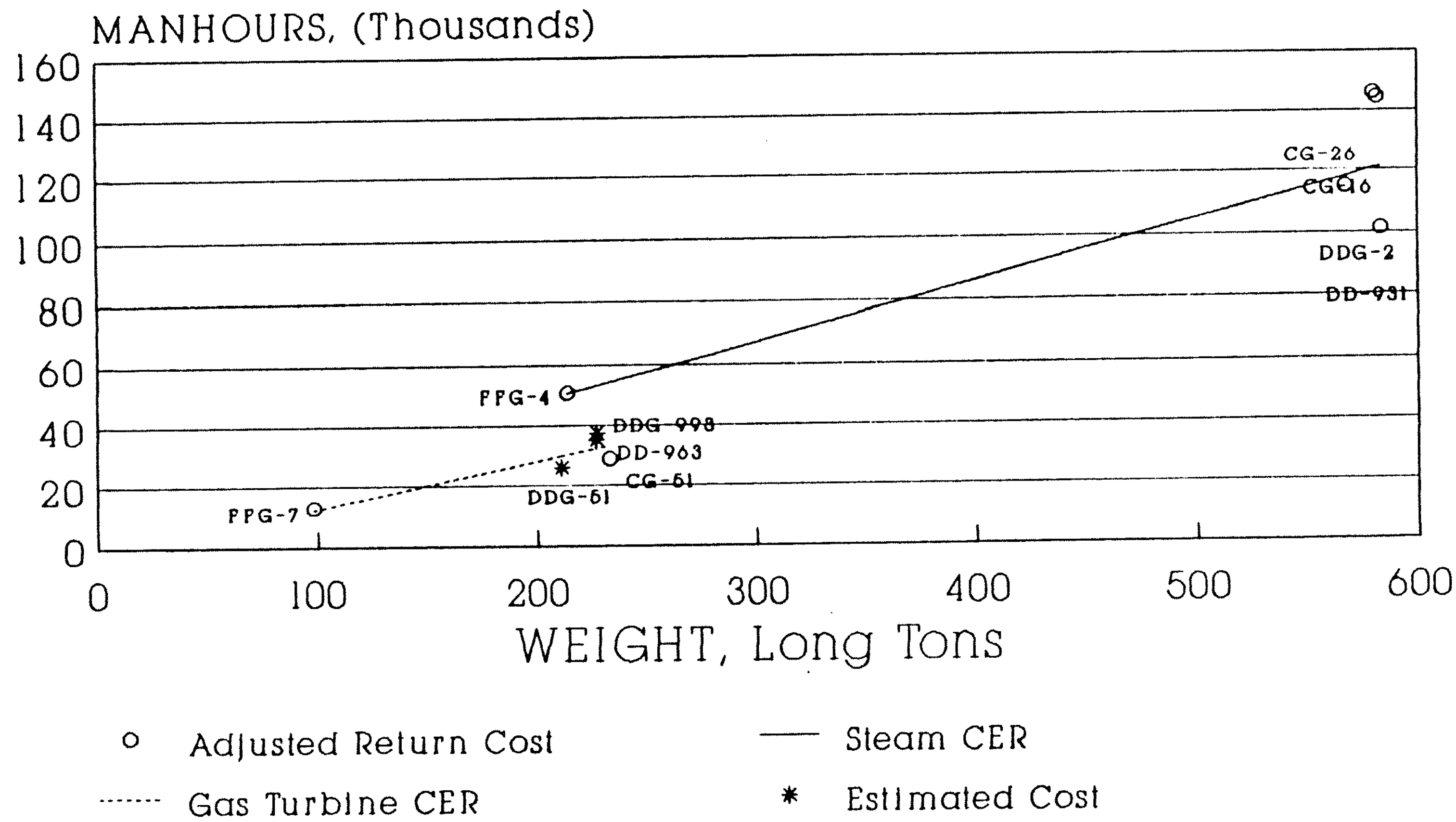


FIGURE 3-20

PROPULSION ENERGY SYSTEMS
GROUP 2A
LABOR

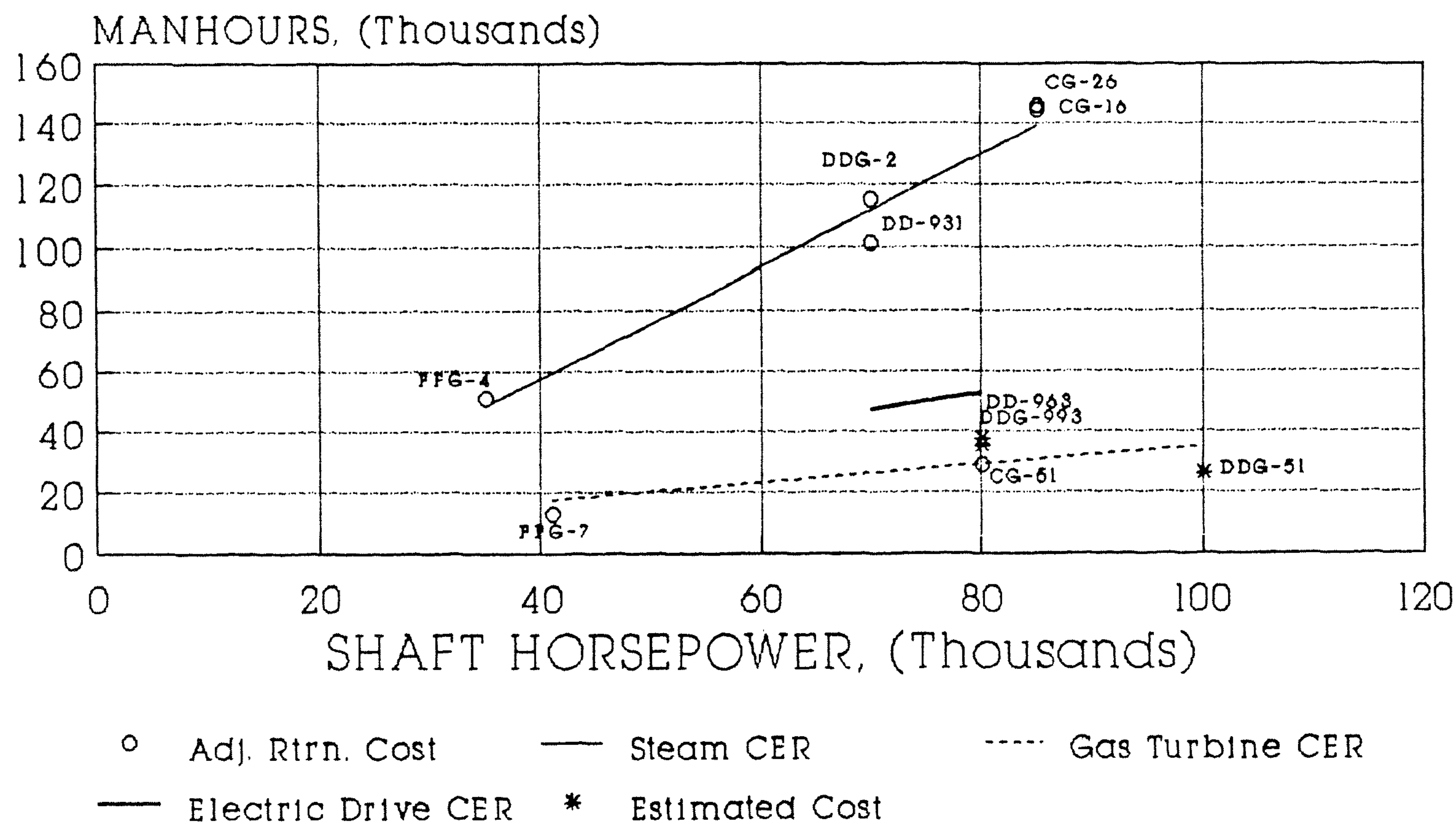


FIGURE 3-21

reasonable correlation with both SHP and group 2B weight as the algorithms below show. Algorithms and graphs for Group 2B costs as functions of both SHP and Group 2B weight are provided because one variable (SHP) provides a better correlation for fixed pitch propellers and the other variable (Group 2B weight) provides better correlation for controllable pitch propellers.

CER:	\$= 15.6 SHP + 138,000
Variable:	Shaft Horsepower
Application:	Fixed Pitch
Adjusted r^2:	.8439, 5 points

OR

CER:	\$= 6905 WT + 327,000
Variable:	Group 2B Weight
Application:	Fixed Pitch
Adjusted r^2:	.5774, 5 points

AND

CER:	\$= 109.6 SHP - 201,000
Variable:	Shaft Horsepower
Application:	Controllable Pitch
Adjusted r^2:	.3988, 4 points

OR

CER:	\$= 31,230 WT + 1,698,000
Variable:	Group 2B Weight
Application:	Controllable Pitch
Adjusted r^2:	.4661, 4 points

LABOR FACTOR: Man-hours versus shaft horsepower (SHP) provides a good correlation for both fixed pitch and controllable pitch propellers. The DD-963 and DDG-993 were not included in the controllable pitch propeller algorithm because they are quite high and may reflect inaccuracies because feasibility level estimates were the primary bases for those points. The DD-963/993 propulsion train should be very similar in costs to that of CG and DDG-51 since they are basically the same systems.

CER:	MH = .35 SHP + 6,780
Variable:	Shaft Horsepower
Application:	Fixed Pitch
Adjusted r^2:	.6934, 5 points

CER:	MH = .275 SHP - 1,478
Variable:	Shaft Horsepower
Application:	Controllable Pitch
Adjusted r^2:	.8738, 3 points

See Figures 3-22 through 3-24 for graphs of data points.

Group 2C - <u>Propulsion Gases Systems</u>

This group includes the combustion air system, uptakes, etc. For electric drive use the algorithms for gas turbine prime movers.

MATERIAL FACTOR: The steam vessels are included in one algorithm and the gas turbine vessels in another. A gas turbine engine requires larger ducting for intakes and exhausts. This equates to 60 percent increase in area over that required for a comparable SHP output steam plant; however, there is no requirement for forced draft blowers. The fact that the CG-26 was not a lead ship lowered its costs due to a multiple buy. Therefore, the CG-26 was not included in the steam algorithm.

CER:	\$ = 27.4 SHP - 774,000
Variable:	Shaft Horsepower
Application:	Steam
Adjusted r^2:	.81819, 4 points

CER:	\$ = 44.6 SHP - 1,491,500
Variable:	Shaft Horsepower
Application:	Gas Turbine
Adjusted r^2:	.9928, 4 points

PROPULSION TRAIN SYSTEMS
GROUP 2B
MATERIALS COST

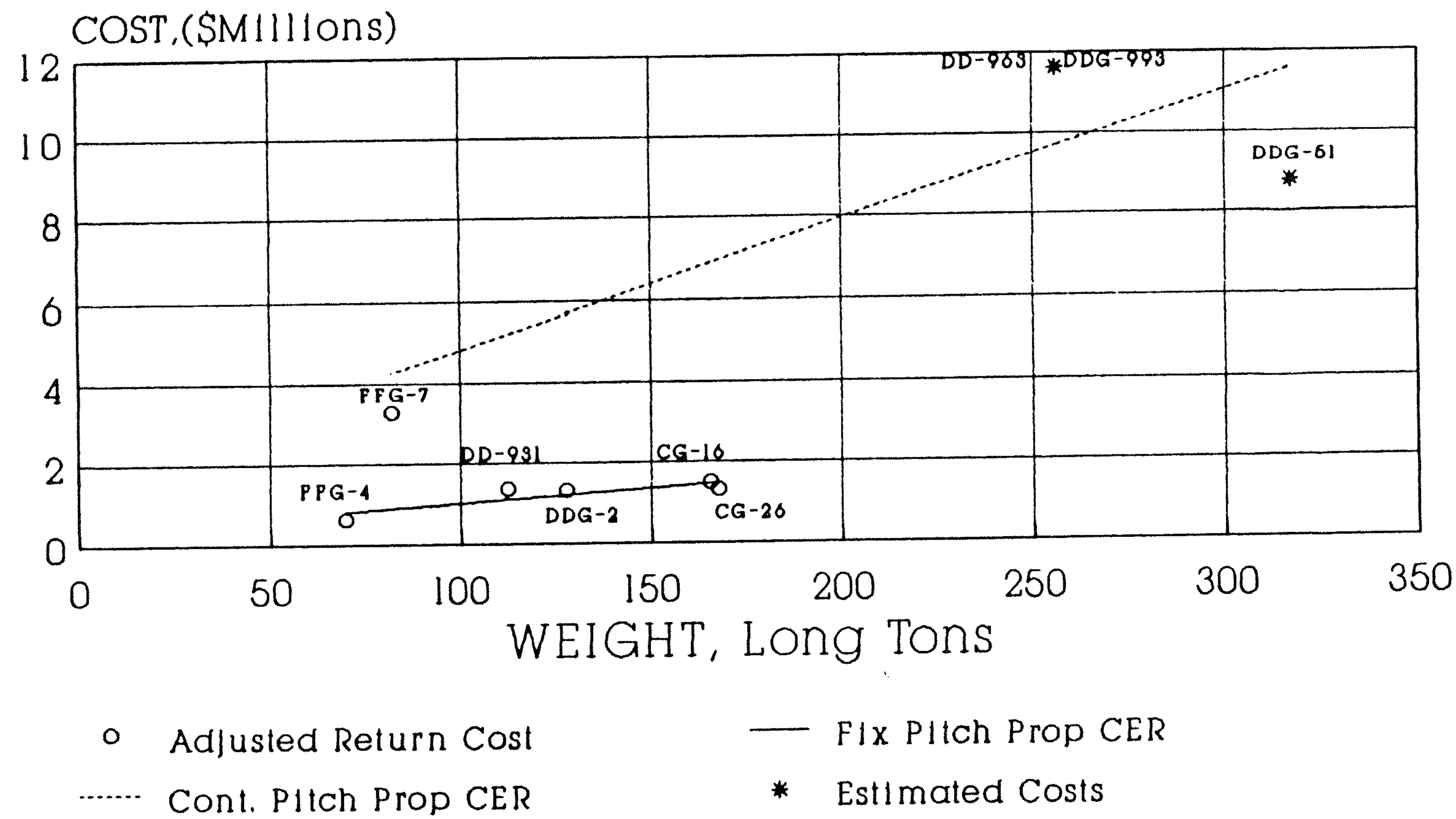


FIGURE 3-22

PROPULSION TRAIN SYSTEMS
GROUP 2B
MATERIALS COST

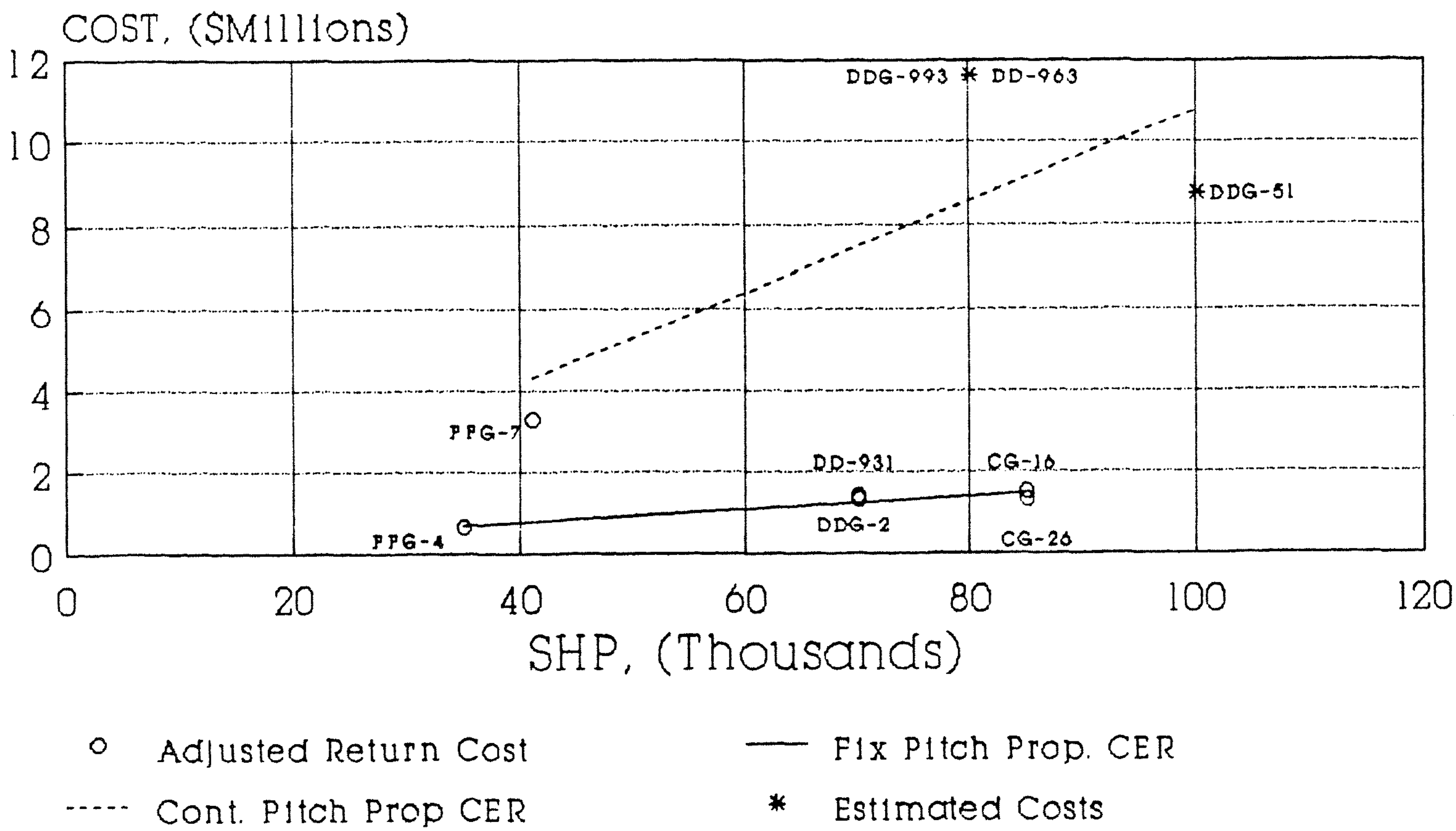


FIGURE 3-23

PROPULSION TRAIN SYSTEMS
GROUP 2B
LABOR

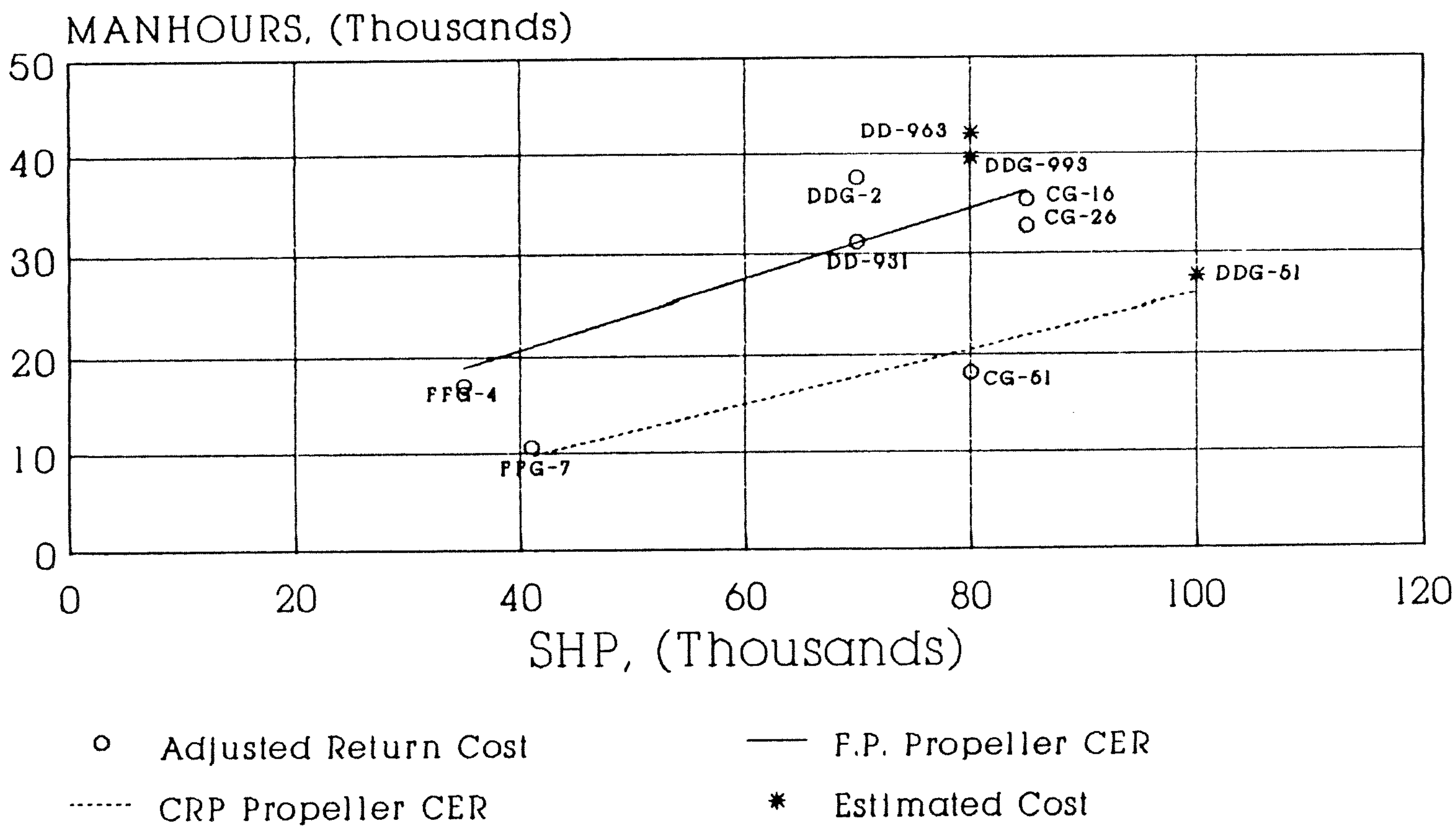


FIGURE 3-24

LABOR FACTOR: Man-hours versus Group 2C weight showed good correlation for both steam and gas turbine plants. The CG-51 is the only hard data point for the upper end of the gas turbine horsepower range and it is higher than the DD-963, DDG-993 and DDG-51 estimates, but was included with these points in the development of the algorithm.

CER:	MH = 857 WT - 9550
Variable:	Group 2C Weight
Application:	Steam
Adjusted r^2:	.8207, 4 points

CER:	MH = 327 WT + 2650
Variable:	Group 2C Weight
Application:	Gas Turbine
Adjusted r^2:	.8978, 4 points

See Figures 3-25 and 3-26 for graphs of data points.

Group 2D - Propulsion Service Systems

This group includes control systems, seawater circulating and cooling system, H.P steam drain system, fuel service, and lube oil systems.

MATERIAL FACTOR: The steam powered ships were addressed as one line and the gas turbines with automated controls should be considered as another algorithm. The cost versus shaft horsepower graphed best for steam; while gas turbine costs did not correlate well with either SHP or Group 2D weight. For gas turbine plants with automatic controls it is recommended a constant cost of $5,000,000 be used. This is also a reasonable value for electric drive.

CER:	$ = 13.6 SHP + 186,000
Variable:	Shaft Horsepower
Application:	Steam
Adjusted r^2:	.7621, 5 points

PROPULSION GASES SYSTEMS
GROUP 2C
MATERIALS COST

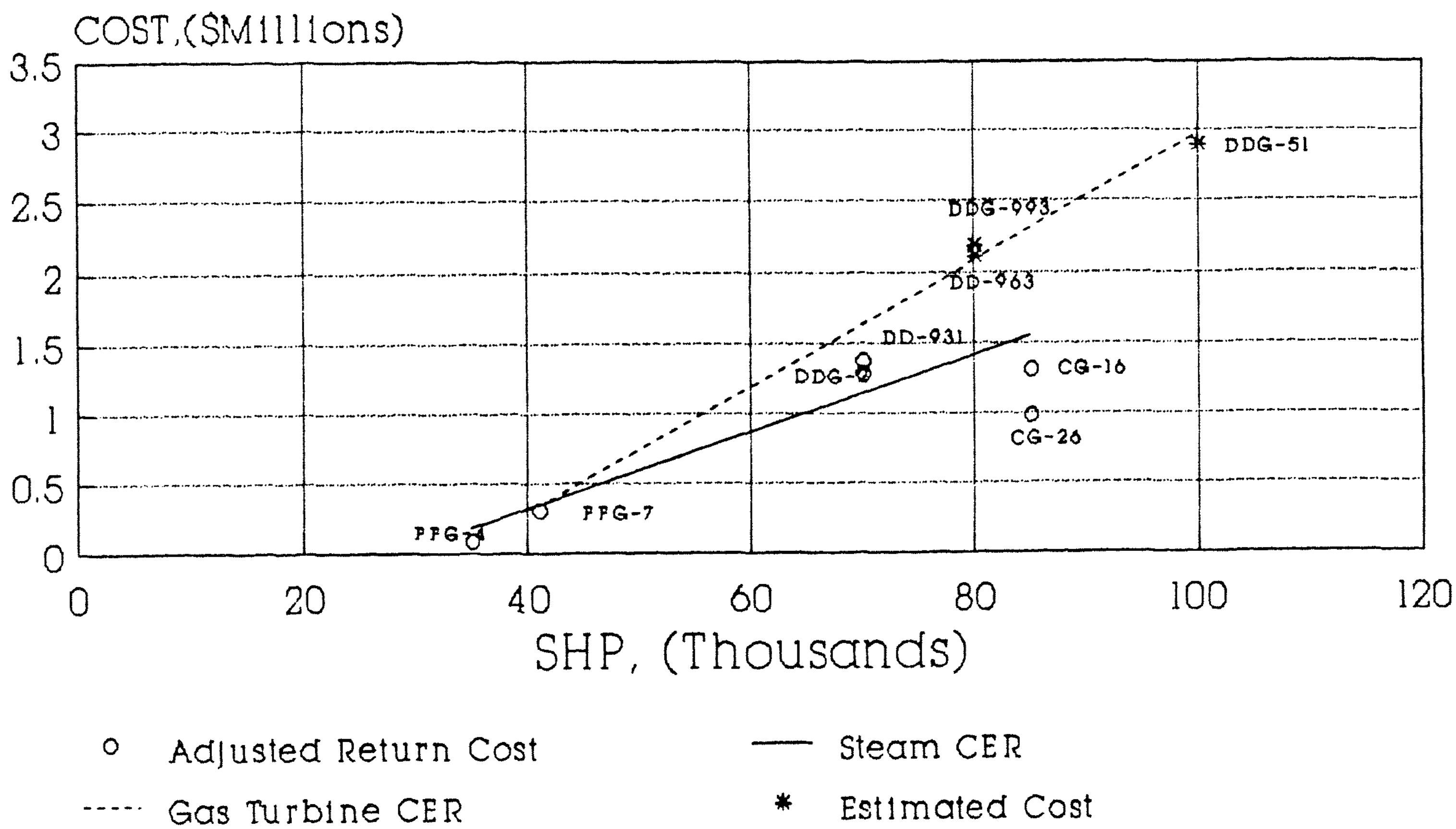


FIGURE 3-25

PROPULSION GASES SYSTEMS
GROUP 2C
LABOR

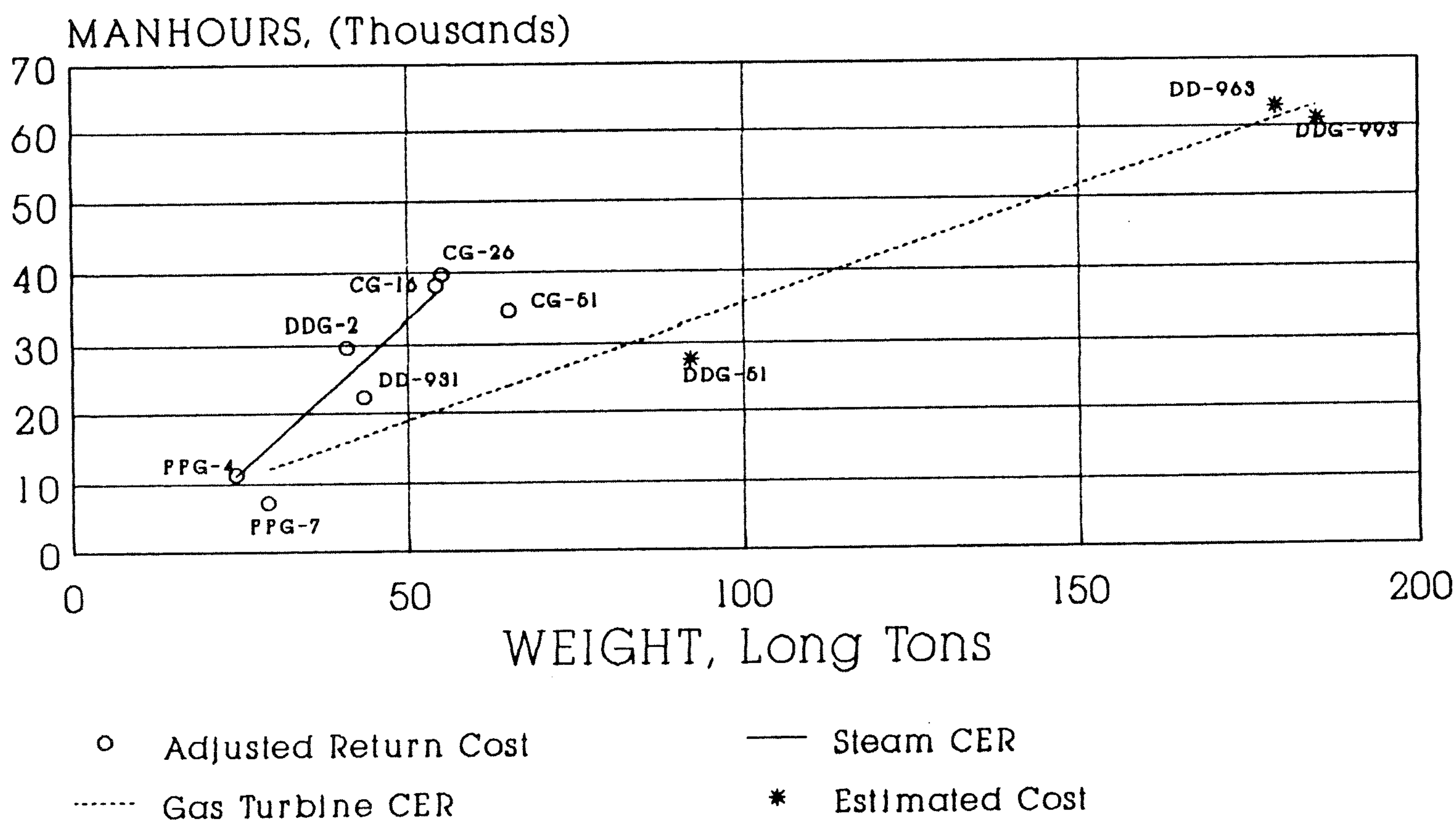


FIGURE 3-26

OR

CER:	$\$ = 46\ (SHP)^{0.906}$
Variable:	Shaft Horsepower
Application:	Steam
Adjusted r^2:	.876, 5 points

AND

CER:	$ = 5,000,000
Variable:	N/A
Application:	Gas Turbine
Adjusted r^2:	N/A

LABOR FACTOR: Labor costs for all ships correlate very well when graphed against weight for both steam and gas turbine plants.

CER:	MH = 510.2 WT - 3,330
Variable:	Group 2D Weight
Application:	Steam
Adjusted r^2:	.9347, 5 points

CER:	MH = 667 WT + 19,630
Variable:	Group 2D Weight
Application:	Gas Turbine
Adjusted r^2:	.7759, 5 points

See Figures 3-27 through 3-29 for graphs of data points.

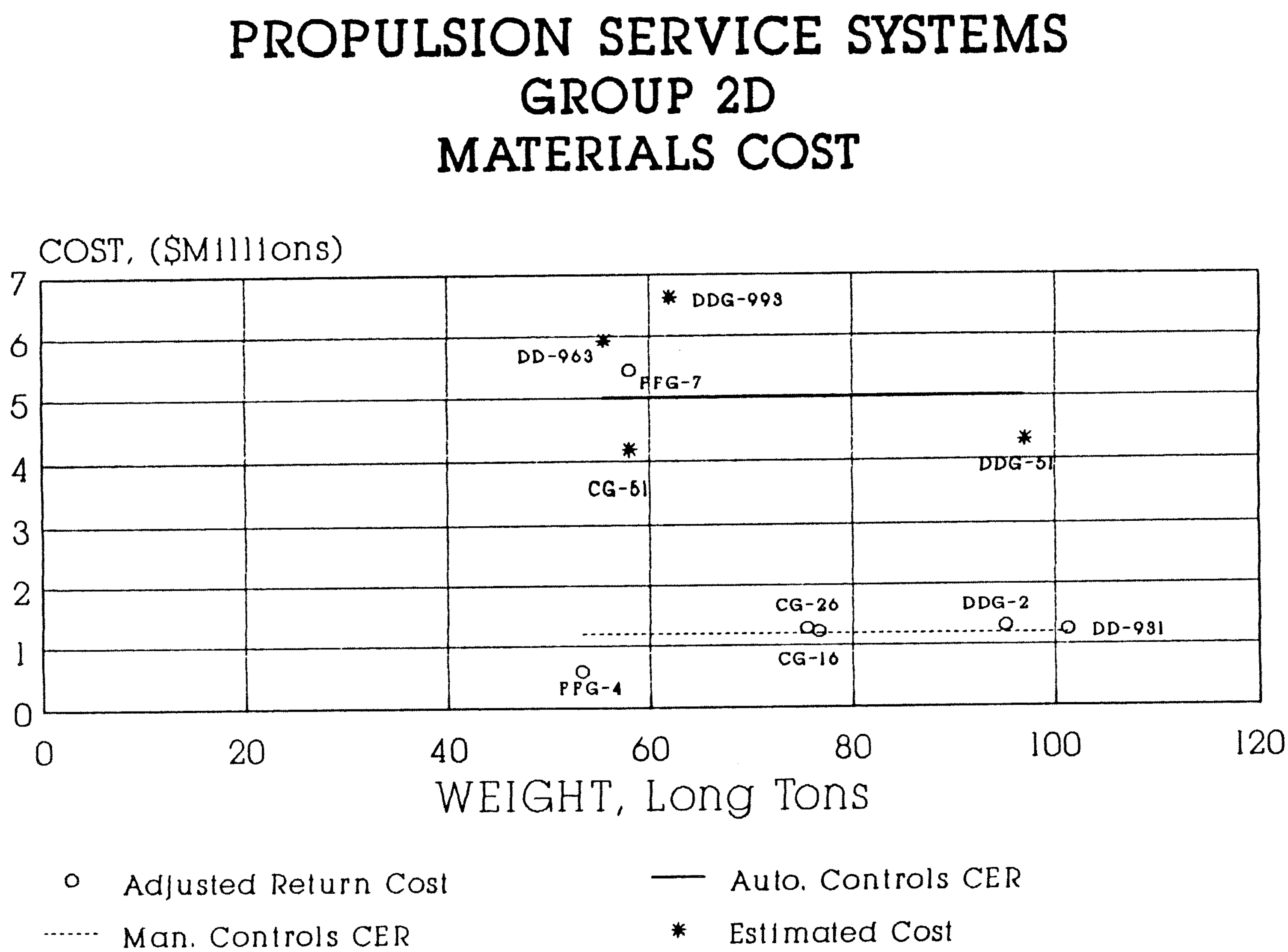

PROPULSION SERVICE SYSTEMS
GROUP 2D
MATERIALS COST
COST, ($Millions)
DDG-993
DD-963
FFG-7
CG-51
DDG-51
CG-26
DDG-2
DD-931
CG-16
FFG-4
WEIGHT, Long Tons
Adjusted Return Cost
Auto. Controls CER
Man. Controls CER
Estimated Cost

FIGURE 3-27

PROPULSION SERVICE SYSTEMS
GROUP 2D
MATERIALS COST

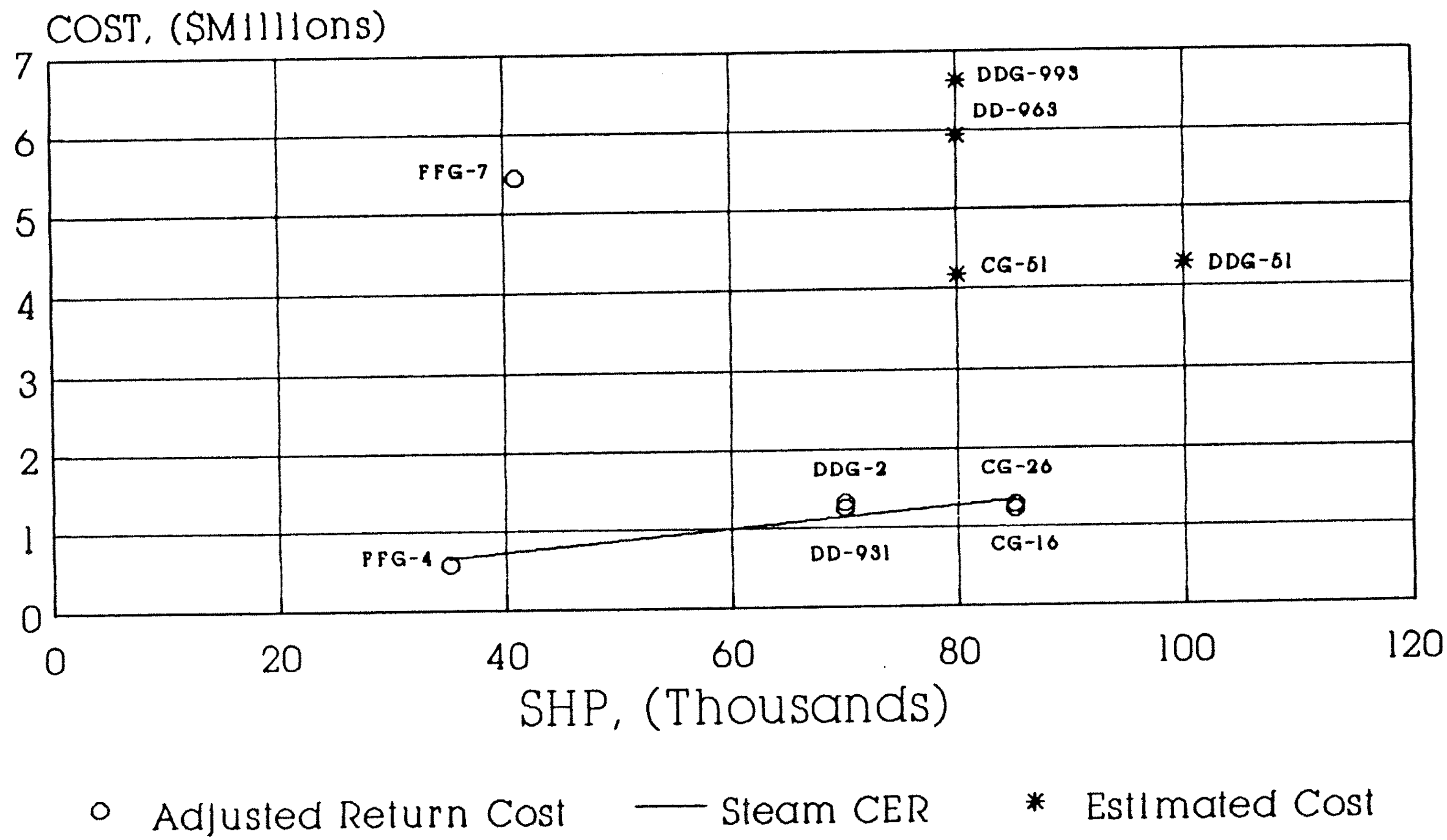


FIGURE 3-28

PROPULSION SERVICE SYSTEMS
GROUP 2D
LABOR

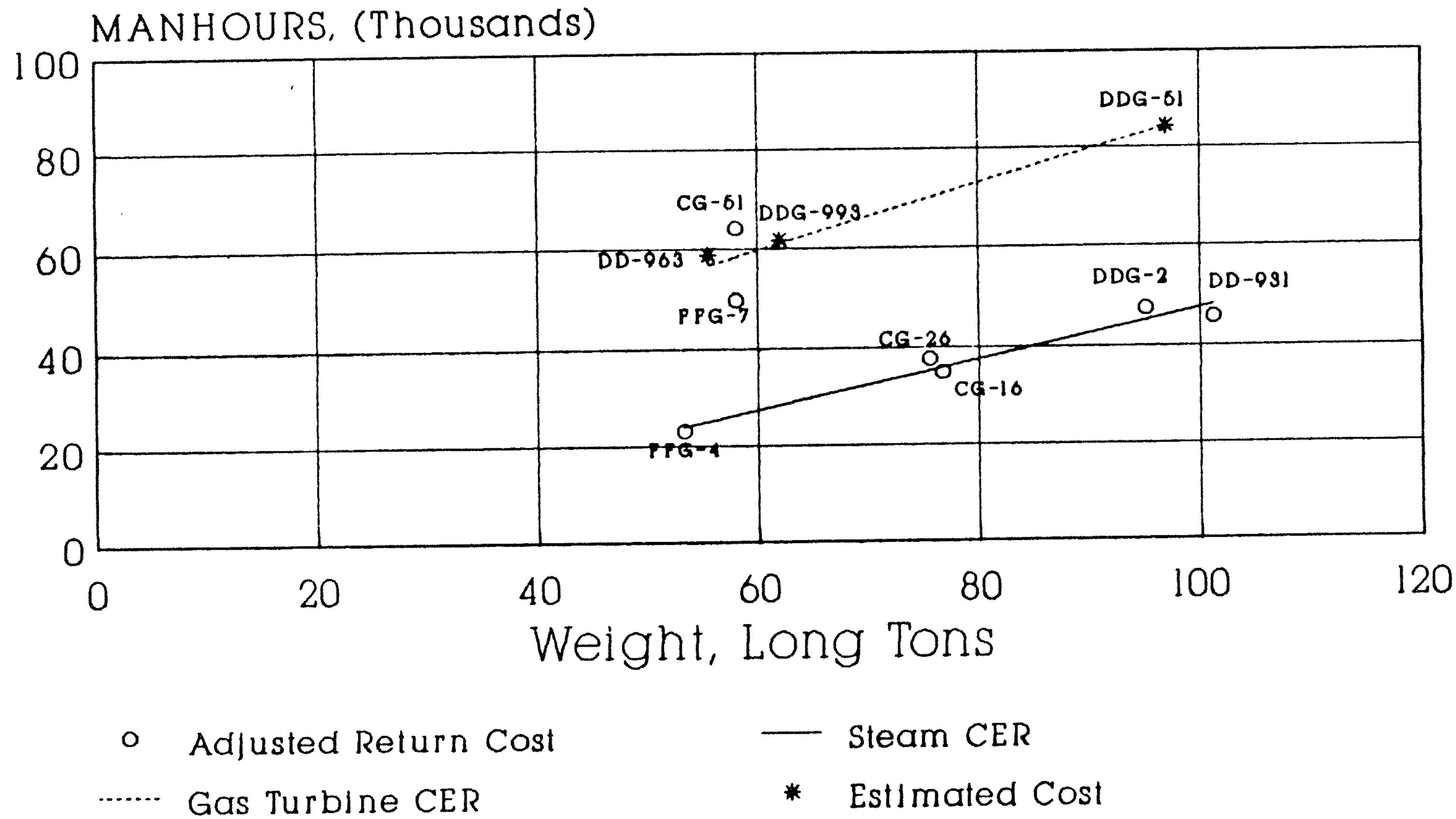


FIGURE 3-29

3.4.3 Group 3 - Electrical Plant

Group 3 is comprised of the following two-digit cost groups:

3A Electrical Power Generation

3B Electrical Power Distribution

The algorithms for the one-digit Group 3 are discussed as follows:

MATERIAL FACTOR: The electrical systems are usually a function of the ship's propulsion system, total installed electric power, and the ship's size. A ship with a steam plant can have a mix of steam, ships service and diesel emergency generators, while a geared gas turbine ship will generally have all diesel or all gas turbine generator sets. An exception may be in an integrated electric plant where a combination might be found. (The diesel generators costed here were customized for the FFG-7.) Material costs as a function of power installed (kilowatts) were examined for each of four different possible plants, but good correlation was found for only one plant type. Instead a plot against total Group 3 weight appears to yield the best data fit, excluding CG-47, which cannot be explained.

