AN ANALYSIS OF U.S. FISHING BOATS - DIMENSIONS, WEIGHTS AND COSTS

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ABSTRACT

The authors have compiled information on the dimensions, weights and costs of the principal types of U. S. Built, steel-hulled fishing vessels. These data have been analyzed and the results are presented graphically in the form of curves.

Methods of estimating weights and costs are suggested and the influence of overhead, wage rates, profit and miscellaneous costs are discussed. The proposed cost estimates are assimilated into a final set of curves showing the trends in total cost for vessels of various sizes and powers.

Since there is an apparent need for such a thing the paper concludes with a proposed cost and weight recording system suitable for small-craft yards.

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INTRODUCTION

Aim

Naval architects are becoming increasingly aware of the importance of economic considerations in making technical decisions. More and more they are coming to realize that the best measure of engineering success is commercial success. The prospective fishing boat owner may be impressed with the naval architect's calculations of stability, strength and fuel rate; but what he is really interested in knowing is, first of all, how much the boat will cost and second, how soon he can expect the profits to repay his investment. It is the primary intent of this paper to suggest means by which the naval architect can show the prospective owner how variations in possible size or power will influence building costs. Since any cost analysis involves prior dimension and weight studies, the paper deals, not only in cost estimating, but in weight and dimension approximations as well.

Scope

As the title indicates, this study is confined to American type fishing boats, principally trawlers, tuna clippers, seiners and combination craft. Unless otherwise stated, all figures are based on steel hull construction although deckhouses may be either steel or wood. Vessel sizes range up to 200 feet (60 m) in length. Propulsion is by single screw diesel engines in powers up to 2000 BHP.

With a little care and judgment, the results of the study can be applied to fishing vessels falling outside the above mentioned scope.

Difficulties Encountered

In gathering the information for this study, the authors were impressed by two things: 1) almost without exception, administrators and technical people are extremely willing to cooperate in furnishing cost and weight figures, but: 2) the very common failure to keep any sort of systematic record of costs and weights meant that, for the most part, these people were simply unable to contribute. In other instances, their recording systems were so confused as to preclude any usefulness to an outsider.

While one does not expect to find much factual cost information in the published literature, it is really cause for dismay to comb every available technical writing on fishing boat design only to find next to nothing published on weights. (Reference 6 is a notable exception). Let this be a plea, then, to future writers: publish your weight breakdown, or if you have none, at least state the deadweight and displacement at some specified waterline!

While the dearth of cost and weight figures was extremely discouraging, it was nevertheless decided to embark on the study and to publish the findings. This would at least present a target for the discussors to pelt, and it is the authors' hope that the accumulated missiles will at least double the paper's value.

Finally, since there is an apparent need for such a thing, the paper closes with a proposed cost and weight recording system which the authors feel would be suitable for most small-craft yards.

PROPORTIONS

Figures 1, 2 and 3 show the principal dimensions of the major types of U. S. built fishing craft, while Figures 4, 5 and 6 show the approximate relationship between length and displacement. These figures were developed as part of the weight study but should also prove useful in preliminary design. The mean lines drawn on the charts represent good average practice but are not intended as the final word. In many instances, special operating conditions will dictate departures from these mean values.

An attempt was made to utilize Posdunine's formula relating length, displacement and speed (Reference 5).

