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ANALYSIS AND STATISTICS OF LARGE TANKERS

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by

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ABBREVIATIONS AND SYMBOLS

A	Uniform annual returns before tax
AAC	Average annual cost
ACCR	Annual cost of capital recover = CR x P
C	Annual transport capacity
CR	Capital recovery factor (before tax) = A/P
DWT	Deadweight
i	Annual interest rate at before-tax level, compounded annually
M	Million
N	Number of years; usually the economic life of the investment
P	Total initial investment, or construction cost
PW	Present worth factor or discount factor, single payment
RFR	Required freight rate
SPW	Series present worth factor
t	Tax rate
Y	Uniform annual costs of operation, exclusive of capital costs
DEFEN	Defender
CHAL	Challenger

CONTENTS

ABSTRACT

In this paper I have compiled operating statistics for tankers in the 50,000- to 500,000-ton range.* These statistics are plotted for construction cost, insurance cost, crew cost, maintenance and repair cost, fuel consumption, and overhead cost, all versus total deadweight.

Actual operating time of tankers in the 200,000-ton range is limited to the Tokyo Maru (150,000 tons) and the Idemitsu Maru (206,000 tons). However, these statistics are also based on the expected operating costs of the 312,000-ton tankers presently under construction, and the 500,000-ton tanker being designed by Mitsubishi Heavy Industries, Ltd.

In Appendices I and II, a proposed 1,000,000-ton tanker is compared with the Idemitsu Maru for two trade routes. The objective of this comparison is to find the maximum permissible construction cost of the megaton tankers by using the required freight rate of the Idemitsu Maru as an economic goal.

I hope that these tentative and somewhat premature operating costs will be of assistance in determining the merit of proposed large tankers, as well as acquainting the reader with methods of analyzing such expenditures.

*Unless otherwise specified, weight figures in this paper refer to long tons of deadweight capacity.

TANKER GROWTH

In an article on the launching of the 47,450-ton tanker *Spyros Niarchos* in 1955, W. F. Johnson stated:

> The launching was more than just the baptism of another super tanker, it was an occasion of significance, both nationally and internationally, in a number of directions .... she is the world's largest tanker. (1)*

Since 1955, the title "world's largest tanker" has been claimed for nine different ships, one holding the honor for only seven days. The following list illustrates the rapid growth of tankers within the past decade:

NAME	DWT (tons)	BUILT	LAUNCHED
Sinclair Petrolore	56,089	Japan	1956
Universe Leader	85,515	Japan	1957
Universe Apollo	104,520	Japan	1959
Manhattan	108,590	USA	1962
Nissho Maru	130,250	Japan	1962
Tokyo Maru	130,250	Japan	1966
Idemitsu Maru	206,000	Japan	1966 (2, 3, 4, 5)

*Numbers in brackets designate references at end of paper.

National Bulk Carriers Inc. recently placed orders with Ishikawajima-Harima Heavy Industries Co (IHI) and Mitsubishi Co. for six tankers, each of 312,000 tons. The first of these future champions was launched in February 1968 from IHI with a section of the port side and the bow missing. When completed in a larger repair dock, the ship will have the following characteristics: length--1,135 ft, beam--175 ft, draft--72 ft, propulsion--37,400-shp, reheat steam turbine with single screw propulsion, speed--16 knots, cost--$21 million. (6)

Several oil companies are presently evaluating tanker designs for 500,000 tons and larger, to be used with central oil terminals in Northern Europe. Mitsubishi Heavy Industries, Ltd. has completed a preliminary design for a 500,000-ton tanker, and three students at The University of Michigan have recently designed a megatanker (1,000,000 tons DWT). (7)

Shipping experts agree that, technically, the size of future tankers is unrestricted, since the land-sea interface problem is nonexistent due to offshore cargo-handling equipment. However, shallow ocean passages, such as the Straits of Dover or Malacca, will limit the draft of future ships operating on such trade routes.

OIL TRANSPORTATION

As a result of modern industrial and private needs, oil demand has been growing rapidly. Factories and mills throughout the world have switched from coal to fuel oil, and while this has hurt the coal industry, it has brought about modernization of equipment, raised levels of efficiency, and reduced costs within industrial plants. The oil consumption of Japan alone has increased nearly three-fold since 1954.