CER:	\$ = 42,300 WT - 1,123,000
Variable:	Group 3 Weight
Application:	All
Adjusted r^2:	.9161, 9 points

LABOR FACTOR: The graph of man-hours versus weight also correlated very well for all types of power plants. The CG-47 was not included because it was much higher than the trend and, as with materials, cannot be explained.

CER:	MH = 1,059 WT - 6,650
Variable:	Group 3 Weight
Application:	All
Adjusted r^2:	.8877, 10 points

See Figures 3-30 through 3-33 for graphs of data points.

Group 3A Electrical Power Generation

This group includes ship service power generation, emergency generators, power conversion equipment, diesel and turbine support systems.

MATERIAL FACTOR: Ship electrical generation system costs are usually a function of the ship's total installed electric power, which correlates with ship's size. The type of propulsion system, which determines which type of generators are to be used, should also be considered. Cost versus installed generating power was evaluated for four combinations: gas turbine propulsion with diesel electric generators, gas turbine with gas turbine generators, steam propulsion with steam turbine generators, and steam propulsion with steam turbine and diesel generators. (Beginning with the FF-1040, there was a major change in design criteria: a separate emergency generator was eliminated and, instead, one of the ship's service generators was a diesel.) These configurations were also investigated for cost versus weight, which yielded a better correlation. It is noted that the steam diesel combination is less expensive than all steam, and the actual slope of this algorithm is based on conjecture.

CER:	$ = 6,035 WT + 2,653,000
Variable:	Group 3A Weight
Application:	Steam Turbine Generators
Adjusted r^2:	.7418, 4 points

ELECTRIC PLANT
GROUP 3
MATERIALS COST

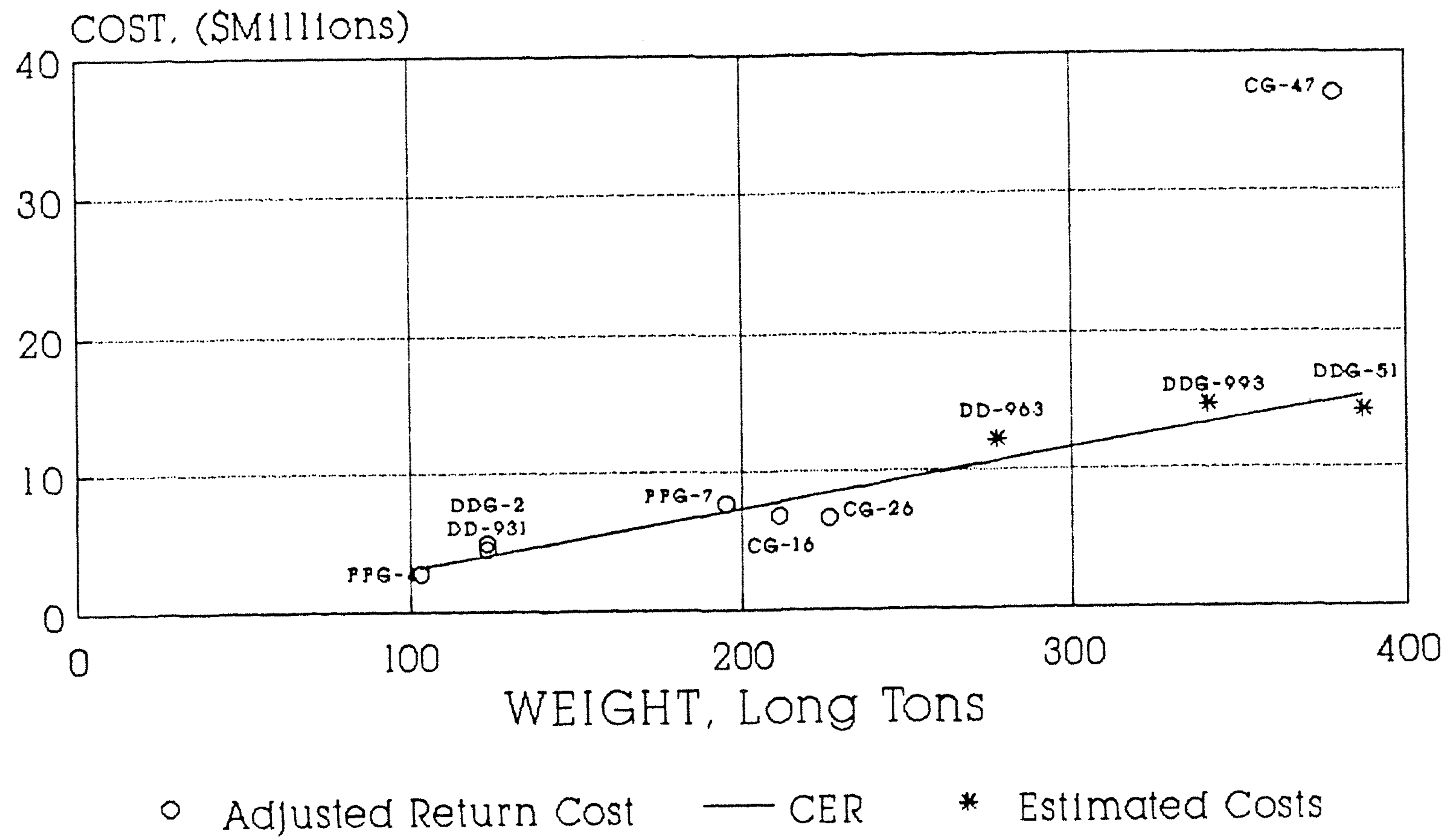


FIGURE 3-30

ELECTRIC PLANT
GROUP 3
MATERIALS COST

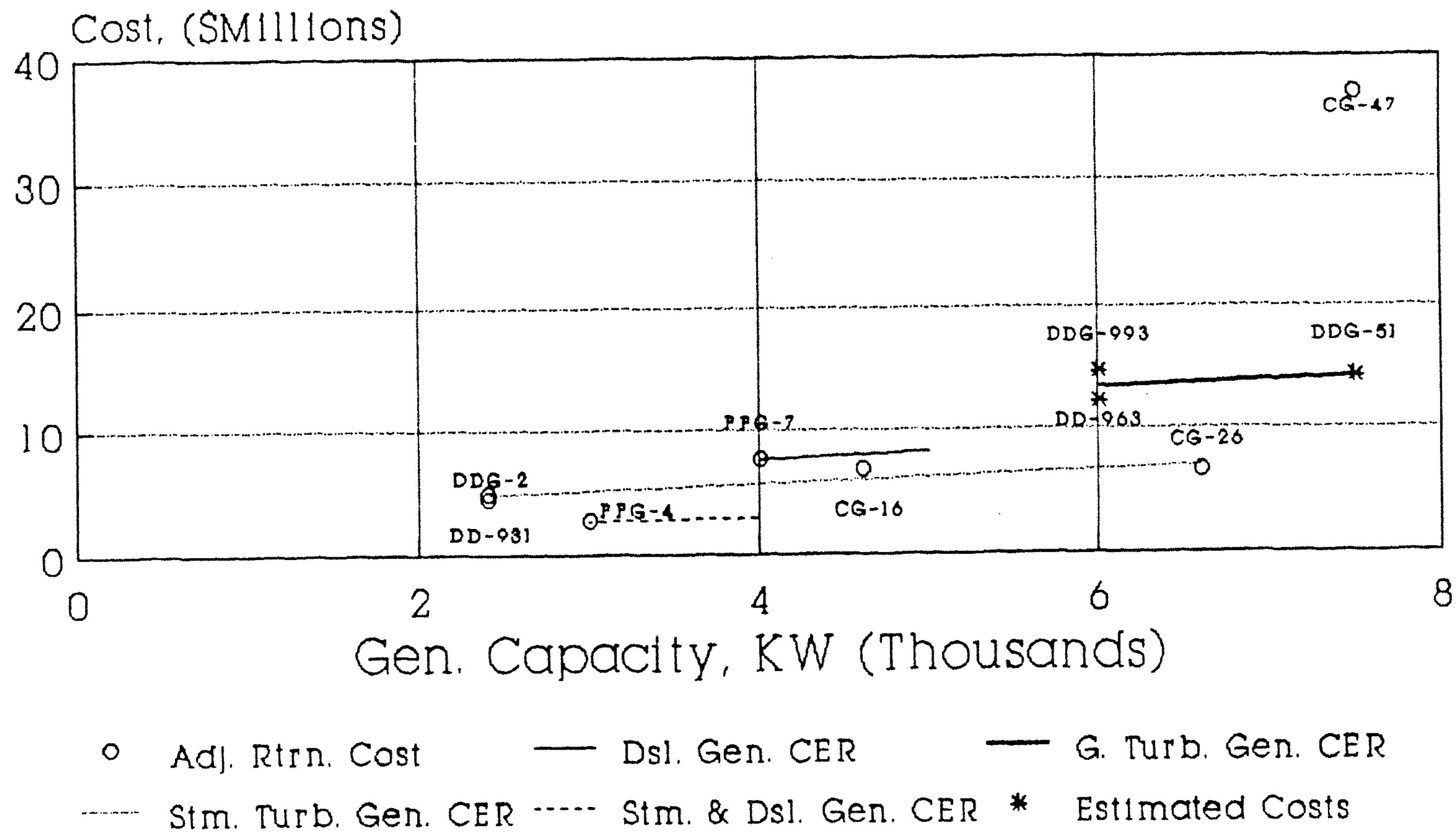


FIGURE 3-31

ELECTRIC PLANT
GROUP 3
LABOR

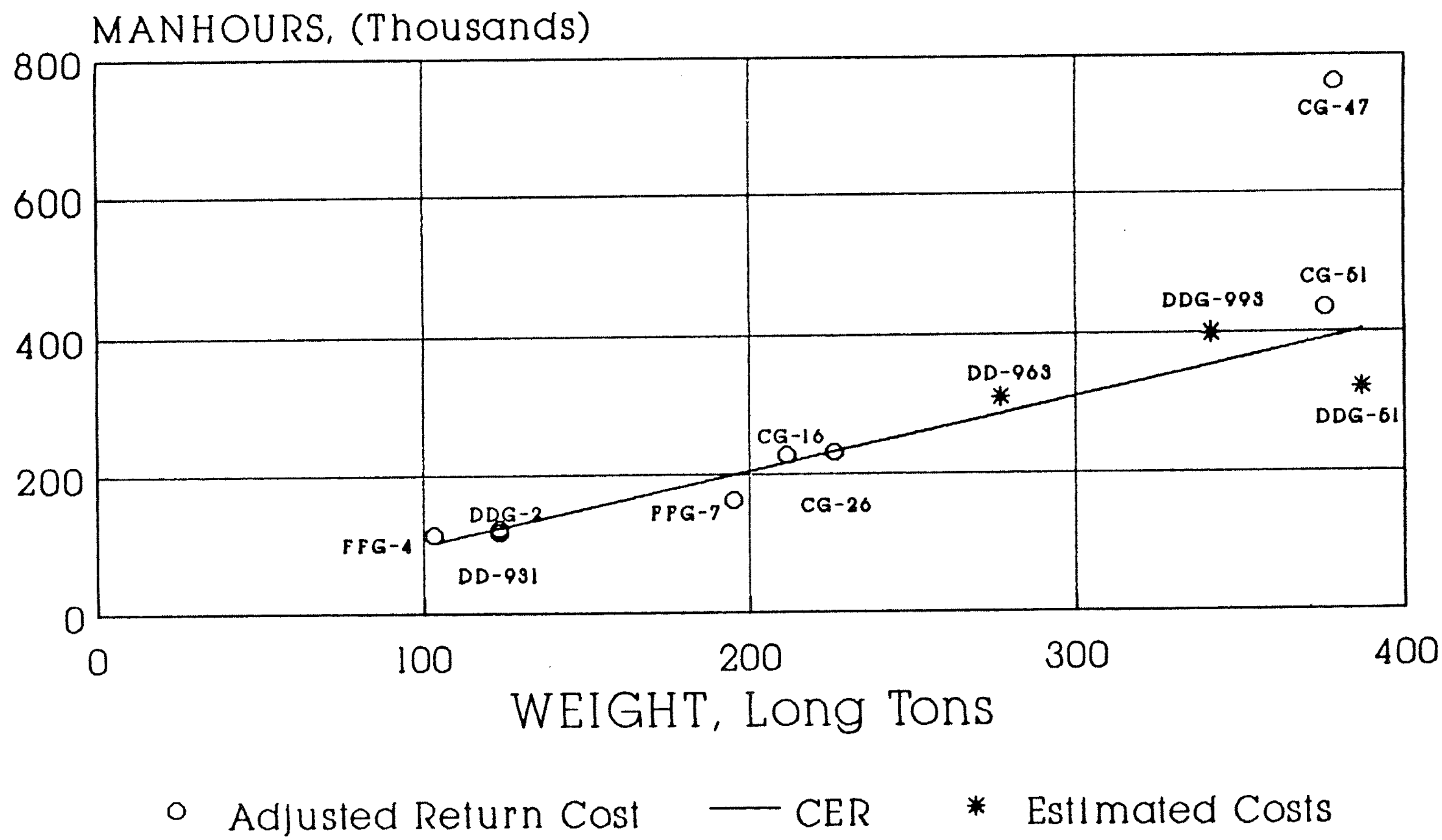


FIGURE 3-32

ELECTRIC PLANT
GROUP 3
LABOR

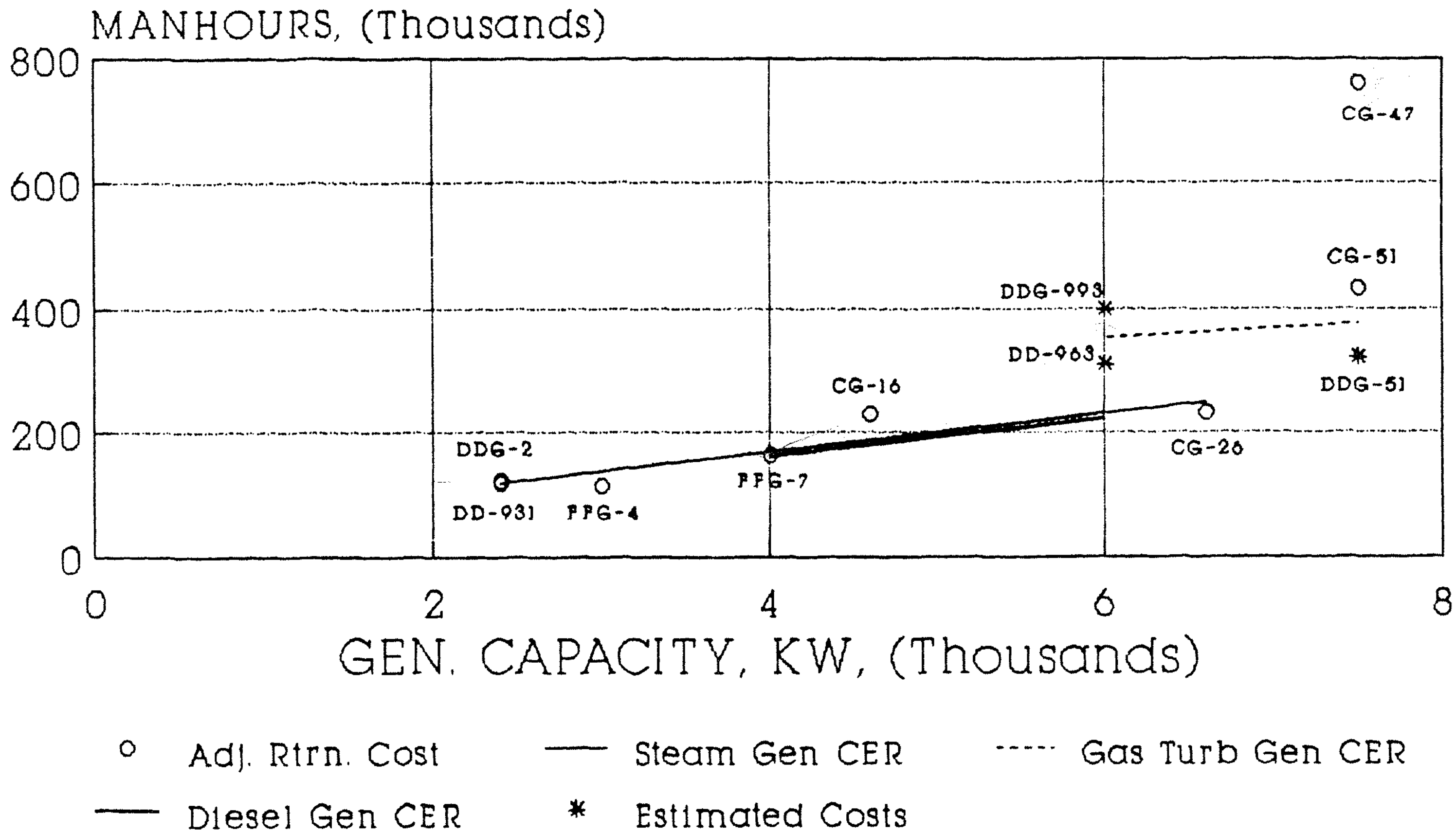


FIGURE 3-33

CER: $ = 3,054 WT + 1,343,000
Variable: Group 3A Weight
Application: Steam and Diesel Generators
Adjusted r^2: N/A

CER: $ = 122,445 WT - 8,889,00
Variable: Group 3A Weight
Application: Gas Turbine
Adjusted r^2: .965, 4 points

CER: $ = 171,675 WT - 1,246,000
Variable: Group 3A Weight
Application: Diesel Generators (for G.T.)
Adjusted r^2: N/A

LABOR FACTOR: One algorithm is sufficient for Group 3A labor man-hours graphed as a function of the group weight. The DDG-51 was omitted because of the low value for this group, which could result from the extensive preoutfitting proposed for that ship. Alternatively a separate trend line encompassing FFG-7, DD-963, DDG-993, CG-51 and DDG-51, all of which used preoutfitting, is another possibility.

CER: MH = 203 WT + 1,140
Variable: Group 3A Weight
Application: All
Adjusted r^2: .9068, 9 points

See Figures 3-34 through 3-37 for graphs of data points.

Group 3B - Electrical Power Distribution

This group includes batteries and service facilities, ship service, emergency and casualty power cable system, switchgear and panels, lighting distribution and fixtures.

ELECTRICAL POWER GENERATION
GROUP 3A
MATERIALS COST

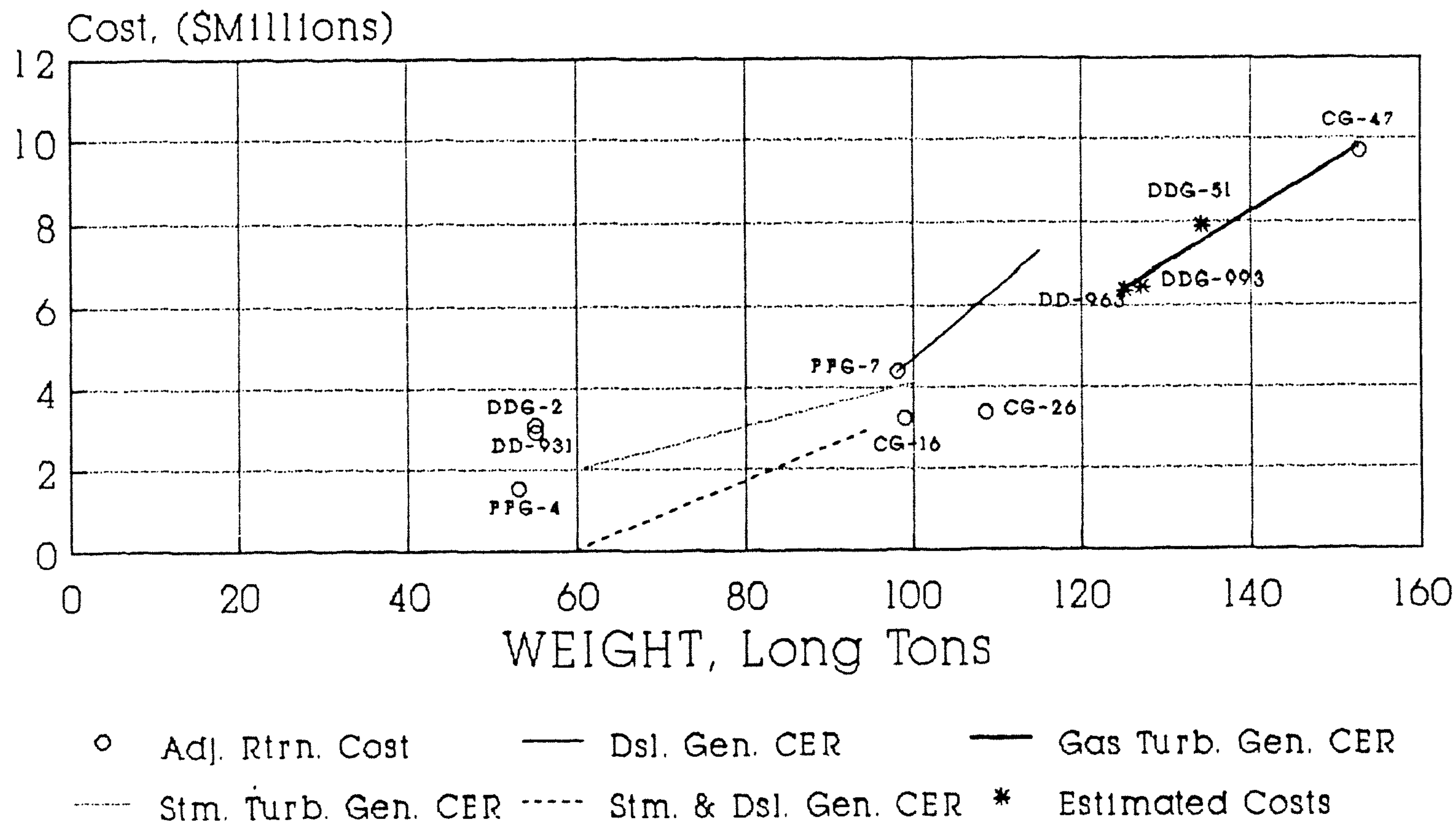


FIGURE 3-34

ELECTRICAL POWER GENERATION
GROUP 3A
MATERIALS COST

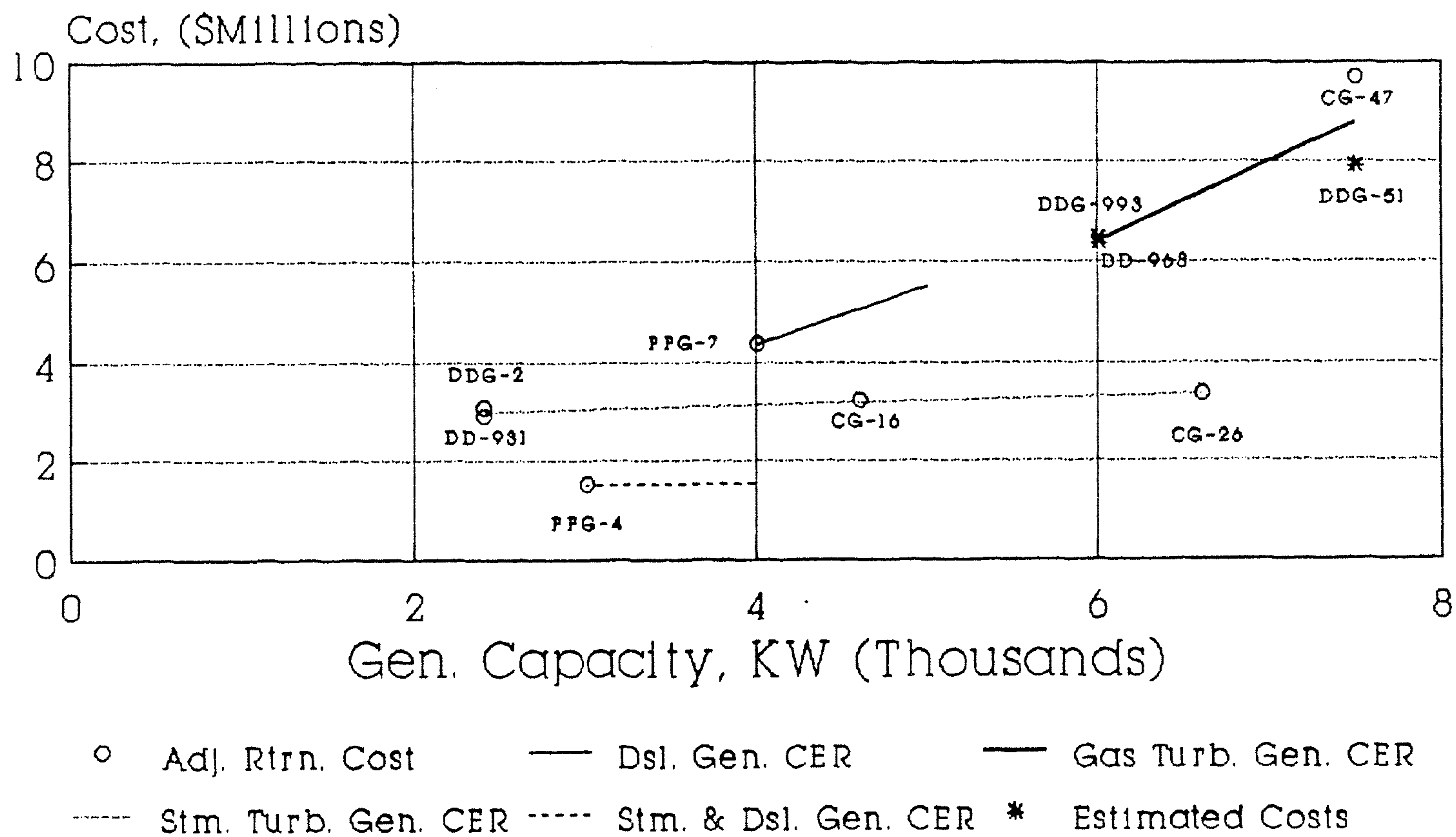


FIGURE 3-35

ELECTRICAL POWER GENERATION
GROUP 3A
LABOR

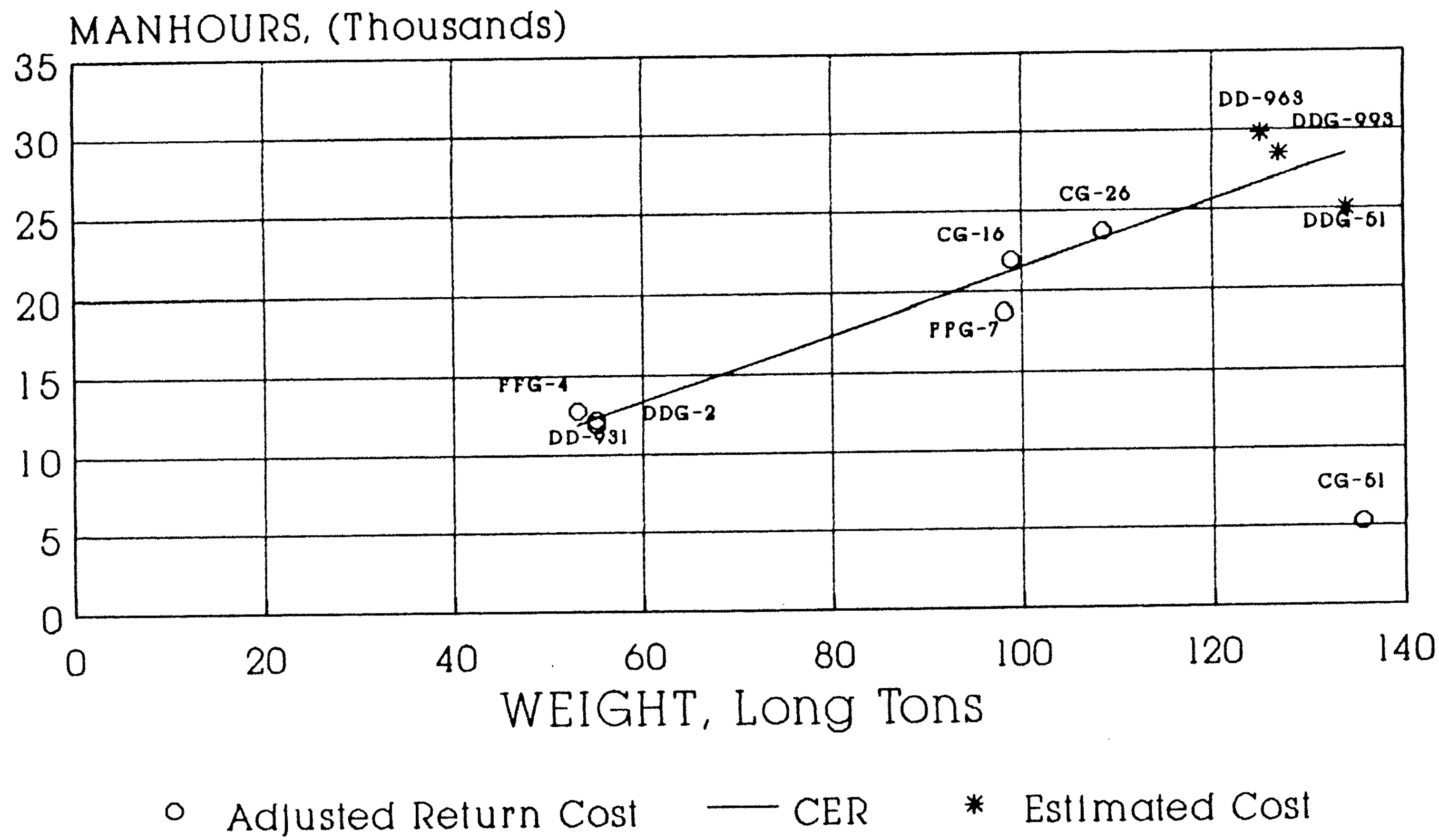


FIGURE 3-36

ELECTRICAL POWER GENERATION
GROUP 3A
LABOR

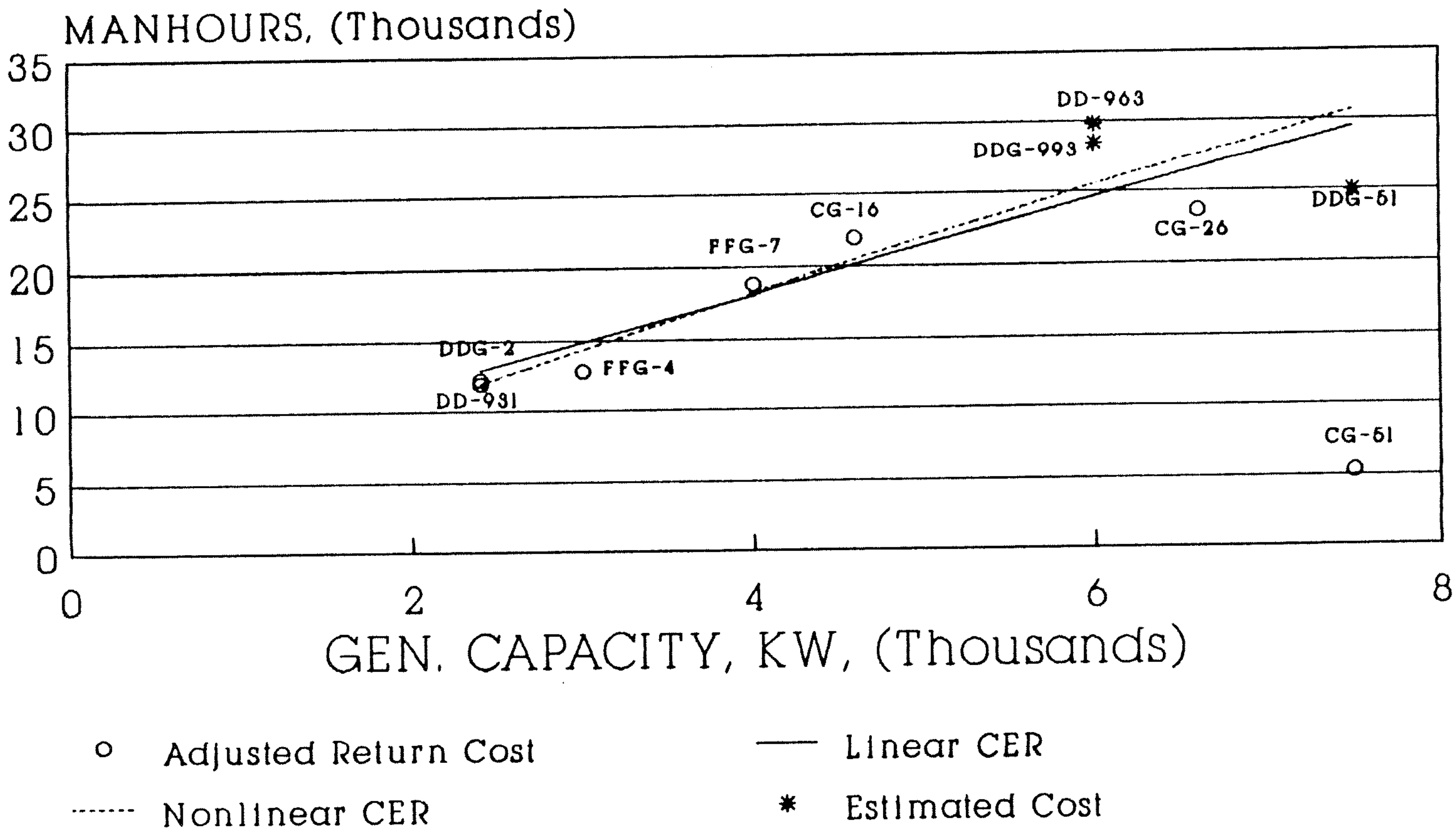


FIGURE 3-37

MATERIAL FACTOR: The power distribution system depends more upon the ship's size than anything else. It also depends upon the type of switchboards used. Some switchboards are made of aluminum, some of steel. The weights can also vary among the different manufacturers. Later development in circuit technology also has lightened the weight for the newer ships. It appears that the later ships have a slightly lower cost per ton value, and were, therefore, incorporated in a separate algorithm.

CER:	$ = 34,150 WT - 573,000
Variable:	Group 3B Weight
Application:	Pre-1965
Adjusted r2:	.9464, 5 points

OR

CER:	$ = 8,900 (WT) 1.249
Variable:	Group 3B Weight
Application:	Pre-1965
Adjusted r2:	.957, 5 points

CER:	$ = 23,200 WT + 1,717,000
Variable:	Group 3B Weight
Application:	Post-1965
Adjusted r2:	.4245, 4 points

LABOR FACTOR: In the cases of man-hours versus weight, a single algorithm graphed well. In this instance the FFG-7 and DDG-2 fall below the line (these are the only ships known to have steel switchboards), but this departure does not seem large enough to require a separate algorithm. Only the DDG-51 was excluded from the algorithm, since it was felt that the estimated value may be low.