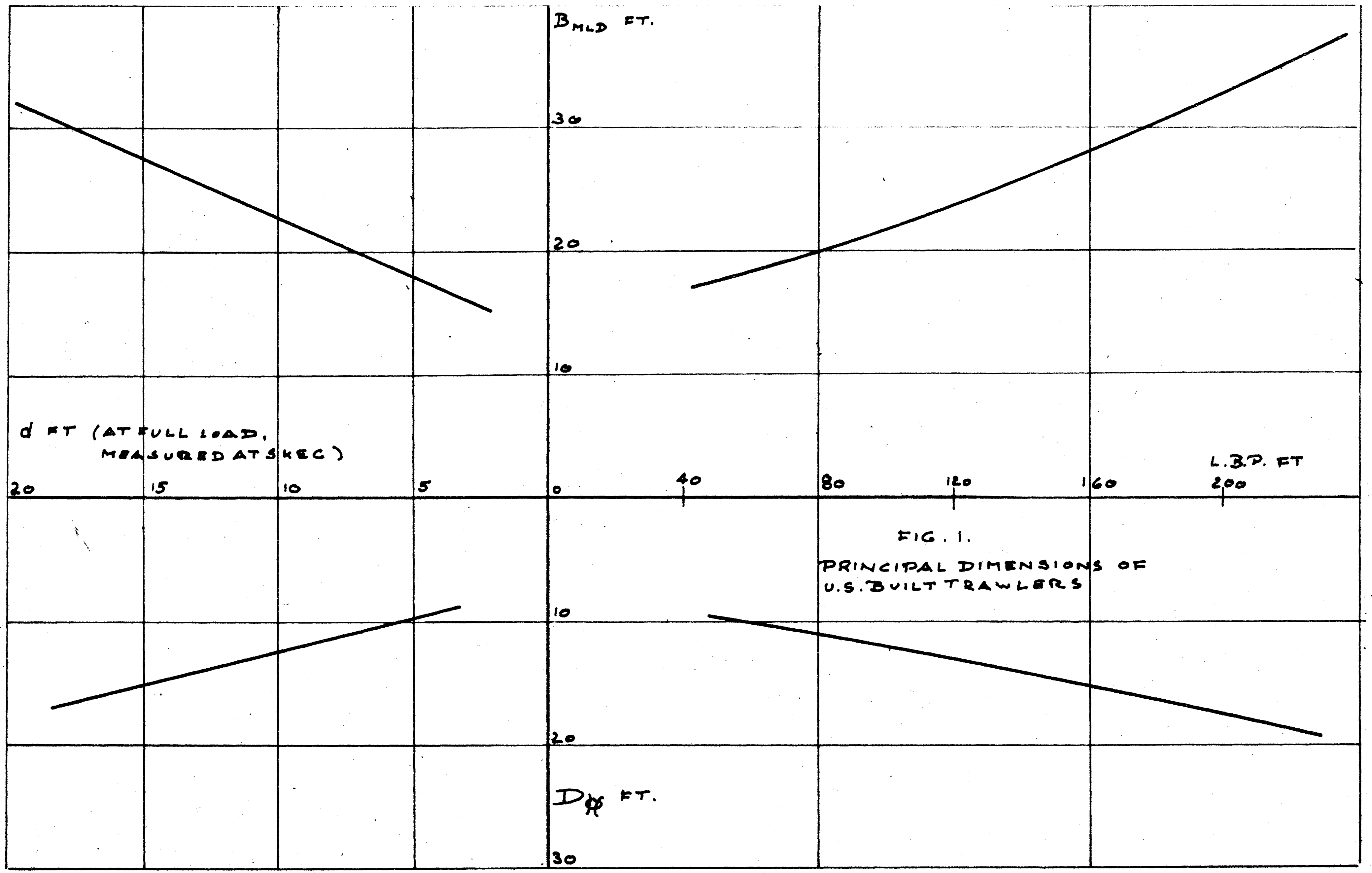

FIG. 1.
PRINCIPAL DIMENSIONS OF U.S. BUILT TRAWLERS

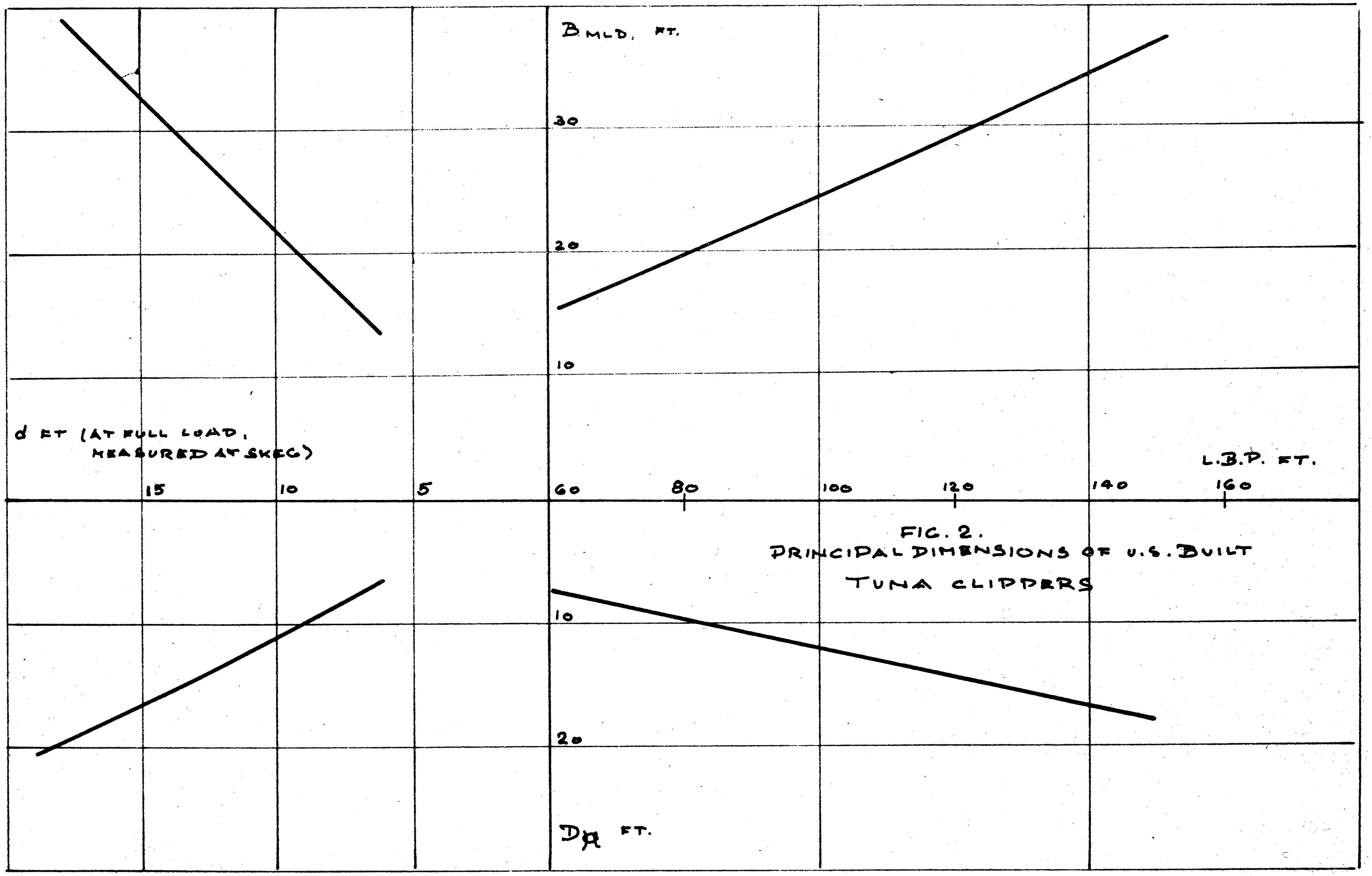

FIG. 2.
PRINCIPAL DIMENSIONS OF U.S. BUILT
TUNA CLIPPERS

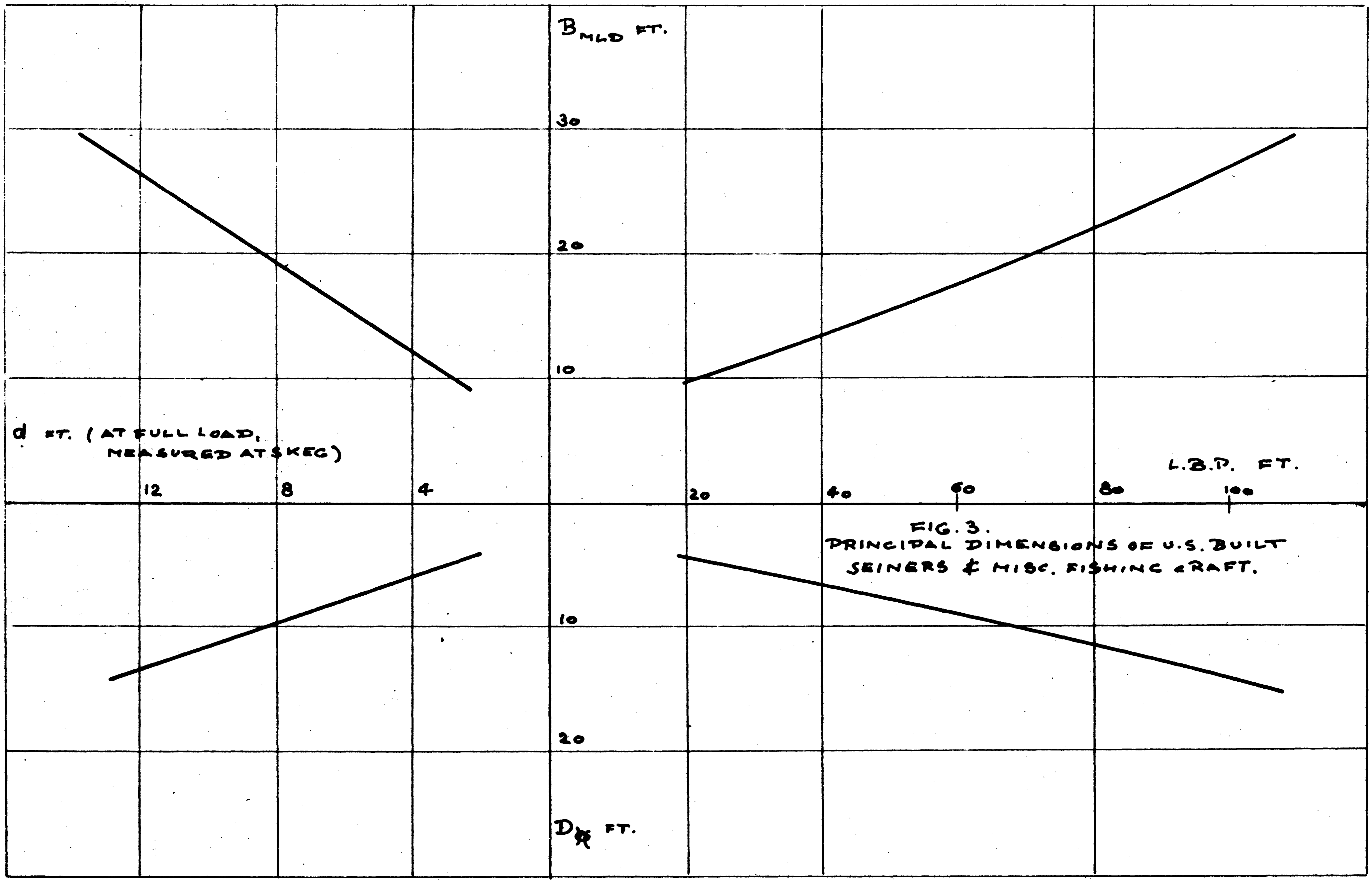

FIG. 3.
PRINCIPAL DIMENSIONS OF U.S. BUILT SEINERS & MISC. FISHING CRAFT.

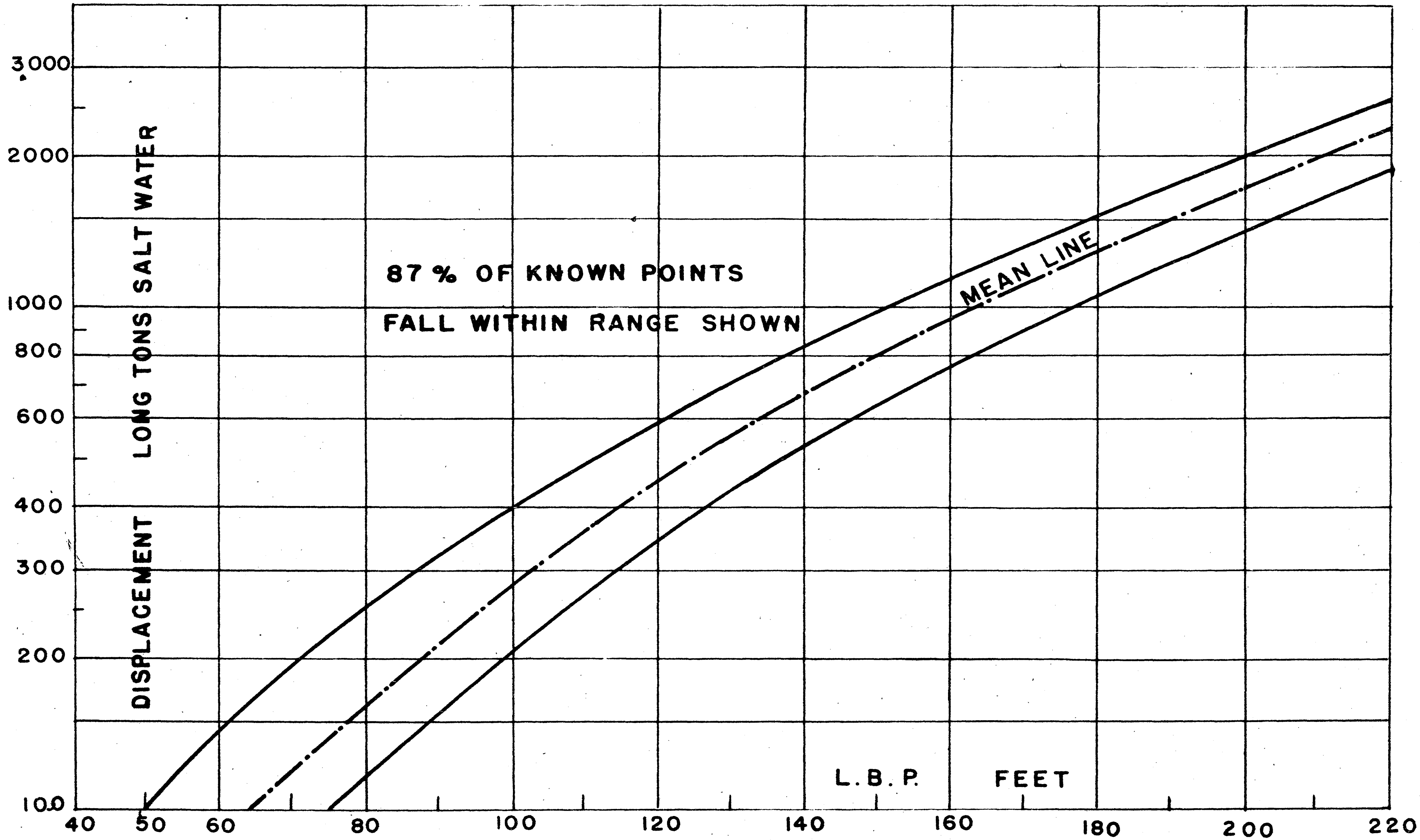

FIG. 4 : DISPLACEMENT vs LENGTH , U.S. BUILT TRAWLERS

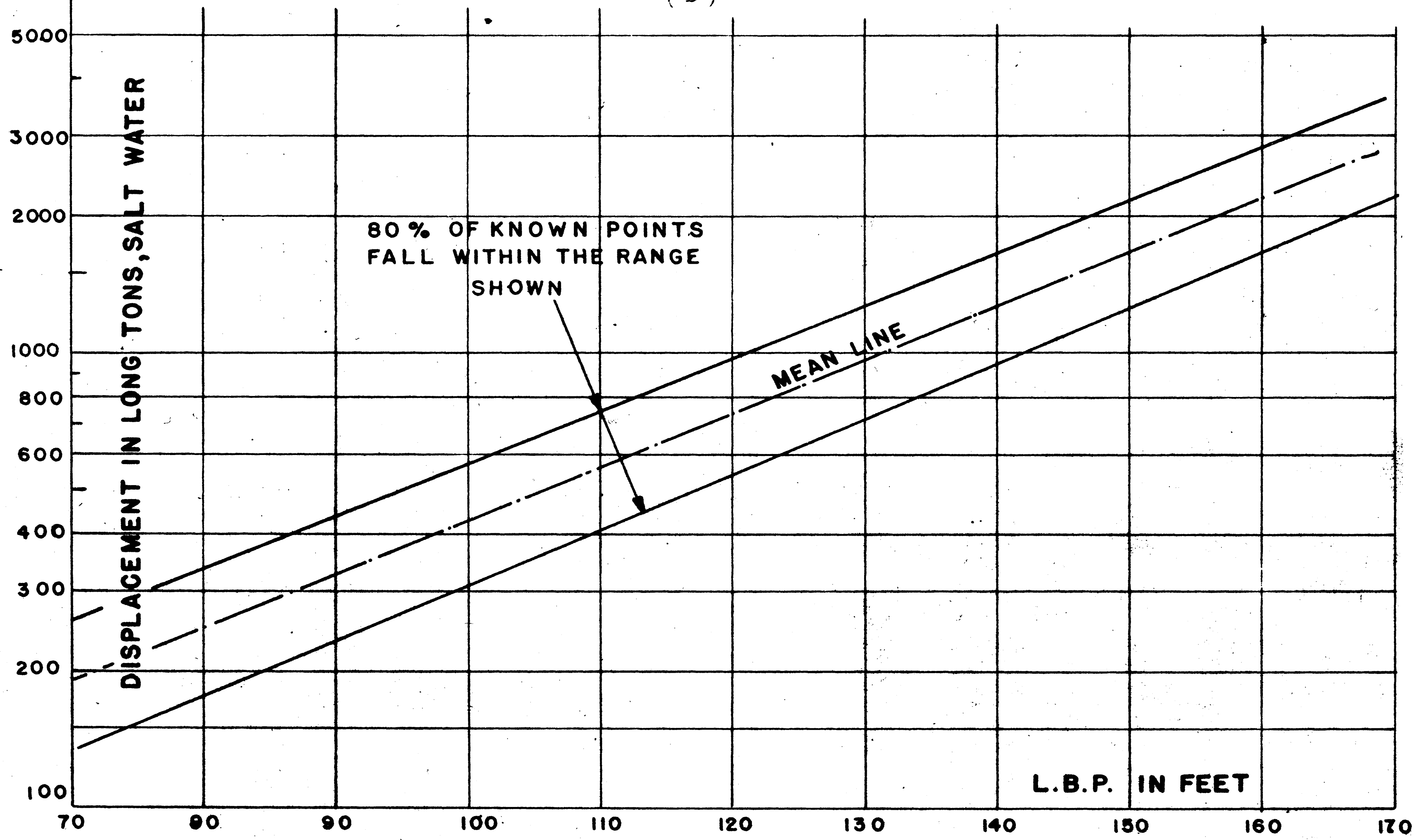

FIG. 5 : DISPLACEMENT VS LENGTH, U.S. BUILT TUNA CLIPPERS

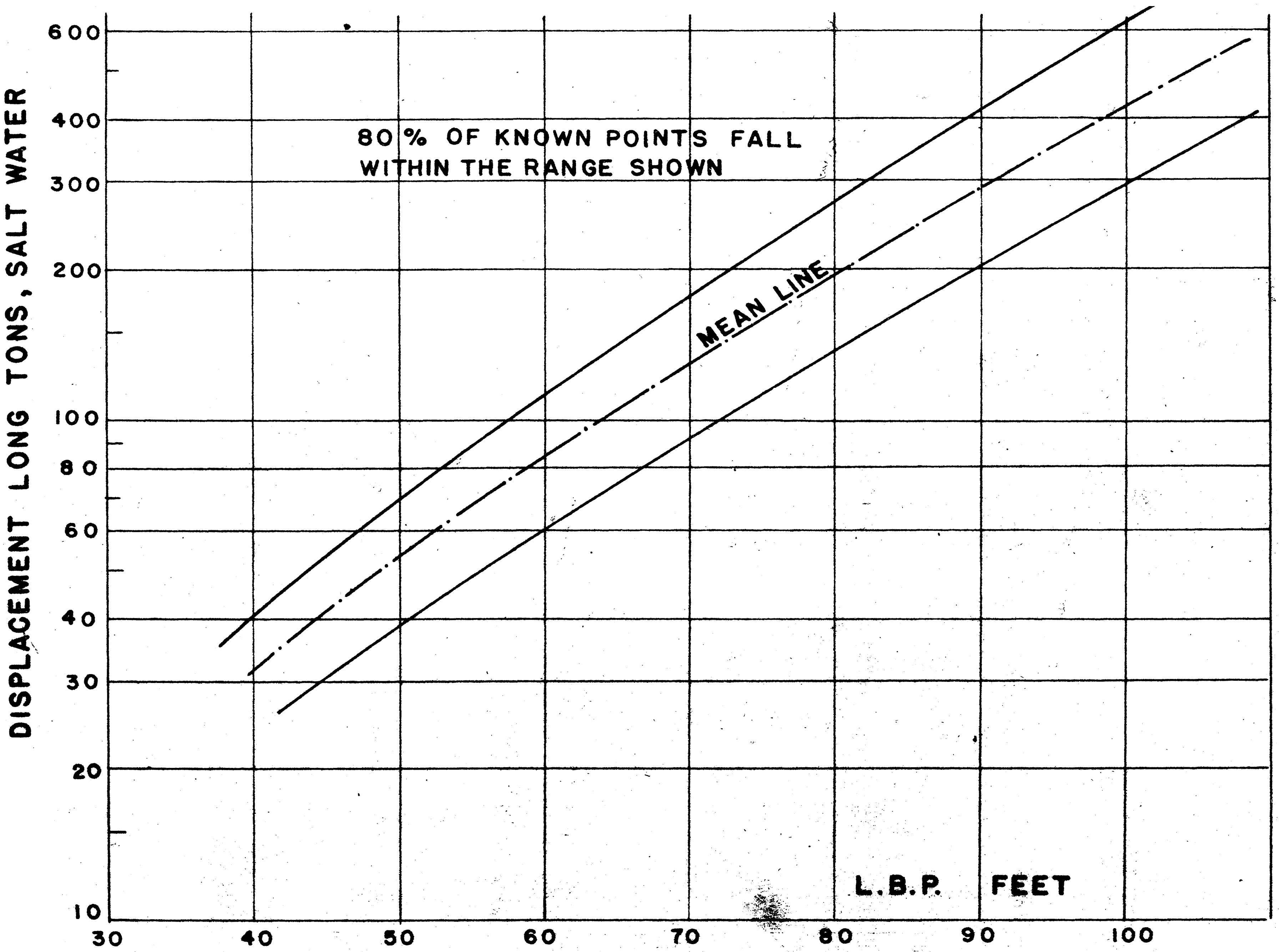

FIG. 6: DISPLACEMENT VS LENGTH FOR U.S. BUILT SEINERS & MISCELLANEOUS FISHING CRAFT.