Oil companies have met competition by building refineries near consumption areas thereby requiring large quantities of crude oil to be transported from distant oil fields. This shipping cost represents as much as 20 percent of the selling price of the refined oil. Even though some oil has been discovered in Africa and Nigeria, which shortens the distance to the refineries of Northern Europe and the Americas, the major oil reserves are still in the Middle East. For this reason most of the crude oil shipments will continue to originate in the Persian Gulf and the discovery of a limited supply of oil nearer the refineries will have little effect on tanker size or transport methods.

Pipelines, like large tankers, have been the object of many studies during recent years. The increase in the diameter of the lines, more reliable pumps, and an improved usage factor due to inter-oil company cooperation have resulted in a considerable expansion of this system. In circumstances where they cut distances, pipelines become attractive; however, mile for mile, tankers provide a more economical form of transport. In addition, pipelines are strategically and politically vulnerable to interruption and have no operating flexibility.

Recent evaluations of pipeline versus tanker have generally used a 50,000-ton tanker as the basis of comparison. As larger tankers become more common, the economic advantage of marine transport will be further enhanced. (8)

CONSTRUCTION COST

Shipbuilding costs are highly important to tanker owners, whether these be independent owners or affiliates of oil companies. A company with a given oil transport need may be able to meet that need with a fleet of ten 50,000-ton tankers, at a total cost of $50,000,000, or a single 500,000-ton tanker, at a cost of $32,000,000. In general, the capital investment is less for a fleet of larger ships than for the same total deadweight in smaller ships. For this reason, the capital component in the cost of carrying oil decreases as tanker size increases.

There are several reasons for the reduction in capital cost per deadweight ton. The hull weight does not increase proportionally with cargo capacity; furthermore, auxiliary equipment, pumps and pipeline systems are relatively insensitive to size. Accommodation cost is a function of the ship's complement, which is nearly constant in tankers from 50,000 to 500,000 tons; thus, it decreases per ton of deadweight with an increase in size (9, 10, 11).

Figure 1 illustrates these reductions. It shows that construction cost per ton is $100 for a 50,000-ton tanker and only $66 for a 500,000-ton tanker.