CER:	MH = 1,800 WT - 7,440
Variable:	Group 3B Weight
Application:	All
Adjusted r2:	.9863, 9 points

See Figures 3-38 and 3-39 for graphs of data points.

ELECTRICAL POWER DISTRIBUTION
GROUP 3B
MATERIALS COST

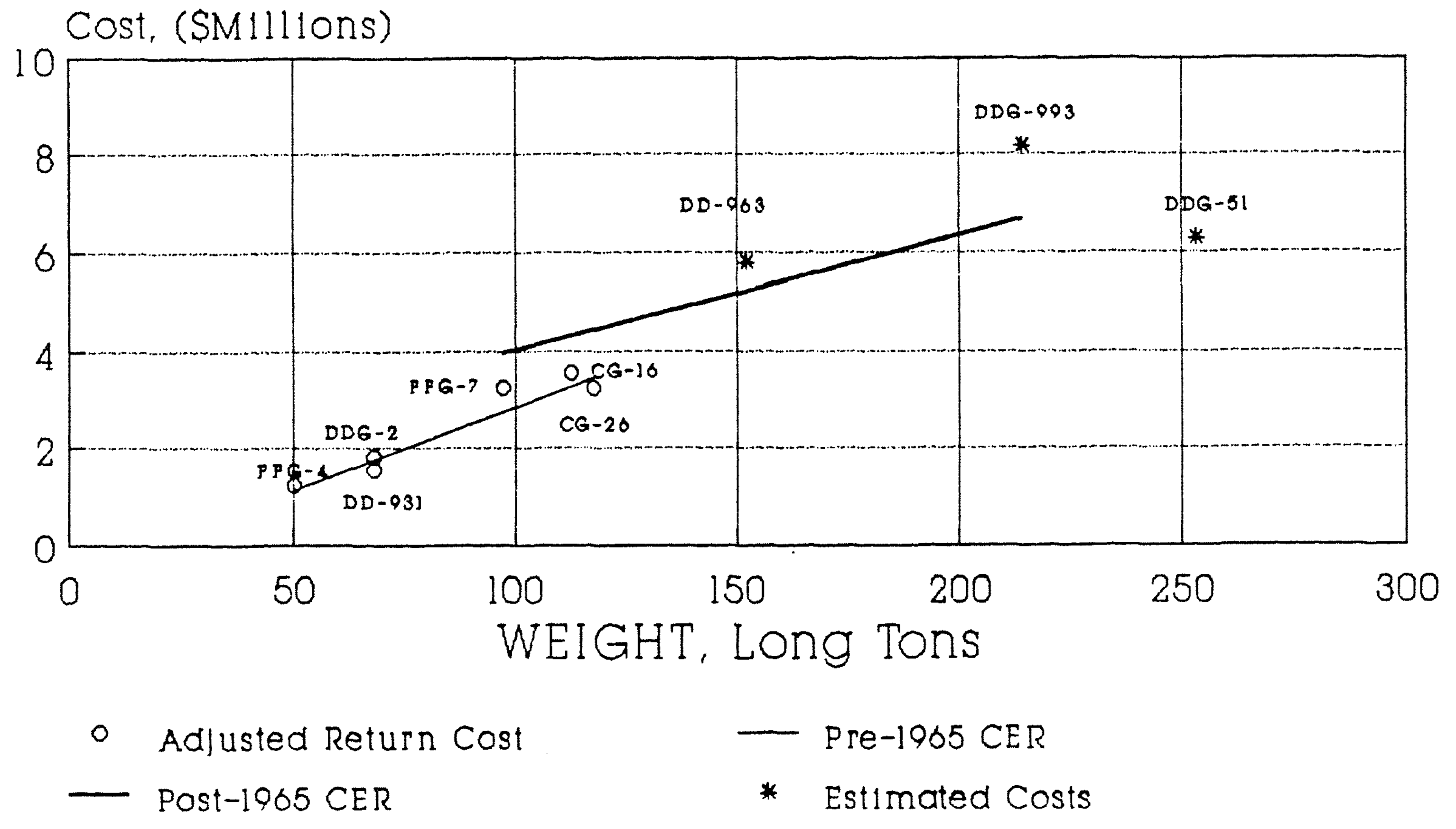


FIGURE 3-38

ELECTRICAL POWER DISTRIBUTION
GROUP 3B
LABOR

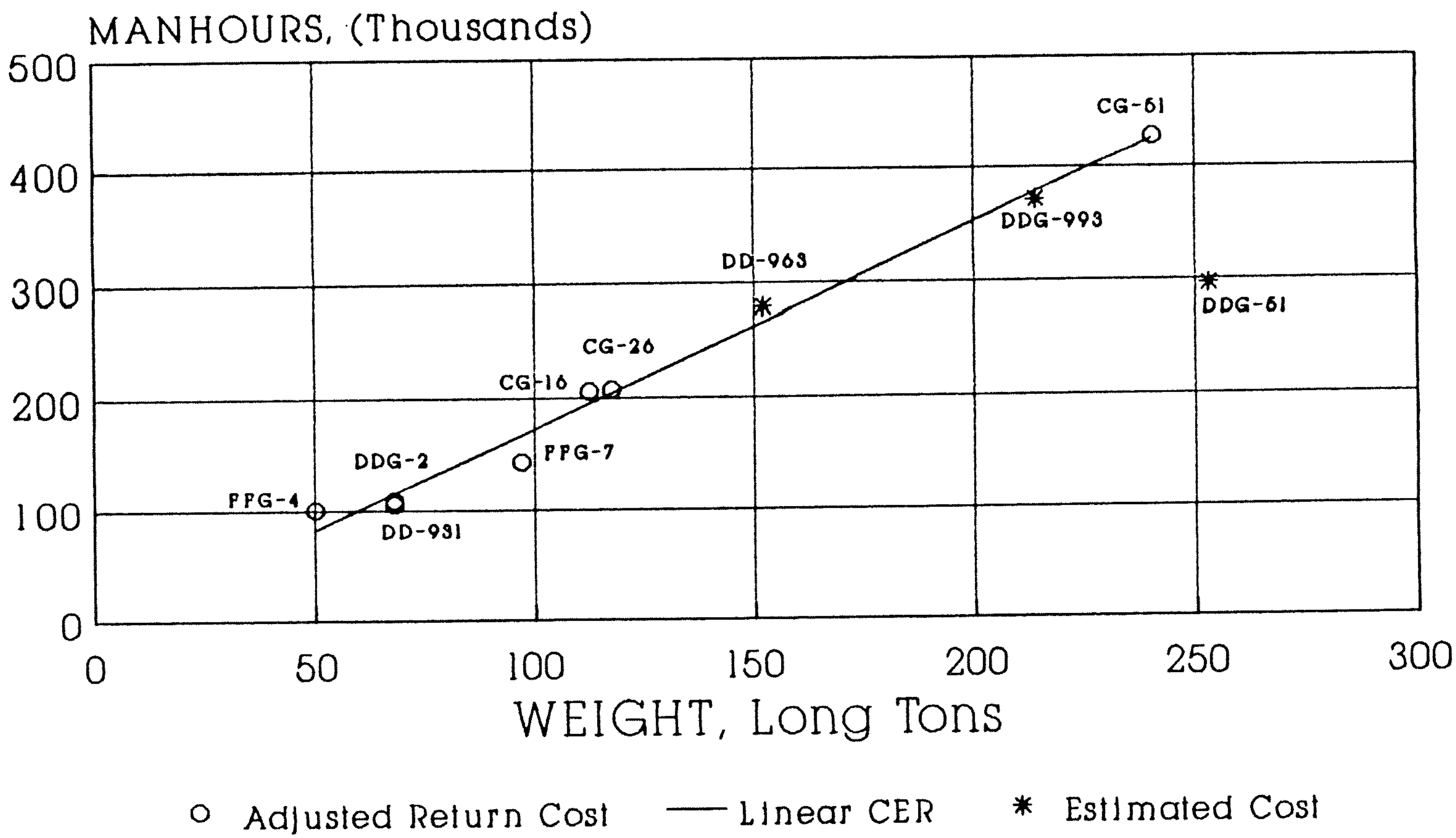


FIGURE 3-39

3.4.4 Group 4 - Command and Surveillance

Group 4 is comprised of the following two-digit cost groups:

4A Vehicle Command

4B Weapons Command

The algorithms for the one-digit Group 4 are discussed as follows:

MATERIAL FACTOR: Material costs are estimated as a function of total ship volume with two alrogithms, one for earlier technology systems and one for current technology systems, because this yielded the only reasonable relationship. As will be mentioned in Group 4B, there may be deviations in material costs depending on the systems installed. This does not include the material costs of GFE. The CG-47 was not included because it is not known what was included in its return cost values.

CER:	\$ = 1.555 Vol + 638,000
Variable:	Total Ship Volume
Application:	Pre-1965 Technology
Adjusted r^2:	.40, 5 points

CER:	\$ = 6.774 Vol - 834,700
Variable:	Total Ship Volume
Application:	Post-1965 Technology
Adjusted r^2:	.2283, 5 points

LABOR FACTOR: Group 4 man-hours may be estimated on the basis of weight with two algorithms -- a pre-1965 technology and a post-1965 technology algorithm. The DDG-51 estimate was not included in the post-1965 CER because it appears to be unrealistically high, partly because of the workload factor adjustment applied to all DDG-51 labor values.

CER: $MH = 473\ WT + 43{,}500$
Variable: Group 4 Weight
Application: Pre-1965 Technology
Adjusted r^2: .9759, 5 points

OR

CER: $MH = 3490\ (WT)^{0.699}$
Variable: Group 4 Weight
Application: Pre-1965 Technology
Adjusted r^2: .988, 5 points

CER: $MH = 706\ WT + 7{,}500$
Variable: Group 4 Weight
Application: Post-1965 Technology
Adjusted r^2: .6925, 5 points

OR

CER: $MH = 593\ (WT)^{1.034}$
Variable: Group 4 Weight
Application: Post-1965 Technology
Adjusted r^2: .85, 5 points

See Figures 3-40 and 3-41 for graphs of data points.

Group 4A - Vehicle Command

This group includes navigation equipment, interior communication, and countermeasures systems (degaussing).

MATERIAL FACTOR: Material costs for Group 4A fall into two groups -- a pre-1965 technology and a post-1965 technology. These groups were evaluated for correlation with weight, volume and installed 400 Hz power, because much of this equipment is driven by 400 Hz power. There was no discernible relationship for weight or volume. The only meaningful relationship was with installed 400 Hz power. The DD-963 and DDG-993 are outliers.

COMMAND AND SURVEILLANCE
GROUP 4
MATERIALS COST

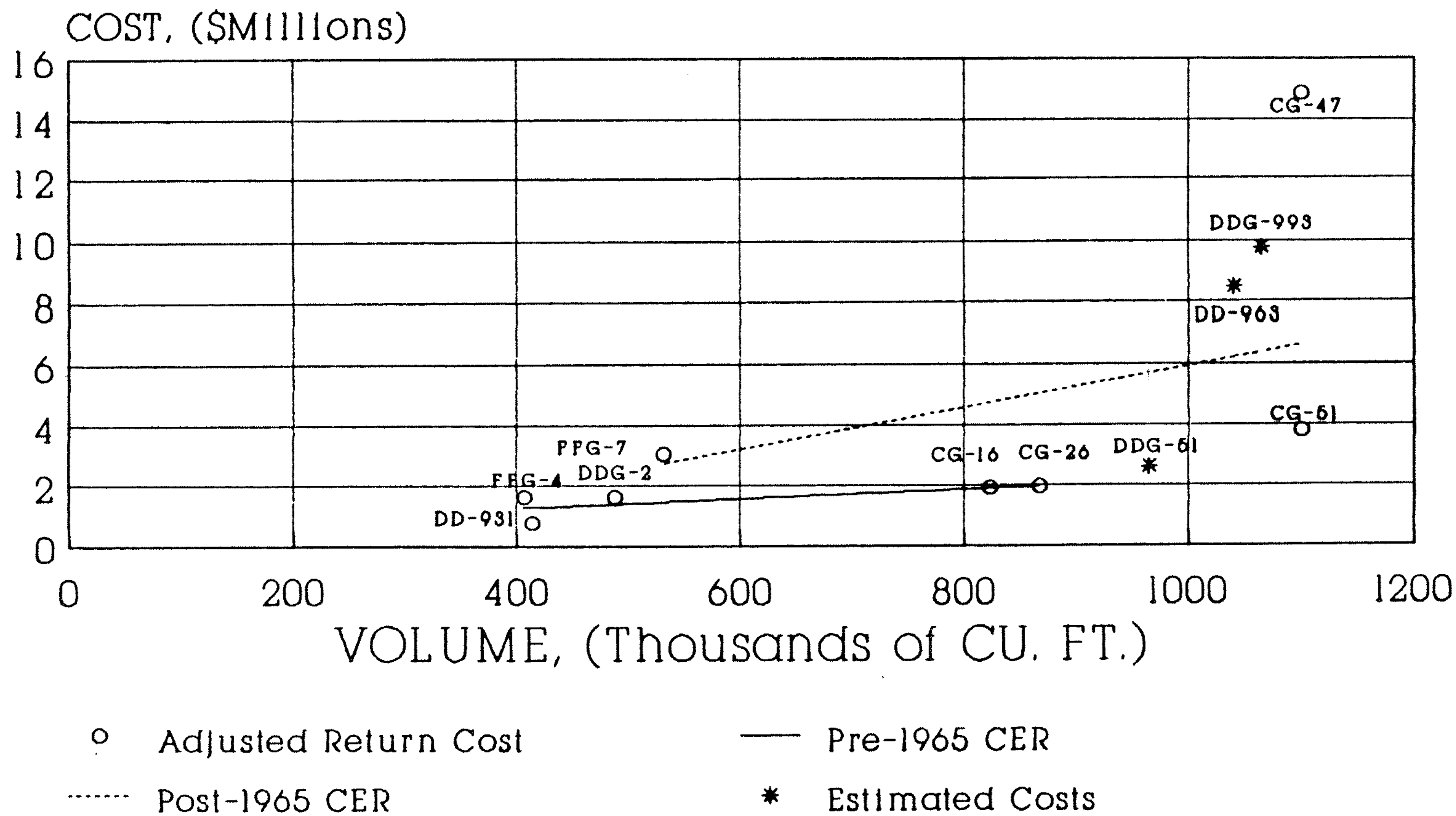
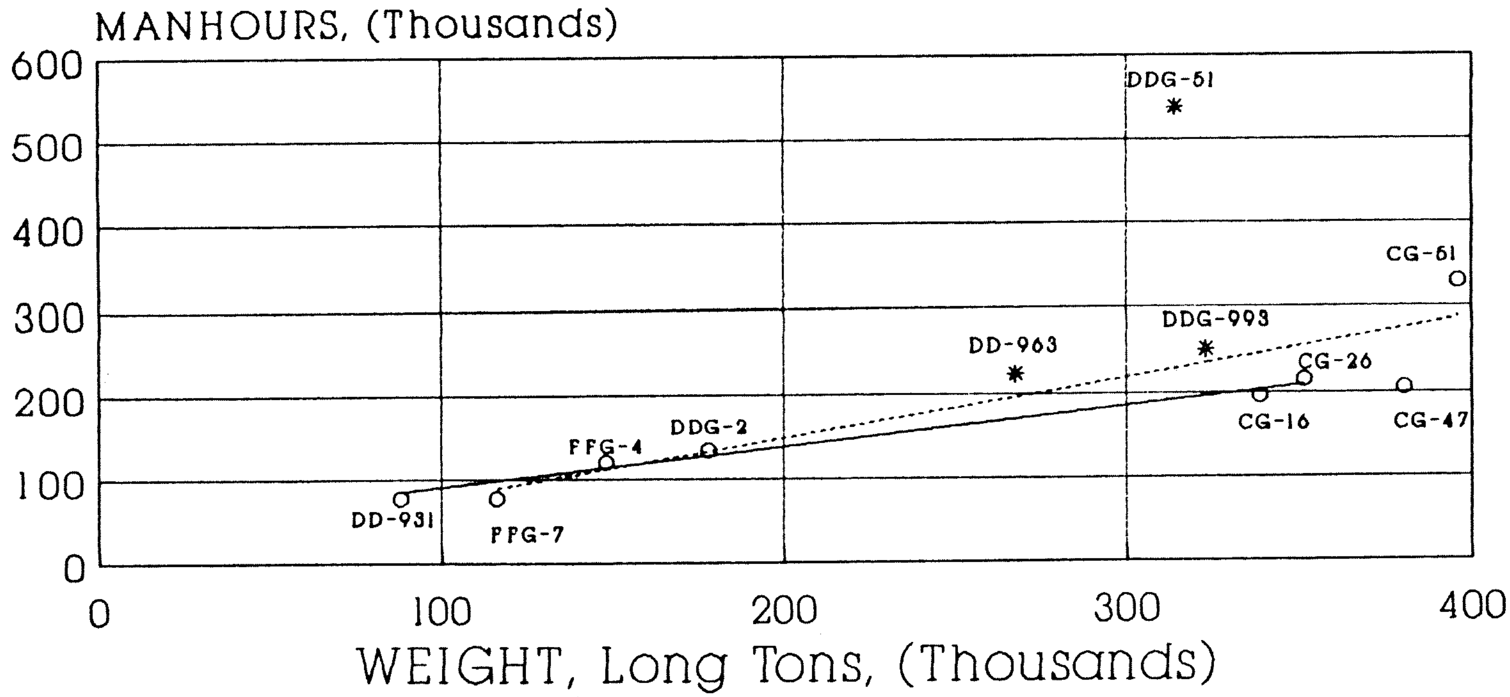


FIGURE 3-40

COMMAND AND SURVEILLANCE
GROUP 4
LABOR



o Adjusted Return Cost
—— Pre-1965 CER
······· Post-1965 CER
* Estimated Costs

FIGURE 3-41

CER:	$\$ = 268\ KW + 769{,}000$
Variable:	Installed 400 Hz Kw
Application:	Pre-1965 Technology
Adjusted r^2:	.5192, 5 points

OR

CER:	$\$ = 411{,}400\ (KW)^{0.142}$
Variable:	Installed 400 Hz Kw
Application:	Pre-1965 Technology
Adjusted r^2:	.814, 5 points

CER:	$\$ = 1544\ KW + 740{,}000$
Variable:	Installed 400 Hz Kw
Application:	Post-1965 Technology
Adjusted r^2:	.9989, 3 points

If 400 Hz power is unknown, use $ 1.0 million for pre-1965 and $ 2.0 million for post 1965 technology.

LABOR FACTOR: Group 4A man-hours can be estimated as a function of weight for both types of technology. Labor man-hours for current technology systems are slightly higher than those of pre-1965 technology. The DDG-51 point was disregarded for the reasons discussed with the Group 4 one-digit algorithm.

CER:	$MH = 985\ WT - 8{,}000$
Variable:	Group 4A Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.9712, 5 points

OR

CER:	$MH = 375\ (WT)^{1.197}$
Variable:	Group 4A Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.986, 5 points

CER:	MH = 2127 WT - 72,600
Variable:	Group 4A Weight
Application:	Post-1965 Technology
Adjusted r^2:	.6694, 5 points

OR

CER:	$MH = 11,000 [10^{.01(WT)}]$
Variable:	Group 4A Weight
Application:	Post-1965 Technology
Adjusted r^2:	.891, 5 points

See Figures 3-42 and 3-43 for graphs of data points.

Group 4B Weapons Command

This group includes only installation costs for fire control systems, electronic countermeasures, radar and sonar systems. (The installed system's acquisition costs are not included in this model.)

MATERIAL FACTOR: Communication, sensor and weapon control items are essentially independent of the ship's size or weight parameters. In many cases they represent the ship's mission or its reason for existence. For this programming quality cost estimate, this group's installation costs can be estimated based on the appropriate technology line as a function of weight. Group costs may vary because they include highly specialized equipment usually chosen for certain weapons systems or combinations thereof. It appears that the post-1965 technology costs may be levelling off with respect to weight due to improvements in technology. It appears that a line through the DDG-51 and CG-51 is more representative of current trends than the FFG 7. Also, since the DD 963 and DDG 993 values were based on FFG 7 algorithms they were not used in developing the CER.

VEHICLE COMMAND
GROUP 4A
MATERIALS COST

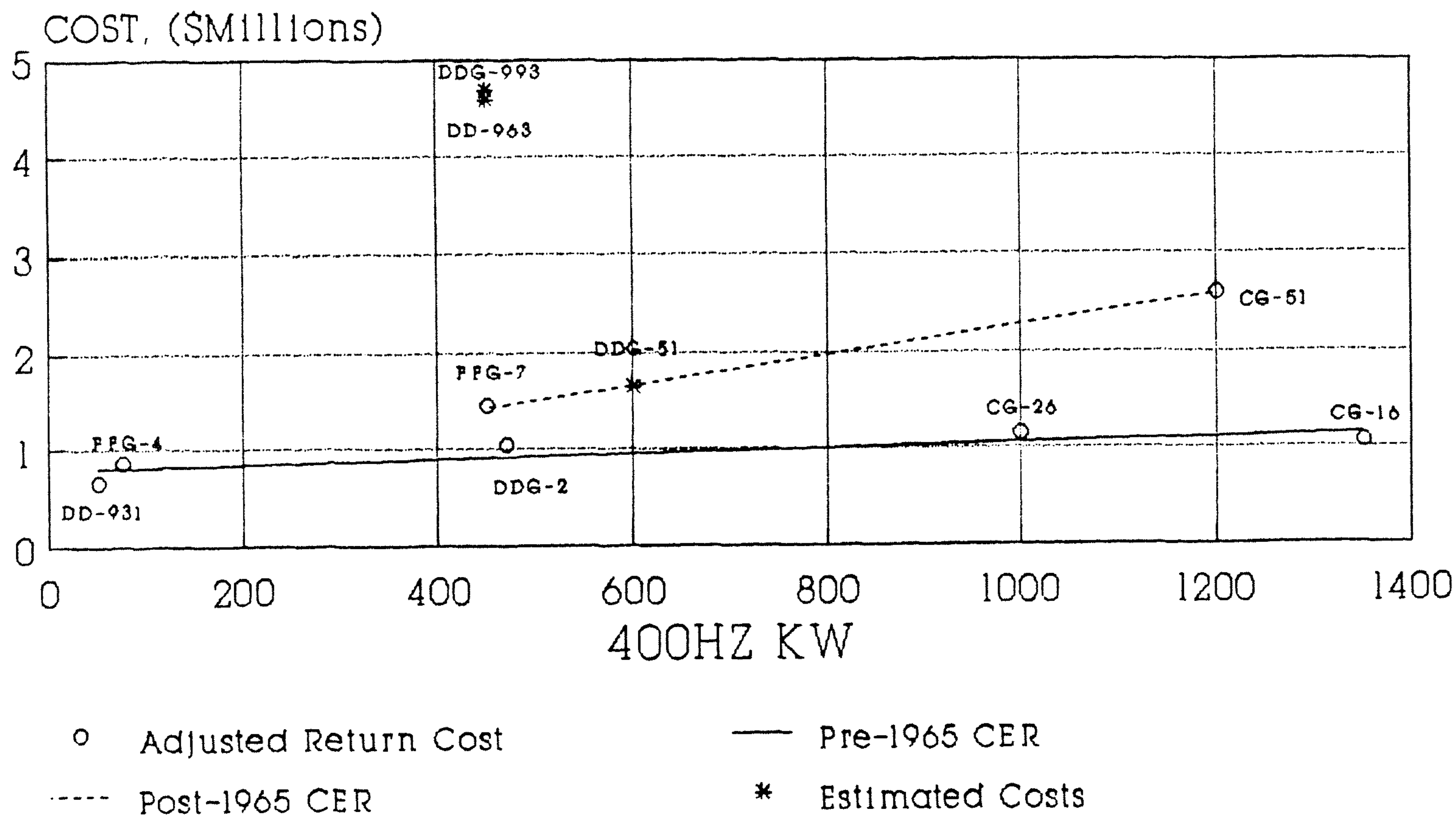


FIGURE 3-42

VEHICLE COMMAND
GROUP 4A
LABOR

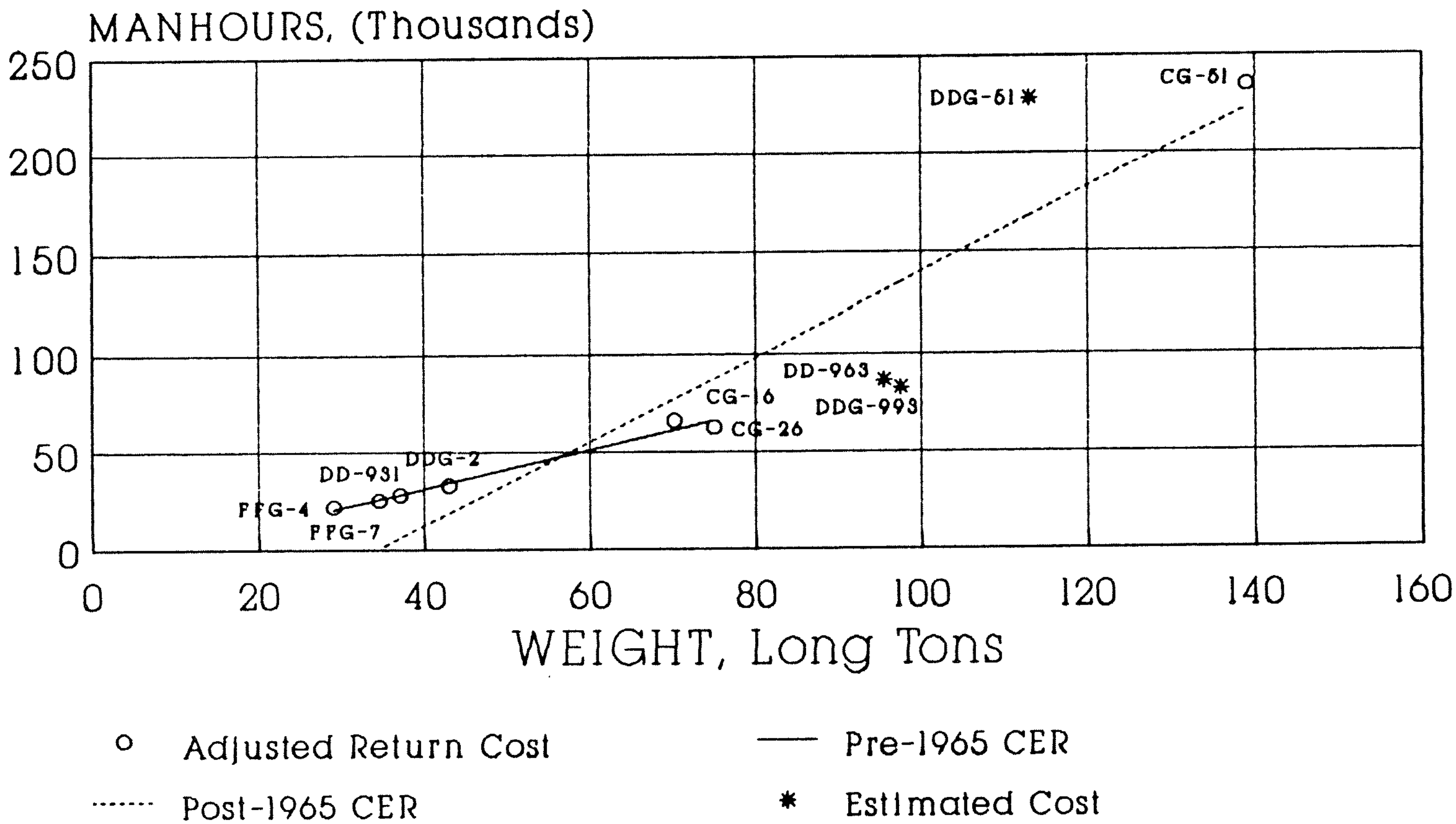


FIGURE 3-43

CER:	$\$ = 2597\ WT + 638{,}000$
Variable:	Group 4B Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.597, 5 points

OR

CER:	$\$ = 2100\ (WT)^{1.102}$
Variable:	Group 4B Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.724, 5 points

CER:	$\$ = 3620\ WT + 248{,}800$
Variable:	Group 4B Weight
Application:	Post-1965 Technology
Adjusted r^2:	N/A

LABOR FACTOR: Group 4B man-hours can be estimated based upon the group weight. The choice of weapons command equipment does not radically affect the man-hours involved. The DDG-51 was excluded from the algorithm because of its high value.

CER:	$MH = 379\ WT + 42{,}200$
Variable:	Group 4B Weight
Application:	All
Adjusted r^2:	.5337, 9 points

OR

CER:	$\$ = 3{,}910\ (WT)^{0.695}$
Variable:	Group 4B Weight
Application:	All
Adjusted r^2:	.711, 9 points

See Figures 3-44 and 3-45 for graphs of data points.

WEAPONS COMMAND
GROUP 4B
MATERIALS COST

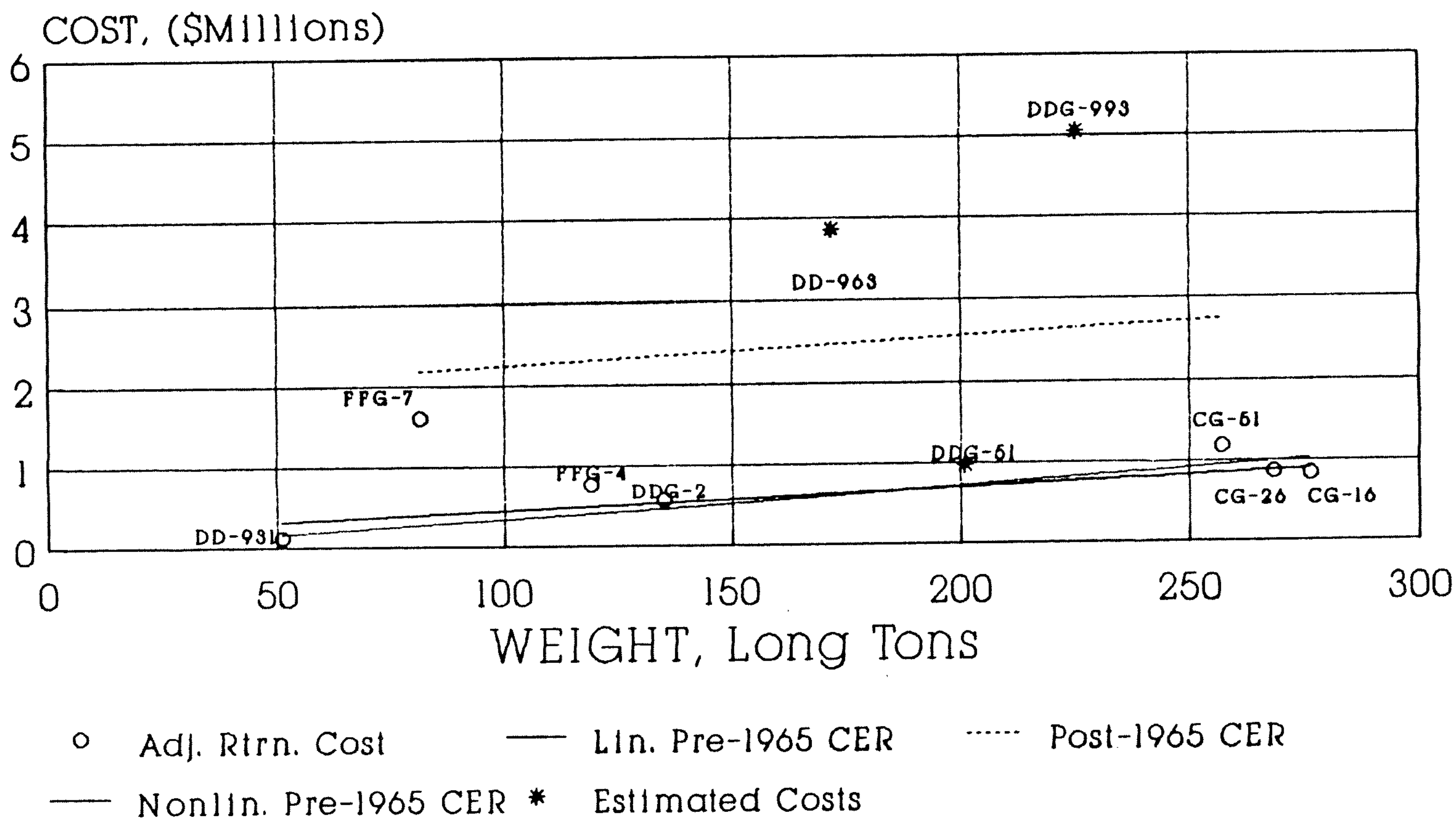


FIGURE 3-44

WEAPONS COMMAND
GROUP 4B
LABOR

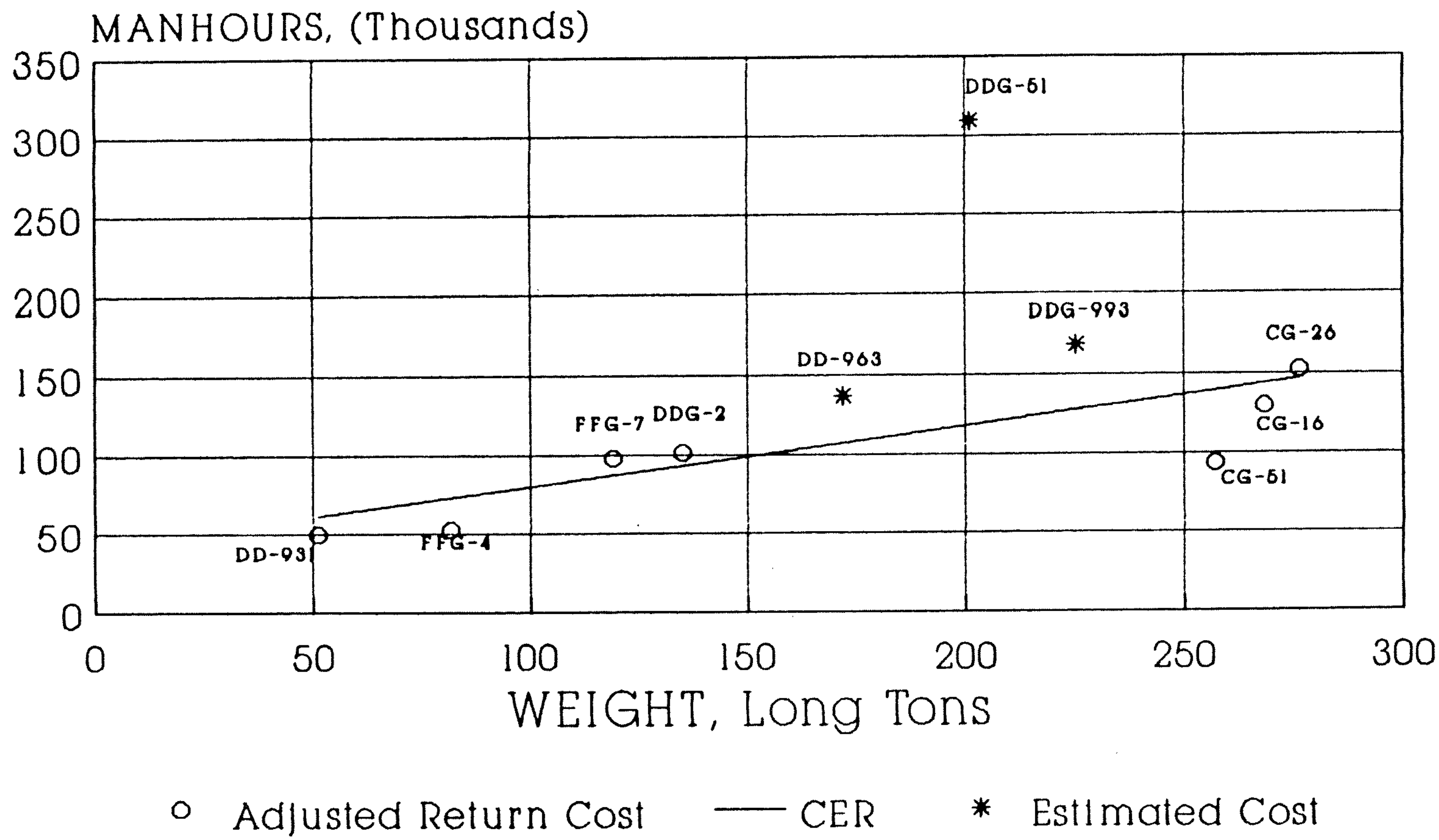


FIGURE 3-45

3.4.5 Group 5 - Auxiliary Systems

Group 5 is comprised of the following two-digit cost groups:

5A Environmental Systems
5B Fluid Systems
5C Maneuvering Systems
5D Equipment Handling Systems

The algorithms for the one-digit Group 5 are discussed as follows:

MATERIAL FACTOR: At the one-digit level, weight is used as the independent variable for Group 5. For material costs, there are two algorithms, one for pre-1965 ships and one for post-1965 ships. These lines are primarily influenced by technological and configuration differences in HVAC and fluid systems. The lower value of the DDG-51 is a result of electric heat, and it also may be possible to have two post-1965 lines as was done with Group A; however, this level of precision was not considered necessary at the 1-digit level.

CER:	\$ = 7,692 WT + 1,767,5000
Variable:	Group 5 Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.76435, 5 points

CER:	\$ 27,900 WT + 446,000
Variable:	Group 5 Weight
Application:	Post-1965 Technology
Adjusted r^2:	.8242, 5 points

LABOR FACTOR: Group 5 labor figures can be estimated best as a function of weight. An algorithm for pre-1965 ships and one for post-1965 are plotted. The labor trend for the pre-1965 ships is higher than the post-1965 in part because of differences in construction practices where more detailed drawings and procedures and preoutfitting are now invoked, requiring less actual construction labor to install components. In almost all of Group 5, the learning curve effect can be seen in CG-26 since it followed CG-16 at the same yard and has basically the same systems. As with materials for Group 5, it may be possible to have two trend lines for the post-1965 ships.

CER:	MH = 1,094 WT - 46,900
Variable:	Group 5 Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.9166, 5 points

CER:	MH = 982 WT - 115,300
Variable:	Group 5 Weight
Application:	Post-1965 Technology
Adjusted r^2:	.8136, 5 points

OR

CER:	$MH = 122 (WT)^{1.287}$
Variable:	Group 5 Weight
Application:	Post 1965-Technology
Adjusted r^2:	.90, 5 points

See Figures 3-46 and 3-47 for graphs of data points.

Group 5A - Environmental Systems

This group includes the heating, ventilation and air conditioning systems plus the refrigerated spaces.

MATERIAL FACTOR: Several parameters were examined for Group 5A, including weight, volume and cubic number. Group 5A material costs as a function of weight produced the best correlation and falls into the following categories: steam heat systems, electric heat systems or waste heat derived heat systems.