It was not found to be particularly applicable, however, except for trawlers in the range of length between 110 feet (34 m) and 170 feet (52 m). The formula then is as follows:

$$L.B.P. = C \frac{V_K}{V_K + 2} \Delta^{1/3}$$

where C = 18.4 based on existing data

V_K = normal sea speed in knots

Δ = displacement in long tons, salt water

(If using metric tons, a value of $C = 5.58$ will give L.B.P. in meters).

WEIGHTS

General

Naval architects have an acute need in knowing how to estimate weights on a proposed vessel. First, and most obvious, such knowledge is essential as a means of guaranteeing sufficient payload capacity, stability, trim and similar technical considerations. Second, it furnishes a rational method for estimating most of the components of building cost.

This section is devoted to the problem of estimating weights in the early stages of design and presupposes the dimensions and power have been tentatively set.

The proposed cost and weight breakdown presented at the end of the paper does not in every instance agree with the one used in this study. The authors were forced to depart from what they considered best because of the manner in which their available weight data were broken down.

Structural Hull Weight

This category includes the main hull structure, superstructure, deckhouse, bulkheads, bulwarks, decks, foundations, etc.

In general, welded steel construction is assumed although the deck houses will usually be of wood except in the larger trawlers.

Figure 7 may be used to estimate the net weight of steel in any normal type of fishing vessel with wood deckhouse. When the deckhouse is of steel, its weight in tons can be estimated (Reference 6) as 0.004 times the product of the structure's length, width and height. In metric units, the constant would become 0.144. These figures appear to be on the safe side. The same reference states that wood deckhouses will weigh the same as steel.

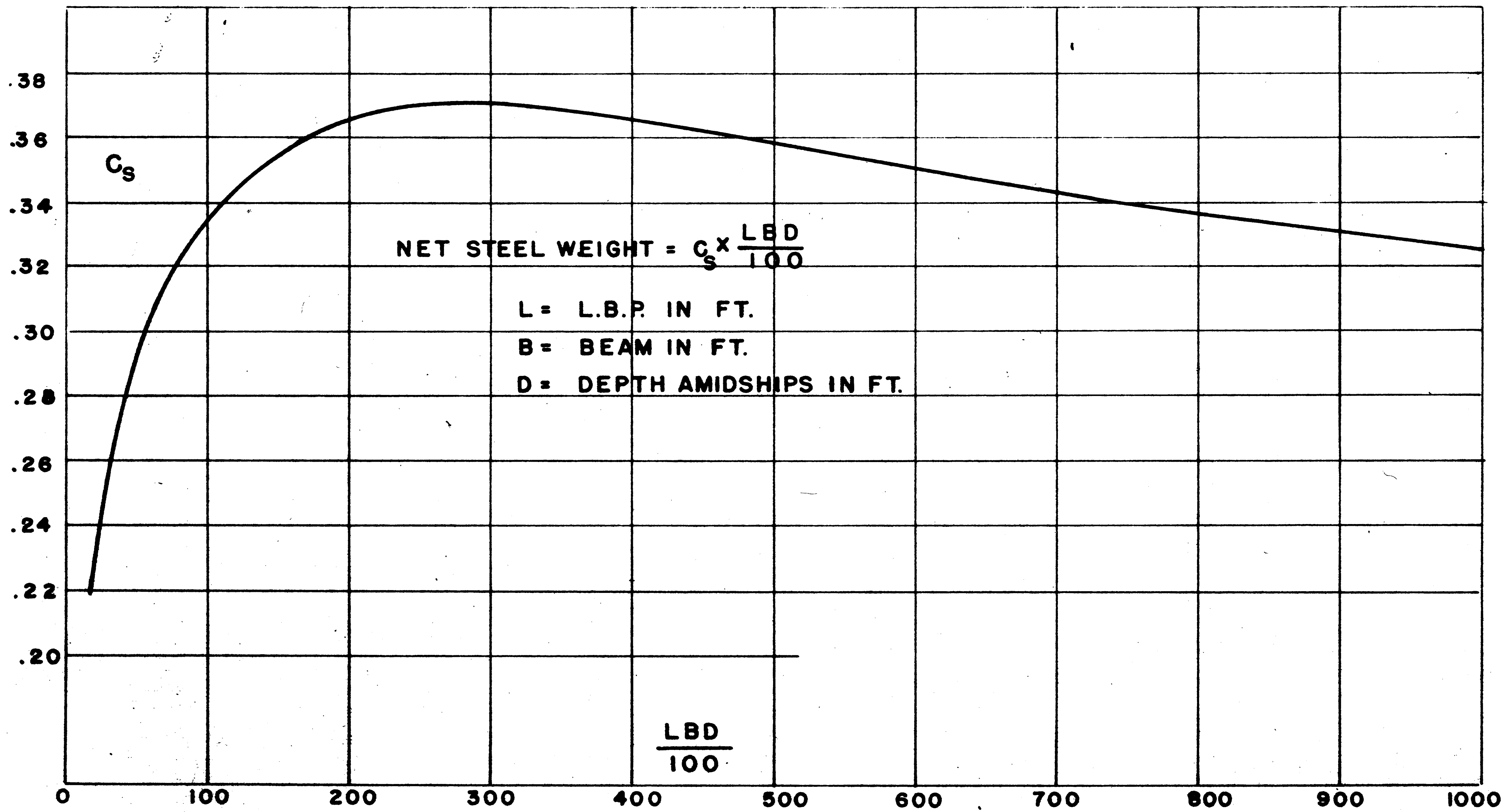

FIG. 7: NET STEEL WEIGHT COEFFICIENTS for SEINERS & TUNA CLIPPERS
(FOR TRAWLERS WITH STEEL DECK HOUSES, ADD 0.03 TO C_s VALUE GIVEN FROM CURVE)

If the dimensions of the deckhouse are unknown, the following approximations may be used for either wood or steel:

Seiners: deckhouse weight $= \frac{LBD}{100} \times 0.025$

Tuna Clippers: deckhouse weight $= \frac{LBD}{100} \times 0.015$

Figure 7 shows the influence of size (as measured by the cubic number: $\frac{LBD}{100}$ in cubic feet) on the weight characteristics. This parameter is commonly used in big ship analysis and seems quite in order for small craft as well. Above a cubic number of 300, the unit weights decrease as size increases. This is quite in keeping with similar plots on large ships and agrees with common sense. In the smaller sizes, however, the trend is reversed. This can be explained by the fact that the raised superstructures which are standard on the larger craft usually disappear as size lessens and finally, in the smallest craft, the deck will be partially or completely eliminated.

Considerable deviation from normal weights can be expected. Extent of superstructure, block coefficient and arbitrary choice of plating thickness will all influence the final figure. It is surprising, then, to find that Figure 7 seems to be generally correct within 10 percent in the range of sizes above a cubic number of 100.

Fixed Ballast

There is considerable variation in the amount of fixed ballast carried in different craft and in many instances it is omitted altogether. No correlation seems to exist between ballast weight and vessel size. Its weight cannot be fixed in the preliminary design stage but is generally introduced only as found necessary for stability after the design is fairly well advanced. While ballast must not be overlooked in the weight analysis, it is of only minor importance in figuring costs.

Outfitting and Hull Engineering Weight

This category includes such items as the rudder, propeller and shafting, bait boxes, hull piping, joiner work, wiring, refrigeration equipment, ventilation, heating, hatches and rigging.

Figure 8 can be used to estimate the weight of outfitting and hull engineering. The figure shows the influence of size on this weight category and it is found that the unit weight definitely increases with vessel size. While this is quite the opposite of the case in

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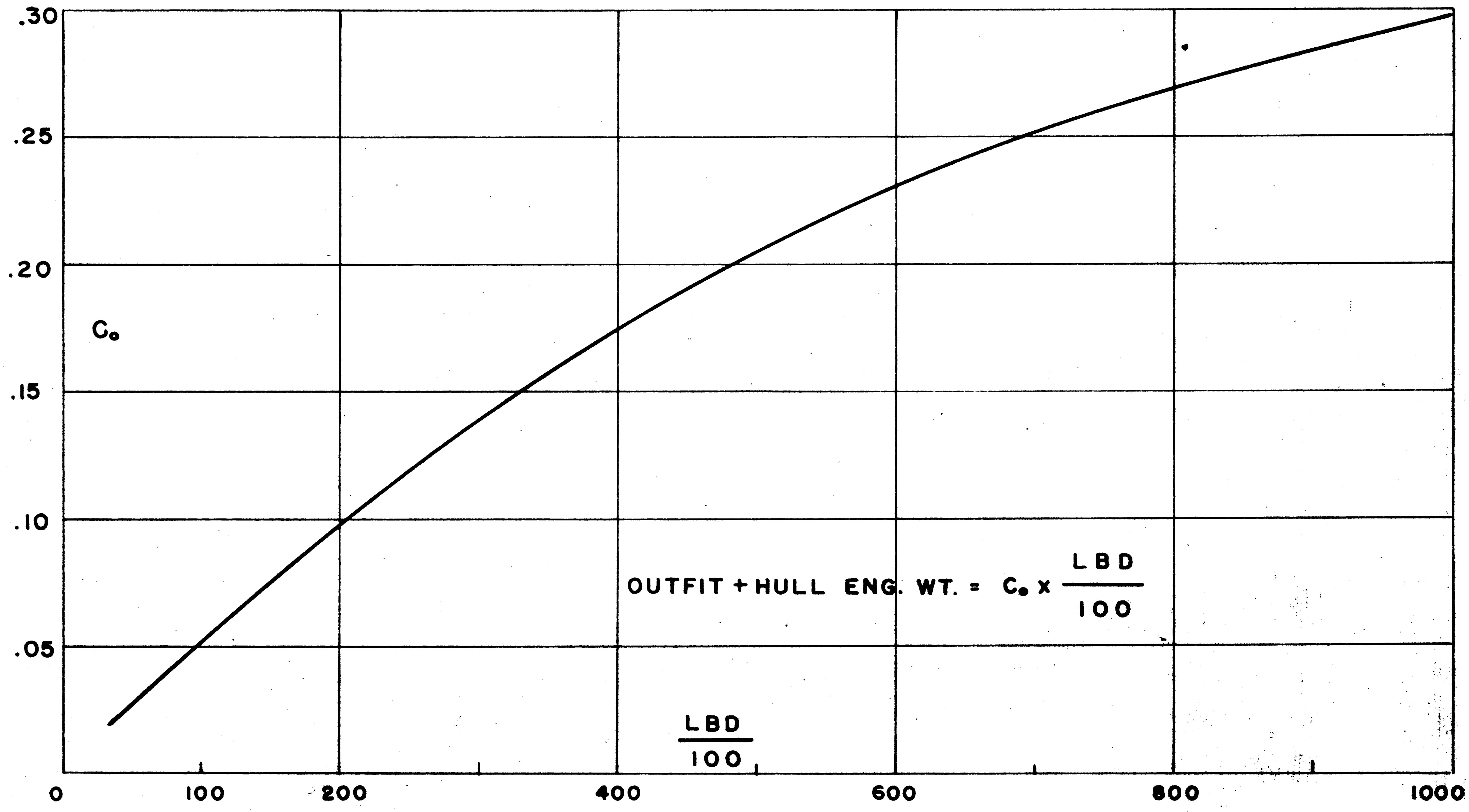

FIG. 8 : OUTFITTING WEIGHT COEFFICIENT VS CUBIC NUMBER

larger ships, it can be explained by the fact that larger fishing craft tend strongly towards a greater use of electronic gear, deck machinery, steering gear and "hotel service" systems. In the extremely small sizes, weights within this category are almost non-existent.

Actual data points from existing ships show considerable variation and in some cases depart from the mean line by as much as 30 to 35 percent. While Figure 8 is believed to indicate the general trend, it should be used with a great deal of caution.

Fishing Gear Weight

This category consists essentially of that portion of the vessel's fishing equipment, such as trawl winches, gurdies, and seine reels, which are more or less secured in place. It specifically exempts fish nets, fish lines, poles and other loose gear which the fisherman can change at will. Work boats used primarily for fishing are included here whereas life boats would be grouped with outfitting. Bait tanks are grouped with hull engineering because of their elaborate piping.

It is difficult to generalize about this category. Its weight will depend on the fishing method to be used and normally the owner will dictate the equipment to the naval architect.