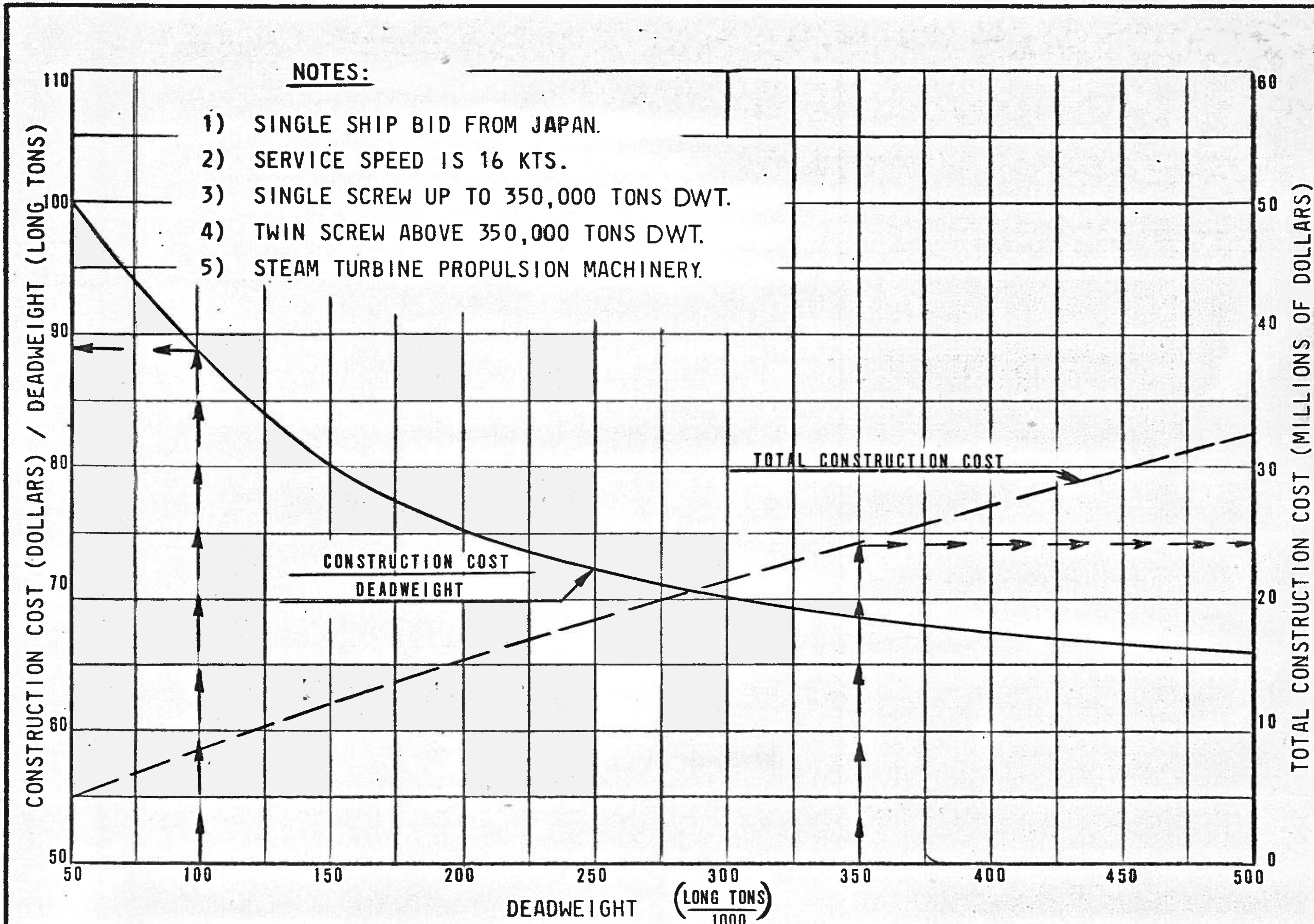


FIG. 1 CONSTRUCTION COST VS. DEADWEIGHT

MAINTENANCE AND REPAIR COST

Maintenance cost of the hull is a function of surface area, trade route, invested cost, and owner's requirements. Various anticorrosive measures, including long-lasting paints, have reduced the maintenance cost of the hull structure for today's tankers; however, automation equipment requires a great deal of preventative maintenance, as well as specially trained personnel. These factors have resulted in a predicted maintenance cost of $500,000 per year for a 500,000-ton tanker as compared to $200,000 per year for a 50,000-ton tanker. Nonetheless, the maintenance cost per ton of deadweight has been reduced by a factor of four in going from 50,000 to 500,000 tons.

Neither the power requirement nor the physical size of the propulsion machinery increases at the same rate as deadweight. The machinery repair and maintenance costs are a function of the engine size and the displacement. Thus, while the absolute cost does rise, the cost per deadweight ton is reduced. Figure 2 combines the cost of maintenance and repair for both the hull and the machinery.