AUXILIARY SYSTEMS
GROUP 5
MATERIALS COST

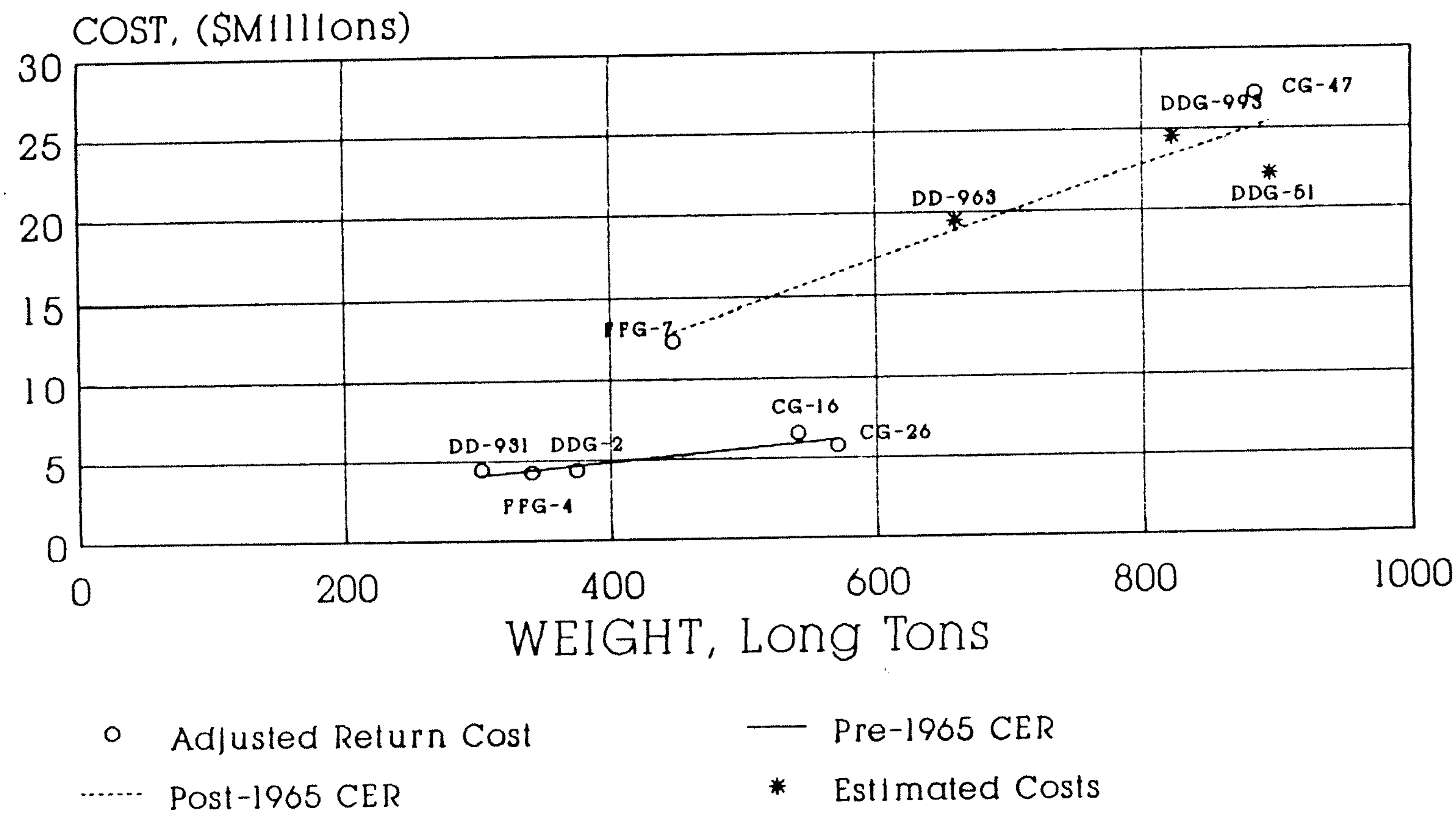


FIGURE 3-46

AUXILIARY SYSTEMS
GROUP 5
LABOR

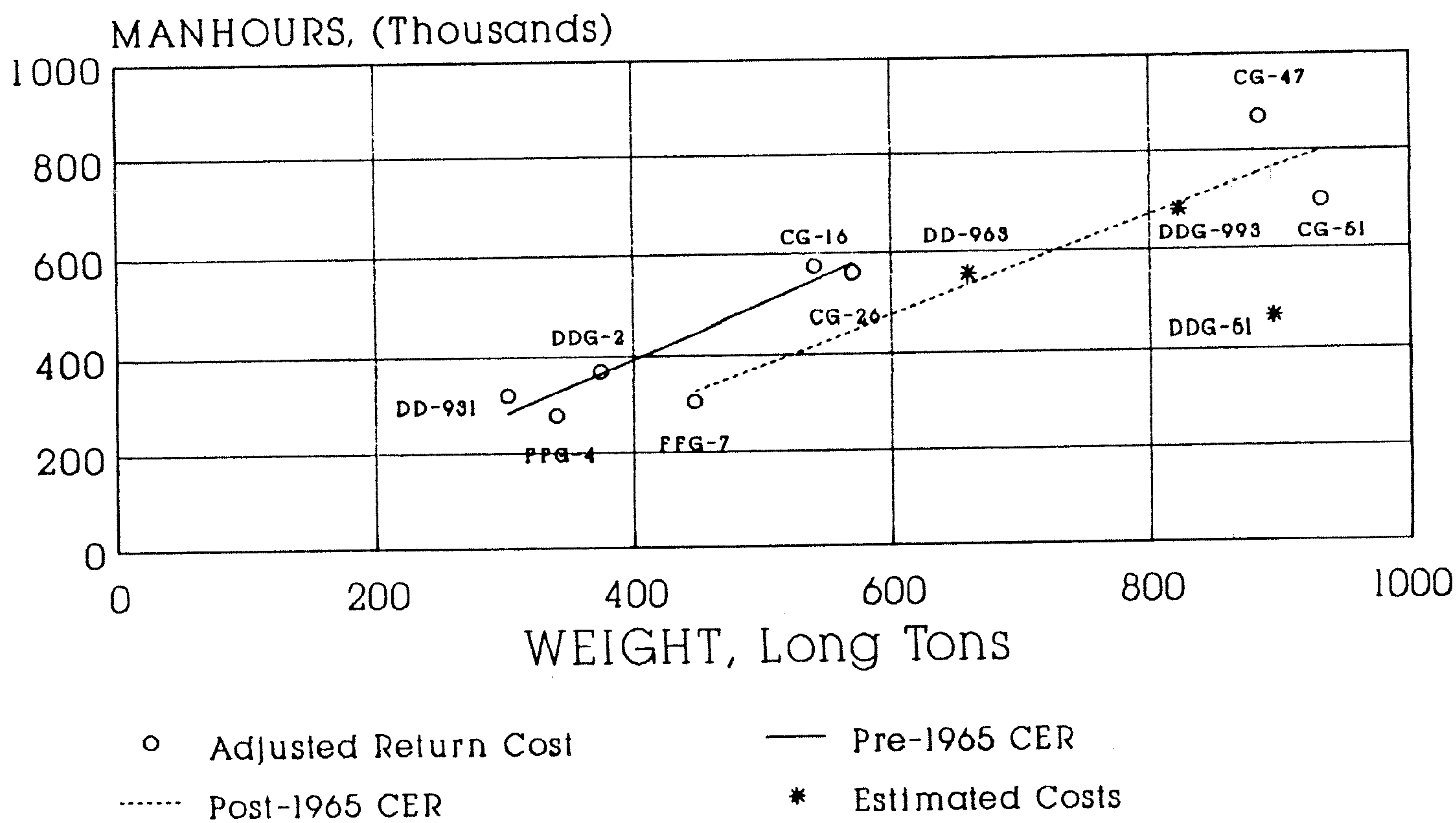


FIGURE 3-47

The waste heat line includes the waste heat boilers and associated piping systems. One factor that could not be broken out is the effect of habitability standards on the data, although this was not anticipated to be a major driver on this group.

CER: $ = 10,664 WT + 185,500
Variable: Group 5A Weight
Application: Steam Heat
Adjusted r^2: .8272, 5 points

CER: $ = 34,120 WT - 1,148,000
Variable: Group 5A Weight
Application: Waste Heat
Adjusted r^2: .871, 3 points

CER: $ = 7,890 WT + 1,797,000
Variable: Group 5A Weight
Application: Electric Heat
Adjusted r^2: N/A, 2 points

LABOR FACTOR: The man-hours for Group 5A as a function of weight fall into the same major categories: steam heat systems, electric systems, and waste heat derived heat systems. The post-1965 electric heat line reflects the relative simplicity associated with installation of this equipment.

CER: MH = 1,403 WT + 27,050
Variable: Group 5A Weight
Application: Steam Heat
Adjusted r^2: .8532, 5 points

CER: MH = 454 WT + 64,820
Variable: Group 5A Weight
Application: Electric Heat
Adjusted r^2: N/A, 2 points

CER: MH = 566 WT + 163,850
Variable: Group 5A Weight
Application: Waste Heat Systems
Adjusted r^2: .27,4 points

See Figures 3-48 and 3-49 for graphs of data points.

Group 5B Fluid Systems

This group includes plumbing, firemain, drainage, ballast, freshwater, steam, compressed air and fuel systems.

MATERIAL FACTOR: The components of Group 5B are functions of several different ship parameters, such as volume (firemain), length x beam (L x B) (drainage and ballast), complement (plumbing and freshwater), aircraft (fuel), and others. Group cost as a function of volume yielded the best correlation, particularly for post-1965 ships. The algorithm plotted for early ships represents only steam vessels with pre-1965 habitability standards for plumbing and freshwater systems. Of these the FFG-4 has prairie masker while the rest do not and the CG-26 and FFG-4 have one helicopter, which requires an additional fuel system on board. These differences do not seem to make a marked difference when the cost is derived as a function of either group weight or ship volume. The post-1965 algorithm represents gas turbine vessels with no steam auxiliary systems and generally includes prairie masker and extensive "clean" or compensated ballast systems, and except for DDG-51, two helicopters. The gas turbine ships also require more sophisticated fuel treatment systems.

CER: \$ = 3.1 Vol + 1,121,000
Variable: Total Ship Volume
Application: Pre-1965 Technology
Adjusted r^2: .911, 5 points

ENVIRONMENTAL SYSTEMS
GROUP 5A
MATERIAL COSTS

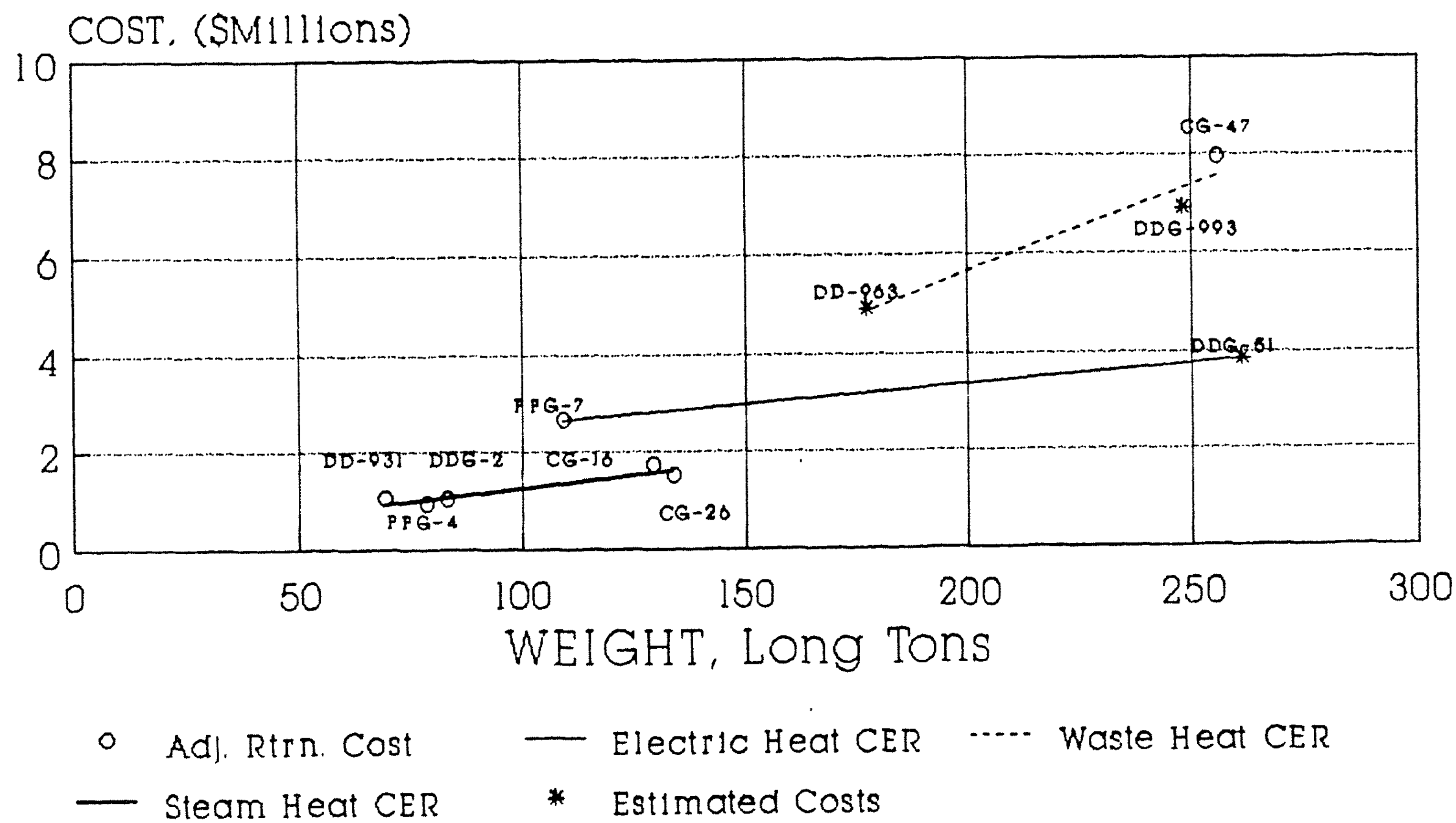


FIGURE 3-48

ENVIRONMENTAL SYSTEMS
GROUP 5A
LABOR

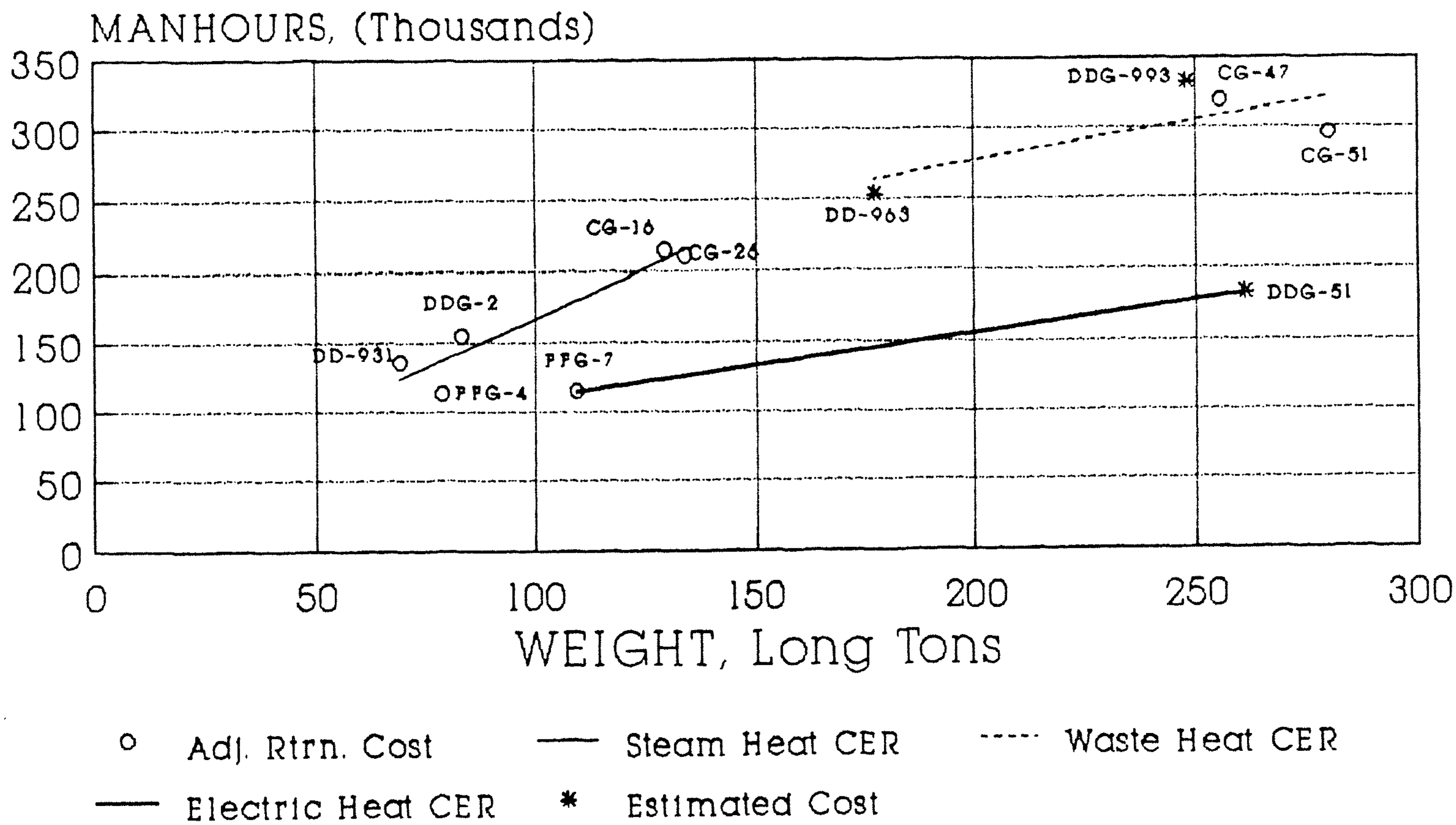


FIGURE 3-49

OR

CER:	$\$ = 74{,}200\ (WT)^{0.682}$
Variable:	Group 5 Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.926, 5 points

CER:	$\$ = 8.15\ Vol + 3{,}623{,}000$
Variable:	Total Ship Volume
Application:	Post-1965 Technology
Adjusted r^2:	.6472, 4 points

OR

CER:	$\$ = 25{,}347\ WT + 2{,}922{,}000$
Variable:	Group 5B Weight
Application:	Post-1965 Technology
Adjusted r^2:	.2575, 4 points

LABOR FACTOR: The considerations followed in developing the Group 5B material cost algorithms also apply to the labor curves; however, correlation with weight is best for man-hours. The pre-1965 algorithm is higher than the post-1965 due to the steam piping installation and more extensive pre-outfitting in the post-1965 ships.

CER:	$MH = 1{,}125\ WT - 31{,}300$
Variable:	Group 5B Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.9807, 5 points

CER:	$MH = 902\ WT - 34{,}530$
Variable:	Group 5B Weight
Application:	Post-1965 Technology
Adjusted r^2:	.6378, 5 points

See Figures 3-50 through 3-52 for graphs of data points.

FLUID SYSTEMS
GROUP 5B
MATERIALS COST

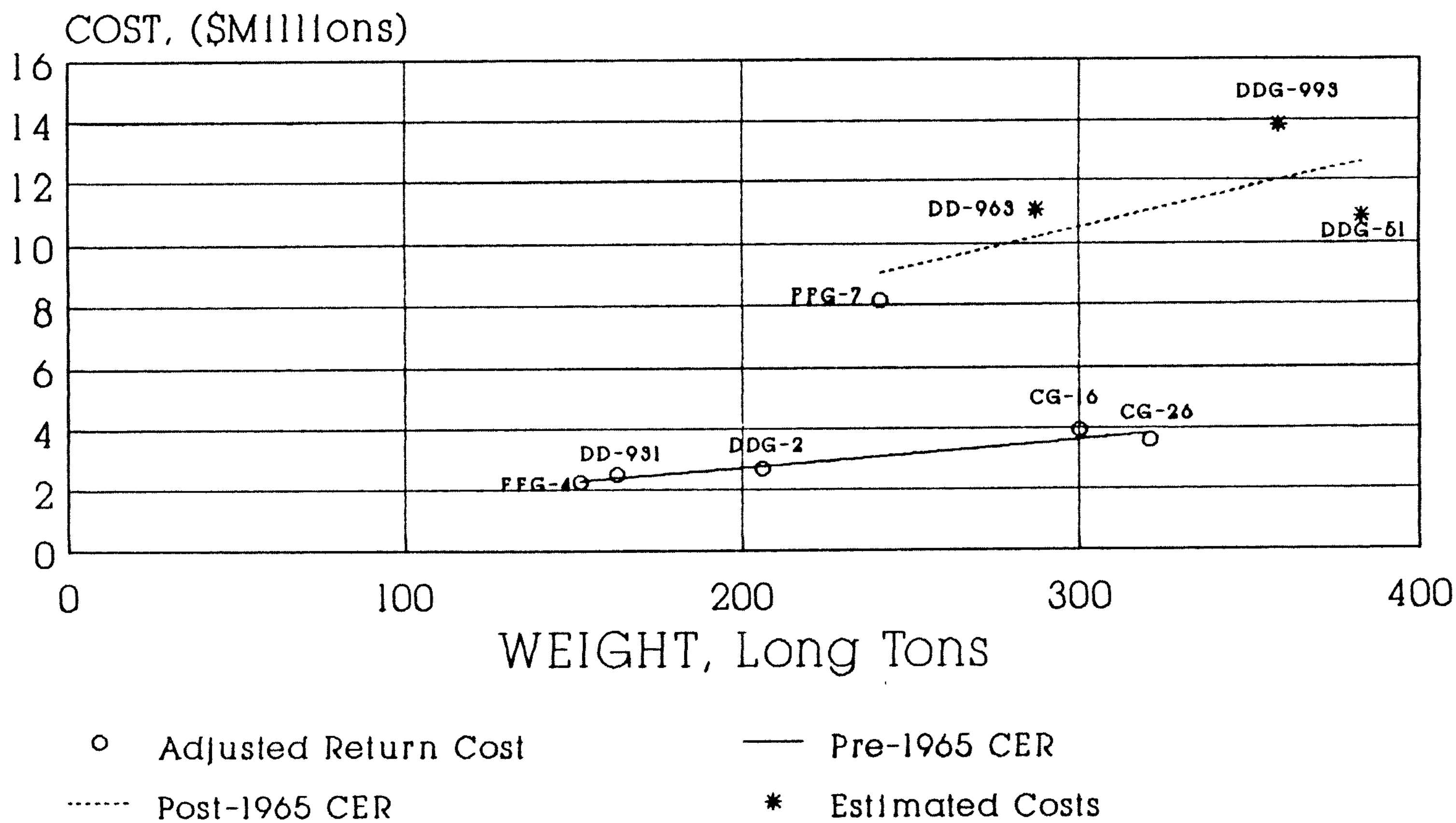


FIGURE 3-50

FLUID SYSTEMS
GROUP 5B
MATERIALS COST

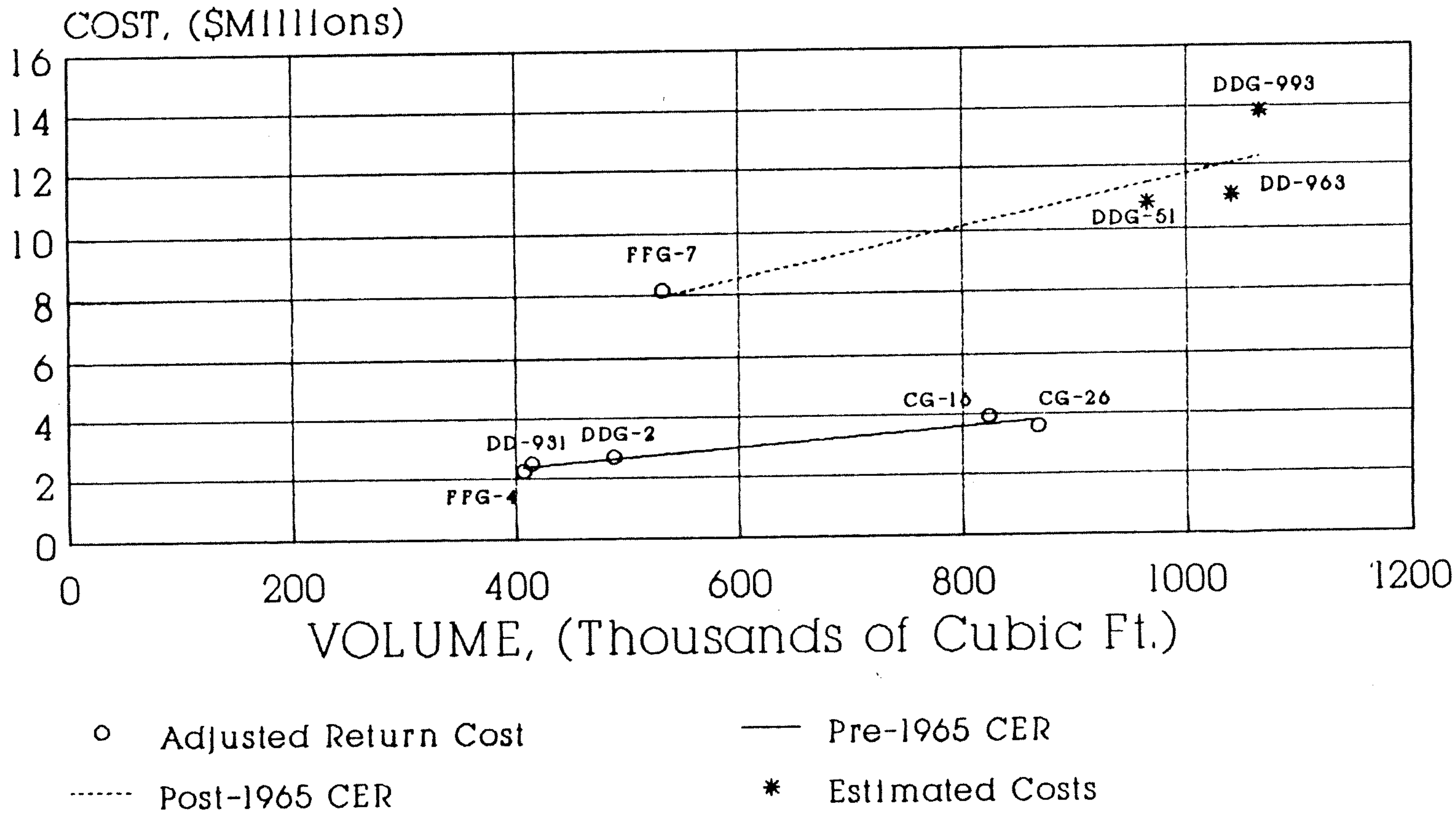


FIGURE 3-51

FLUID SYSTEMS
GROUP 5B
LABOR

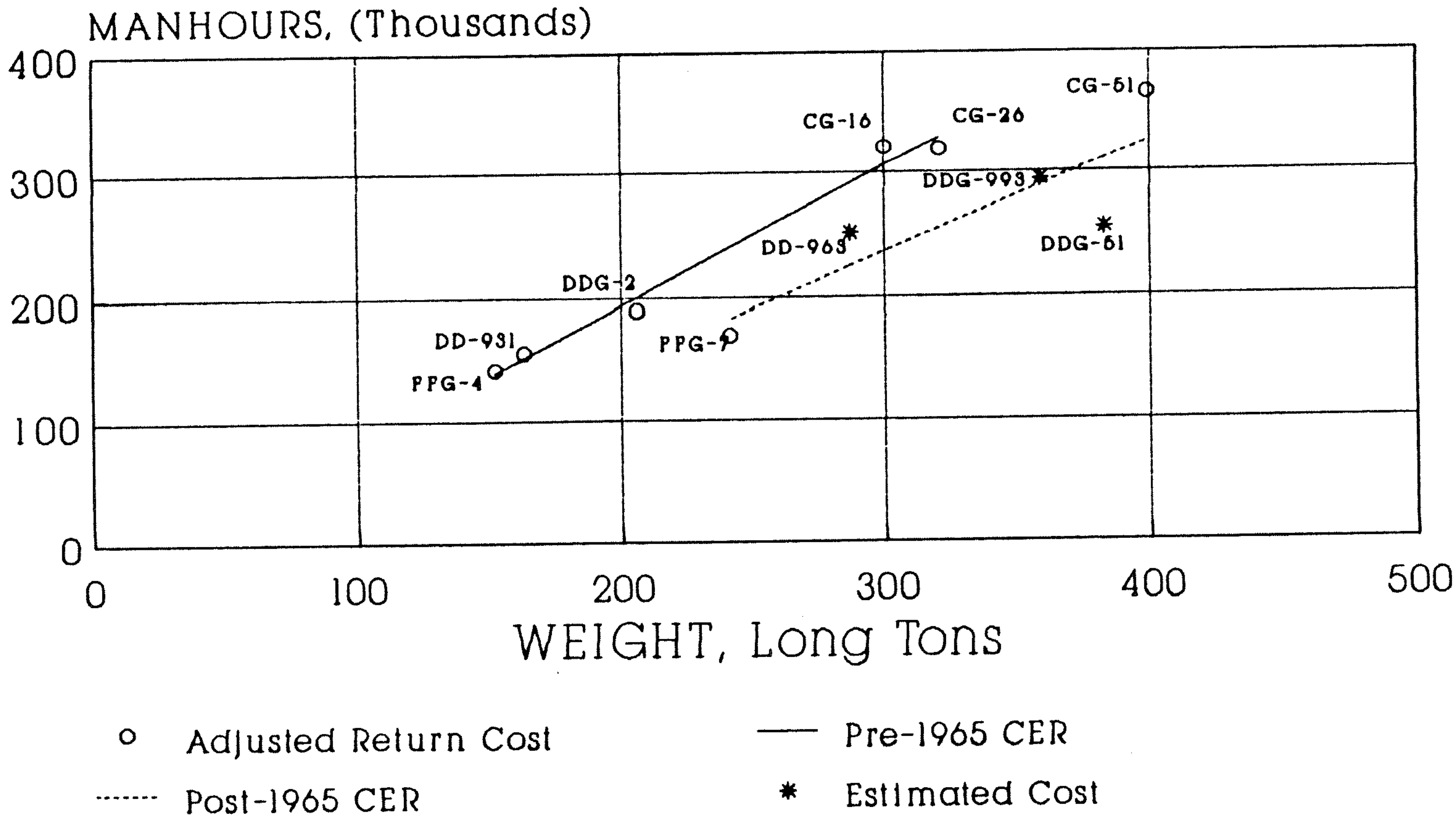


FIGURE 3-52

Group 5C - Maneuvering Systems

This group includes the steering system and rudders.

MATERIAL FACTOR: A number of geometrical parameters were evaluated to assess Group 5C costs. None provided as good correlation as weight. The single rudder ships are FFG-4, FFG-7, and CG-16, while all the others have two. Although it would be expected that twin rudder ships would be more expensive per ton, these data indicate that a single algorithm is satisfactory. DDG-51 is unusually high and has been excluded.

CER:	$\$ = 44{,}800\ [10^{0.02(WT)}]$
Variable:	Group 5C Weight
Application:	2-Rudder Ships
Adjusted r^2:	.908, 7 Points

CER:	$\$ = 39{,}980\ WT - 971{,}000$
Variable:	Group 5C Weight
Application:	1-Rudder Ships
Adjusted r^2:	N/A, 1 point

LABOR FACTOR: Man-hours are also a function of Group 5C weight with CG-26 and DD-931 as outliers on the 2-rudder algorithm. DD-931 has somewhat high man-hours for this group because of possible errors in the original classification of its weights. CG-16 is high for a single rudder ship and has been excluded because it cannot be explained.

CER:	$MH = 119.5\ WT + 4{,}160$
Variable:	Group 5C Weight
Application:	2-Rudder Ships
Adjusted r^2:	.7986, 6 points

OR

CER:	$MH = 685\ (WT)^{0.686}$
Variable:	Group 5C Weight
Application:	2-Rudder Ships
Adjusted r^2:	.842, 6 points

CER:	$MH = 392\ WT - 11{,}660$
Variable:	Group 5C Weight
Application:	1-Rudder Ship
Adjusted r^2:	N/A, 2 points

See Figures 3-53 and 3-54 for graphs of data points.

Group 5D Equipment Handling Systems

This group includes mooring systems, aircraft handling systems, elevators, stabilizers and other miscellaneous auxiliary machinery.

It is generally difficult to find algorithms for group 5D material or labor costs because these components are characteristically vendor supplied, highly specialized, and individually tailored for each ship.

MATERIAL FACTOR: Items such as elevators and windlasses can vary greatly in cost and weight between different vendors. A major factor of this vendor material cost is the Navy's software requirements for the vendors on top of the shipyard software requirements (Groups 8 and 9). Although the original version of the model did not identify an algorithm for this group, it is possible to now fit a rough relationship because of recent data and estimates. A separate algorithm is provided for more recent ships having embarked aircraft. CG-26 has a single helicopter with a relatively primitive support facility; therefore, it is lower than the twin helo ships and has been excluded from the current technology group.

MANEUVERING SYSTEMS
GROUP 5C
MATERIALS COST

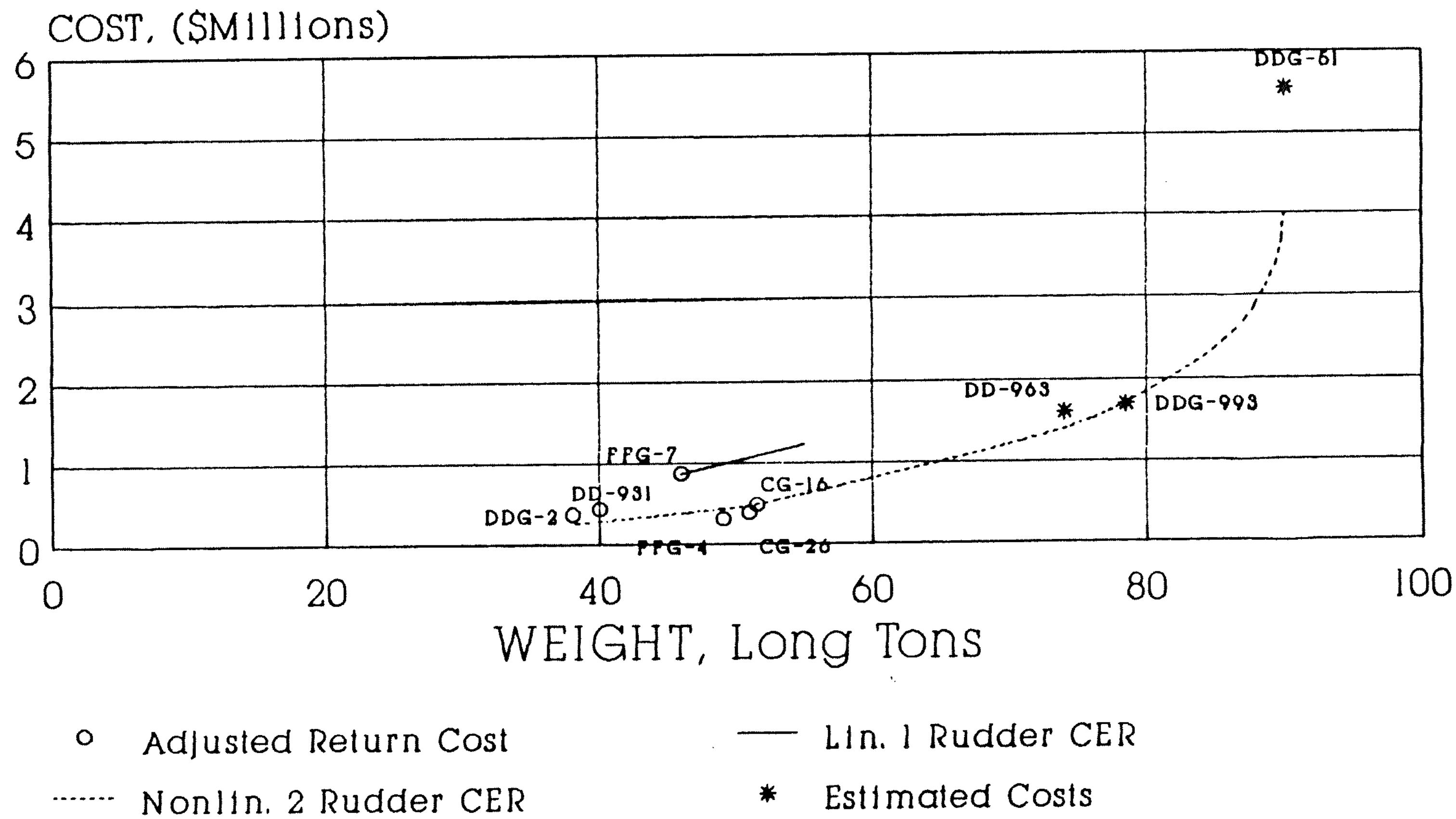


FIGURE 3-53

MANEUVERING SYSTEMS
GROUP 5C
LABOR

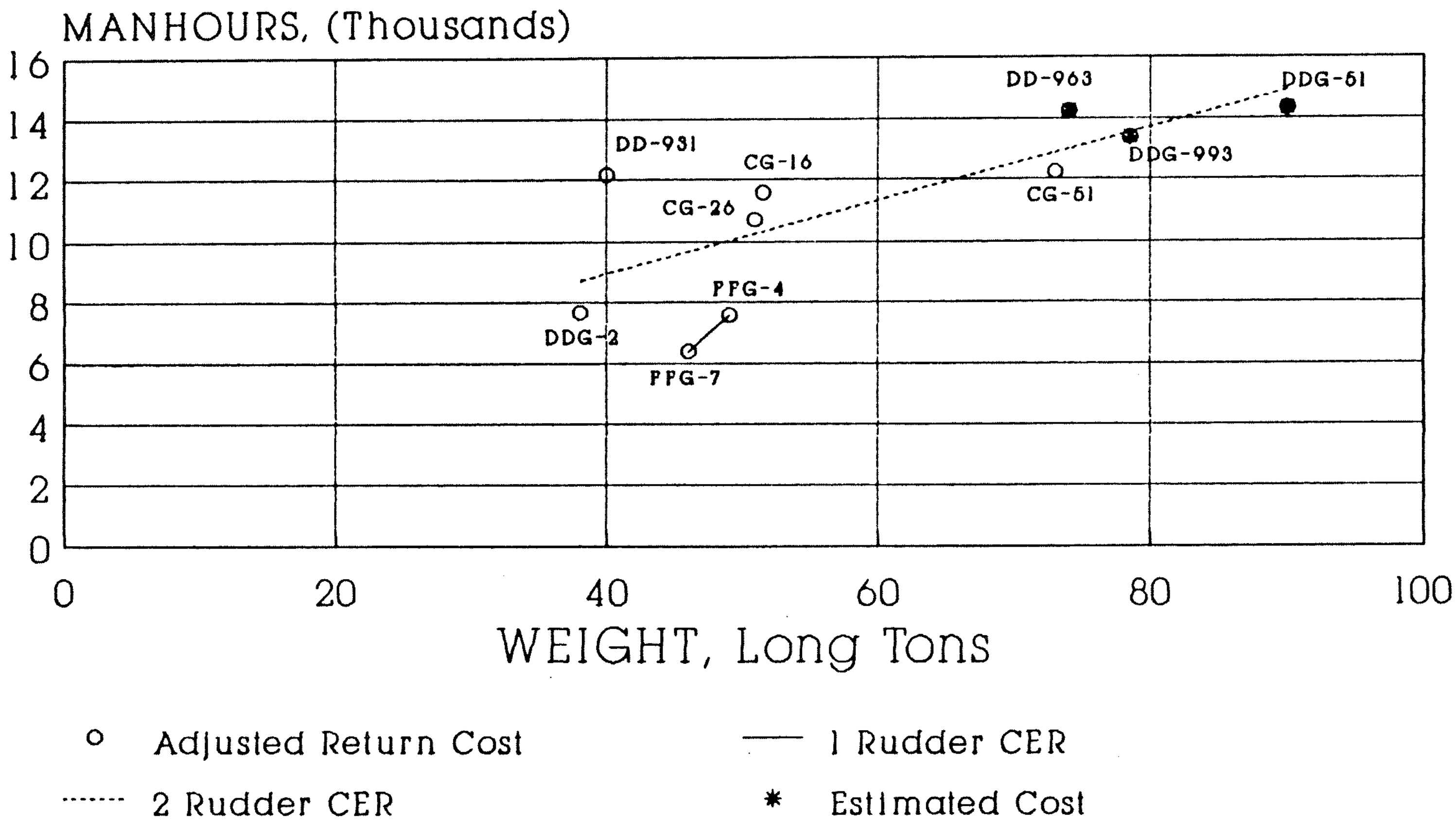


FIGURE 3-54

CER:	$ = 15,223 WT - 277,000
Variable:	Group 5D Weight
Application:	All ships
Adjusted r^2:	.8288, 9 points

CER:	$\$ = 15,500\ (WT)^{0.977}$
Variable:	Group 5D Weight
Application:	Current Technology (air-capable ships)
Adjusted r^2:	.891, 4 points

LABOR FACTOR: An algorithm was determined as a function of vessel length, using actual return costs only, since all the estimated values were either very low or high.