In seiners, this weight will vary from about 10 percent of the light ship weight in 30 ft. (10 m) boats to about 2 percent in 85 ft. (26 m) boats. For small trawlers, this ratio should be about 5 percent in the smaller sizes and somewhat less in the larger sizes.

Perhaps this category should have been at the top of the list because the fishing method dictates the gear which in turn is the crux of the vessel design.

Main Propulsion Machinery Weight

This category includes the main propulsion engine together with its lubricating oil, fuel oil and cooling systems. Also included are the gears, starting air system and controls.

U. S. fishing vessels today are almost 100 percent diesel powered with single screw propulsion. As a general rule, the engines are installed as single rather than multiple units. Direct connected engines are frequently found on the bigger vessels while geared engines are more commonly found in the smaller craft where weight and speed restrictions are acute.

Figure 9 has been prepared as an aid in figuring the weight of the main propulsion machinery. It should be noted that the weights are plotted on a basis of brake horsepower. This is not to be confused with shaft

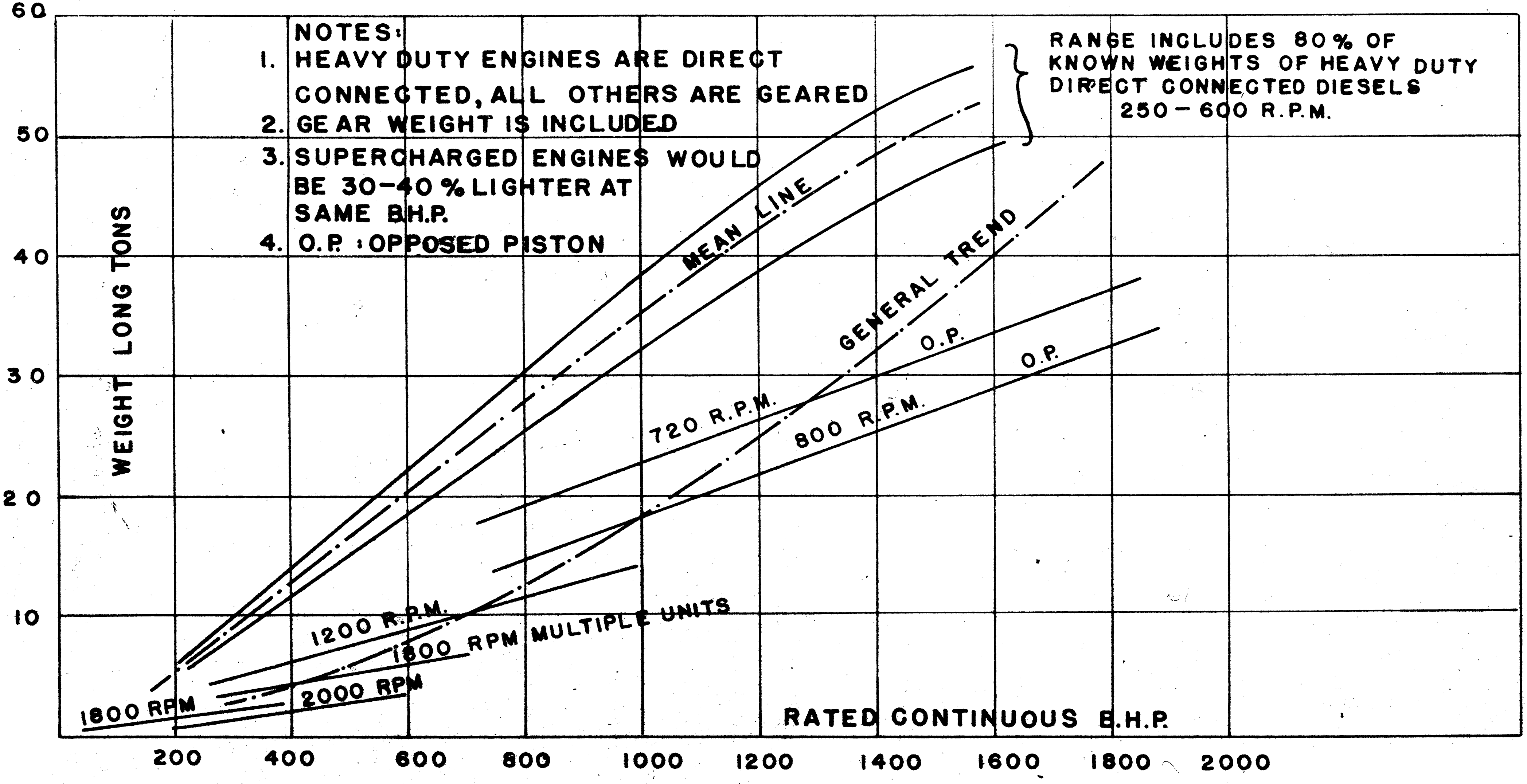

FIG. 9: DRY WEIGHT of U.S. DIESEL ENGINES

horsepower which will be somewhat smaller. References 1 and 4 contain excellent conversion factors for various arrangements.

Liquids within the machinery will add a small extra weight, perhaps 2.5 percent to the dry weights shown in Figure 9.

The weight of propeller, shafting and shaft bearings, really should be included in this category. However, the data available to the authors generally grouped these weights with hull engineering so this practice was of necessity followed here. The outfitting and hull engineering weights of Figure 8 take this into account.

<u>Auxiliary Machinery Weight</u>

This category includes all the engine room items other than those directly concerned with the main engine.

The weight of most of the auxiliary machinery, such as the generators, bilge pumps and refrigeration machinery, is more a function of vessel size than of the rated horsepower of the main engine. This weight category is therefore analyzed on a basis of cubic numbers.

Figure 10 indicates a rough method for approximating the weight of the auxiliary machinery. The unit weights tend to increase with size because of the increasing

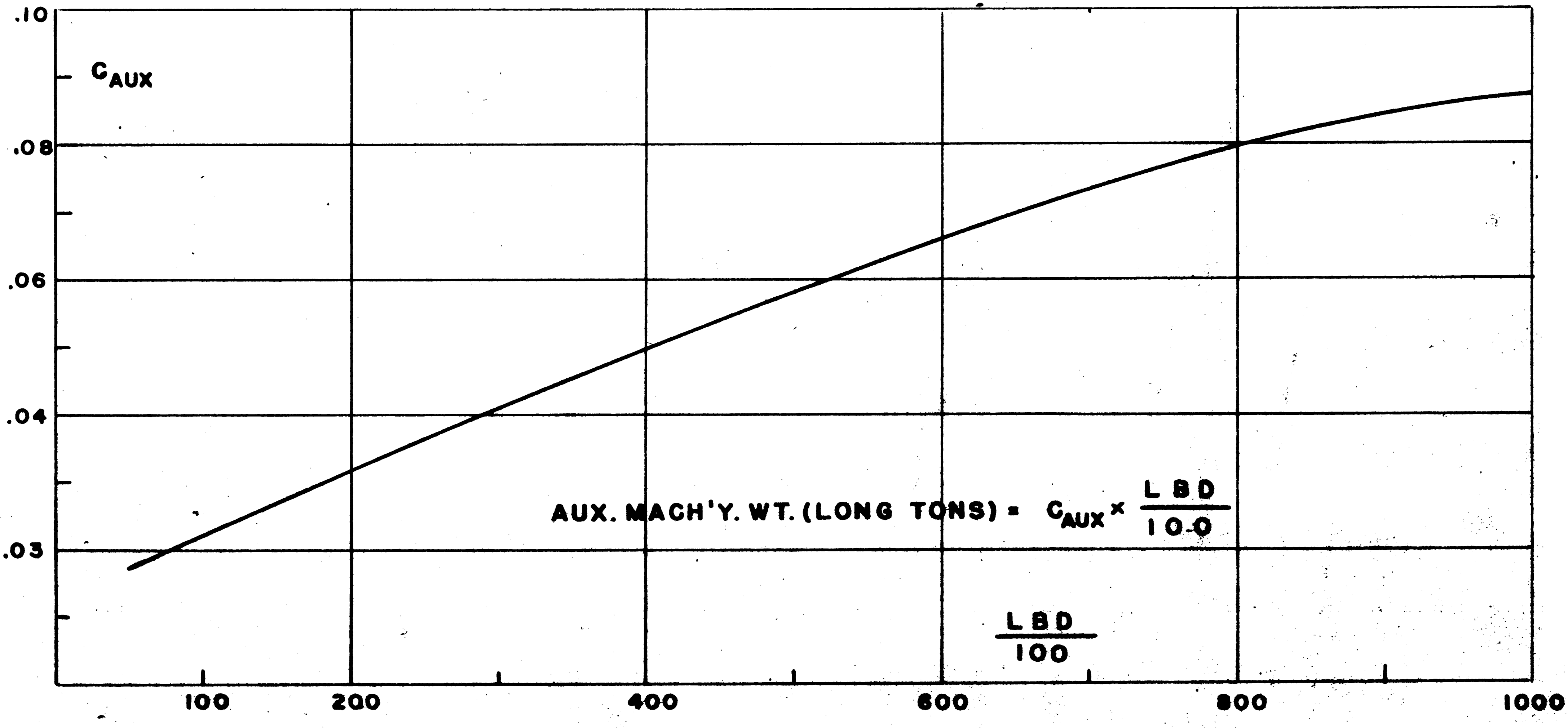

FIG. 10: AUXILIARY WEIGHT COEFFICIENT VS CUBIC NUMBER

importance of auxiliary mechanisms in the larger craft. Individual deviations from the mean line may be as much as 80 percent so that this plot should be used with care. Perhaps some of the discussors can suggest a better method of approach.

Light Ship

The summation of all of the above weight categories (that is: structural hull, fixed ballast, outfitting and hull engineering, fishing gear, main propulsion machinery and auxiliary machinery) equals Light Ship. For a specific design, the prudent naval architect will also append a designer's margin of from 5 percent to 20 percent depending on his confidence in his estimates. In the case of wood hulls, another 10 percent for soakage may be added.

Figure 11 shows the general trends of light ship weight versus cubic number. It is obvious that many factors can throw an actual weight figure off these mean lines. Trawlers, in particular, seem to be stoutly built and tend towards weights between 15 percent and 25 percent above the curve values.

Deadweight and Displacement

The difference between the design displacement and the light ship weight is of course the deadweight. This

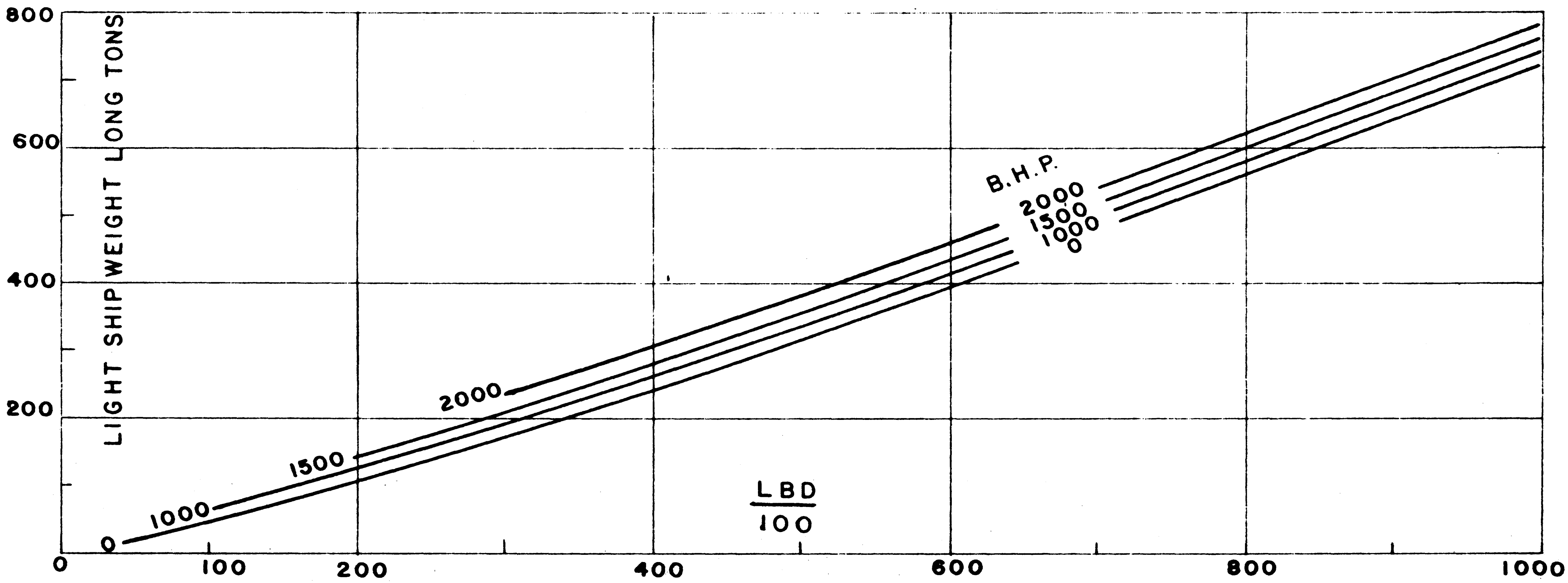

FIG. 11: LIGHT SHIP WEIGHT VS CUBIC NUMBER
(EXCLUSIVE OF FISHING GEAR)

comprises the variable weights which the fisherman can use in various combinations and over which the naval architect will have no control. While it is beyond the scope of this paper to provide means of estimating these variable weights, the suggested breakdown of cost and weight at the end of the paper will serve as a reminder as to what should be considered.