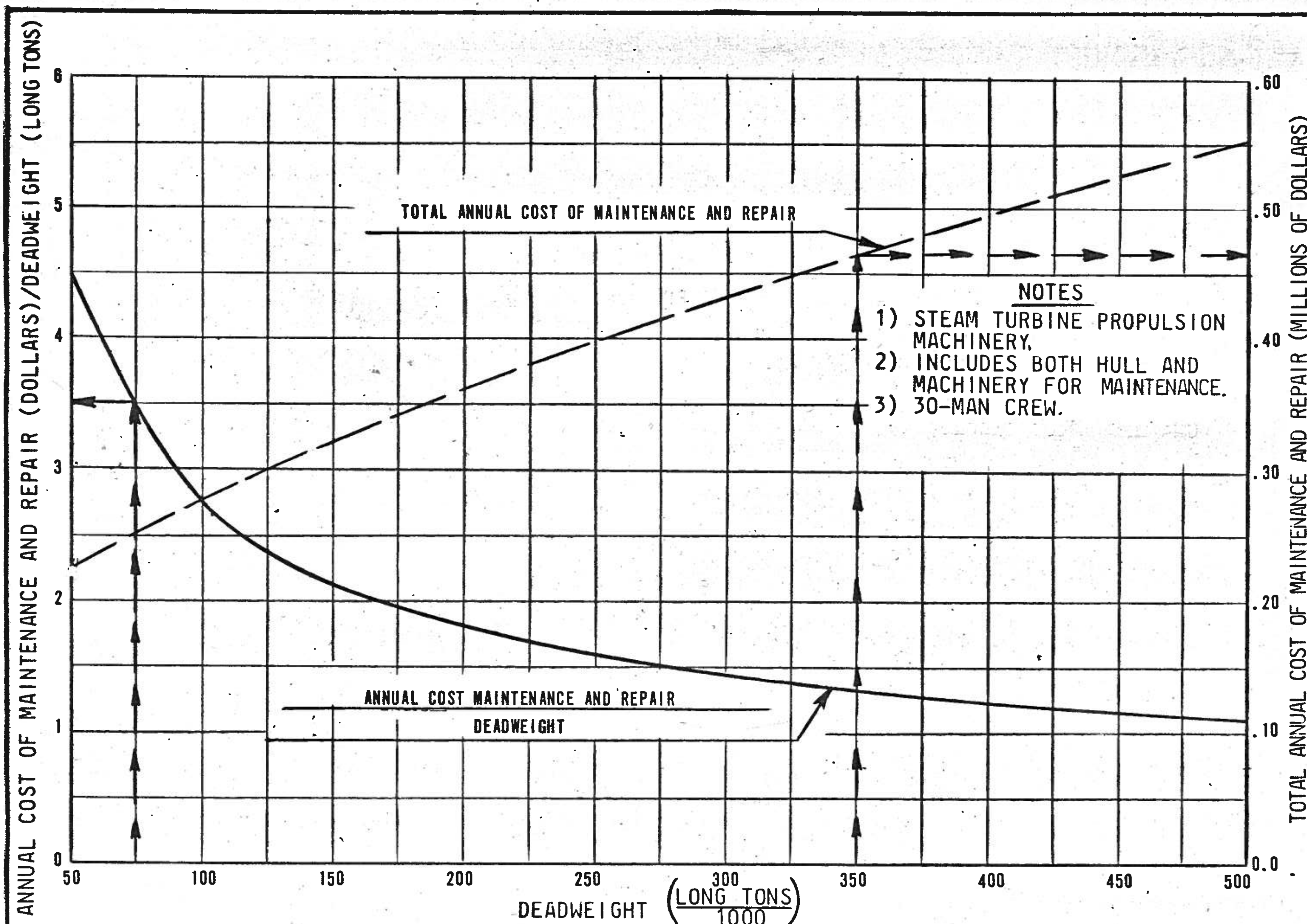


FIG. 2 ANNUAL COST OF MAINTENANCE AND REPAIR VS. DEADWEIGHT

CREW COST

The crew requirement (30 to 35 men) for a 500,000-ton tanker is nearly the same as for a tanker of 50,000 tons; thus, the crew cost per ton of deadweight is inversely proportional to the deadweight. The capital costs of automation equipment form a smaller percentage of the total cost in a larger ship. Therefore, a higher degree of automation becomes economically more attractive as the construction costs increase. Furthermore, the size and weight of such components as mooring lines and cargo-handling equipment in larger tankers may in itself demand mechanization, since these items cannot be handled manually.

As automation is introduced, crew members at the lower end of the wage scale are displaced. Thus, the average annual cost per crew member increases with displacement. Owners of tankers in the 50,000-ton range estimate their average annual cost per crew member, including benefits, at $13,000, whereas, the amount for tankers in the 200,000-ton range is $14,500 (Figure 3).