CER:	MH = 70.7 Length - 46,870
Variable:	Total Ship Length
Application:	All
Adjusted r^2:	.6532, 7 points

See Figures 3-55 and 3-56 for graphs of data points.

EQUIPMENT HANDLING SYSTEMS
GROUP 5D
MATERIALS COST

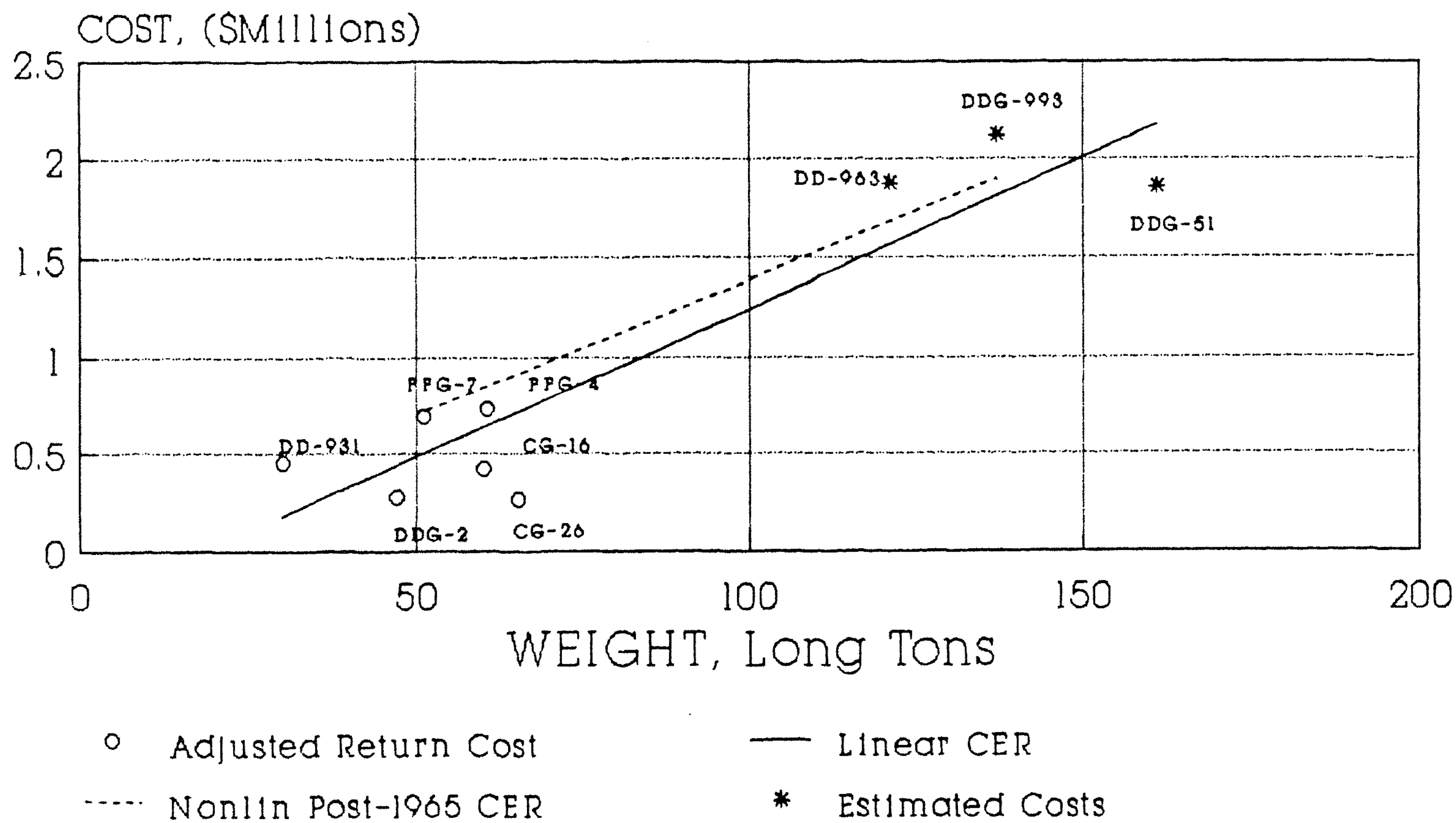


FIGURE 3-55

EQUIPMENT HANDLING SYSTEMS
GROUP 5D
LABOR

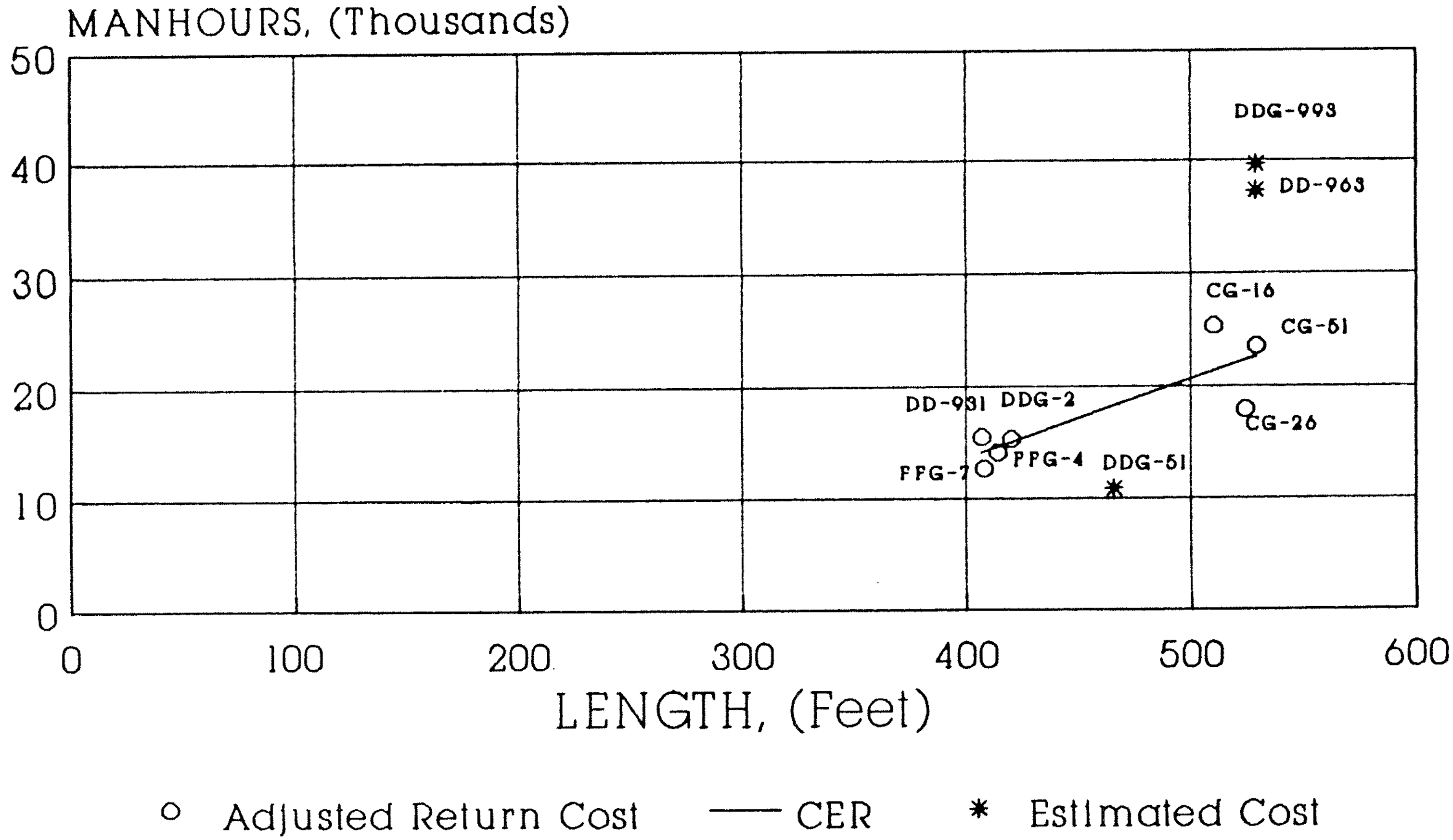


FIGURE 3-56

3.4.6 Group 6 - Outfit and Furnishings

Group 6 is comprised of the following two-digit cost groups:

6A Hull Fittings
6B Nonstructural Subdivisions
6C Preservation
6D Ship Support
6E Habitability

The algorithms for the one-digit Group 6 are discussed below:

MATERIAL FACTOR: For the two-digit Group 6 material costs, several different parameters emerged as the most appropriate variable depending on the category of outfit being costed. For example, Group 6B graphs best as a function of the total ship volume while Group 6C reflects the impact of the ships dimensions (L x B). Despite these differences, for the aggregate Group 6, the independent variables of either complement or length x beam (L x B) produce the best fit. For both variables, there are two algorithms reflecting the change in habitability standards, i.e., pre-1965 and post-1965 trends.

CER:	\$ = 7850 COMP - 278,000
Variable:	Total Ship Complement
Application:	Pre-1965 Standards
Adjusted r^2:	.7915, 5 points

CER:	\$ = 20,000 COMP + 12,600
Variable:	Total Ship Complement
Application:	Post-1965 Standards
Adjusted r^2:	.989, 6 points

OR

CER:	$\$ = 220\ (L \times B)^{0.929}$
Variable:	Length x Beam
Application:	Pre-1965 Standards
Adjusted r^2:	.818, 5 points

CER:	$\$ = 33\ (L \times B)^{1.185}$
Variable:	Length x Beam
Application:	Post-1965 Standards
Adjusted r^2:	.884, 5 points

LABOR FACTOR: As with the Group 6 material costs the Group 6 two-digit level labor functions used different parameters. For the total Group 6 man-hours, the vessel's total group weight can be used to estimate man-hours. Only one algorithm is required as all the return costs and estimated costs fall close to the trend line.

CER:	MH = 1,261 WT - 18,350
Variable:	Group 6 Weight
Application:	All
Adjusted:	.9635, 11 Points

See Figures 3-57 and 3-58 for graphs of data points.

Group 6A Hull Fittings

This group includes hull fittings, boats, liferafts and associated gear.

MATERIAL FACTOR: Group 6A material costs as a function of weight fall into two algorithms, one for current (post-1965) technology and one for earlier (pre-1965) technology. Most of the equipment is standardized in type and weight for destroyers.

OUTFIT AND FURNISHINGS
GROUP 6
MATERIALS COST

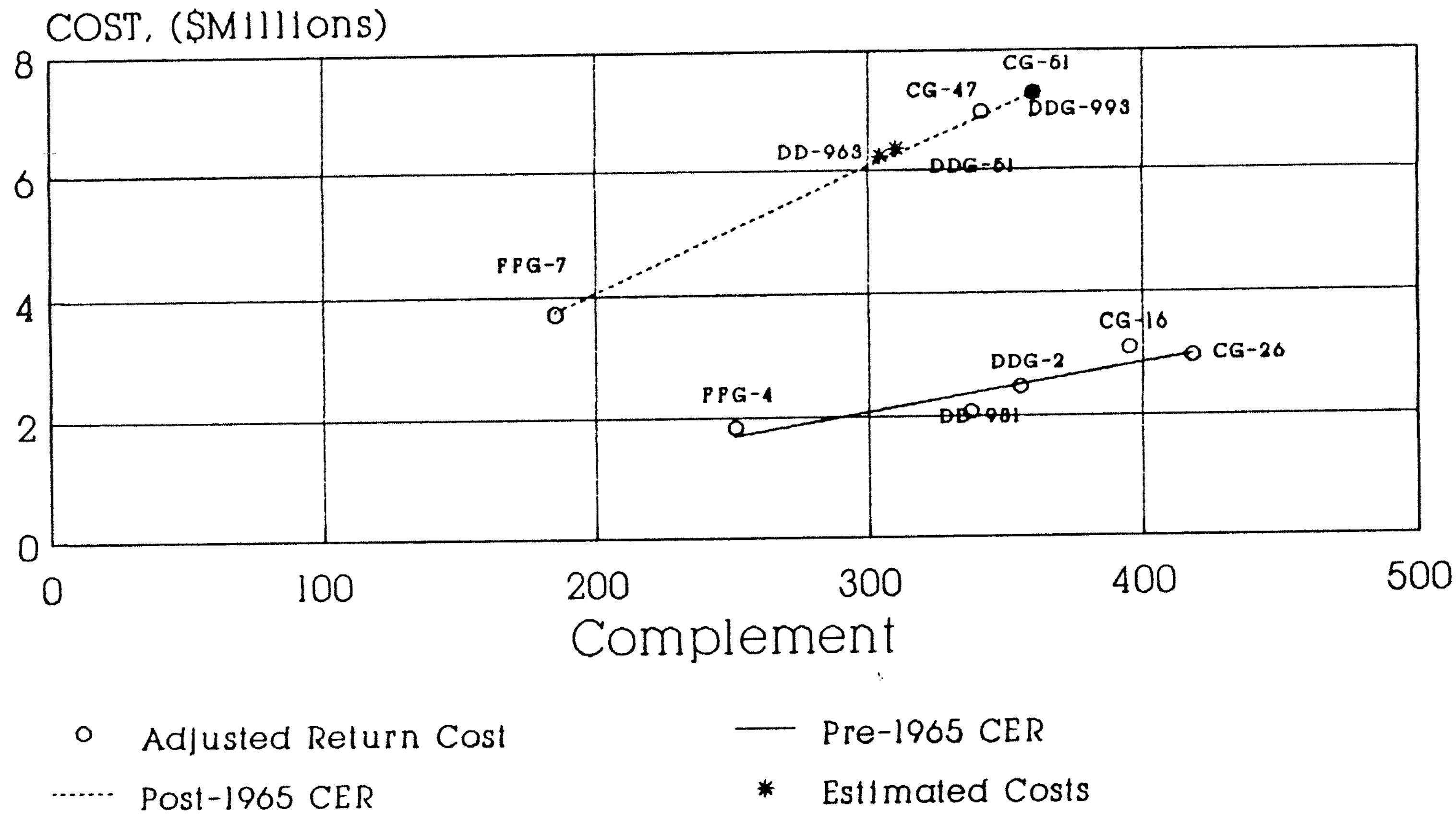


FIGURE 3-57

OUTFIT AND FURNISHINGS
GROUP 6
LABOR

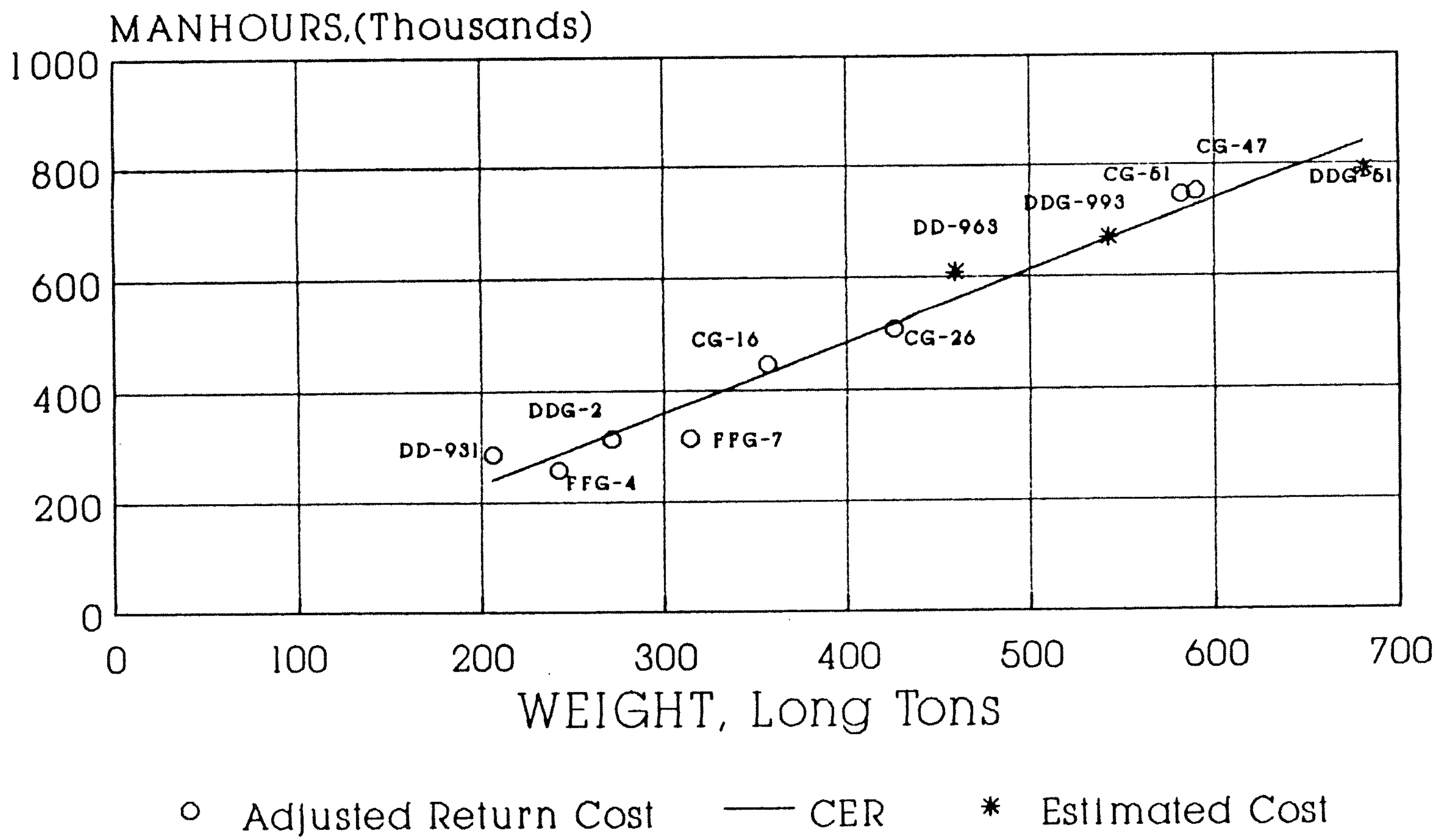


FIGURE 3-58

CER: $ = 2,450 WT + 291,000
Variable: Group 6A Weight
Application: Pre-1965 Technology
Adjusted r^2: .6761, 4 points

CER: $ = 23,800 WT - 94,400
Variable: Group 6A Weight
Application: Post-1965 Technology
Adjusted r^2: .9579, 5 points

LABOR FACTOR: Two sets of algorithms for 6A labor are provided to estimate the man-hours based on the length x beam of the ships: one set being linear and the other non-linear. In actuality, one algorithm for both pre-and post-1965 would be adequate.

CER: MH = 1.98 (L x B) -15,830
Variable: Length x Beam
Application: Pre-1965 Technology
Adjusted r^2: .913, 5 points

OR

CER: $MH = .0056 (L \times B)^{1.54}$
Variable: Length x Beam
Application: Pre-1965 Technology
Adjusted r^2: .924, 5 points

CER: MH = 2.07 (L x B) -19,120
Variable: Length x Beam
Application: Post-1965 Technology
Adjusted r^2: .8856, 5 points

OR

CER: $MH = .0029 (L \times B)^{1.6}$
Variable: Length x Beam
Application: Post-1965 Technology
Adjusted r^2: .947, 5 points

See Figures 3-59 and 3-60 for graphs of data points. It should be noted that the graphs only show plots for the linear relationship, since the non-linear curves are too close to the linear curves to differentiate between them.

Group 6B Non-structural Subdivisions

This group includes ladders, non-structural bulkheads and doors, sheathing, etc.

MATERIAL FACTOR: Two algorithms are required for Group 6B material costs to cover pre-1965 habitability standards and post-1965 habitability standards and to account for the more extensive use of non-metallic bulkheads in the later ships. Several parameters were investigated to determine the best fit, which proved to be ship volume. Cost versus group weight also produced a satisfactory algorithm. For the pre-1965 standard algorithm, there are no significant variations. The post-1965 standards are anchored by the FFG-7 and CG-51.

CER:	$ = .19 (VOL) + 189,000
Variable:	Total Ship Volume
Applicaton:	Pre-1965 Habitability
Adjusted r^2:	.7468, 5 points

CER:	$ = 1.13 (VOL) + 132,600
Variable:	Total Ship Volume
Application:	Post-1965 Habitability
Adjusted r^2:	.6535, 5 points

CER:	$ = 2,523 (WT) + 174,000
Variable:	Group 6B Weight
Application:	Pre-1965 Habitability
Adjusted r^2:	.7356, 5 points

HULL FITTINGS
GROUP 6A
MATERIALS COST

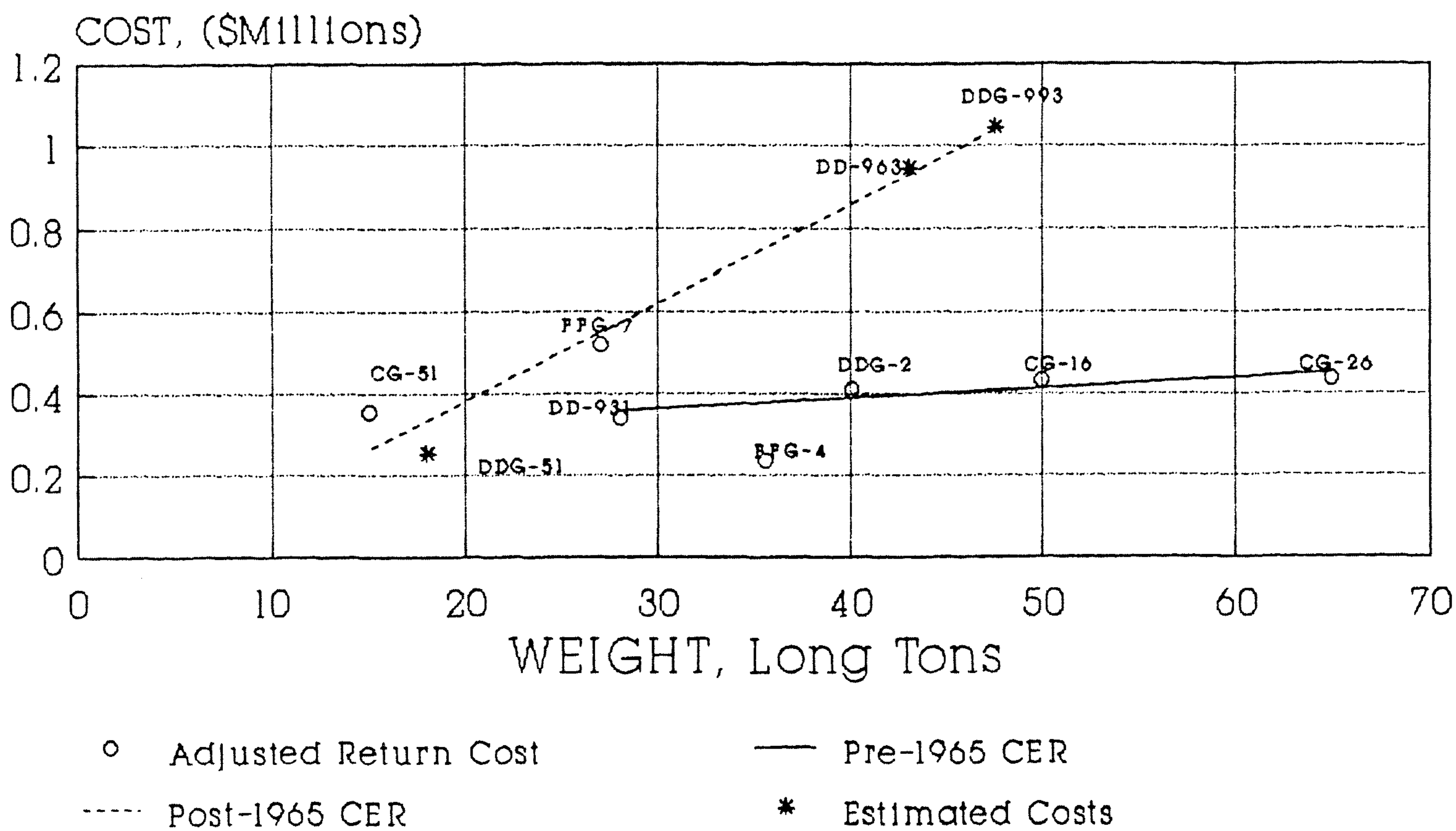


FIGURE 3-59

HULL FITTINGS
GROUP 6A
LABOR

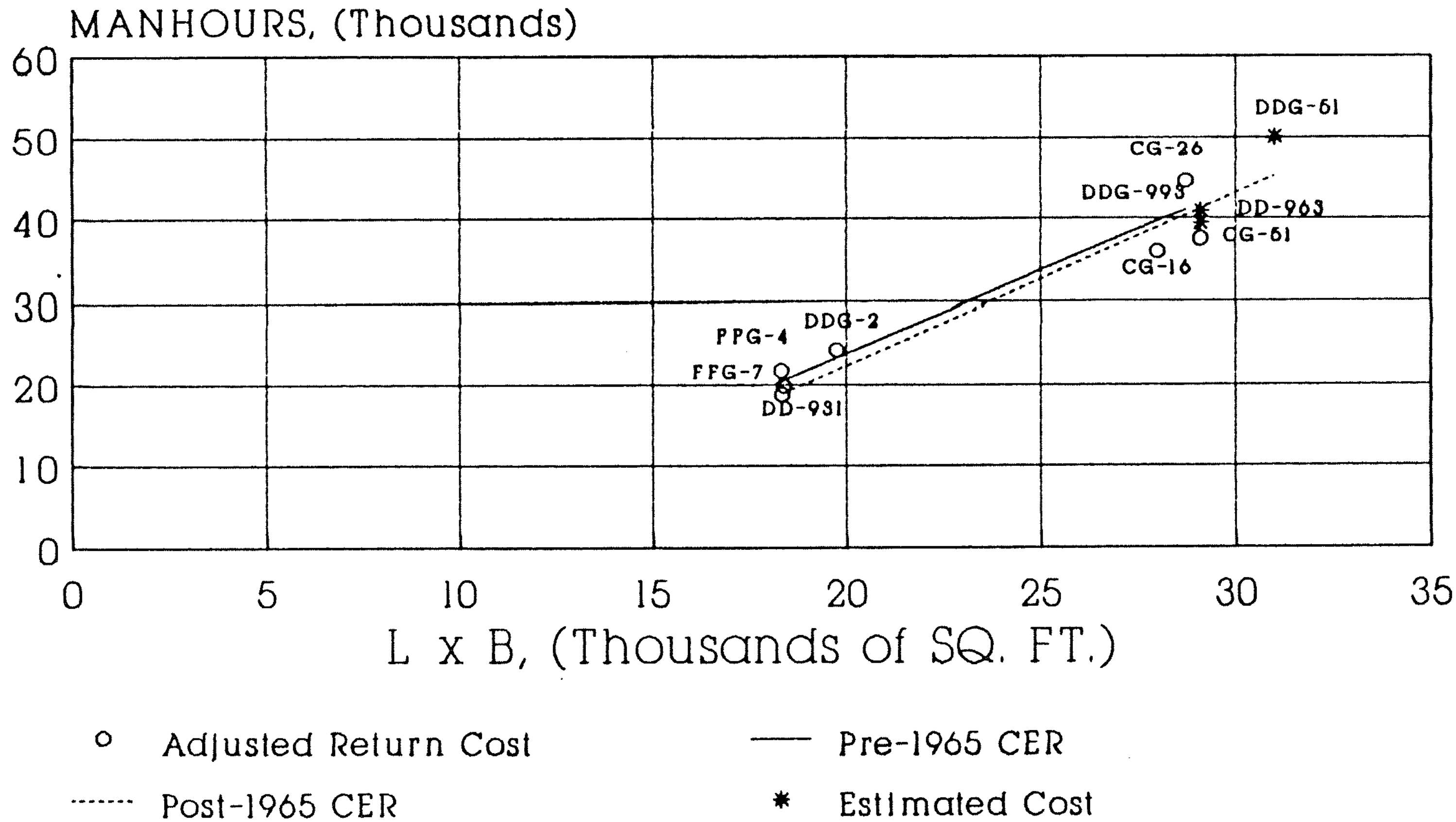


FIGURE 3-60

CER: $ = 14,786 (WT) - 170,000
Variable: Group 6B Weight
Application: Post-1965 Habitability
Adjusted r2: .4408, 4 points

OR

CER: $ = 1.13 (VOL) + 132,600
Variable: Total Ship Volume
Application: Post-1965 Habitability
Adjusted r2: .773, 5 points

LABOR FACTOR: For the Group 6B man-hours, several parameters were tried with the most satisfactory algorithm being man-hours as a function of the group weight. For the pre-1965 habitability standard ships FFG-4 is an outlier, possibly as a result of the way weights were cataloged. The post-1965 algorithm reflects increased standards for compartmentation, sheathing and the like. The DD-963 and DDG-993 were outliers on this algorithm, since they were estimates.

CER: MH = 222 WT + 57, 150
Variable: Group 6B Weight
Application: Pre-1965 Technology
Adjusted r2: .4382, 4 points

CER: MH = 94 WT + 81,450
Variable: Group 6B Weight
Application: Post-1965 Technology
Adjusted r2: .035, 3 points

See Figures 3-61 through 3-63 for graphs of data points.

Group 6C <u>Preservation</u>

This group includes painting, deck covering, and hull insulation.

NON-STRUCTURAL SUBDIVISIONS
GROUP 6B
MATERIALS COST

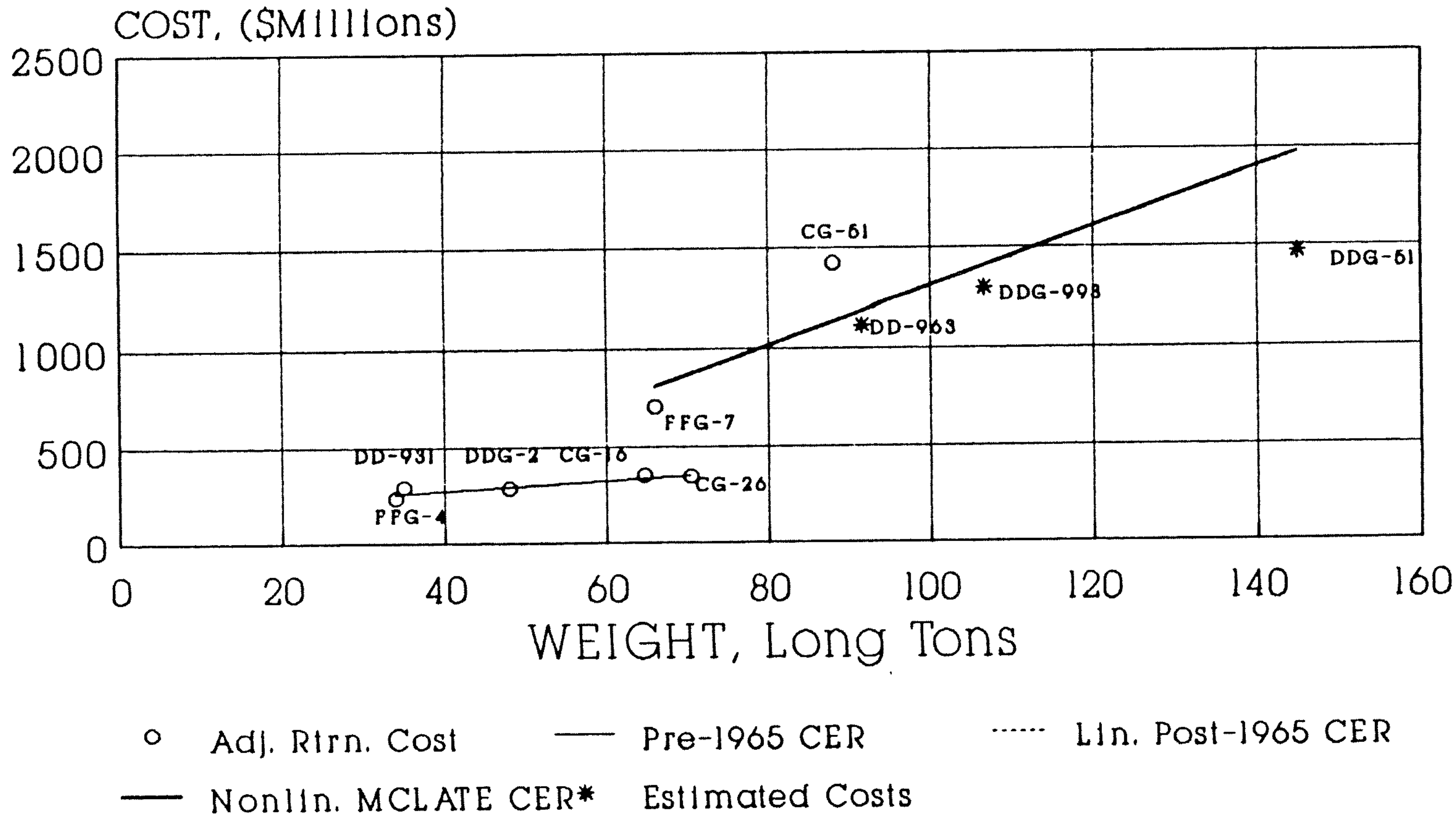


FIGURE 3-61

NON-STRUCTURAL SUBDIVISIONS
GROUP 6B
MATERIALS COST

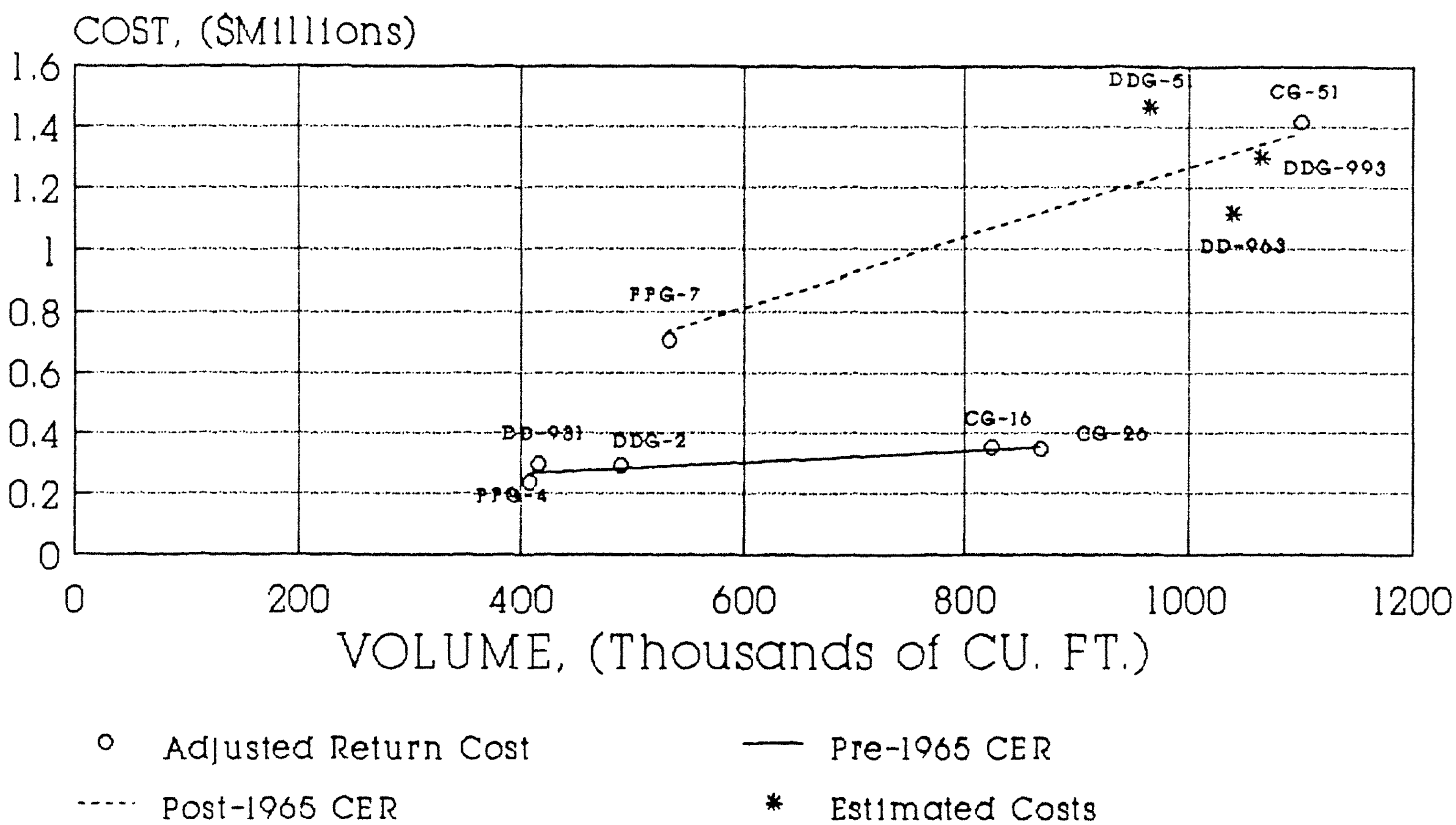


FIGURE 3-62

NON-STRUCTURAL SUBDIVISIONS
GROUP 6B
LABOR

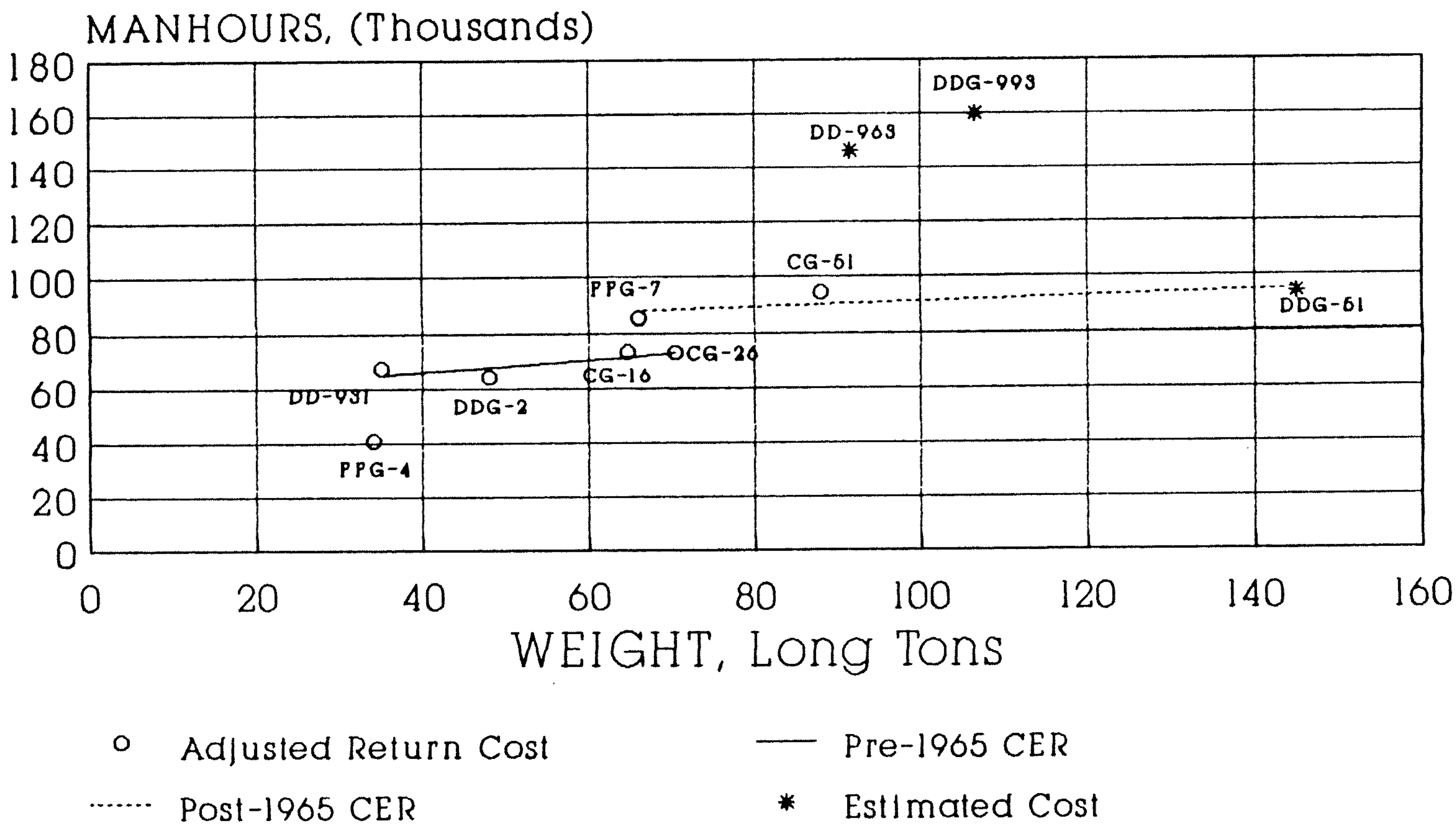


FIGURE 3-63

MATERIAL FACTOR: The best independent variable to estimate Group 6C costs is weight. Painting (SWBS Element 631) is usually a function of the Group 1 total weight, or ship volume while deck covering is a function of the length x beam (L x B) and the habitability standards under which the ship was constructed. SWBS Element 633, hull insulation, is also partially a function of the habitability standard and volume; therefore, it is logical that material costs as a function of (L x B) fall into two algorithms -- earlier versus current habitability standards. The current standards include the use of better thermal and acoustic insulation (higher HVAC standards) and lighter weight, more expensive carpeting and the accommodations instead of tile. The reason for FFG-4 being lower in material costs is a lower figure for sonar sound damping insulation. Also apparent is the strong correlation of costs with group weight as provided in the algorithms as a function of weight. The CG-51 is an outlier because of the use of an expensive, advanced deck covering.