CONSTRUCTION COSTS

General

The very nature of boat building costs is such that it is quite impossible to write a definitive treatise on the subject. Variations in design, differing production methods between yards, changing hourly rates, disparity between local taxes and shifting dollar values all place any cost analysis on shaky gouund. This does not rule out the usefulness of such studies, however. When engineering economy is used as a tool in design, it is generally satisfactory to have correct relative values of cost. Therefore, while the end results of a comprehensive study may not be exact today (and will surely be wrong tomorrow) they can still serve a very useful purpose.

The remainder of this section outlines a method for estimating the cost of construction of a single-contract,

U. S. built, steel fishing vessel. Dollar values are based on mid-1958 conditions. The term "material cost" includes not only outside purchases, but services of vendors' engineers and similar expenditures.

Structural Hull Costs

These will vary with the steel weight which can be estimated from Figure 7.

Net steel weight should be increased by about 15 percent to arrive at the invoiced weight. Current delivered costs are about $200 per long ton from the steel mill or about $250 per long ton from a warehouse.

The man-hours of labor involved in the steel hull construction can be estimated from Figure 12. These values include mold loft work and wooden forms.

Wood deckhouses may be estimated on a basis of $250 per long ton of material and 100 man-hours per long ton for labor. Both figures are based on the finished weight.

Outfitting and Hull Engineering Costs

These will depend on the weight of material involved, and this can be estimated from Figure 8.

The material costs will average about $265 per long ton, based on the net weight. The figure may be considerably higher, however, if a greater-than-average amount of electronic gear is installed.

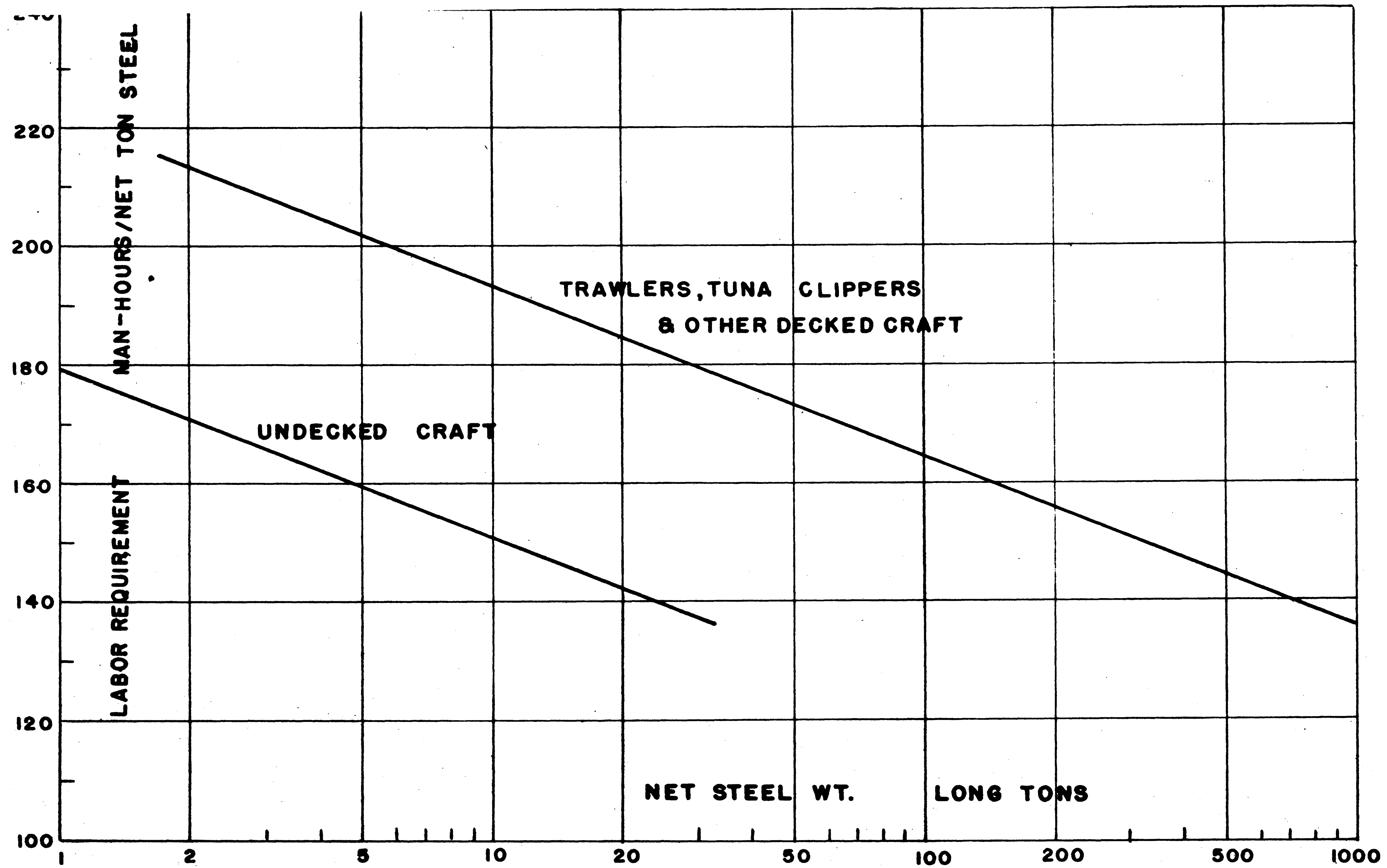

FIG. 12 STEEL HULL LABOR REQUIREMENTS

The man-hours required to fabricate and install the outfitting and hull engineering items can be approximated by the use of Figure 13.

Fishing Gear Costs

This particular category is one in which the authors could find no exact information. It seems reasonable to believe, however, that the unit costs for both material and labor should be very nearly the same as for outfitting and hull engineering. Recent trends towards power reels and other labor-saving devices will, of course, tend to increase costs within this category.

Main Propulsion Machinery Costs

The material costs for the main engine may be obtained from the various diesel engine manufacturers or, lacking that source, by reference to Figure 14.

The labor of installing the main engine should vary with the weight of the unit. This may run around 50 man-hours per long ton. See Figure 9.

Auxiliary Machinery Costs

These figures may be estimated on a weight basis, Figure 10. Material costs should average about $1200 per long ton. The labor involved in handling and installing the auxiliary machinery generally requires about 180 man-hours per long ton.

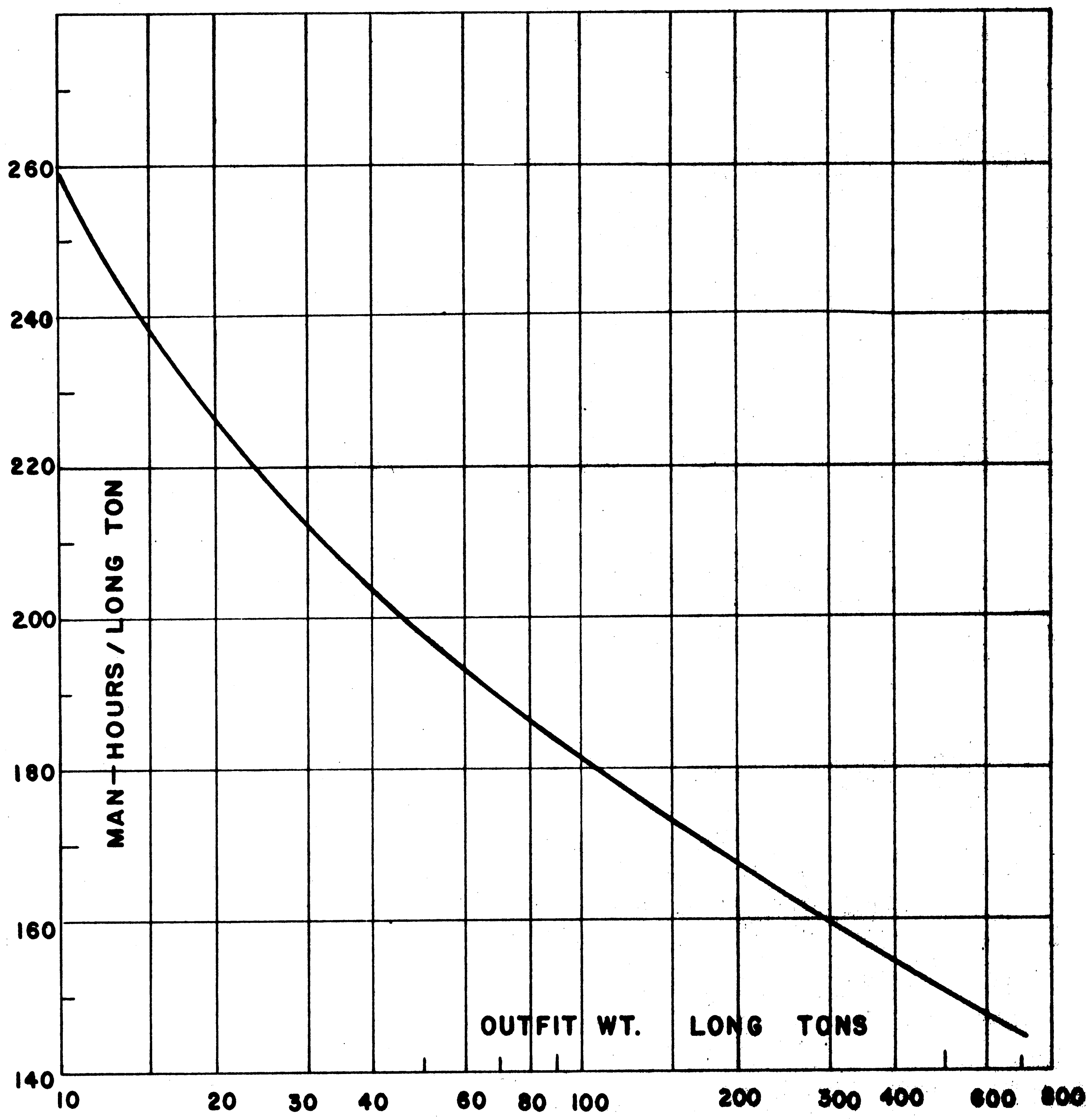

FIG. 13 : OUTFITTING MAN HOURS PER TON

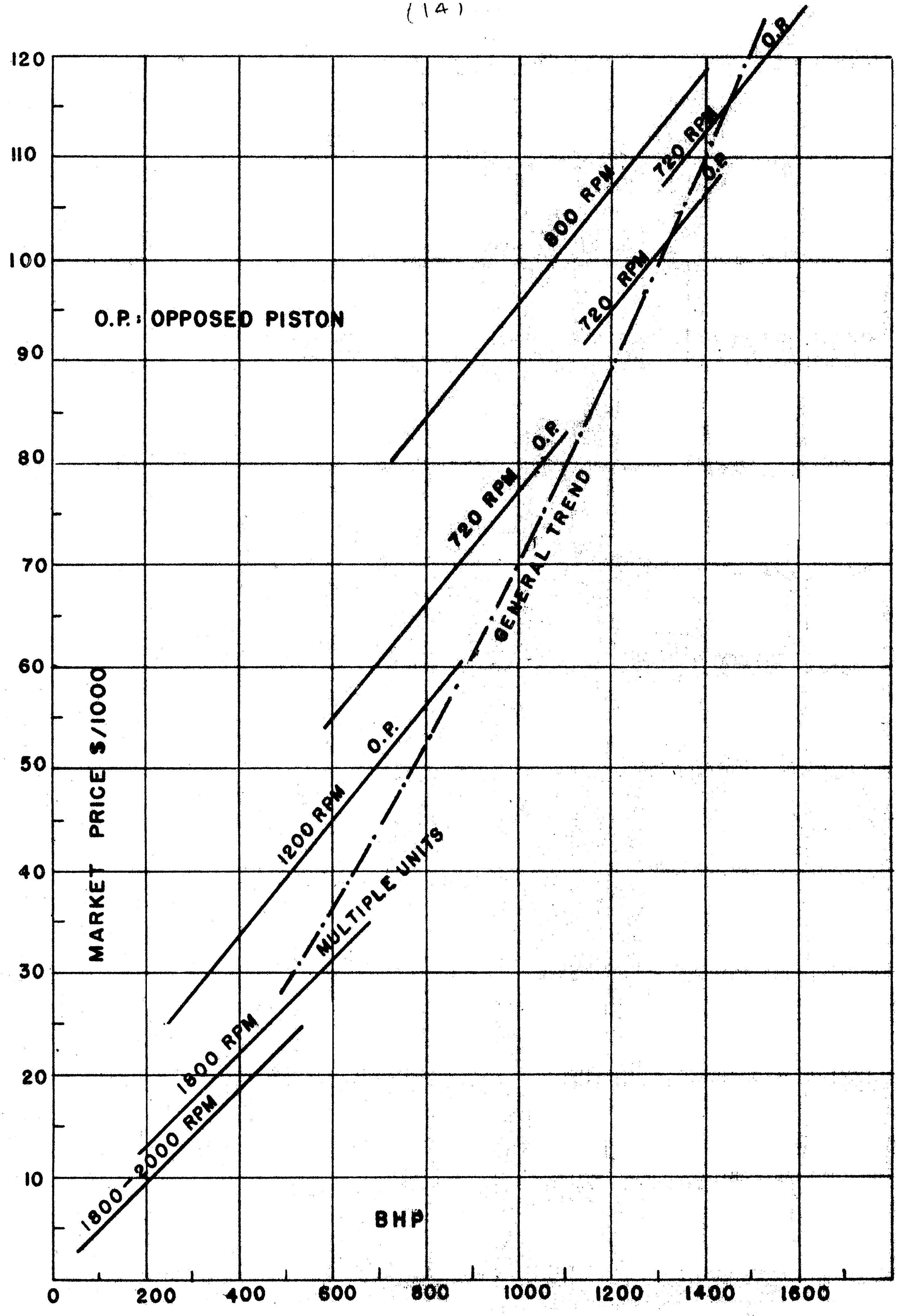

FIG. 14: U.S. MARINE DIESEL ENGINE COSTS

Hourly Rates

The average hourly rates including a normal amount of bonus and overtime pay comes to about $2.65 on the East Coast and $2.75 on the West Coast.