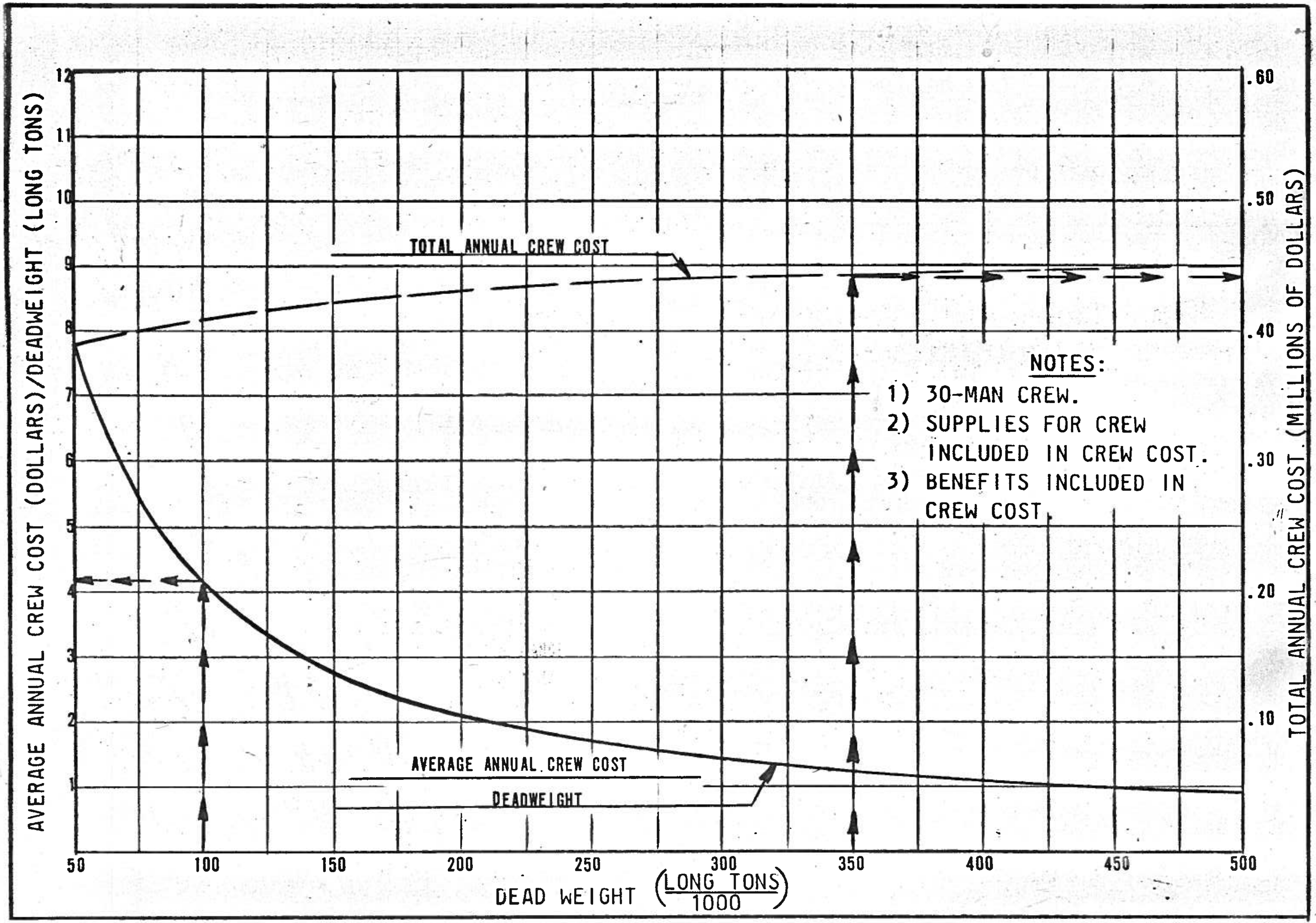


FIG. 3 AVERAGE ANNUAL CREW COST VS DEADWEIGHT

INSURANCE COST

The cost of insurance is divided into two categories: protection and indemnity insurance, and hull and machinery insurance. Figure 4 combines both insurance premiums into a single annual cost, which is plotted against deadweight.

Protection and indemnity insurance protects the owner against lawsuits arising primarily from his crew. Therefore, this premium may be estimated as a function of the ship's complement. Since the crew size is nearly the same for 50,000 to 500,000-ton tankers, the protection and indemnity insurance is likewise nearly the same over the same range.

Benford estimates the annual cost of protection and indemnity insurance as $965 per member of the ship's crew. (12) Information gathered about the Nissho Maru and Idemitsu Maru shows an annual cost of $1005 per crew member. (13) As tanker size increases, the degree of automation increases, thus reducing the number of hazardous tasks. The first analysis may indicate that the protection and indemnity premiums should decrease; however, automation demands a more sophisticated crew, which in addition to being technically trained is also more aware of associated legal rights.

Therefore, protection and indemnity premium costs actually may increase with larger tankers.

Hull and machinery insurance protects the owner against the loss or damage of his ship. This premium is a function of the invested cost of the ship, the owner's past record, and the trade route. In this case, too, the information gathered was reasonably close to Benford's formula for the annual cost of hull and machinery insurance as $10,000 + 0.007 of the invested cost.

The insurance cost represents approximately 7 percent of the annual operating cost of a 50,000-ton tanker, whereas, for a 200,000-ton tanker this cost may be as much as 15 percent. Thus, with larger tankers the owner's past record and the selected trade route will play more important roles since they affect a parameter that tends to increase with ship size.