CER:	$\$ = 46.3\ (L \times B) - 320{,}000$
Variable:	Length x Beam
Application:	Pre-1965 Technology
Adjusted r^2:	.8682, 5 points

CER:	$\$ = 106\ (L \times B) - 1{,}294{,}000$
Variable:	Length x Beam
Application:	Post-1965 Technology
Adjusted r^2:	.7999, 4 points

OR

CER:	$\$ = .19\ (L \times B)^{1.151}$
Variable:	Length x Beam
Application:	Post-1965 Technology
Adjusted r^2:	.936, 4 points

CER:	\$ = 155 (L x B) -1,892,000
Variable:	Length x Beam
Application:	Advanced Coverings
Adjusted r^2:	N/A

OR

CER:	\$ = 8,832 WT - 172,000
Variable:	Group 6C Weight
Application:	All
Adjusted r^2:	.9262, 9 points
CER:	\$ = 12,386 WT - 241,500
Variable:	Group 6C Weight
Application:	Advanced Coverings
Adjusted r^2:	N/A

LABOR FACTOR: Using the independent variable of group weight yields an algorithm with a higher coefficient of determination when dividing the data into pre-1965 and post-1965 technology groups, possibly as a result of less labor intensive painting methods used recently.

CER:	MH = 1,954 WT - 24,140
Variable:	Group 6C Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.8566, 5 points
CER:	MH = 2,378 WT - 110,000
Variable:	Group 6C Weight
Application:	Post-1965 Technology
Adjusted r^2:	.9021, 5 points

OR

CER:	MH = 230 (WT) 1.386
Variable:	Group 6C Weight
Application:	Post-1965 Technology
Adjusted r^2:	.955, 5 points

See Figures 3-64 through 3-66 for graphs of data points.

PRESERVATION
GROUP 6C
MATERIALS COST

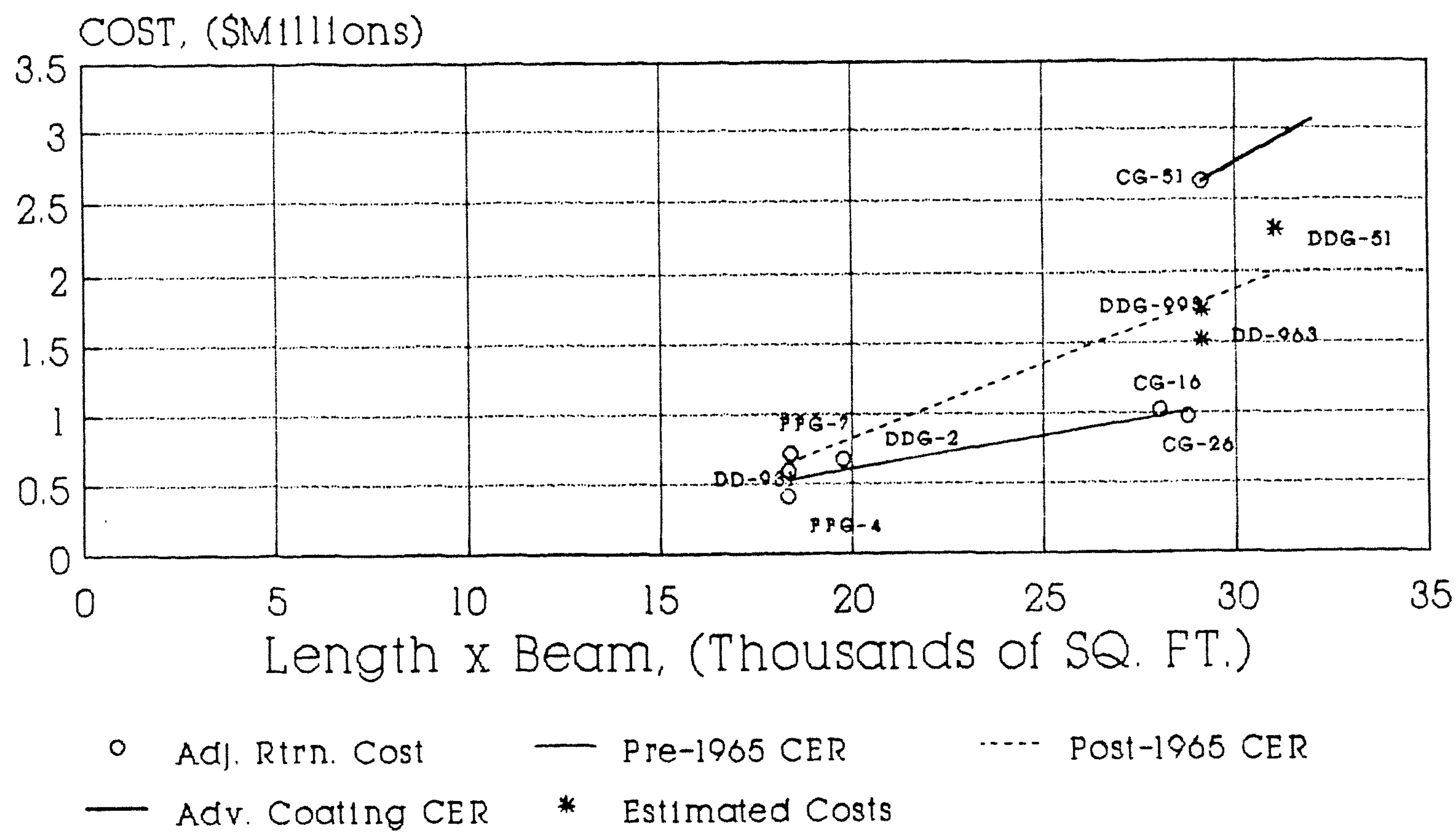


FIGURE 3-64

PRESERVATION
GROUP 6C
MATERIALS COST

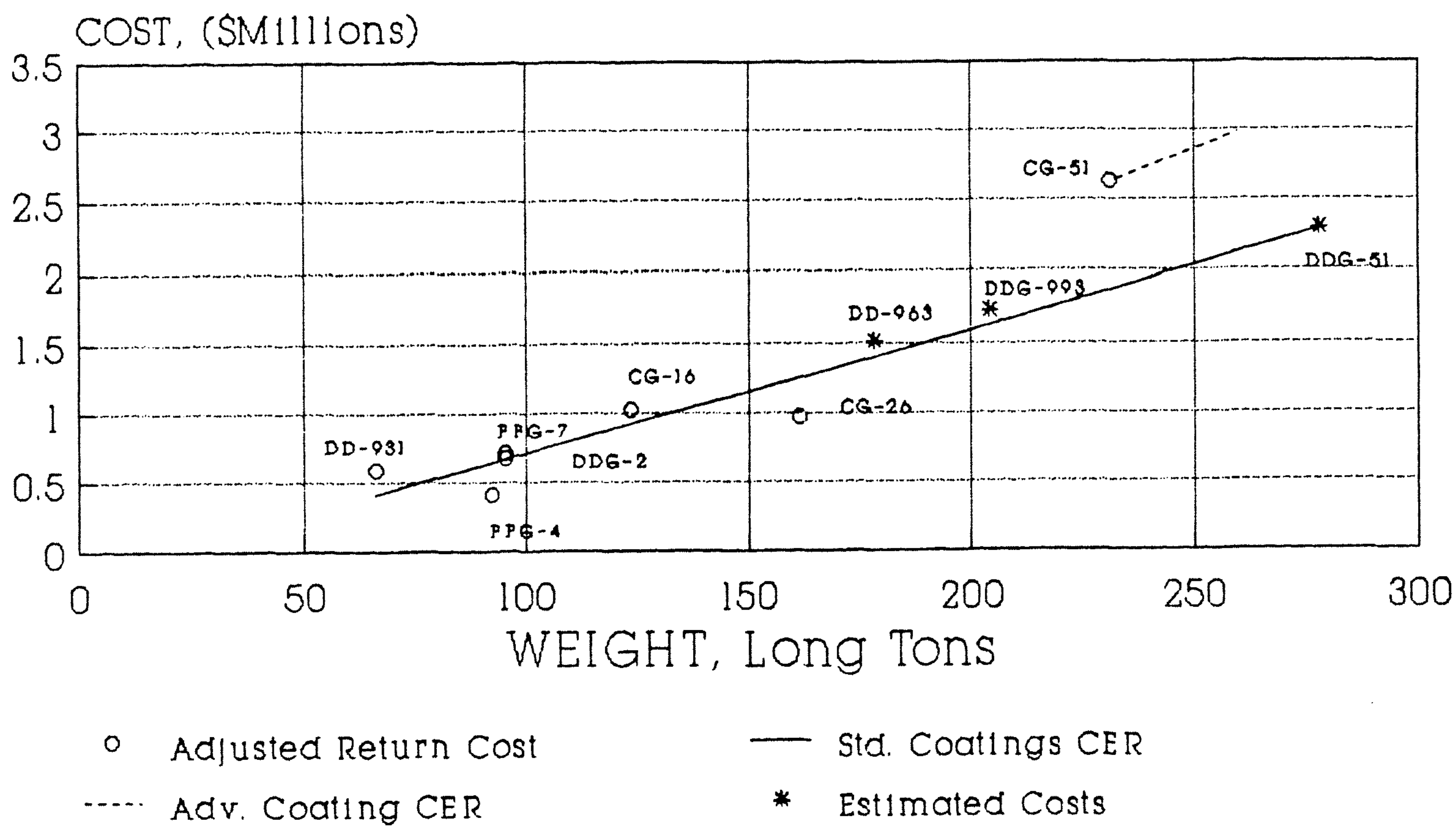


FIGURE 3-65

PRESERVATION
GROUP 6C
LABOR

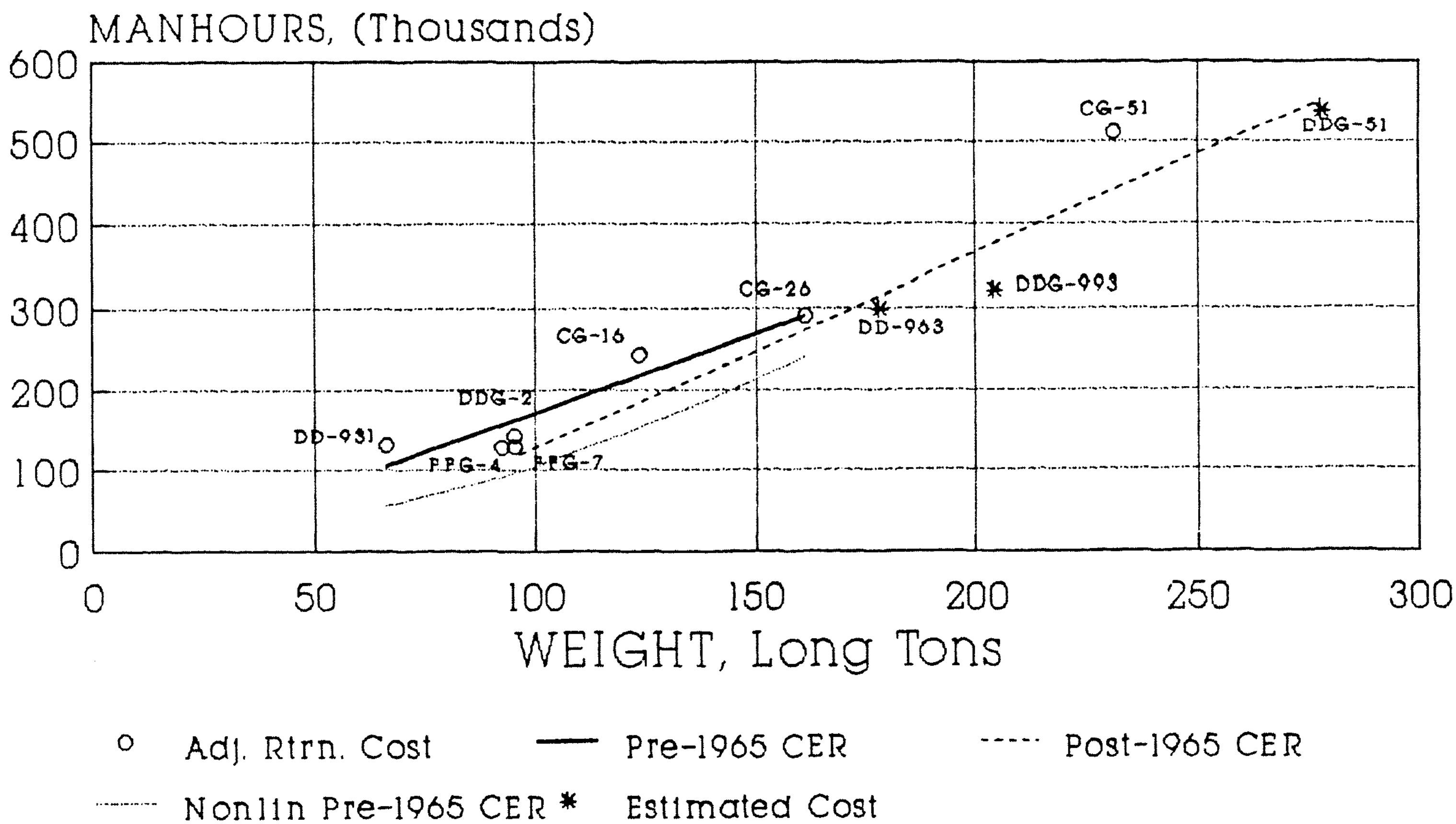


FIGURE 3-66

Group 6D Ship Support

This group includes storerooms and equipment for utility spaces and workshops. A utility space is defined as any space that is required aboard the ship to provide for the basic necessities of the crew.

MATERIAL FACTOR: The algorithm for Group 6D material costs as a function of complement covers two habitability standards -- 1956 to 1965 standards and post-1965 to the latest habitability standards. The new standards include the heavy VIDMAR storage cabinets, improved facilities for the crew, and increased locker and stowage space per man. Two different variables are suggested for this group. Pre-1965 ships costs correlate best with weight while post-1965 ships correlate best with complement.

CER:	\$ = 3809 WT + 106,000
Variable:	Group 6D Weight
Application:	Pre-1965 Habitability
Adjusted r^2:	.7488, 4 points

CER:	\$ = 1,120 COMP + 278,200
Variable:	Complement
Application:	Post-1965 Habitability
Adjusted r^2:	.4198, 5 points

LABOR FACTOR: For Group 6D man-hours, the independent variable of cubic number is sufficient for a good estimate. This algorithm includes all ships with the exception of the DDG-993 which is high and does not correlate well with the return costs for CG-51 and the DDG-963 estimate.

CER:	MH = 2.3 CN + 30,500
Variable:	Cubic Number
Application:	All
Adjusted r^2:	.8973,9 points

See Figures 3-67 through 3-70 for graphs of data points.

SHIP SUPPORT
GROUP 6D
MATERIALS COST

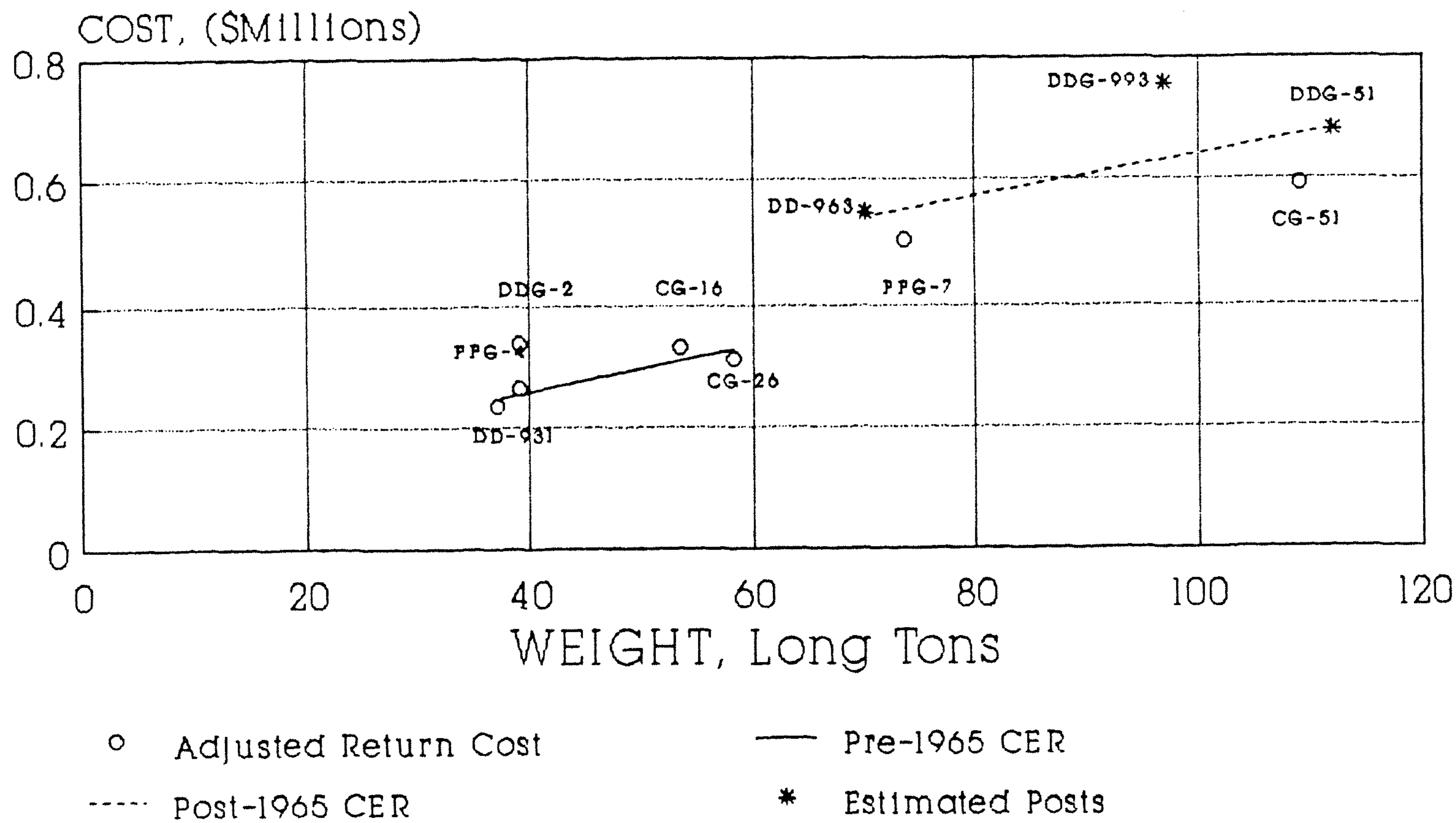


FIGURE 3-67

SHIP SUPPORT
GROUP 6D
MATERIALS COST

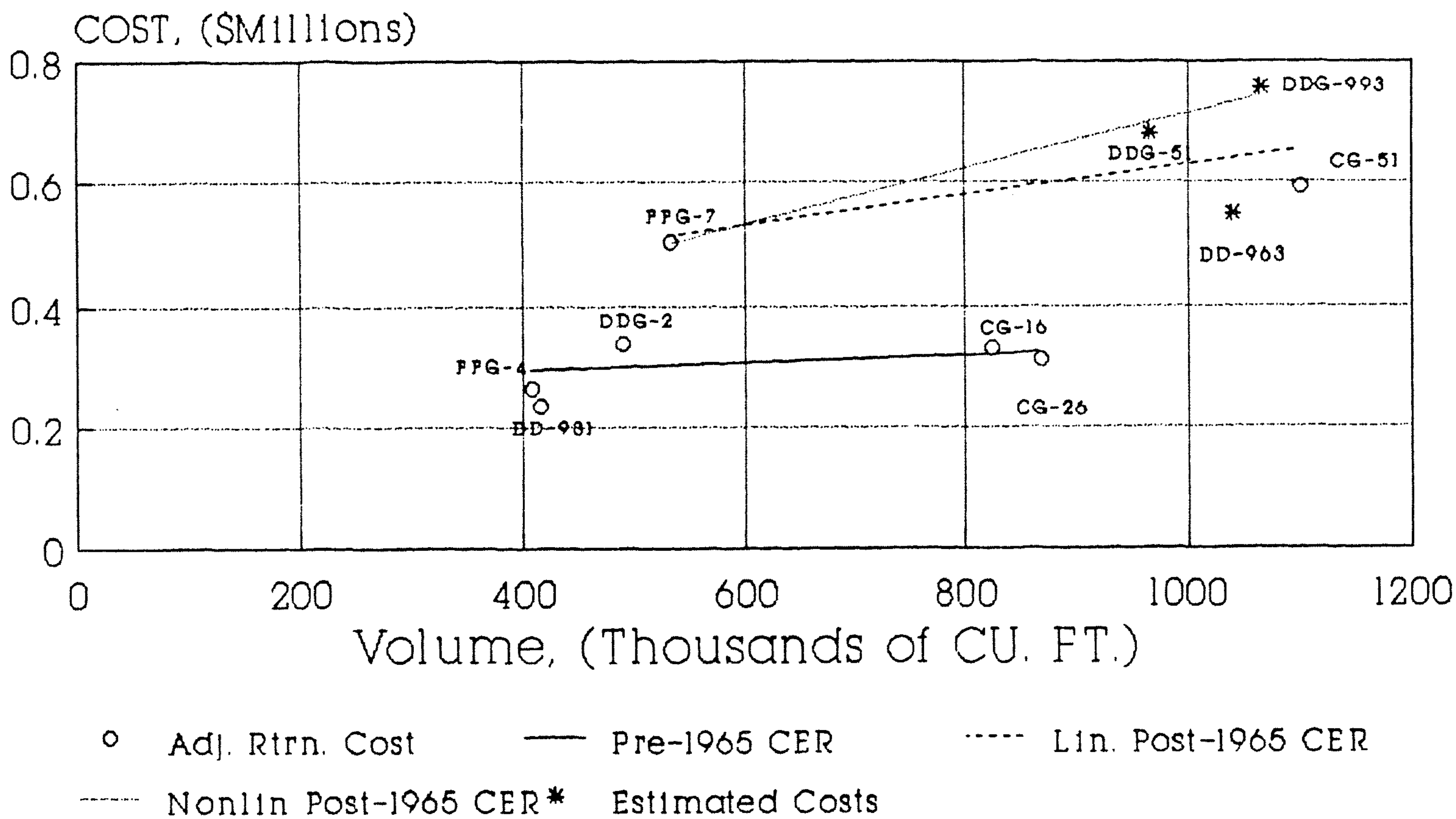


FIGURE 3-68

SHIP SUPPORT
GROUP 6D
MATERIALS COST

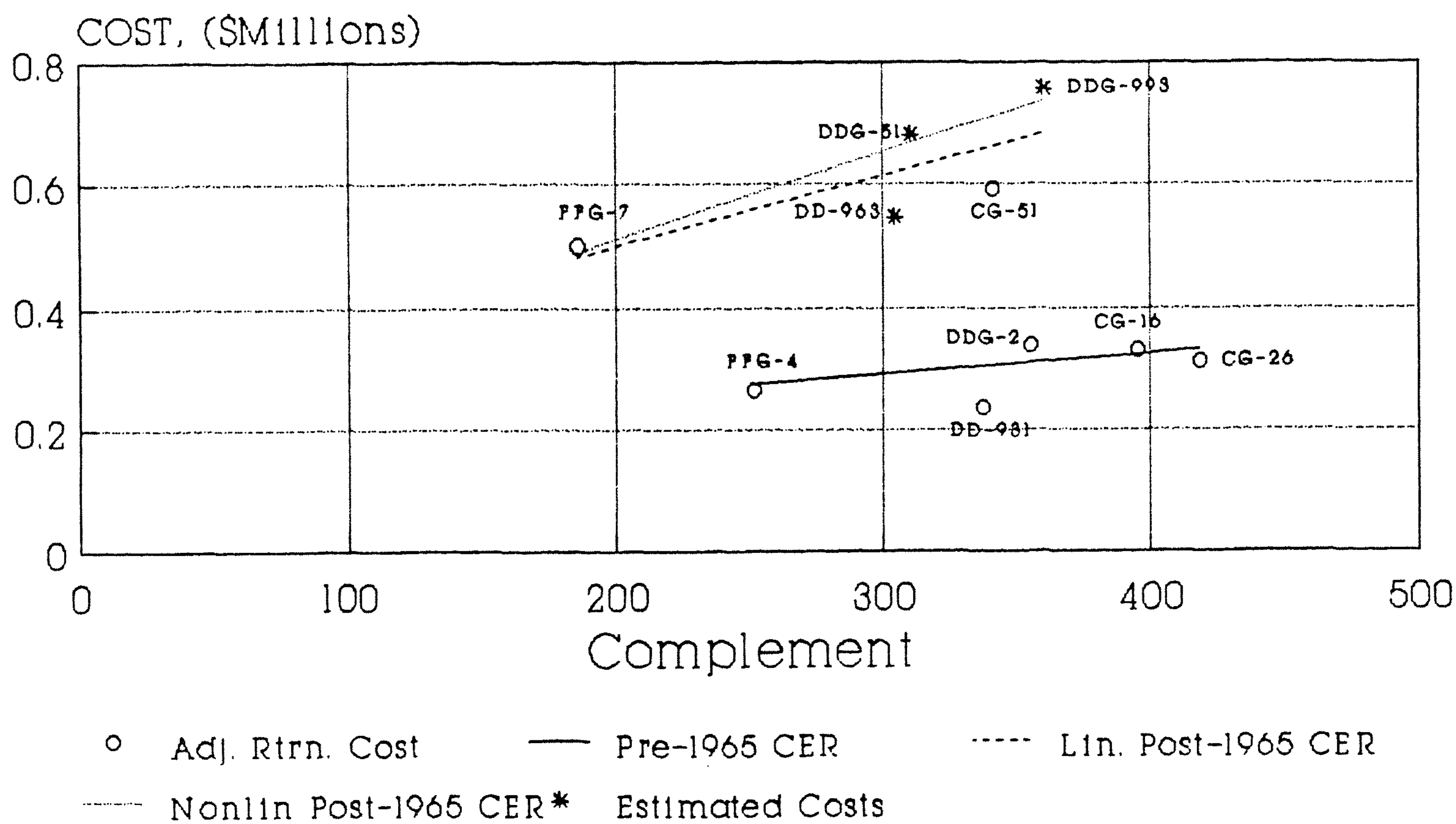


FIGURE 3-69

SHIP SUPPORT
GROUP 6D
LABOR

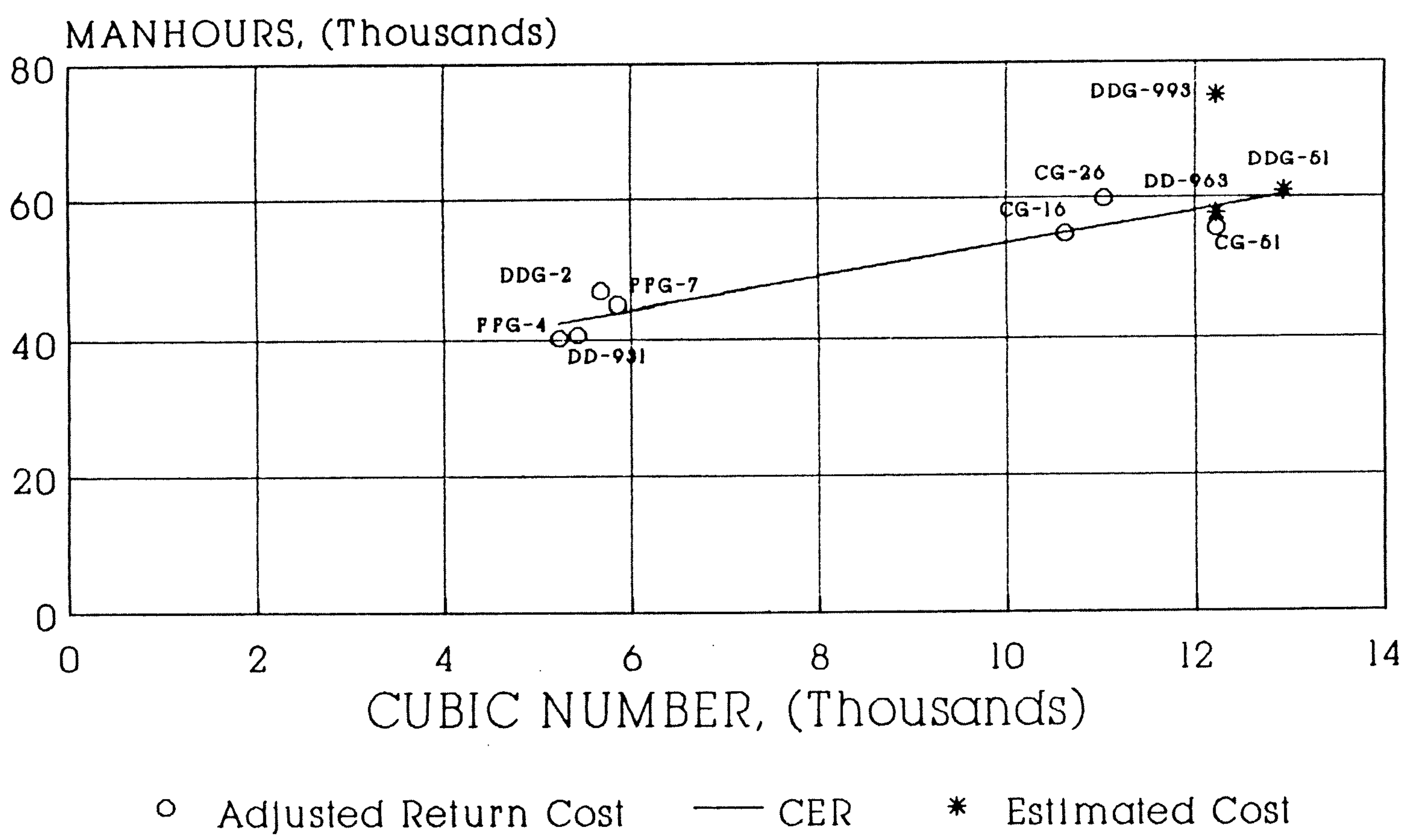


FIGURE 3-70

Group 6E Habitability

This group includes furnishings for living spaces, machinery spaces medical spaces, and galley.

MATERIAL FACTOR: The two algorithms for Group 6E material costs as a function of weight represent the change in habitability standards between the pre-1965 standards and the post-1965 habitability standards. Surprisingly, in this instance, cost as a function of complement has a low coefficient of determination. The DD-963 and DDG-993 were outliers for the post-1965 algorithm, when considered against the return costs for FFG-7 and CG-51 along with the DDG-51 estimate.

CER:	\$ = 10,270 WT + 238,000
Variable:	Group 6E Weight
Application:	Pre-1965 Habitability
Adjusted r^2:	.8471, 5 points

CER:	\$ = 7,210 WT + 888,000
Variable:	Group 6E Weight
Application:	Post-1965 Habitability
Adjusted r^2:	.7619, 3 points

LABOR FACTOR: For Group 6E, the independent variable of complement appears to be satisfactory for estimating man-hours with two algorithms, pre-1965 standards and post-1965 standards.

CER:	MH = 87 COMP + 5,300
Variable:	Complement
Application:	Pre-1965 Habitability
Adjusted r^2:	.8568, 5 points

CER:	MH = 69 COMP + 24,360
Variable:	Complement
Application:	Post-1965 Habitability
Adjusted r^2:	.9692, 3 points

See Figures 3-71 through 3-73 for graphs of data points.