Overhead

This cost division includes most of the operating expenses which cannot be charged to any particular contract. Executives' salaries, watchmen's wages, property taxes and fuel costs represent a few typical examples. The total cost chargeable to any given boat will depend on the number of contracts handled during the year and numerous other factors.

Overhead is generally estimated as a percentage of the direct labor costs and various yards report this running from as low as 30 percent to as high as 125 percent. For general purposes, a figure of 80 percent is appropriate.

Miscellaneous Costs, Profit and Insurance

The sub-total of all material costs listed above, should be increased by about 5 percent and labor costs (not overhead) by some 10 percent to cover engineering, launching, material handling, cleaning, trials and other necessary miscellaneous costs.

For estimating purposes, a profit of 10 percent of all of the above costs is frequently assigned. Insurance on the vessel may add another 1/2 to 1-1/2 percent.

Duplication

Building several consecutive boats from the same set of drawings, templates and forms will, of course, effect considerable savings in cost. In addition to the non-recurring expenses just mentioned, there are reductions due to increased labor efficiency and vendors' savings.

The cost of each of two identical vessels may be only 90 percent of the cost of a single boat. If the number of repetitions reaches eight or ten, the unit cost should level out at about 80 percent of the single-contract cost.

Sample Estimate

The Appendix contains a sample estimate which illustrates the use of the foregoing cost and weight estimates. The example is based on an actual bid job and shows satisfactory agreement with the average of the bids submitted.

<u>Cost Summary</u>

The preceding parts of this section suggest methods for estimating costs of the major components of fishing boats. The method of presentation allows the reader to modify those particular items for which he has more authentic estimating data. Where facility is more important than accuracy, however, the following material should prove convenient. The detailed figures of the previous paragraphs have been assimilated in order to provide curves of total cost for fishing craft of various sizes and powers.

Figure 15 shows the general trends in material costs and labor requirements for vessels of different sizes. <u>The costs associated with buying and installing the main engine and fishing gear are specifically excluded</u>. The figures are high enough to include miscellaneous material and labor costs (engineering, launching, etc.) but no overhead, profit or insurance.

Figure 16 shows the general trends in the cost of furnishing and installing the main engine. These curves are quite rough and are intended only for quick estimates. The values are high enough to include miscellaneous material and labor costs. The total cost curve also includes overhead at 80 percent of labor, profit at 10 percent and insurance at 1 percent. Hourly rates are assumed to be $2.75.

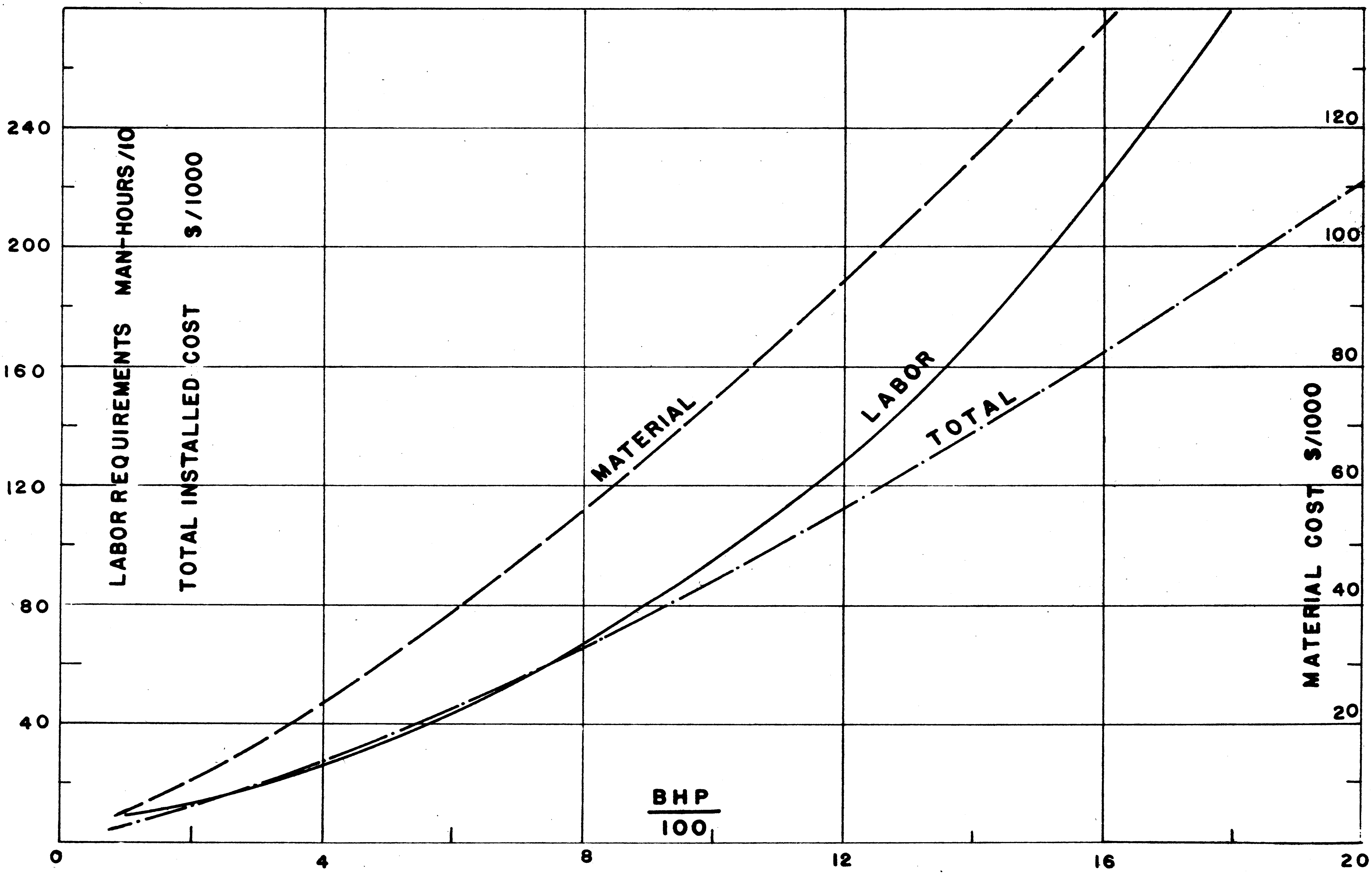

FIG 16 : APPROXIMATE MAIN ENGINE COSTS

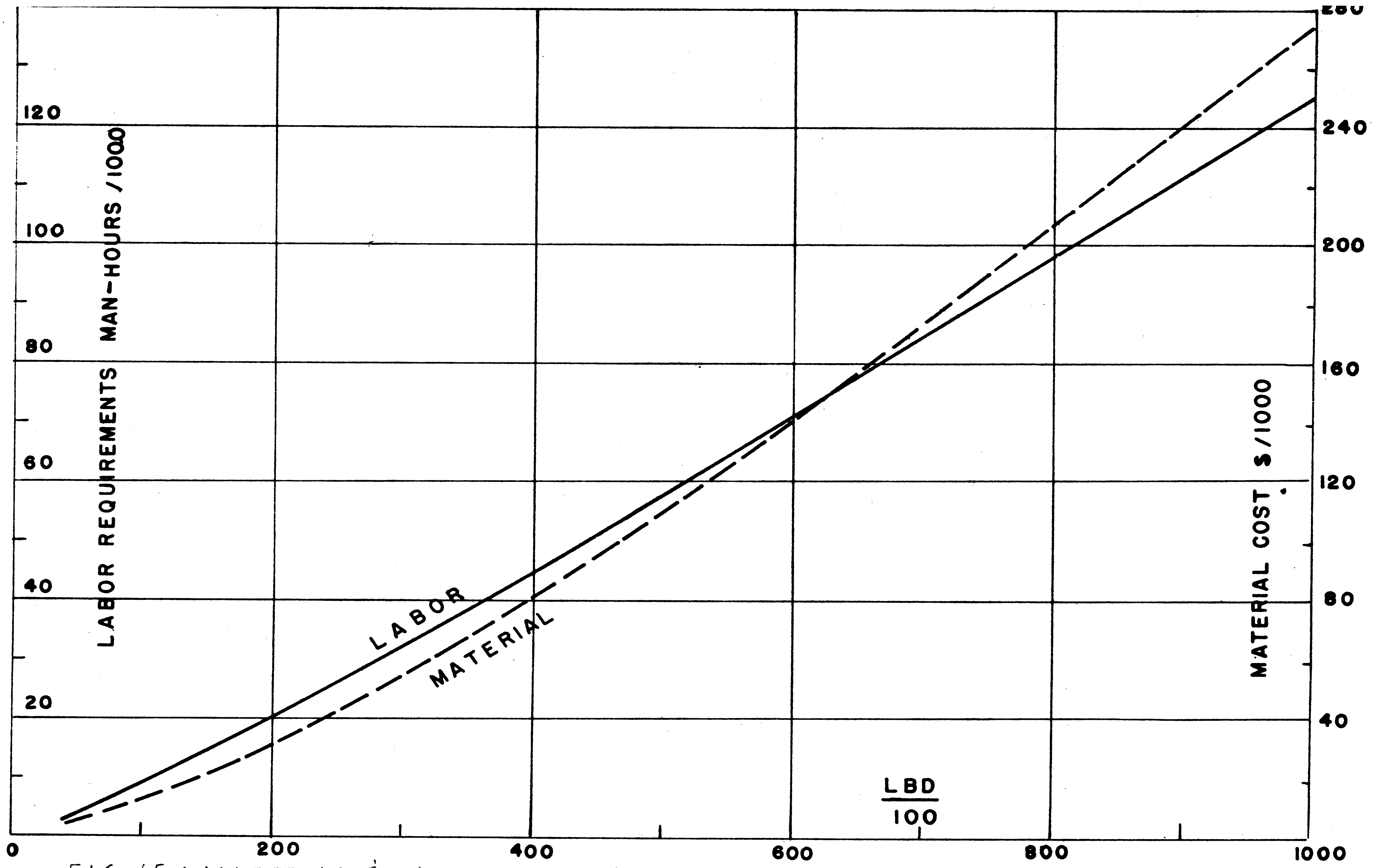

FIG. 15: MATERIAL & LABOR COSTS (EXCLUSIVE OF MAIN ENGINE & FISHING GEAR.

Figure 17 shows the trends in total cost for fishing vessels of various sizes and powers. The curve of zero power represents a hull without main engine and is based on the material and labor curves of Figure 15 with an hourly rate of \$2.75, overhead at 80 percent, 10 percent profit and 1 percent insurance. The other contours are taken by combining Figures 15 and 16. It is probable that trawlers would tend to cost from 5 to 10 percent more than indicated by the curves.

Figure 18 shows the approximate relationship between vessel length and cubic number. This allows quick conversion to the size parameter used in the curves when thinking in terms of vessel length. Obviously, such an approximation causes a further lessening in the accuracy of the estimate.

For rule-of-thumb estimates, the following approximations have been derived from Figures 16 and 17:

a) Total cost, exclusive of main engine and fishing gear, in thousands of dollars:

$$= 0.70 \times \frac{LBD}{100}, \text{ when } \frac{LBD}{100} \text{ is less than } 250$$

$$= 1.09 \times \frac{LBD}{100} - 100, \text{ when } \frac{LBD}{100} \text{ is greater than } 250$$

b) Cost of furnishing and installing main engine, in thousands of dollars:

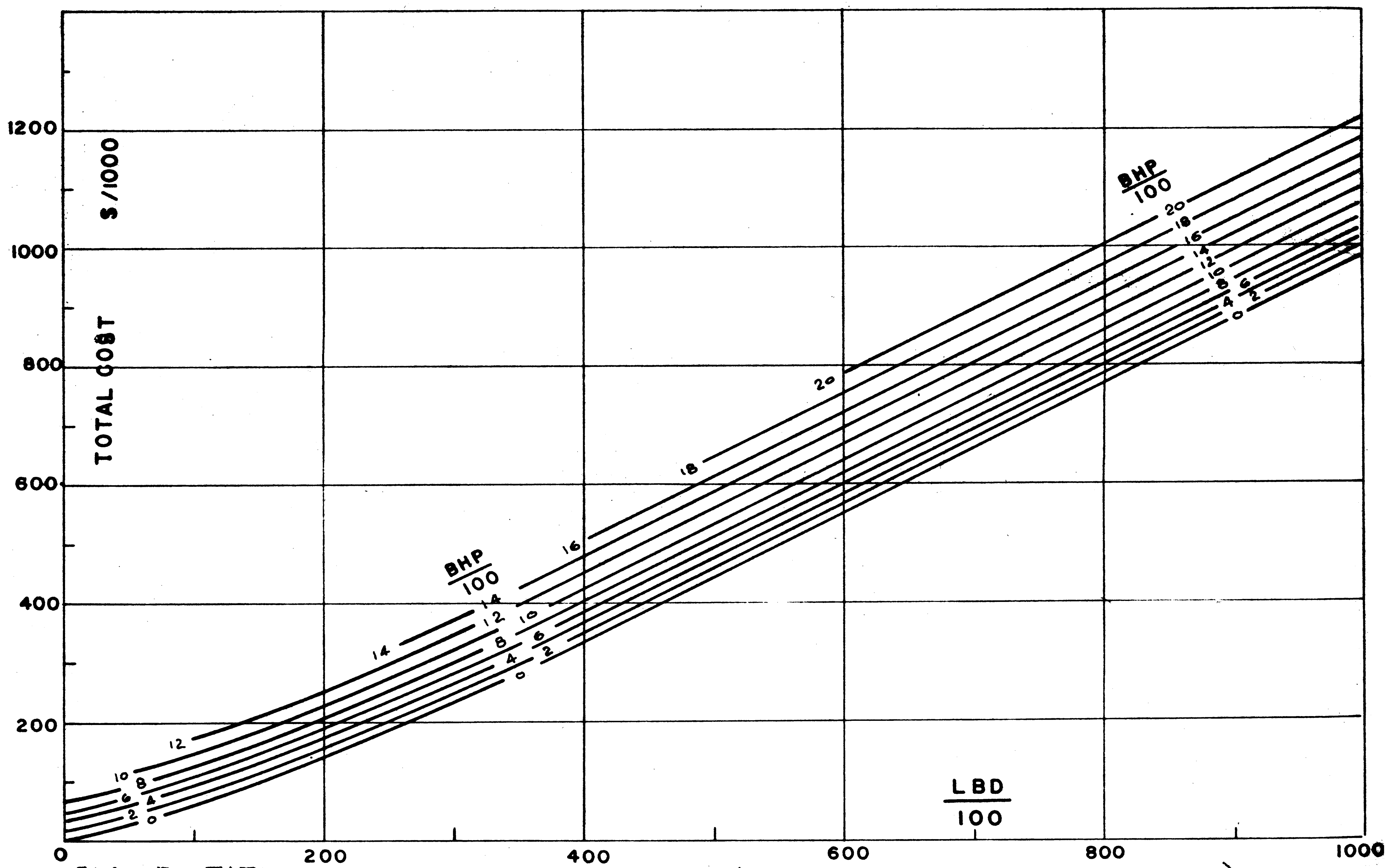

FIG. 17: TOTAL COST VS CUBIC NUMBER (EXCLUSIVE OF FISHING GEAR)

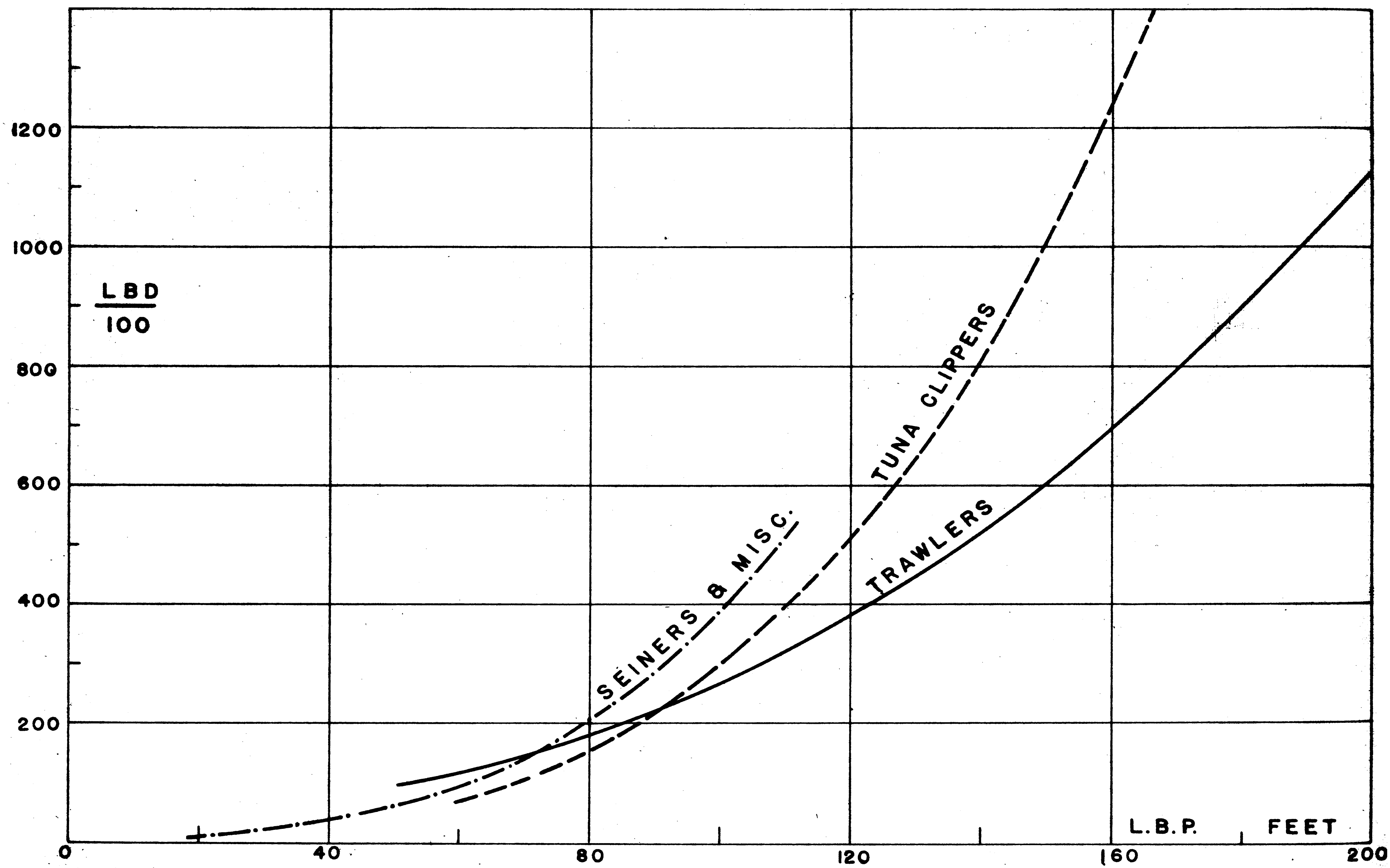

FIG. 18 : APPROXIMATE RELATIONSHIP BETWEEN LENGTH & CUBIC NUMBER

$$= 6.7 \times \frac{BHP}{100}\text{, when BHP is less than 600}$$

$$= 13 \times \frac{BHP}{100} - 38\text{, when BHP IS greater than 600}$$

PROPOSED COST AND WEIGHT SYSTEM

General

By way of definition, we are speaking here of the categories into which one may divide both the costs and weights involved in building a boat. Each category is given a codified number for ease of identification and the same code numbers are used on every boat building contract. After a few boats have been built and recorded under such a system, the yard will possess a goldmine of economic and technical data of great usefulness in subsequent contracts. The following departments will be particularly benefitted:

1) Accountants, who must keep a record of how the money is received and disbursed.

2) Cost estimators, who must be able to predict quickly and accurately how much any proposed vessel should cost even when the new design is different than any other previously built.

3) Naval architects, who must be able to assure the owner of adequate capacity, and proper stability and trim.

4) Production planners, who must have some basis for predicting labor requirements and for gauging progress during construction.

The ideal system should be identical for both weight and cost records. When this is so, the estimator can readily establish a large number of exceedingly useful coefficients, such as man-hours per ton for steel shell construction. Thus, as each contract is completed, weights and costs are analyzed and the resulting coefficients plotted or otherwise recorded. Then, when a competitive bid is requested, the estimator can use these tools for predicting the cost of each element of the proposed craft. The new design may at first seem radical, but when broken down into each of its components, it can be analyzed with confidence. This is not to say that any estimating system will eliminate the need for judgment and common sense. It is simply that a bid prepared by these means is bound to be better than one arrived at by gazing at the ceiling or by going to the other extreme and estimating the cost of installing each individual plate and angle.

The system should be detailed enough to yield reasonably meaningful coefficients and one should not try to lump ill-assorted items into one category. On the other hand, a certain amount of compromise is necessary here or things will become altogether too complicated. The yard supervisors, who are responsible for keeping track of the man-hours devoted to each type of work, are generally not too well qualified to memorize a long and elaborate list of charge numbers and their meanings. Overly complicated systems defeat their own purpose since they lead to sloppy reporting. It is suggested that the best place to effect these compromises is in the smaller, less expensive, categories where rather crude estimates can do little harm.

When installing a system such as proposed here, it is important to remember that it cannot possibly work without the active cooperation of the yard supervisors. These individuals must be properly indoctrinated and convinced of the importance of reporting time accurately and they must, of course, be furnished copies of the numbering system.

The cost numbers should be made an integral part of each drawing number and all material should be plainly marked with its appropriate number.

In studying and comparing various existing systems, four different philosophies seem to have been applied. Some yards divide the work according to what the object is: bulkheads, foundations, rudders, etc. Others may divide it up according to who does it: sheet iron, plumbing, painting, etc. A variation on this is a division according to what sort of tools are used on the object. Most systems now in use show the combined influence of all these philosophies and most contain rather peculiar oddities having their roots in the history of the yard. Several years ago the U.S. Navy considered adopting a system based entirely on function. Thus the charge number for propulsion machinery, as an example, would embrace not only the engine and gears but associated foundations, wiring and piping. The proposed system had considerable merit but was too alien to established systems in yards throughout the country.

First Proposal

The first proposed method for breaking down cost and weight has been prepared by the authors and can be recommended for all kinds of small craft construction. It is generally similar to those used in large shipyards. It differs principally in that special categories are established for deckhouses as well as for special equipment--in our case, fishing gear. Deckhouses are set out because of wide differences in configuration between various types of boats. Another point of difference is that hull engineering is lumped with outfitting because of the difficulty of drawing a line between them in small craft work. Finally, engine room auxiliaries are independent of the main engine since their functions are more akin to the hull than to the prime mover.

The breakdown is made according to what the object is, rather than who builds it, what tools are used, or what function it fulfills.

An outline of the first proposal follows. The list is by no means complete but enough details are given to express the authors' ideas. Each yard will have its own special requirements and these may vary somewhat depending on the type of vessel. In any event, every conceivable item of work should be set down in one category or another. This will prevent vacillation in the case of ill-defined items and insure that nothing is forgotten in a cost estimate.

<u>Zero Division</u> (cost items involving no material going into the ship)

01 Engineering and design

02 Specifications and contract plans

03 Insurance and miscellaneous fees

04 Staging, launching, cleaning, temporary lights, inspection and other miscellaneous labor and material

05 Mold loft work

06 Tests and trials

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99 Handling materials involved in the above

<u>100 Division</u> (Hull structure)

100 Shell plating and bulwarks

101 Double bottom framing

102 Other framing

103 Tanktop

104 Decks, hatch coamings and pillars

105 Bulkheads

106 Foundations

107 Castings and forgings

108 Fastenings

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199 Structural material handling (no weight)

Note: The cost of fitting and welding two items in different categories should be charged to the smaller of the two items. For example, the work of fastening a frame to the shell would be charged to the frame.