HABITABILITY
GROUP 6E
MATERIALS COST

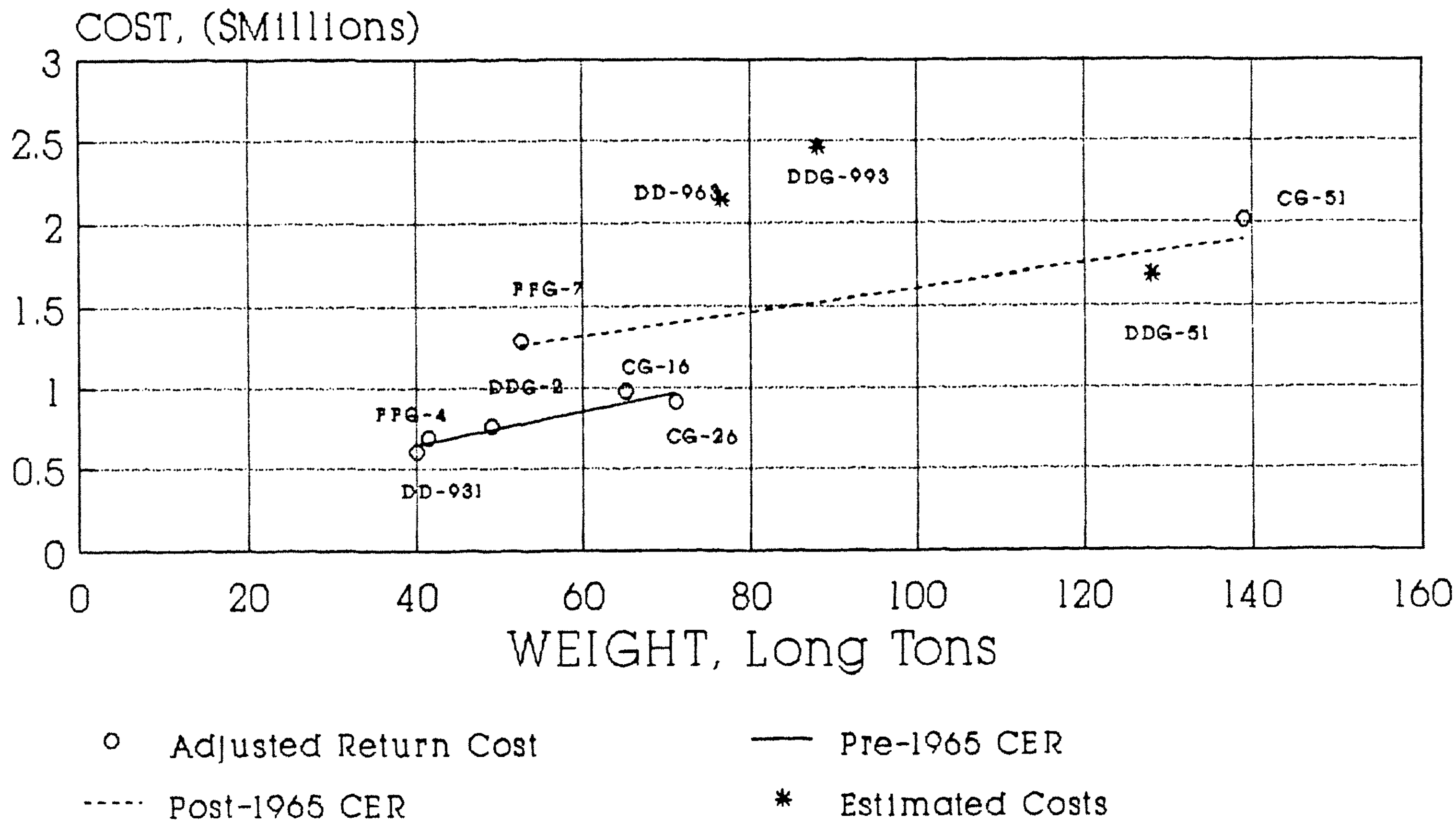


FIGURE 3-71

HABITABILITY
GROUP 6E
MATERIALS COST

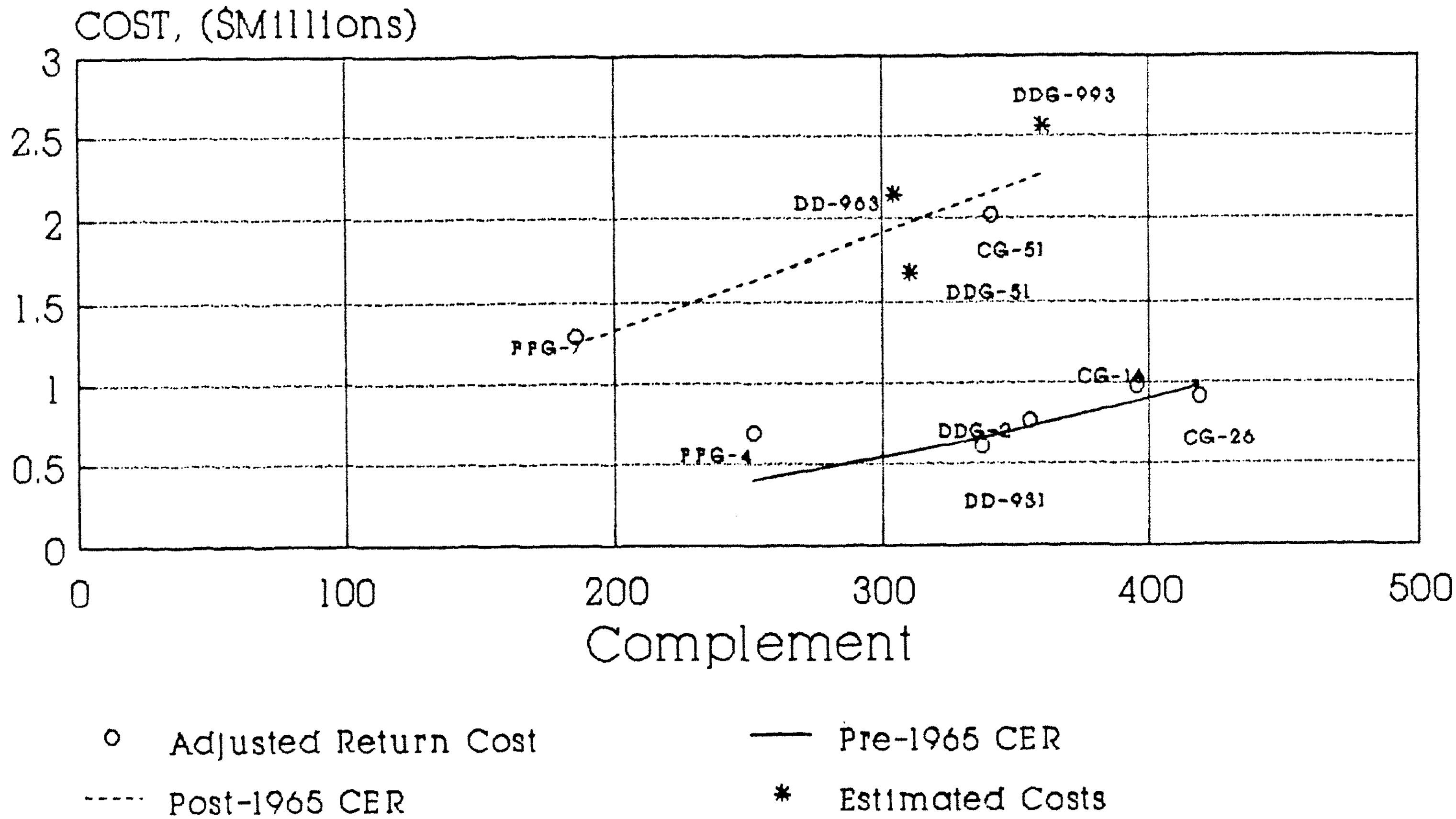


FIGURE 3-72

HABITABILITY
GROUP 6E
LABOR

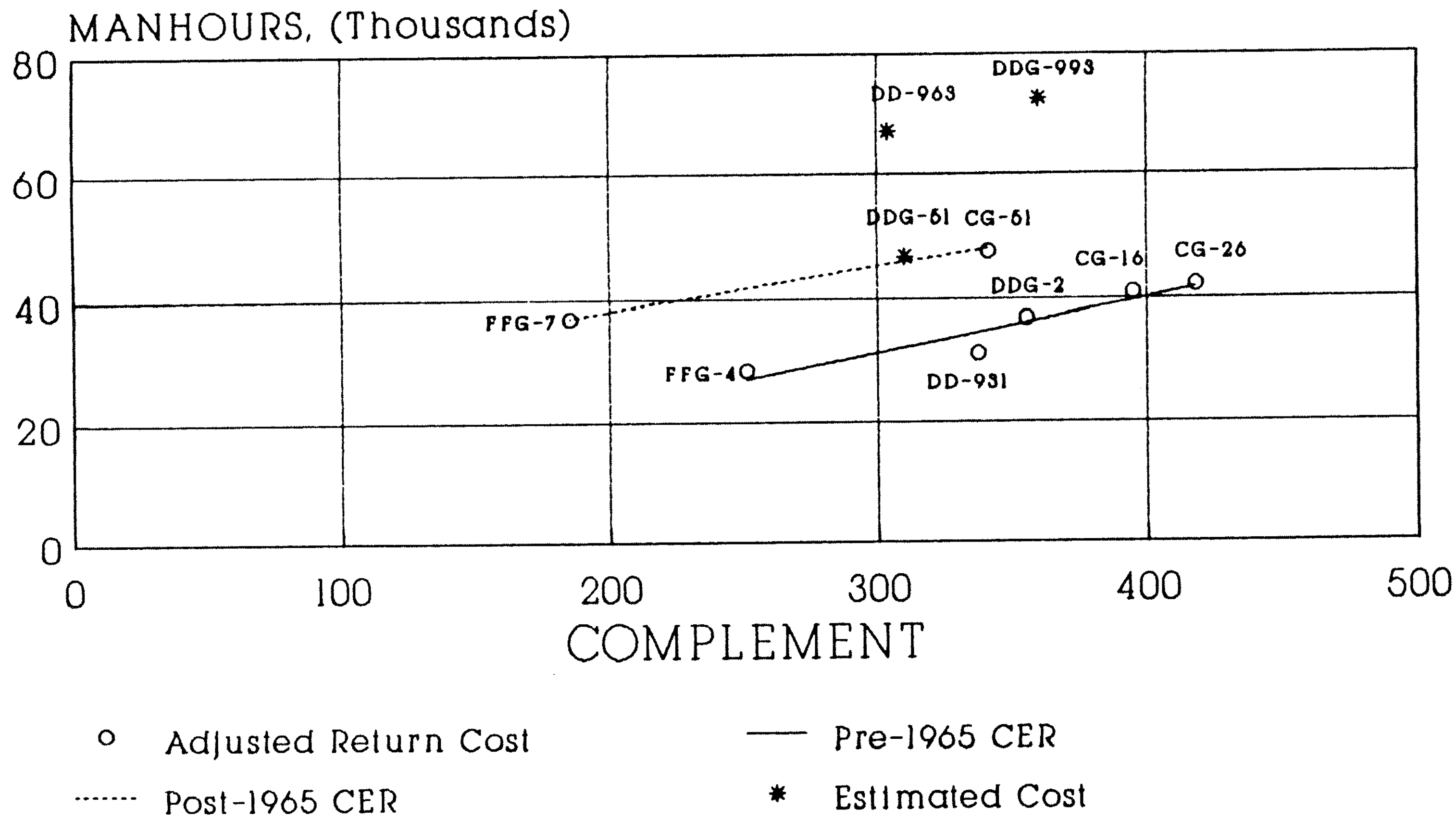


FIGURE 3-73

3.4.7 Group 7 - Armament

This group includes only the installation of ordnance handling equipment, gun/missile systems, munitions stowage, etc.

MATERIAL FACTOR: Group 7 material costs would be expected to be related to the weapons systems installed, their state-of-the-art in terms of system sophistication and complexity, and the function the ship is designed to perform. The cost relationships for Group 7 materials are apparently independent of any identifiable parameters and could loosely be construed to relate only to ships with and without VLS. (DDG-51 and CG-51 are the only ones having costs associated with VLS.) For this reason a constant value was selected for each ship group.

CER:	$ = Constant at $900,000
Variable:	N/A
Application:	Non VLS
Adjusted r^2:	N/A, 1 point

CER:	$ = Constant at 200,000
Variable:	N/A
Application:	VLS
Adjusted r^2:	N/A , 1 point

LABOR FACTOR: Group 7 man-hours appear to be a function of the group weight, and are not that dependent on the particular weapons systems involved or their complexity. The recent ships are lower than earlier ones because recent weapons systems are more modular and less demanding with respect to alignment.

CER:	MH = 492 WT -26,780
Variable:	Group 7 Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.8015, 5 points

OR

CER:	MH = 25,100 $[10^{.0022(WT)}]$
Variable:	Group 7 Weight
Application:	Pre-1965 Technology
Adjusted r^2:	.90, 5 points

CER:	MH = 188 WT + 4,830
Variable:	Group 7 Weight
Application:	Post-1965 Technology
Adjusted r^2:	.9964, 4 points

See Figures 3-74 and 3-75 for graphs of data points.

ARMAMENT
GROUP 7
MATERIALS COST

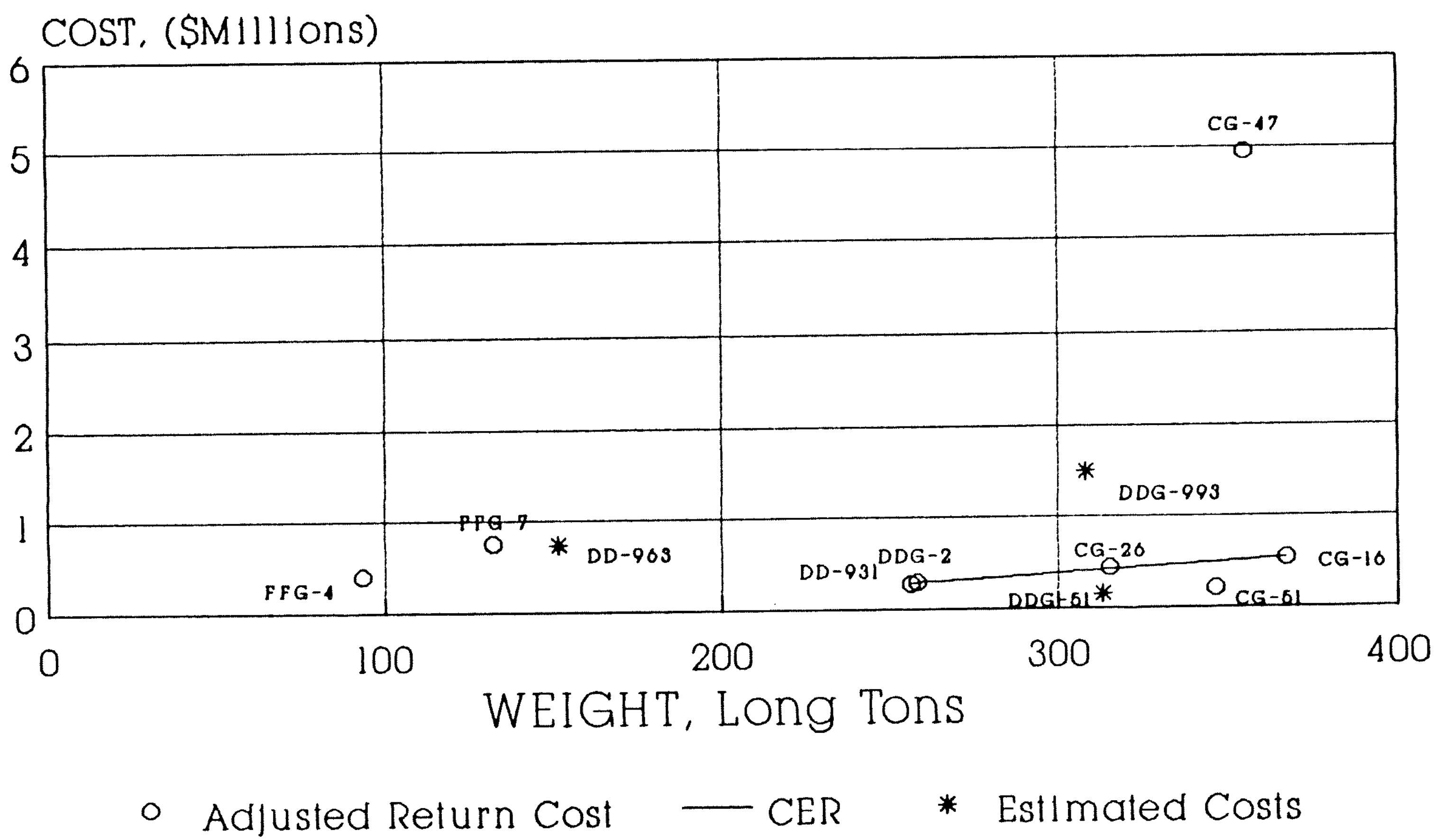


FIGURE 3-74

ARMAMENT
GROUP 7
LABOR

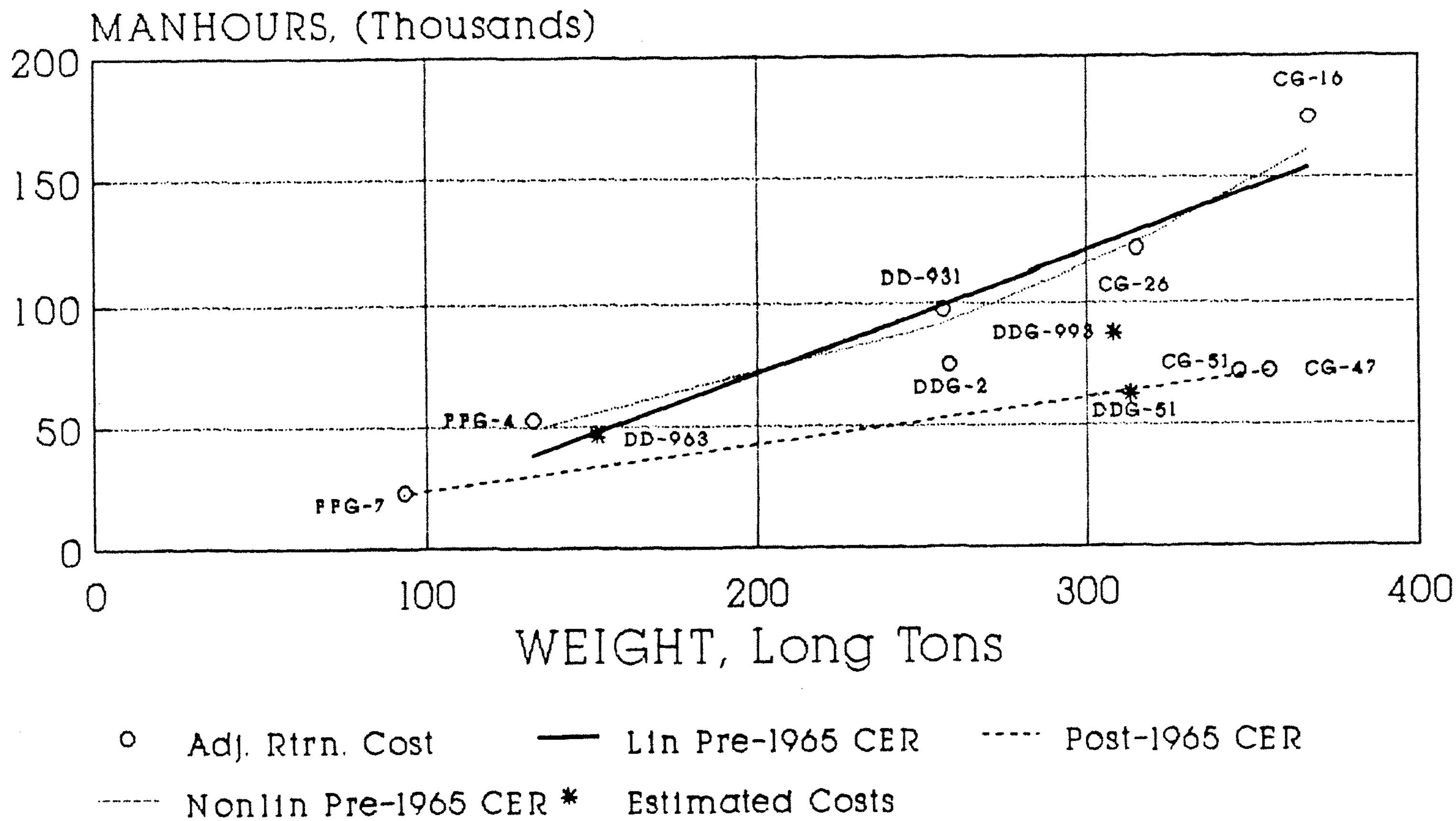


FIGURE 3-75

3.5 SWBS Groups 8 and 9

3.5.1 SWBS Group 8 - Integration/Engineering

SWBS Group 8 encompasses a wide variety of shipbuilder engineering support during construction. Included in this are the following elements:

- o Design support - specifications, weight, computer programs, engineering calculations, models and mockups, photographs, design/engineering liaison, lofting

- o Quality assurance - tests and inspections, trials support, inclining experiment and trim dive, combat systems checkout, certification standards

- o Integrated logistics support (ILS) engineering - maintenance, support and test equipment, supply support, transportation engineering drawings and specifications, technical manuals and other data, facilities, personnel and training, training equipment

- o Authorized repair planning and funding

- o Special purpose items - human factors, standardization value engineering, reliability and maintainability (RMA) data management, project management

Whereas SWBS Groups 1-7 are related to the construction of the ship and tend to follow reasonable trends, SWBS Group 8 relates to support requirements placed on the shipyard by the Navy, which are subject to change as Navy policy changes. Over the past 10 years, the Group 8 support has grown dramatically in response to the increased demand for project management support and increased focus on ILS, RMA, human factors and the like. With tightening budgets and the maturity of some of these support programs, it is unlikely that the growth will continue and it is probable that there will be a gradual decline in Group 8 support.

In the 1980 version of this model, Group 8 costs were based on BIW experience on the FFG 7 program. In this revision, data from BIW (Reference 9 and 10) and Ingalls Shipbuilding (Reference 11) were available for the AEGIS Ships CG 51, DDG 51 and CG 47. Figure 3-76 shows the values for the Group 8 costs for these ships in 1986 dollars. The estimators at BIW believe the CG 51 is an excessively high number. Also the DDG 51 data is based on an estimate not return costs. However, the numbers indicate a dramatic increase in Group 8 between the FFG 7 and the newer AEGIS ships, even taking into consideration differences in ship size and complexity.

Figure 3-76 SWBS Group 8 Material and Labor Costs

Ship	Shipyard	Material Cost $M (1986)	Labor Manhours (thousands of mhrs)
FFG 7	BIW	0.6	307
CG 51	BIW	27.8	3,452
DDG 51	BIW	11.3	1,564
CG 47	ISI	21.3	2,538

For the purposes of this model, a value of $20 million for material costs and 1.5 million manhours for labor manhours has been selected for SWBS Group 8. This is between the DDG 51 and CG 47 values and is representative of a large AEGIS combatant. It also reflects consideration of future budgets and the maturity of many of the support programs. For smaller non-AEGIS combatants, these values should be scaled down by as much as a factor of 10.

3.5.2 SWBS Group 9 - Ship Assembly and Support Services

SWBS Group 9 encompasses the general shipyard support services required for construction of the ship that do not fall within any of the previous SWBS Groups. Included in SWBS Group 9 are the following:

- Ship assembly identification
- Non-engineering contractual and production support services - assist ships force, insurance, trials support, delivery support, fire and flooding protection, tests and inspection support, weighting and recording, administrative contract data requirements, fitting-out support
- Construction support - staging, scaffolding and cribbing services, temporary utilities and services, material handling and removal cleaning services, molds and templates, jigs fixtures and spec. tools, launching, drydocking

As with SWBS Group 8, SWBS Group 9 costs have increased over the past 10 years. This growth is attributable, in part, to the general growth in support services to respond to Navy requirements, as well as the increased planning and coordination required for extensive pre-outfitted construction. The growth in SWBS Group 9 costs has not been as dramatic as SWBS Group 8 since the SWBS Group 9 activities are primarily in support of construction activities within the yard.

In the 1980 version of the model, SWBS Group 9 costs were related to the length of time the vessel is in the shipyard. This convention is carried over for this update. Figure 3-77 shows the values for the Group 9 costs for the FFG 7, CG 51, DDG 51 and CG 47 in 1986 dollars. The material cost value for the CG 47 is considered high for unexplainable reasons.

Figure 3-77 SWBS Group 9 Material and Labor Costs

Ship	Shipyard	Months in ShipYard	Material Cost thousands of $/mo (1986)	Labor Manhours thousands of mhrs/mo
FFG 7	BIW	30	46	16
CG 51	BIW	42	161	65
DDG 51	BIW	38	112	32
CG 47	ISI	40*	267	37

* Estimate

The BIW estimators also believe the CG 51 value is higher than it should be. Also, the DDG 51 is based on an estimate and not return costs.

For the purposes of this model, a value of 120,000 $/mo for material costs and 35,000 manhours/month for labor manhours has been selected for Group 9. This is slightly higher than the DDG 51 estimates, which are the best data currently available. This represents the value for a large AEGIS combatant. For smaller non-AEGIS combatants, these values should be scaled down by as much as a factor of two.

4.0 CONCLUSION AND RECOMMENDATIONS

The original 1980 model was considered by NCA to be an excellent model from the point of view of accuracy and ease of use. The major limitation of the model was the lack of data on recently constructed AEGIS cruisers and destroyers. This meant the original model did not account for new technologies on these ships, nor did it account for increases in the management and support areas, which are now a major part of the ship construction program.

This revision to the model has retained the positive elements of the original model, while attempting to improve upon the data base. The revision includes new data on the DDG 51, CG 47 and CG 51 (considered equivalent to a lead ship from BIW's perspective). The data base was computerized and the data was analyzed for each cost group and new CER's developed based on this analysis. Also, an analysis was made of non-linear relationships for the data (Reference 17) and these non-linear relationships are used when appropriate. Finally, all costs were revised to 1986 values using the NAVSEA standards. These revisions should make the model current. The computerization of the data base should also allow for easier future updates as well as allow NCA personnel to do additional data analysis, if required.

The primary recommendation is that the data base be updated as new ships or technologies evolve. Special attention should be given to future trends in shipbuilding practices, such as increased automation, changes in union/management relationships, or dramatic changes in the industrial base, as they will have significant effects on the cost estimating relationship provided in this model. Similarly, changes in Navy requirements and policy will also affect the cost estimating relationships presented in the model, with potential budgetary constraints having significant impacts on the SWBS Group 8 and 9 support costs.

5.0 REFERENCES

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2. SWBS, NAVSEA 0900-LP-03909010, NAVSEC, February 1985.

3. BSCI NAVSHIPS 0902-2002-2000, February 1965.

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APPENDIX A

DATA WORK SHEETS

The worksheets provided are to be used in conjunction with the CER's and Figures provided in Chapter 3 of this report.

TABLE A-1

INPUT DATA REQUIREMENTS TABLE
ONE-DIGIT LEVEL COST MODEL

SHIP CHARACTERISTIC	COMMENTS	SHIP ______ VALUE
Group 1 Weight	Long Tons	
Group 3 Weight	Long Tons	
Group 4 Weight	Long Tons	
Group 5 Weight	Long Tons	
Group 6 Weight	Long Tons	
Group 7 Weight	Long Tons	
Cubic Number	LxBxD ÷ 100	
Shaft Horsepower	SHP	
Kilowatts	KW	
Length x Beam	Square Feet	
Superstructure Material	Aluminum or Steel	
Propulsion Type and Number of Shafts	Steam, Gas turbine Single Shaft, etc.	
Generator Type	Steam, Diesel, etc.	
Habitability Standard	Year habitability standards designed to	
"MISSILE"/"NON-MISSILE"	Whether or not the vessel has missile magazine flooding requirements	
Level of Technology	Early or Current	
Heating System	Steam or Electric	
Months Construction	Approximately 30 months for an FFG-7 type vessel	

TABLE A-2
SUMMARY: MATERIAL COSTS & LABOR MAN-HOURS
ONE-DIGIT LEVEL COST MODEL

COST GROUP	DESCRIPTION	MATERIAL COST	LABOR MAN-HOURS
1	HULL STRUCTURE		
2	PROPULSION PLANT		
3	ELECTRIC PLANT		
4	COMMUNICATIONS AND SURVEILLANCE		
5	AUXILIARY SYSTEMS		
6	OUTFIT AND FURNISHINGS		
7	ARMAMENT		
8	INTEGRATION/ENGINEERING		
9	SHIP ASSEMBLY AND SUPPORT SERVICES		
TOTAL MATERIAL COSTS AND MAN-HOURS			
	PRODUCTIVITY ADJUSTMENT (Labor Man-hours x Productivity Section 3.2.1)		x
	LABOR RATE ($/Man-Hour)[1]		x
	TOTAL LABOR COST[2]		$
	INFLATION FACTOR (Section 3.2.1)[3]	x	
	TOTAL MATERIAL COST[2]	$	
	+ TOTAL LABOR COST	+$	
	TOTAL BASIC SHIP CONSTRUCTION COST[2]	$	

1. The labor rate selected in $/man-hour is the appropriate rate for the funding outlay profile.
2. The costs are program dollars.
3. The inflation factor is to adjust from dollars to the actual delivery year dollars.

TABLE A-2
OUTPUT WORKSHEET
ONE-DIGIT LEVEL COST MODEL

INDEDENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 1 - HULL STRUCTURE		
MATERIAL COSTS		
Cubic Number = ____________		
OR		
Group 1 Weight = ____________		
LABOR MAN-HOURS		
Cubic Number = ____________		
OR		
Group 1 Weight = ____________	$ =	MH =
GROUP 2 - PROPULSION PLANT		
MATERIAL COSTS		
SHP = ____________		
Type of Propulsion = ____________		
No. of Shafts = ____________		
LABOR MAN-HOURS		
SHP = ____________		
Type of Propulsion = ____________	$ =	MH =
GROUP 3 - ELECTRICAL SYSTEM		
MATERIAL COSTS		
Group 3 Weight = ____________		
LABOR MAN-HOURS		
Group 3 Weight = ____________		
Type of Generators = ____________	$ =	MH =
GROUP 4 - COMMAND AND CONTROL		
MATERIAL COSTS		
Total Ship Volume = ____________		
Level of Technology = ____________		
LABOR MAN-HOURS		
Group 4 Weight = ____________	$ =	MH =

TABLE A-2
OUTPUT WORKSHEET (Continued)
ONE-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MANHOURS
GROUP 5 - AUXILIARY SYSTEMS		
MATERIAL COSTS		
Group 5 Weight = ______		
Heating System = ______		
MISSILE = ______		
LABOR MAN-HOURS		
Group 5 Weight = ______		
Heating System = ______		
MISSILE = ______	$ =	MH =
GROUP 6 - OUTFIT AND FURHISHINGS		
MATERIAL COSTS		
Length x Beam = ______		
Habitability Standard = ______		
OR		
Total Ship Complement = ______		
Level of Technology = ______		
LABOR MAN-HOURS		
Group 6 Weight = ______		
Habitability Standard = ______	$ =	MH =
GROUP 7 - ARMAMENT		
MATERIAL COSTS		
Cost = 900,000 (non VLS)		
Cost = $200,00 (VLS)		
LABOR MAN-HOURS		
Group 7 Weight = ______	$ =	MH =
GROUP 8 - DESIGN & ENGINEERING SERVICES		
MATERIAL COSTS		
1986 Cost = $ 20,000,000		
LABOR MAN-HOURS		
1986 Hours = 1,500,000	$ =	MH =

OUTPUT WORKSHEET (Continued)
ONE-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE		MATERIAL COSTS	LABOR MAN-HOURS
<u>GROUP 9 - CONSTRUCTION SERVICES</u>			
MATERIAL COSTS =			
1986 Cost =	$120,000/month of construction		
LABOR MAN-HOURS =			
1986 Hours =	35,000 manhours/month of construction	$ =	MH =

TABLE A-4
INPUT DATA REQUIREMENTS TABLE
TWO-DIGIT LEVEL COST MODEL

SHIP CHARACTERISTIC	COMMENTS	SHIP ______ VALUE
Group 1A Weight	Long Tons	
Group 1B Weight	Long Tons	
Group 1C Weight	Long Tons	
Group 1D Weight	Long Tons	
Group 2D Weight	Long Tons	
Group 3A Weight	Long Tons	
Group 3B Weight	Long Tons	
Group 4A Weight	Long Tons	
Group 4B Weight	Long Tons	
Group 5A Weight	Long Tons	
Group 5B Weight	Long Tons	
Group 5D Weight	Long Tons	
Group 6A Weight	Long Tons	
Group 6B Weight	Long Tons	
Group 6D Weight	Long Tons	
Group 6E Weight	Long Tons	
Group 7 Weight	Long Tons	
Cubic Number	LxBxD ÷ 100	
Shaft Horsepower	SHP	
Kilowatts	KW	

TABLE A-4
INPUT DATA REQUIREMENTS TABLE
TWO-DIGIT LEVEL COST MODEL (Continued)

SHIP CHARACTERISTIC	COMMENTS	SHIP_____ VALUE
LxH/100	Square Feet	
LxB	Square Feet	
LxD	Square Feet	
Complement		
Superstructure Material	Aluminum or Steel	
Type of Propulsion Plant	Steam, Gas Turbine, etc.	
Generator Type	Steam, Diesel, etc.	
Level of Technology	Early or Current	
Heating System	Steam or Electric	
"MISSILE"/"NON-MISSILE"	Whether or not the vessel has missile magazine flooding requirements	
Habitability Standards	Year habitability standards designed to	
Months Construction	Approximately 30 months for an FFG-7 type vessel	

TABLE A-5
OUTPUT WORKSHEET
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 1A - STRUCTURAL ENVELOPE/SUBDIVISIONS MATERIAL COSTS GROUP 1A WT = ________ LABOR MAN-HOURS CUBIC NO. = ________ GROUP 1A WT = ________	$ =	MH =
GROUP 1B - SUPERSTRUCTURE MATERIAL COSTS GROUP 1B WT = ________ SUPERSTRUCTURE MTL = ________ LABOR MAN-HOURS GROUP 1B WT = ________ SUPERSTRUCTURE MTL = ________	$ =	MH =
GROUP 1C - FOUNDATIONS MATERIAL COSTS GROUP 1C WT = ________ TYPE OF PROPULSION PLANT = ________ LABOR MAN-HOURS GROUP 1C WT = ________ TYPE OF PROPULSION PLANT = ________	$ =	MH =
GROUP 1D - STRUCTURAL ATTACHMENTS MATERIAL COSTS GROUP 1D WT = ________ LABOR MAN-HOURS GROUP 1D WT = ________	$ =	MH =

TABLE A-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 2A - PROPULSION ENERGY SYSTEMS MATERIAL COSTS GROUP 2A WEIGHT = ______ TYPE OF PROPULSION PLANT = ______ LABOR MAN-HOURS GROUP 2A WEIGHT OR SHP = ______ TYPE OF PROPULSION PLANT =	$ =	MH =
GROUP 2B - PROPULSION TRAIN SYSTEMS MATERIAL COSTS SHP = ______ GROUP 2B WEIGHT = ______ LABOR MAN-HOURS SHP = ______	$ =	MH =
GROUP 2C - PROPULSION GASES SYSTEMS MATERIAL COSTS SHP = ______ TYPE OF PROPULSION PLANT = ______ LABOR MAN-HOURS GROUP 2C WEIGHT = ______	$ =	MH =
GROUP 2D - PROPULSION SERVICE SYSTEMS MATERIAL COSTS SHP = ______ TYPE OF PROPULSION PLANT = ______ LABOR MAN-HOURS GROUP 2D WEIGHT = ______	$ =	MH =

TABLE A-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 3A - ELECTRICAL POWER GENERATION		
MATERIAL COSTS		
GROUP 3A WEIGHT = ______		
GENERATOR TYPE = ______		
LABOR MAN-HOURS		
GROUP 3A WT = ______	$ =	MH =
GROUP 3B - ELECTRICAL POWER DISTRIBUTION		
MATERIAL COSTS		
GROUP 3B WT = ______		
LABOR MAN-HOURS		
GROUP 3B WT = ______	$ =	MH =
GROUP 4A - VEHICLE COMMAND		
MATERIAL COSTS		
INSTALLED 400 Hz KW = ______		
LEVEL OF TECNNOLOGY = ______		
LABOR MAN-HOURS		
GROUP 4A WT = ______	$ =	MH =
GROUP 4B - WEAPONS COMMAND		
MATERIAL COST		
GROUP 4B WT = ______		
LEVEL OF TECHNOLOGY = ______		
LABOR MAN-HOURS		
GROUP 4B WT = ______	$ =	MH =

TABLE A-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 5A - ENVIRONMENTAL SYSTEMS		
MATERIAL COSTS		
GROUP 5A WT = ______		
HEATING SYSTEM = ______		
LABOR MAN-HOURS		
GROUP 5A WT = ______		
HEATING SYSTEM = ______	$ =	MH =
GROUP 5B - FLUID SYSTEMS		
MATERIAL COSTS		
TOTAL SHIP VOLUME = ______		
GROUP 5B WT = ______		
MISSILE = ______		
LABOR MAN-HOURS		
GROUP 5B WT = ______		
MISSILE = ______	$ =	MH =
GROUP 5C - MANEUVERING SYSTEMS		
MATERIAL COSTS		
GROUP 5C WEIGHT = ______		
LABOR MAN-HOURS		
GROUP 5C WEIGHT = ______	$ =	MH =
GROUP 5D - EQUIPMENT HANDLING SYSTEMS		
MATERIAL COSTS		
GROUP 5D WT = ______		
LABOR MAN-HOURS		
TOTAL SHIP LENGTH = ______	$ =	MH =

TABLE A-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 6A - HULL FITTINGS		
MATERIAL COSTS		
GROUP 6A WEIGHT = ______		
LEVEL OF TECHNOLOGY = ______		
LABOR MAN-HOURS		
L x B = ______	$ =	MH =
GROUP 6B - NON-STRUCTURAL SUBDIVISIONS		
MATERIAL COSTS		
TOTAL SHIP VOLUME = ______		
GROUP 6B WT = ______		
HABOTABILITY STANDARDS = ______		
LABOR MAN-HOURS		
GROUP 6B WT = ______	$ =	MH =
GROUP 6C - PRESERVATION		
MATERIAL COSTS		
L x B = ______		
GROUP 6C WT = ______		
LEVEL OF TECHNOLOGY = ______		
LABOR MAN-HOURS		
GROUP 6C WT = ______	$ =	MH =
GROUP 6D - SHIP SUPPORT		
MATERIAL COSTS		
GROUP 6D WT = ______		
COMPLEMENT = ______		
HABITABILITY STANDARDS = ______		
LABOR MAN-HOURS		
CUBIC NUMBER = ______		
HABITABILITY STANDARDS = ______	$ =	MH =

TABLE A-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

INDEPENDENT VARIABLE	MATERIAL COSTS	LABOR MAN-HOURS
GROUP 6E - HABITABILITY MATERIAL COSTS GROUP 6E WT = ________ HABITABILITY STANDARDS = ________ LABOR MAN-HOURS COMPLEMENT = ________	$ =	MH =
GROUP 7 - ARMAMENT MATERIAL COSTS LEVEL OF TECHNOLOGY = ________ LABOR MAN-HOURS LEVEL OF TECHNOLOGY = ________	$ =	MH =
GROUP 8 - INTEGRATION/ENGINEERING MATERIAL COSTS 1986 COST = $ ________ LABOR MAN-HOURS 1986 HOURS = ________	$ =	MH =
GROUP 9 - SHIP ASSEMBLY AND SUPPORT SERVICES MATERIAL COST 1986 COST = $/MONTH CONSTRUCTION LABOR MAN-HOURS 1986 HOURS = /MONTH CONSTRUCTION	$ =	MH =

TABLE A-6
SUMMARY: MATERIAL COSTS AND LABOR MAN-HOURS
TWO-DIGIT LEVEL COST MODEL

COST GROUP	DESCRIPTION	MATERIAL COSTS	LABOR MAN-HOURS
1A	STRUCTURAL ENVELOPE/SUBDIVISIONS		
1B	SUPERSTRUCTURE		
1C	FOUNDATIONS		
1D	STRUCTURAL ATTACHMENTS		
2A	PROPULSION ENERGY SYSTEMS		
2B	PROPULSION TRAIN SYSTEMS		
2C	PROPULSION GASES SYSTEMS		
2D	PROPULSION SERVICE SYSTEMS		
3A	ELECTRICAL POWER GENERATION		
3B	ELECTRICAL POWER DISTRIBUTION		
4A	VEHICLE COMMAND		
4B	WEAPONS COMMAND		
5A	ENVIRONMENTAL SYSTEMS		
5B	FLUID SYSTEMS		
5C	MANEUVERING SYSTEMS		
5D	EQUIPMENT HANDLING SYSTEMS		
6A	HULL FITTINGS		
6B	NON-STRUCTURAL SUBDIVISIONS		
6C	PRESERVATION		
6D	SHIP SUPPORT		
6E	HABITABILITY		
7	ARMAMENT		
SUBTOTAL	MATERIAL COST AND MAN-HOURS		

TABLE A-6
SUMMARY: MATERIAL COSTS AND LABOR MAN-HOURS
TWO-DIGIT LEVEL COST MODEL (Continued)

COST GROUP	DESCRIPTION	MATERIAL COSTS	LABOR MAN-HOURS
SUBTOTAL MATERIAL COSTS AND MAN-HOURS			
8	INTEGRATION/ENGINEERING		
9	SHIP ASSEMBLY AND SUPPORT SERVICES		
TOTAL MATERIAL COSTS AND MAN-HOURS			
PRODUCTIVITY ADJUSTMENT (Labor Man-Hours x Productivity Section 3.2.1)			x
LABOR RATE ($/Man-Hour)[1]			x
TOTAL LABOR COST[2]			$
INFLATION FACTOR (Section 3.2.1)[3]		x	
TOTAL MATERIAL COST[2]		$	
+ TOTAL LABOR COST		+$	
TOTAL BASIC SHIP CONSTRUCTION COST[2]		$	

1. The labor rate selected in $/man-hour is the appropriate rate for the funding outlay profile.
2. The costs are program dollars.
3. The inflation factor is to adjust from 1980 dollars to the actual delivery year dollars.

APPENDIX B

WEIGHT, LABOR AND MATERIAL COST DATA

TABLE B-1

PERCENTAGE OF LIGHT SHIP WEIGHT (IN COST GROUP)

COST GROUP	DD 931	DDG 2	CG 16	CG 26	FFG 4	FFG 7	DDG 51	DDG 40	FF 1052	DD 963	DDG 993	CG 51	% AVG. SHIPS
1 A	28	28	37	38	37	35	34					32	
B	3	3	3	3	3	4	6					6	
C	3	4	4	3	3	5	6					6	
D	2	2	2	3	3	2	4					4	
SUBTOTAL:	36	36	46	47	46	46	50	42	47	53	51	48	46.0
2 A	21	18	12	11	9	5	3					3	
B	4	4	3	3	3	3	5					5	
C	1	1	1	1	1	1	1					1	
D	4	3	2	2	2	1	1					2	
SUBTOTAL:	30	26	18	17	15	10	10	22	15	13	11	11	17.0
3 A	2	2	2	2	2	3	2					2	
B	2	2	2	2	2	4	4					4	
SUBTOTAL:	4	4	4	4	4	4	6	4	4	5	5	6	5.0
4 A	1	1	1	1	1	1	2					2	
B	2	4	6	6	5	3	4					3	
SUBTOTAL:	3	5	7	7	6	4	6	5	7	6	6	5	6.0
5 A	3	3	3	3	3	4	4					4	
B	6	7	6	6	6	9	6					6	
C	1	1	1	1	2	2	1					1	
D	1	1	1	1	3	2	3					3	
SUBTOTAL:	11	12	11	11	14	17	14	12	13	13	14	14	13.0
6 A	1	1	1	1	1	1	1					1	
B	1	1	1	1	1	3	1					2	
C	2	3	2	3	4	4	3					4	
D	2	2	2	2	2	2	2					2	
E	1	1	1	1	2	2	2					2	
SUBTOTAL:	7	8	7	8	10	12	9	8	9	7	8	11	8.0
7 SUB-TOTAL	9	8	7	6	5	4	5	7	5	3	5	5	5.0
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

WEIGHT DATA (LONG TONS)

COST GROUP	DDG-51	CG-51	CG-47	FFG-7	DD-963	DDG-993	FFG-4	CG-26	CG-16	DDG-2	DD-931
1A	1985	2300	2193.7	928.5	2292	2311.5	918	1947	1903.7	917	786
1B	297	435	476.6	105	194	261	65	136.5	148.5	114	75
1C	376	434	399	138	295.5	369	95	175.6	150	121	98
1D	351	273	264	63.5	309	380	75	162.6	123	66	61
SUBTOTAL	3009	3442	3333.3	1235	3090.5	3321.5	1153	2421.7	2325.2	1218	1020
2A	211	233	230.7	98	227	227	213.7	580	581.8	567.5	583.2
2B	317	314	306.3	82	256	256	69.8	167.5	165.3	127.6	112.2
2C	92	65	72.2	29	179	185	24.2	55	54.2	40.8	43.4
2D	97	58	55.8	58	55.5	62	53.3	75.5	76.7	95.1	101.2
SUBTOTAL	717	670	665	267	717.5	730	361	878	878	831	840
3A	134	135.5	152.6	98	125	127	53	108.5	98.8	55	55
3B	253	240.5	226.1	97	152	214	50	117.5	112.4	68	68
SUBTOTAL	387	376	378.7	195	277	341	103	226	211.2	123	123
4A	113	139	121.3	34.5	95.5	97.5	29	75	70.2	43	37
4B	201	257	259.2	81.5	172	225.5	119	276.4	268.3	135	51
SUBTOTAL	314	396	380.5	116	267.5	323	148	351.4	338.5	178	88
5A	261	280	255.5	109	177	248	78.5	133.6	129	83	69
5B	383	399	391.53	241	287	358.5	152	320.6	299.9	206	163
5C	90	73	69.7	46	74	78.5	49	50.9	51.5	38	40
5D	161	180	167.2	51	121	137	60.5	65.2	59.9	47	30
SUBTOTAL	895	932	883.93	447	659	822	340	570.3	540.3	374	302
6A	18	15	13.8	27	43	47.5	35.5	64.9	49.9	40	28
6B	145	88	116.3	66	91.5	106.5	34	70.4	64.7	48	35
6C	278	231	242	95	178	204	92	161.1	123.3	95	66
6D	112	109	119.8	73.5	70	97	39	58.1	53.3	39	37
6E	128	139	98	52.5	76.5	88	41.5	70.9	65	49	40
SUBTOTAL	681	582	589.9	314	459	543	242	425.4	356.2	271	206
7	313	346	355	93	151.5	308	132	315	367	258	256
TOTAL	6316	6744	6586.33	2667	5622	6388.5	2479	5187.8	5016.4	3253	2835

LABOR COSTS (THOUSANDS OF MANHOURS)

COST GROUP	DDG-51	CG-51	CG-47	FFG-7	DD-963	DDG-993	FFG-4	CG-26	CG-16	DDG-2	DD-931
1A	536.0	483.0	514.0	241.5	528.8	500.7	213.3	381.5	361.2	238.6	203.8
1B	120.3	168.4	129.0	45.7	102.3	129.2	28.9	64.0	63.0	53.1	46.4
1C	186.1	167.1	82.9	41.7	107.1	125.6	32.4	102.7	91.5	40.0	29.2
1D	134.3	70.0	82.9	11.0	74.7	86.2	22.7	102.0	72.9	21.0	16.3
SUBTOTAL	976.6	888.5	808.9	339.8	812.9	841.8	297.4	650.2	588.7	352.7	295.7
2A	26.0	28.8	46.5	12.7	37.4	35.1	50.6	145.7	144.3	114.9	101.0
2B	27.6	18.1	46.5	10.6	42.2	39.6	17.0	32.6	35.3	37.5	31.1
2C	27.5	34.4	46.5	7.1	62.9	61.1	11.3	39.6	38.0	29.5	22.3
2D	84.4	63.9	46.5	49.8	58.8	61.7	22.9	37.4	34.7	47.5	45.8
SUBTOTAL	165.4	145.2	186.1	80.2	201.3	197.5	101.7	255.4	252.3	229.4	200.2
3A	24.9	5.3	380.2	18.9	29.8	28.4	12.7	23.6	21.9	12.2	11.9
3B	296.8	427.4	380.2	145.0	280.1	370.3	100.2	207.3	205.7	108.9	105.3
SUBTOTAL	321.7	432.7	760.4	163.9	309.9	398.8	112.9	230.9	227.6	121.0	117.1
4A	228.5	235.0	102.5	25.2	86.0	82.5	21.6	62.3	65.7	32.6	28.0
4B	309.0	93.7	102.5	52.6	137.0	168.7	97.6	152.4	129.5	101.2	49.2
SUBTOTAL	537.6	328.7	205.0	77.8	223.0	251.1	119.2	214.7	195.1	133.9	77.2
5A	183.5	295.0	318.8	115.6	252.8	332.6	112.7	210.0	214.2	154.6	135.6
5B	254.5	365.3	183.1	170.7	250.7	294.0	141.5	319.4	321.0	189.4	156.0
5C	14.3	12.2	183.1	6.4	14.2	13.4	7.5	10.7	11.6	7.6	12.2
5D	10.9	23.6	183.1	12.7	37.2	39.6	14.1	17.9	25.5	15.3	15.5
SUBTOTAL	463.1	696.1	868.2	305.4	554.9	679.5	275.9	558.0	572.2	367.0	319.3
6A	50.1	37.4	149.9	20.0	39.4	40.8	21.7	44.5	35.9	24.2	18.7
6B	94.0	93.9	149.9	85.5	146.2	159.7	40.6	72.8	73.2	63.9	67.1
6C	537.5	510.5	149.9	129.2	298.4	321.1	126.7	289.7	241.7	141.5	129.9
6D	60.8	55.5	149.9	45.4	57.7	75.0	40.7	59.7	54.7	46.7	40.2
6E	46.7	47.4	149.9	37.4	67.2	72.6	28.4	42.0	40.9	36.8	31.2
SUBTOTAL	789.0	744.7	749.3	317.6	608.9	669.4	258.0	508.7	446.3	313.2	287.0
7	62.0	71.1	71.8	22.8	45.8	87.4	52.6	120.9	174.2	74.6	97.0
TOTAL	3086.9	3304.0	3649.7	1307.5	2756.8	3125.4	1217.7	2538.9	2456.4	1591.8	1393.6

MATERIAL COSTS (CONSTANT 1986 $THOUSANDS)

COST GROUP	DDG-51	CG-51	CG-47	FFG-7	DD-963	DDG-993	FFG-4	CG-26	CG-16	DDG-2	DD-931
1A	2014.6	3215.6	8238.8	912.7	2955.6	2980.8	731.4	2509.4	2856.7	1749.9	1129.6
1B	1081.9	2124.1	4982.5	478.7	956.4	1286.7	290.8	624.9	768.4	760.2	435.4
1C	445.1	1062.0		285.7	661.6	826.2	121.5	214.1	248.0	222.7	125.2
1D	1443.0	2360.1		776.1	4083.4	5021.7	871.3	424.4	322.1	927.0	738.7
SUBTOTAL	4984.8	8761.8	18870.8	2453.1	8657.1	10115.4	2015.0	3772.7	4195.2	3659.8	2428.9
2A	17652.0			11029.1	29193.3	29193.3	5899.1	10945.7	15985.6	15989.1	13427.3
2B	8741.9			3257.9	11622.4	11622.4	622.2	1300.5	1482.8	1301.7	1363.3
2C	2893.9			298.4	2104.4	2175.0	78.5	972.6	1306.0	1279.1	1363.3
2D	4297.6			5425.8	5932.9	6627.7	580.5	1275.7	1221.3	1312.4	1245.1
SUBTOTAL	33585.4		35413.8	20011.2	48853.0	49618.4	7180.3	14494.4	19995.6	19882.3	17399.0
3A	7886.5		9690.4	4360.8	6356.5	6458.2	1504.5	3340.9	3209.3	3077.0	2900.5
3B	6277.8			3236.9	5796.2	8160.5	1228.4	3227.0	3540.4	1800.6	1541.4
SUBTOTAL	14164.3		36957.0	7597.7	12152.7	14618.6	2732.9	6567.9	6749.7	4877.6	4441.9
4A	1651.2	2596.1		1447.1	4594.9	4691.1	850.4	1135.9	1048.9	1036.3	652.4
4B	977.1	1180.0		1596.6	3850.3	5048.0	757.2	831.5	860.5	572.2	112.7
SUBTOTAL	2628.3	3776.1	14829.9	3043.7	8445.2	9739.1	1607.6	1967.4	1909.3	1608.5	765.1
5A	3856.4		7938.0	2657.2	4930.8	6908.7	917.9	1494.7	1713.8	1020.3	1039.2
5B	10848.5			8130.7	11064.7	13821.2	2248.2	3585.9	3918.9	2683.5	2483.2
5C	5542.5			868.2	1596.1	1693.1	309.3	379.9	481.5	361.4	429.9
5D	1851.3			690.2	1871.3	2118.8	726.5	263.6	415.8	272.1	450.7
SUBTOTAL	22098.9		27214.2	12346.3	19462.9	24541.9	4201.9	5724.0	6530.1	4337.4	4403.0
6A	252.1	354.0		518.7	943.9	1042.7	234.4	434.3	430.5	406.8	340.8
6B	1466.9	1416.0		702.2	1112.4	1294.7	234.4	344.0	349.5	286.8	292.1
6C	2285.6	2619.7		705.0	1509.5	1730.0	405.0	965.1	1012.8	669.5	582.9
6D	677.8	590.0		501.4	545.8	756.3	263.8	310.6	329.3	337.4	233.7
6E	1678.7	2006.1		1283.3	2137.0	2458.2	688.5	907.0	972.5	757.6	602.4
SUBTOTAL	6361.0	6985.8	6682.6	3710.5	6248.5	7281.9	1826.1	2961.0	3094.7	2458.1	2051.9
7	152.9	206.5	4943.3	396.3	737.7	1499.8	755.9	439.3	536.3	286.8	272.7
TOTAL	83975.6	19730.17	144911.5	49558.8	104557.2	117415.1	20319.8	35926.6	43010.9	37110.5	31762.5

APPENDIX C

WEIGHT ALGORITHMS

WEIGHT ALGORITHMS

COST GROUP: 1A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
111	SHELL PLATING, SURF. SHIP AND SUBMARINE PRESS. HULL	$W = 2.77$ (HULL VOLUME) $(FT^3) \times 10^{-3}$ (INCLUDES ALL 3-DIGIT ELEMENTS ON THIS PAGE PLUS SOME OF GROUP 1D WEIGHTS, e.g., 161, 163, 167)
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	
141	1ST PLATFORM	
142	2ND PLATFORM	
143	3RD PLATFORM	
144	4TH PLATFORM	
145	5TH PLATFORM	
149	FLATS	
166	SPONSONS	

COST GROUP: 1B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
151	DECKHOUSE STRUCTURE TO FIRST LEVEL	W = 9 (SUPERSTRUCTURE VOLUME (FT^3)) x 10^{-4} IF ALUMINUM, NO GAS TURBINES W = 15 (SUPERSTRUCTURE VOLUME (FT^3)) x 10^{-4} IF STEEL W = 8.5 (SUPERSTRUCTURE VOLUME (FT^3)) x 10^{-4} IF GAS TURBINE NO HELOS OR W = 7.5 (SUPERSTRUCTURE VOLUME (FT^3)) x 10^{-4} IF GAS TURBINE 2 HELOS (INCLUDES ALL 3-DIGIT ELEMENTS ON THIS PAGE AS WELL AS ELEMENTS 167 AND 168 OF GROUP 1D)
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	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 1C

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
182	PROPULSION PLANT FOUNDATIONS	W = .065(WT OF COST GROUPS 2A,+2C,+2D) IF STEAM, OR W = .166 (WT OF SWBS GROUP 2) + 1.5 IF GAS TURBINE
183	ELECTRIC PLANT FOUNDATIONS	W = .1308 (WT OF SWBS GROUP 3)
184	COMMAND AND SURVEILLANCE FOUNDATIONS	W = .08214 (WT OF SWBS GROUP 4) NOTE: EXCLUDE SONAR WATER
185	AUXILIARY SYSTEMS FOUNDATIONS	W = .10 (WT OF SWBS GROUP 5)
186	OUTFIT AND FURNISHINGS FOUNDATIONS	W = .063 (WT OF SWBS GROUP 6)
187	ARMAMENT FOUNDATIONS	W =.075 (WT OF SWBS GROUP 7)

WEIGHT ALGORITHMS (Continued)

COST GROUP: 1D

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
161	STRUCTURAL CASTINGS, FORGINGS, AND EQUIV. WELDMENTS	
162	STACKS AND MACKS (COMBINED STACK AND MAST)	
163	SEA CHESTS	
165	SONAR DOMES	IF SQS-56 W = 1.0 SQS-23 W = 40.0 SQS-53A W = 75.0 SQS-26
167	HULL STRUCTURAL CLOSURES	
168	DECKHOUSE STRUCTURAL CLOSURES	
169	SPECIAL PURPOSE CLOSURES AND STRUCTURES	$W = .833$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
171	MASTS, TOWERS, TETRAPODS	$W = 2.73$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} IF ENCLOSED TOWERS OR $W = 1.31$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} IF OPEN LATTICE
172	KINGPOSTS AND SUPPORT FRAMES	
		NOTE: OTHER WEIGHTS INCLUDED IN COST GROUP 1A OR 1B ESTIMATES. NOTE: WEIGHTS NOT INCLUDED AT ALL IN THIS COST MODEL x 98 WATER x 99 REPAIR PARTS

WEIGHT ALGORITHMS (Continued)

COST GROUP: 2A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
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	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 2B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
243	PROPULSION SHAFTING	$W = (0.4464)(25.2 + (20.16)[SHP/(2 \times RPM)]^{2/3})(LENGTH) \times 10^{-3}$ WHERE: SHP = TOTAL SHIP HORSEPOWER RPM = RPM OF PROPELLER L = SHIP LENGTH
244	PROPULSION SHAFT BEARINGS	$W = 0.15 (W_{243} + W_{245})$ FOR TWIN SHAFT SHIPS
245	PROPULSORS	$W = (2)(68.89 + [((1.0940-0.018619D_p) D_p -15.36) D_p])$ WHERE: D_p = PROPELLER DIAMETER = (LENGTH) + 48 (DRAFT)/75
246	PROPULSOR SHROUDS AND DUCTS	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 2C

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
251	COMBUSTION AIR SYSTEM	
259	UPTAKES (INNER CASING)	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 2D

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
252	PROPULSION CONTROL SYSTEM	
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	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 3A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
311	SHIP SERVICE POWER GENERATION	IF TURBINES W = .027 (KW x N) IF 900 RPM Diesel Generators W = [0.02011(KW) + 5.33] x N IF 1200 RPM Diesel Generators W = [0.01492(KW) + 4.50] x N IF 1800 RPM Diesel Generators W = [0.01382(KW) + 1.51] x N
312	EMERGENCY GENERATORS	W = 0
314	POWER CONVERSION EQUIPMENT	W = 20.6 (400 Hz CONVERTER CAPACITY (KW)) x 10^{-6} + 0.37 (NO. OF HELICOPTERS) + .0639 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 0.96
341	SSTG LUBE OIL	W = 0
342	DIESEL SUPPORT SYSTEMS	IF JACKET WATER WASTE HEAT SYSTEM W = 0.4 x (WEIGHT OF SWBS GROUP 311) + (3.57 x N) NO WASTE HEAT SYSTEM W = 0.4 x (W311)
343	TURBINE SUPPORT SYSTEMS	W = 0 WHERE: KW = RATED GENERATOR CAPACITY N = NUMBER OF GENERATORS

WEIGHT ALGORITHMS (Continued)

COST GROUP: 3B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
313	BATTERIES AND SERVICE FACILITIES	W = 1.56
321	SHIP SERVICE POWER CABLE	W = 3.45 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + .00463 (GENERATING CAPACITY (KW))
322	EMERGENCY POWER CABLE SYSTEM	W = 0
323	CASUALTY POWER CABLE SYSTEM	W = 2.17 (LWL x BEAM) x 10^{-4} - 2.83
324	SWITCHGEAR AND PANELS	W = 2.35 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + .00317 (GENERATING CAPACITY (KW))
331	LIGHTING DISTRIBUTION	W = 1.827 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} - 1.24
332	LIGHTING FIXTURES	W = 1.346 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} - 0.65

WEIGHT ALGORITHMS (Continued)

COST GROUP: 4A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
421	NON-ELECTRICAL/ELECTRONIC NAVIGATION AIDS	W = 0.57
422	ELECTRICAL NAVIGATION AIDS (INCL NAVIG. LIGHTS)	W = 0.78 + 1.69 (IF HELICOPTER EQUIPPED)
423	ELECTRONIC NAVIGATION SYSTEMS, RADIO	W = 0.92
424	ELECTRONIC NAVIGATION SYSTEMS, ACOUSTICAL	W = 0.22
426	ELECTRICAL NAVIGATION SYSTEMS	W = 2.49
427	INERTIAL NAVIGATION SYSTEMS	
428	NAVIGATION CONTROL MONITORING	
431	SWITCHBOARDS FOR I.C. SYSTEMS	W = 0.17 (NO. OF FIRE CONTROL SYSTEM + NO. OF RADAR) + 0.53
432	TELEPHONE SYSTEMS	W = 1.614 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 0.0169 (MANNING) - 8.00
433	ANNOUNCING SYSTEMS	W = 0.45 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
434	ENTERTAINMENT AND TRAINING SYSTEMS	W = 0.18 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} - 0.38
435	VOICE TUBES AND MESSAGE PASSING SYSTEMS	W = 0.19
436	ALARM, SAFETY, AND WARNING SYSTEMS	W = 0.22 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 0.055 (NO. OF GENERATORS) + 8.36 x (PAYLOAD POWER (MW)) x 10^{-5} + 0.26
437	INDICATING, ORDER, AND METERING SYSTEMS	W = 3.87 (NO. OF SHAFTS) - 2.19
438	INTEGRATED CONTROL SYSTEMS	W = 1.01 (NO. OF SHAFTS) - 0.57
439	RECORDING AND TELEVISION SYSTEMS	
443	VISUAL AND AUDIBLE SYSTEMS	W = 0.38
473	TORPEDO DECOYS	W = 1.44 (WEIGHT OF GFE IN 473)
474	DECOYS (OTHER)	W = 1.07 (WEIGHT OF GFE IN 474)
475	DEGAUSSING	W = 4.6 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} - 9.50
476	MINE COUNTERMEASURES	
491	ELECTRONIC TEST, CHECKOUT, AND MONITORING EQUIPMENT	W = WEIGHT OF GFE IN 491
492	FLIGHT CONTROL AND INSTRUMENT LANDING SYSTEMS	
493	NON COMBAT DATA PROCESSING SYSTEMS	
494	METEOROLOGICAL SYSTEMS	
495	SPECIAL PURPOSE INTELLIGENCE SYSTEMS	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 4B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
411	DATA DISPLAY GROUP	W = 1.38 (WEIGHT OF GFE IN 411)
412	DATA PROCESSING GROUP	W = 1.29 (WEIGHT OF GFE IN 412)
413	DIGITAL DATA SWITCHBOARDS	W = 1.94 (WEIGHT OF GFE IN 413)
414	INTERFACE EQUIPMENT	W = 1.43 (WEIGHT OF GFE IN 414)
415	DIGITAL DATA COMMUNICATIONS	
417	COMMAND AND CONTROL ANALOG SWITCHBOARDS	
441	RADIO SYSTEMS	W = 1.34 (WEIGHT OF GFE IN 441)
442	UNDERWATER SYSTEMS	W = 0.22
444	TELEMETRY SYSTEMS	
445	TTY AND FACSIMILE SYSTEMS	W = 1.12 (WEIGHT OF GFE IN 445)
446	SECURITY EQUIPMENT SYSTEMS	W = 1.39 (WEIGHT OF GFE IN 446)
451	SURFACE SEARCH RADAR	W = 1.88 (WEIGHT OF GFE IN 451)
452	AIR SEARCH RADAR (2D)	W = 1.20 (WEIGHT OF GFE IN 452)
453	AIR SEARCH RADAR (3D)	
454	AIRCRAFT CONTROL APPROACH RADAR	
455	IDENTIFICATION SYSTEMS (IFF)	W = 1.29 (WEIGHT OF GFE IN 455)
456	MULTIPLE MODE RADAR	
459	SPACE VEHICLE ELECTRONIC TRACKING	
461	ACTIVE SONAR	
462	PASSIVE SONAR	W = 1.29 (WEIGHT OF GFE IN 462)
463	MULTIPLE MODE SONAR	W = 1.31 (WEIGHT OF GFE IN 463)
464	CLASSIFICATION SONAR	
465	BATHYTHERMOGRAPH	W = 1.67 (WEIGHT OF GFE IN 465)
471	ACTIVE ECM (INCL COMBINATION ACTIVE/PASSIVE)	
472	PASSIVE ECM	W = 1.54 (WEIGHT OF GFE IN 472)
481	GUN FIRE CONTROL SYSTEMS	W = 1.23 (WEIGHT OF GFE IN 481)
482	MISSILE FIRE CONTROL SYSTEMS	W = 1.20 (WEIGHT OF GFE IN 482)
483	UNDERWATER FIRE CONTROL SYSTEMS	W = 2.56 (WEIGHT OF GFE IN 483)
484	INTEGRATED FIRE CONTROL SYSTEMS	
489	WEAPON SYSTEMS SWITCHBOARDS	W = 1.65 (WEIGHT OF GFE IN 489)

WEIGHT ALGORITHMS (Continued)

COST GROUP: 5A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
511	COMPARTMENT HEATING SYSTEM	W = 1.0142 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
512	VENTILATION SYSTEM	W = 7.083 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 27.76 (IF SHIP HAS FAN COIL UNITS)
513	MACHINERY SPACE VENTILATION SYSTEM	W = 1.266 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
514	AIR CONDITIONING SYSTEM	W = .0135 (MANNING) + .022 (TOTAL COMBAT SYSTEM HEAT DISSIPATION (KW)) + 10.0 (VOLUME OF ELECTRONIC SPACES (FT^3)) x 10^{-5} + 3.3 (VOLUME OF OTHER ARRANGEABLE SPACES* (FT^3)) x 10^{-5} * EXCLUDES MACHINERY SPACES, TANKS, AND ELECTRONIC SPACES
516	REFRIGERATION SYSTEM	W = 0.01212 (MANNING)
517	AUXILIARY BOILERS AND OTHER HEAT SOURCES	W = .056 (MANNING)

WEIGHT ALGORITHMS (Continued)

COST GROUP: 5B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
521	FIREMAIN AND FLUSHING (SEA WATER) SYSTEM	W = 98.6 (MISSILE MAGAZINE VOLUME (FT^3)) x 10^{-5} + 45. (VOLUME OF OTHER MAGAZINES (FT^3)) x 10^{-5} + .01414 (TOTAL COMBAT SYSTEM HEAT DISSIPATION-KW) + 8.33 (MANNING) 10^{-3} + 4.55 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 1.4 (NUMBER OF SHAFTS) + 0.5 (IF AT LEAST 1 HELICOPTER IS CARRIED)
522	SPRINKLER SYSTEM	
523	WASHDOWN SYSTEM	W = 1.0 (SUPERSTRUCTURE VOLUME (FT^3)) x 10^{-5}
524	AUXILIARY SEA WATER SYSTEM	
526	SCUPPERS AND DECK DRAINS	W = .17 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
527	FIREMAIN ACTUATED SERVICES - OTHER	
528	PLUMBING DRAINAGE	W = 2.0 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
529	DRAINAGE AND BALLASTING SYSTEM	W = 3.182 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
531	DISTILLING PLANT	W = .027 (MANNING)
532	COOLING WATER	W = .0409 (TOTAL COMBAT SYSTEM HEAT DISSIPATION TO DEMINERALIZED WATER (KW))
533	POTABLE WATER	W = .039 (MANNING)
534	AUX. STEAM AND DRAINS WITHIN MACHINERY BOX	W = 1.3 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
535	AUX. STEAM AND DRAINS OUTSIDE MACHINERY BOX	W = 2.5 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
536	AUXILIARY FRESH WATER COOLING	
541	SHIP FUEL AND FUEL COMPENSATING SYSTEM	W = 26.0 + .018 (FUEL-TONS)
542	AVIATION AND GENERAL PURPOSE FUELS	W = 4.00 (IF ONE OR MORE HELICOPTERS ARE TO BE CARRIED OR REFUELED)
543	AVIATION AND GENERAL PURPOSE LUBRICATING OIL	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 5B (Continued)

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
544	LIQUID CARGO	
545	TANK HEATING	
549	SPECIAL FUEL AND LUBRICANTS, HANDLING AND STOWAGE	
551	COMPRESSED AIR SYSTEMS	W = 2.4 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} WITHOUT PRAIRIE AIR + 1.5 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} FOR PRAIRIE AIR SYSTEM + 8.5 (NO. OF PROPULSION TURBINES) + 1.9 (VOLUME OF WEAPON SPACES (FT^3)) x 10^{-4}
552	COMPRESSED GASES	
553	O_2N_2 SYSTEM	W = .25 (NUMBER OF COMBAT SYSTEMS REQUIRING O_2 OR N_2)
554	LP BLOW	
555	FIRE EXTINGUISHING SYSTEMS	W = 2.74 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
556	HYDRAULIC FLUID SYSTEM	
557	LIQUID GASES, CARGO	
558	SPECIAL PIPING SYSTEMS	
565	TRIM AND HEEL SYSTEMS (SURFACE SHIPS)	
593	ENVIRONMENTAL POLLUTION CONTROL SYSTEMS	W = ..035 (MANNING)
594	SUBMARINE RESCUE, SALVAGE, AND SURVIVAL SYSTEMS	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 5C

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
561 562 568	STEERING AND DIVING CONTROL SYSTEMS RUDDER MANEUVERING SYSTEMS	$W = 3.56_{-3}[(L)(H)]^2 \times 10^{-7} + 4.29 (L)(H) \times 10^{-3} + 2.52$ IF TWIN RUDDER OR $W = 4.456 (L)(H) \times 10^{-3} + 11.2$ IF SINGLE RUDDER WHERE: L = L.B.P. H = DRAFT

WEIGHT ALGORITHMS (Continued)

COST GROUP: 5D

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
571	REPLENISHMENT-AT-SEA SYSTEMS	W = 1.7 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 3.0
572	SHIP STORES AND EQUIPMENT HANDLING SYSTEMS	W = 1.48 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
573	CARGO HANDLING SYSTEMS	
574	VERTICAL REPLENISHMENT SYSTEMS	
581	ANCHOR HANDLING AND STOWAGE SYSTEMS	W = 4.44 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} IF ONE ANCHOR OR W = 5.8 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} IF TWO ANCHORS
582	MOORING AND TOWING SYSTEMS	W = 1.16 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 4.8
583	BOATS, BOAT HANDLING AND STOWAGE SYSTEMS	W = .03 (MANNING) IF 0 BOATS OR W = .03 (MANNING) + 5.8 IF 1 BOAT OR W = .03 (MANNING) + 14.5 IF 2 BOATS
584	MECHANICALLY OPERATED DOOR, GATE, RAMP, TURNTABLE SYSTEM	
585	ELEVATING AND RETRACTING GEAR	
588	AIRCRAFT HANDLING, SERVICING AND STOWAGE	W = 18.5 + NO. OF HELOS IF (RAST & BEAR TRAP) OR W = 10.0 + NO. OF HELOS IF HAULDOWN ONLY OR W = 1.0 + NO. OF HELOS OTHERWISE
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	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6A

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
605	RODENT AND VERMIN PROOFING	
611	HULL FITTINGS	$W = 1.082$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
612	RAILS, STANCHIONS, AND LIFELINES	$W = .98$ (TOTAL SHIP VOLUME (FT^3)) x $10^{-5} - .43$ OR $W = .897$ (TOTAL SHIP VOLUME (FT^3)) x $10^{-5} + 1.64$ IF HELO SAFETY NETS
613	RIGGING AND CANVAS	$W = 0.5$ LWL ≤ 450 OR $W = 1.0$ LWL > 450
625	AIRPORTS, FIXED PORTLIGHTS, AND WINDOWS	$W = .07857$ (VOLUME OF SUPERSTRUCTURE (FT^3)) x 10^{-4}

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6B

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
621	NON-STRUCTURAL BULKHEADS	W = 3.53 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
622	FLOOR PLATES AND GRATINGS	W = 6.04 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 10.94 (IF EMPHASIS ON RELIABILITY AND MAINTENANCE)
623	LADDERS	W = .8866 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
624	NON-STRUCTURAL CLOSURES	W = .794 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
637	SHEATHING	W = .265 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} (EXCLUDES KEVLAR ARMOR WEIGHT)

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6C

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
602	HULL DESIGNATING AND MARKING	
603	DRAFT MARKS	
604	LOCKS, KEYS, AND TAGS	
631	PAINTING	$W = 5.0$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
632	ZINC COATING	
633	CATHODIC PROTECTION	$W = .172$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
634	DECK COVERING	$W = 2.83$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}
635	HULL INSULATION	<u>BASIC 635 WEIGHT:</u> $W = 4.917$ (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} <u>SHIP WITH DIESEL GEN/NO AUX BOILERS:</u> W = BASIC + 10.0 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} <u>SHIP WITH PASSIVE FIRE ZONE PROTECTION:</u> W = BASIC + 7.5 (SUPERSTRUCTURE VOLUME - UPTAKE VOLUME (FT^3)) x 10^{-5}
636	HULL DAMPING	TYPE SONAR AND NOISE REQUIREMENTS DETERMINE WT.
639	RADIATION SHIELDING	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6D

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
654	UTILITY SPACES	
655	LAUNDRY SPACES	
656	TRASH DISPOSAL SPACES	
664	DAMAGE CONTROL STATIONS	W = 5.5 FOR $\Delta \leq$ 5,000 TONS OR W = 6.5 FOR $\Delta >$ 5,000 TONS
665	WORKSHOPS, LABS, TEST AREAS (INCLUDING PORTABLE TOOLS, EQUIPMENT)	W = 1.625 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5} + 3.0
671	LOCKERS AND SPECIAL STOWAGE	W = .0421 (MANNING)
672	STOREROOMS AND ISSUE ROOMS	W = .0667 (MANNING) IF NO VIDMAR CABINETS, OR W = .1667 (MANNING) WITH VIDMAR CABINETS

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6E

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
638	REFRIGERATED SPACES	W = .02376 (MANNING)
641	OFFICER BERTHING AND MESSING SPACES	W = 0.2 (MANNING) + 10.0
642	NONCOMMISSIONED OFFICER BERTHING AND MESSING SPACES	(INCLUDES WEIGHT GROUPS 641, 642, 643, 651 - 656)
643	ENLISTED PERSONNEL BERTHING AND MESSING SPACES	
644	SANITARY SPACES AND FIXTURES	W = .077 (MANNING) - 12.48
645	LEISURE AND COMMUNITY SPACES	W = .0183 (MANNING) - 2.75
651	COMMISSARY SPACES	
652	MEDICAL SPACES	
653	DENTAL SPACES	
661	OFFICES	W = .02833 (MANNING)
662	MACHINERY CONTROL CENTERS FURNISHINGS	W = 1.0 FOR ONE GAS TURBINE OR W = 1.5 FOR TWO GAS TURBINES OR W = 2.0 FOR THREE GAS TURBINES
663	ELECTRONICS CONTROL CENTERS FURNISHINGS	W = 1.0 (TOTAL SHIP VOLUME (FT^3)) x 10^{-5}

WEIGHT ALGORITHMS (Continued)

COST GROUP: 7

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
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	
770	CARGO MUNITIONS	
772	CARGO MUNITIONS HANDLING	
773	CARGO MUNITIONS STOWAGE	
782	AIRCRAFT RELATED WEAPONS HANDLING	

WEIGHT ALGORITHMS (Continued)

COST GROUP: 7

SWBS NO.	DESCRIPTION	WEIGHT ALGORITHMS
783	AIRCRAFT RELATED WEAPONS STOWAGE	
792	SPECIAL WEAPONS HANDLING	
793	SPECIAL WEAPONS STOWAGE	
797	MISCELLANEOUS ORDNANCE SPACES	

APPENDIX D

BSCI/SWBS COMPARISON

BSCI to SWBS Modifications

Group 1A	100 Change Cathodic Protection to 6C
Comment:	This involves about 2,000 man-hours for the electrical type system. Since the total man-hours in each group is rather large, the shift is not significant. The weight shift is negligible.
Group 1D	122 Change Mechanical Operator System to 5D
Comment:	As this includes the power operation for special purpose doors only, the costs are already in 5D.
Group 2B	203 Change Auxiliary S.W. Systems to 5B
Comment:	From a cost standpoint all auxiliary S.W. Systems are now in 5B.
Group 2C	205 Change Stacks and Macks to 1D
Comment:	Splitting the inner and outer stack into different cost groups is not feasible or desired. They are generally built together as a single unit.
Group 4B	405 Change Missiles Monitoring and Test to 7
Comment:	This is a (high dollar) value item which, from a shipyard standpoint, should remain in the 405 Group.
Group 5A	503 Change Refrigerated Space Insulation to 6C
Comment:	This is a separate BIW charge and, therefore, could be changed. However, from a cost standpoint it would seem preferable to leave it with the refrigerated spaces rather than with hull insulation.
Group 5B	505 Change Plumbing Installations to 6E
Comment:	This primarily involves the fixtures only. Unfortunately, the BIW charge includes the associated drains, which could only be sorted out by guess work.
Group 5B	514 Change High Pressure Steam Drain to 2D
Comment:	From a cost standpoint it does not make sense to separate this drain system from the others. Note this is only a very small system.
Group 6A	600 Change Mooring and Towing Fitting to 5D
Comment:	This involves the mooring bitts and chocks that are now included with the other hull fittings. From the BIW standpoint, it would be better to leave them in 6A.
Group 6A	601 Change Boats, Stowage and Handling to 5D
Comment:	This is a separate BIW charge and, therefore, could be changed. It might be questionable from a cost standpoint.
Group 6D	608 Change Hull Repair Parts to 1D
Comment:	Change is insignificant.
Group 6D	609 Change Environmental Pollution Control to 5B
Comment:	From a cost standpoint components such as garbage grinders and trash burners should not be mixed in with piping systems.

APPENDIX E

SHIP SUBSYSTEM COST DRIVERS

GROUP	PARAMETER	DD-931	DDG-2	CG-16	CG-26	FFG-4	FFG-7	DDG-40	FF-1052	DD-963	DDG-993	CG-47	DDG-51
1A	Mild Steel Hull	X				X	X						
	HTS Hull	X	X	X	X				X	X	X	X	X
	HY 80 Hull		X	X			X						
1B	Steel Superstructure												X
	Aluminum Superstructure	X	X	X	X	X	X	X	X	X	X	X	
	Helicopter w/ Hangar				1	1	2		1	1	1	1	
	Helicopter Landing Area Only			X									X
1C	Shock Qualified Foundations				X	X	X			X	X	X	X
	Non-Shock Qualified Foundations	X	X	X	X			X	X				
	Steam (S) or Gas Turbine (G)	S	S	S	S	S	T	S	S	T	T	T	T
1D	Ballistic Plating Yes (Y) / No (N)	N	N	Y	N	N	Y	N	N				Y
	Sonar Size Small (S) / Large (L)	S	S	S	L	L	S		L	L	L	L	L

GROUP	PARAMETER	DD-931	DDG-2	CG-16	CG-26	FFG-4	FFG-7	DDG-40	FF-1052	DD-963	DDG-993	CG-47	DDG-51
2A	Single (S) / Twin (T) Screw	T	T	T	T	S	S	T	S	T	T	T	T
	1200 psig Steam	X	X	X	X	X		X	X				
	Geared Gas Turbine						X			X	X	X	X
	Gas Turbine - Electric												
	Diesel												
	Integrated Electric												
	CODOG												
	Auxiliary Propulsion Units						2						
2B	Fixed Pitch Propellers	X	X	X	X	X		X	X				
	CRP Propellers						X			X	X	X	X
2C	Single Stack or Mack					X	X		X				
	Multiple Stack or Mack	X	X	X	X			X		X	X	X	X
2D	Steam, Non-Automated					X		X	X				
	Non-Steam, Automated						X			X	X	X	X
	Non-Steam, Non-Automated	X	X	X	X								

GROUP	PARAMETER	DD-931	DDG-2	CG-16	CG-26	FFG-4	FFG-7	DDG-40	FF-1052	DD-963	DDG-993	CG-47	DDG-51
3A	Ship's Service Steam Turbo-Generator	4 550-KW	4 550-KW	4 1000-KW	4 1500-KW	2 1000-KW		X	X				
	Diesel Generator	2 100-KW	2 100-KW	1 300-KW	1 300-KW	2 500-KW	4 1000-KW						
	Gas Turbine Generator			1 300-KW	1 300-KW					3 2000-KW	X	X	3 2500-KW
	Integrated Electric												
	400 Hz	MG Sets X	MG Sets X	MG Sets X	MG Sets X	MG Sets X	Static X	X	X	X	X	X	X
3B	Switchboards - Aluminum (A) / Steel (S)	A	S	A	A	A	S						A
4A	Armored Cable	X	X	X	X	X		X					
	Non-Armored Cable						X						X
	Multiplexing												X

GROUP	PARAMETER	DD-931	DDG-2	CG-16	CG-26	FFG-4	FFG-7	DDG-40	FF-1052	DD-963	DDG-993	CG-47	DDG-51
5A	Steam (S) / Electric (E) Heat	S	S	S	S	S	E	S	S	E	E	E	E
	CPS = STOPS = Citadel												X
5B	Missile Magazine Water Cooling						X	X			X	X	X
	Prarie Masker					X	X			X	X	X	
	Clean Ballast						X						
	Compensated Ballast									X	X	X	X
5C	Single (S) / Twin (T) Rudder	T	T	T	T	S	S	T	S	T	T	T	T
	Stabilizers					X			X				
	NIXIE		X	X	X	X	X	X	X	X	X	X	X
5D	Helo Haul Down						X						
	Anchors	2	2	2	2	2	1	2	2	2	2	2	2
	Refueling at Sea	X	X	X	X	X	X	X	X	X	X	X	X

GROUP	PARAMETER	DD-931	DDG-2	CG-16	CG-26	FFG-4	FFG-7	DDG-40	FF-1052	DD-963	DDG-993	CG-47	DDG-51
6A	Boats	2	2	3	4	2	1		2	2	2	2	2
6B	No Sheathing	X	X	X	X	X		X	X				
	Normal Sheathing										X	X	X
	Extensive Sheathing						X			X			
6C	Insul. Type - Structural (S) / Non-Structural (N)	N	N	N	N	N	S			S	S	S	N-St
	Sonar Sound Damping				Full	Partial			X	X	X	X	X
6D	Vidmar Cabinets						X			X	X	X	X
6E	Pre-1965 Habitability Standards	X	X										
	1965 Habitability Standards			X	X	X	X	X	X	X		X	
	1979 Habitability Standards						Met or Exceeded						X