<u>200 Division</u> (Deckhouse)

200 Deckhouse, wheelhouse, etc.

201 Open bridge, wind screens, etc.

202 Wood or metal awnings

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299 Deckhouse material handling (no weight)

<u>300 Division</u> (Outfitting and Hull Engineering)

300 Joiner and carpentry work

301 Hatch covers and other closures

302 Boatswain's and other stores

303 Canvas awnings, hatch covers, etc.

304 Furniture

305 Navigating equipment

306 Masts and rigging (except sailing craft)

307 Electrical wiring, fixtures and appliances

308 Heating, ventilating and air conditioning

309 Refrigeration equipment (outside engine room)

310 Hull insulation

311 Lifeboats and davits

312 Other lifesaving gear, firefighting equipment

313 Bedding, mattresses, linen

314 Galley and messroom equipment

315 Sanitary fixtures

316 Piping outside engine room

317 Steering gear and rudder

318 Deck machinery and mooring equipment

319 Independent tanks

---

399 Outfitting material handling (no weight)

<u>400 Division</u> (Propulsion Machinery)

400 Main engine

401 Reversing and reduction gears

402 Propeller, shafting and bearings

403 Cooling, fuel, lubricating and exhaust systems for main engine

404 Attached auxiliaries

405 Starting equipment

406 Governing and control systems

407 Liquids in propulsion machinery

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499 Propulsion machinery material handling (no weight)

<u>500 Division</u> (Engine Room Auxiliaries)

500 Generators

501 Pumps and compressors

502 Heat exchangers

503 Refrigeration machinery

504 Auxiliary boilers

505 Switchboard and wiring in engine room

506 Service systems for auxiliary machinery

507 Liquids in auxiliary machinery

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599 Engine room auxiliary material handling (no weight)

<u>600 Division</u> (Fixed Ballast)

600 Fixed ballast

7<u>700 Division</u> (Vessel Function)

This category is reserved for equipment peculiar to the needs of various types of craft.

701 Fishing gear and bait tanks on fish boats

702 Towing gear on tugs

703 Cargo gear on coasters

704 Masts, sails and rigging on sailboats

705 Firefighting gear on fireboats

706 Scientific gear on survey vessels

The summation of all of the above weights and costs will indicate the light ship weight and cost of labor and material to the shipyard. If further analysis leading to displacement is desired, the following categories are suggested as extensions of the above (most of these involve no cost to the yard):

800 Division (Cargo Deadweight)

800 Payload, other than passengers

801 Dunnage

900 Division (Miscellaneous Deadweight)

900 Fuel

901 Fresh water (cooling, boiler feed, sanitary and potable)

902 Ballast water

903 Lubricating oil

904 Passengers, crew and effects

905 Stores and provisions

906 Bait and water in bait tanks

907 Nets and other owner's furnished outfit

Second Proposal

Another, more systematic, approach to this problem of identifying the various categories allows considerably finer division of the vessel's components. This method involves the use of primary, secondary and tertiary breakdowns. While boatbuilders may feel that such elaboration is undesirable, there are several advantages to the system. It is so logically arranged that it may be no more difficult to grasp than the simpler appearing first proposal. Further, it would be ideally suited to electronic data processing.

The authors are indebted to Mr. Géza Magyari-Kossa, former cost estimator of the Danube Shipyard in Vác, Hungary for permission to publish this system which he developed several years ago.

Space limitations preclude the presentation of the system in all its details. The rudiments shown below will illustrate the point and readers wishing the full details may obtain copies from the authors.

This is a decimal system. There are ten primary divisions, each of which is divided into ten secondary divisions (or sometimes less). Each secondary division is in turn divided into ten or less tertiary divisions. Thus, a logical arrangement of up to 1000 categories is generated.

Primary Divisions

0 Design and engineering

1 Hull

2 Propelling machinery

3 Auxiliary machinery

4 Piping systems

5 Steering gear and deck machinery

6 Joiner and carpentry work

7 Electrical

8 Owner's outfit and spares

9 Trials and delivery

<u>Typical Secondary Division</u> (Of Primary Division #4: Piping Systems)

40 Bilge and ballast piping

41 Engine room piping

42 Fire system piping

43 Sanitary and potable

44 Special piping

45 Stacks and uptakes

46 Pumps

47 Compressors

48 Tanks

49 (Unassigned)

Typical Tertiary Division (Of Secondary Division #41: Engine Room Piping)

410 Steam Piping

411 Boiler Feed Piping

412 Fuel oil piping

413 Cooling water piping

414 Lubricating oil piping

415 Diesel fuel piping

417 Compressed air piping

417 Exhaust piping

418 (Unassigned)

419 (Unassigned)

CONCLUDING REMARKS

It is the authors' hope that this paper will stimulate fishermen and naval architects to devote more attention to the cost factors in fish boat design. It is their further wish that boatyard managers will install weight and cost accounting systems where they have not already done so. Once this is done it will be up to the naval architects to compile such information in complete, yet concise, form and to publish it for the benefit of all. Perhaps the Food and Agriculture Organization of the United Nations could provide a standard form for the recording and dissemination of such data.

As explained in the Introduction, the authors had to develop the suggested weight and cost figures on totally insufficient data. It will be disappointing indeed if the paper does not invoke a storm of criticism in which the various discussors prove their contentions with generous supplies of factual information.

Finally, the job is at best only half done. Fishermen and naval architects need a complete kit of economic tools in order to make rational design decisions. This study has attempted to show what sort of investment will be required in a fishing boat. What is needed next is a study which will furnish methods for estimating annual profits for craft of various types, sizes and speeds. Then design decisions can be based on the attainment of the maximum possible rate of return on investment, rather than on the crystal ball. References 2 and 3 show what can be done along these lines for larger ships.

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APPENDIX

A. Sample Estimate

To clarify the suggested methods of estimating weights and costs, the following typical problem has been worked out:

Problem: Estimate the deadweight and cost of a single-contract steel tuna clipper of 1200 long tons displacement, powered by a 1600 BHP, 1720 rpm opposed-piston diesel engine. Assume vessel built on the West Coast during 1958. Calculations are done on a slide rule with weights figured no closer than the nearest ton and costs to the nearest $100. Each step is numbered for clarity:

1) From Figure 5, LBP = 138 ft.

2) From Figure 2, Beam = 33.6 ft.

Depth = 16.8 ft.

3) Cubic number, $\frac{LBD}{100} = \frac{138 \times 33.6 \times 16.8}{100} = 780$

4) Steel weight coefficient (Figure 7) = 0.337

5) Steel weight = 0.337 x 780 263 L.T.

6) Wood deckhouse weight = 0.015 x 780 = 12 L.T.

7) Outfitting weight coefficient (Figure 8) = 0.267

8) Outfitting weight = 0.267 x 780 = 208 L.T.

9) Fishing gear weight = nil

10) Main engine weight, wet (Figure 9) = 35 L.T.

11) Auxiliary machinery weight coefficient

(Figure 10) = 0.079

12) Auxiliary machinery weight = 0.079 x 780 = 62 L.T.

13) Weight summary:

Steel hull	263 L.T.
Wood deckhouse	12 L.T.
Outfitting	208 L.T.
Fishing Gear	0 L.T.
Main engine (wet)	35 L.T.
Auxiliary machinery	62 L.T.
Sub-Total	580 L.T.
Designer's margin and leeway for ballast (7½%)	43 L.T.
Light ship	623 L.T.
Displacement	1200 L.T.
Deadweight	577 L.T.

14) Structural hull invoiced weight =

1.15 x 263 = 302 L.T.

15) Structural hull material cost =

$200 x 302 = $ 60,400

16) Structural hull man-hours per ton

of steel (Figure 12) = 153

17) Structural hull man-hours = 153 x 263 = 40,200

18) Wood deckhouse material cost = $250 x 12 = $ 3,000

19) Wood deckhouse man-hours = 100 x 12 =	1200
20) Outfitting material cost = $265 x 208 =	$ 55,200
21) Outfitting man-hours per ton of outfit (Figure 13) =	167
22) Outfitting man-hours = 167 x 208 =	34,700
23) Fishing gear material costs =	nil
24) Fishing gear man-hours =	nil
25) Main engine material cost (Figure 14) =	$124,000
26) Main engine installation man-hours = 50 x 35 =	1,750
27) Auxiliary machinery material costs = $1200 x 62 =	$ 74,400
28) Auxiliary machinery installation man-hours = 180 x 62 =	11,200
29) Total man-hours (sum of lines 17, 19, 22, 24, 26 and 28) x 1.10 =	98,000
30) Total labor cost = $2.75 x 98,000	$269,600
31) Total material cost (sum of lines 15, 18, 20, 23, 25 and 27) x 1.05 =	$333,000

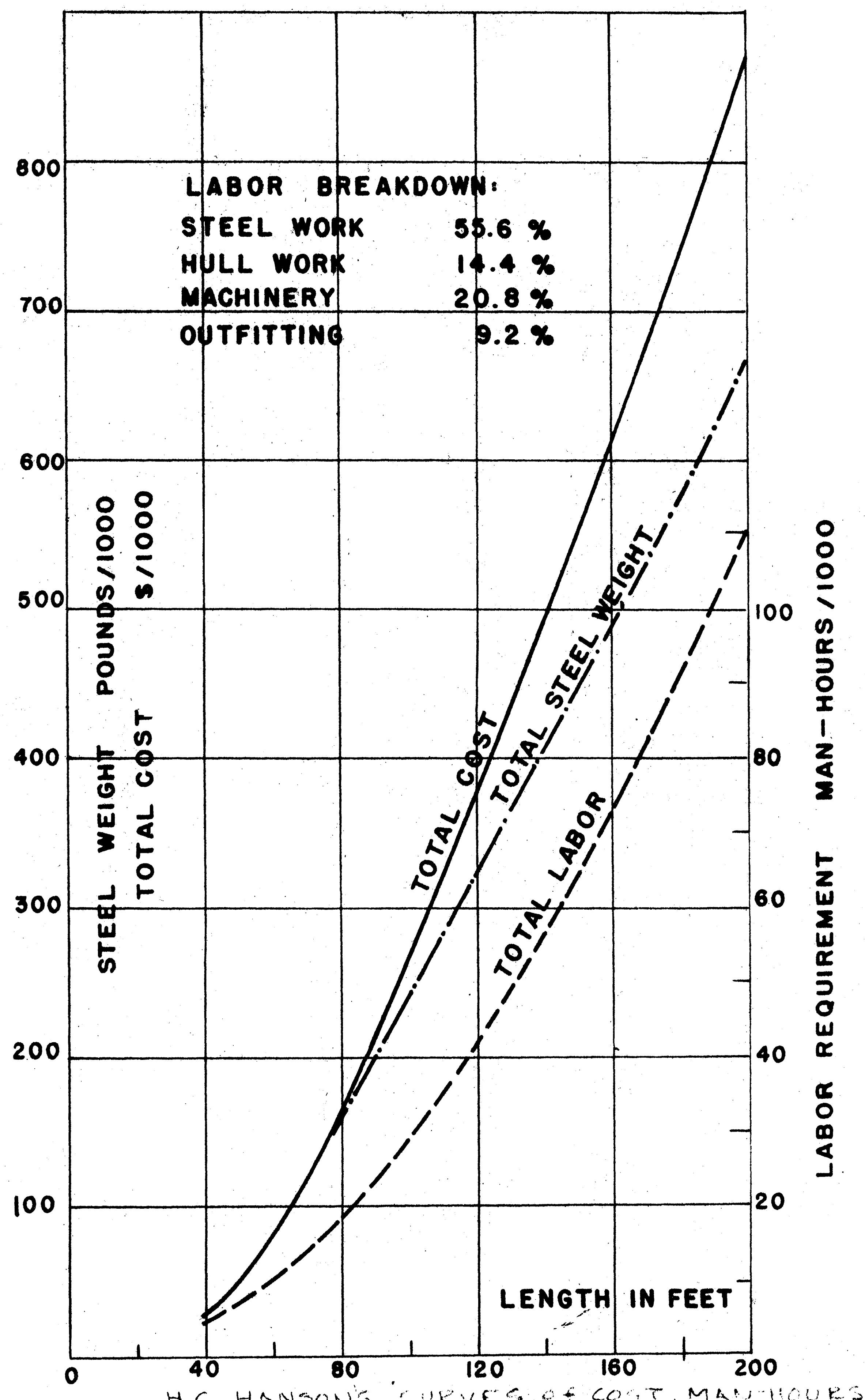

FIG. 19: H.C. HANSON'S CURVES OF COST, MAN-HOURS & STEEL WEIGHT for PACIFIC COAST COMBINATION TYPE VESSELS

(2) Cost Summary

Material	$ 333,000
Labor	269,600
Overhead (80%)	215,700
Sub-Total	818,300
Profit (10%)	81,800
Insurance (1%)	8,200
BID PRICE	$ 908,300

This compares with an average bid of about $855,000 on a recently proposed vessel of comparable size and power. The actual proposal involved the use of a surplus main engine which probably accounts for the difference. It is also possible that profit margins were somewhat reduced owing to the prevalent slump in fish boat construction.

The estimated cost, based on Figure 17 is $920,000 and the rule-of thumb formula happens to give exactly the same figure ($750,000 for hull plus $170,000 for engine).

B. H. C. Hanson's Curves

Figure 19 shows the results of a cost study prepared by Mr. H. C. Hanson of Seattle, Washington. Mr.

Hanson has generously permitted these curves to be included in this paper. While the quantitative values shown in Figure 19 are not in agreement with those developed by the authors, they nevertheless represent the considered opinion of a fish boat designer of many years experience and as such warrant serious consideration.