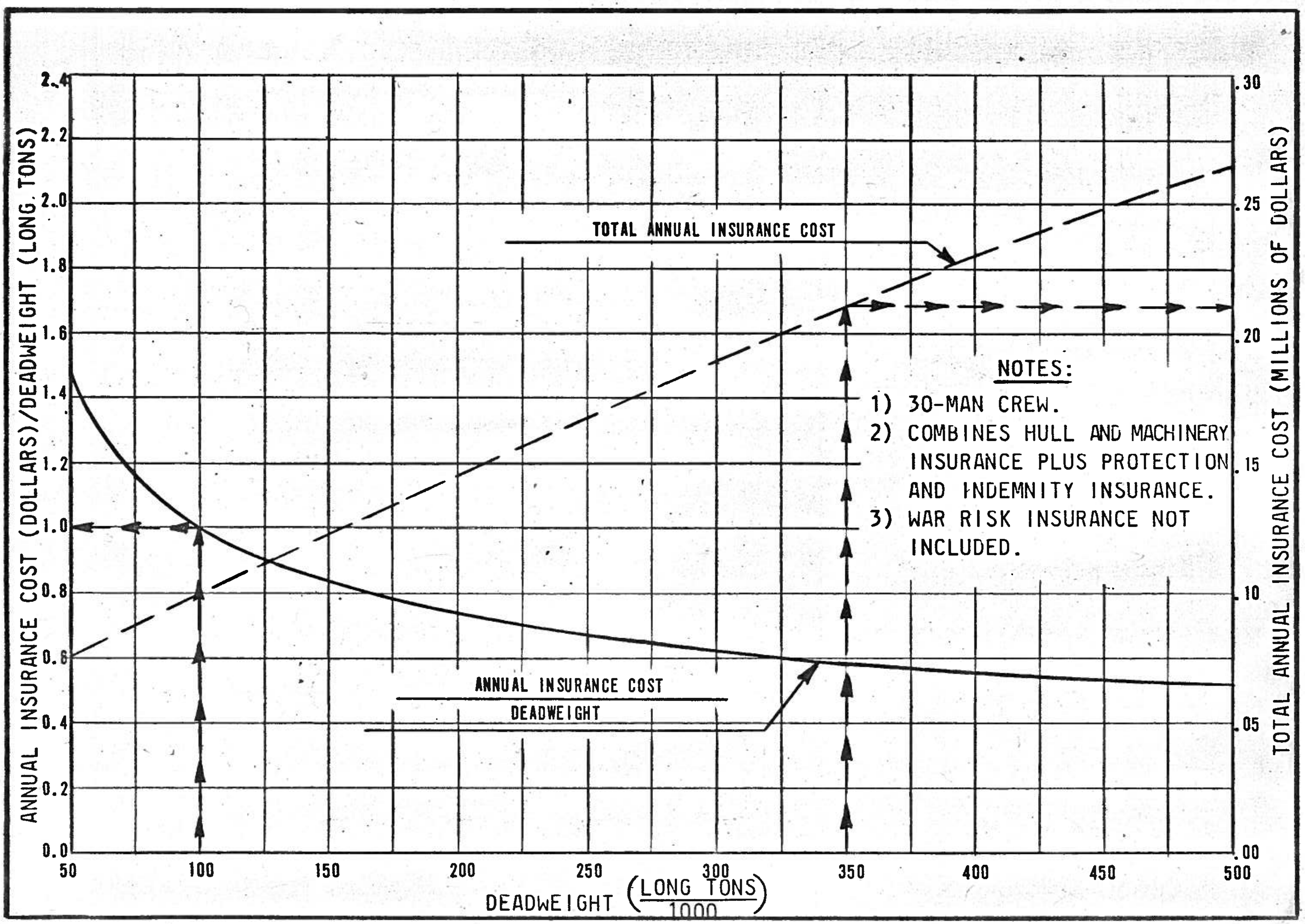


FIG 4 ANNUAL INSURANCE COST VS DEADWEIGHT

FUEL CONSUMPTION

Fuel consumption is critical to any mode of the transportation industry for two reasons: the actual fuel cost and the reduction in payload. In tankers, the reduction in payload is more important. As tankers grow larger, the proportional loss of cargo capacity decreases. For this reason, new concepts that marginally improve fuel consumption are less popular. However, such developments as the application of reheat to a steam turbine installation are being used on larger tankers, since they provide a substantial fuel rate improvement, while using established engineering concepts.

With the power level of about 40,000 shp per shaft on the larger tankers, nuclear propulsion may seem attractive. However, high initial construction cost, manning requirements, and psychological aspects make this form of energy unlikely in the foreseeable future for nonmilitary surface ships.

The fuel cost represents nearly 40 percent of the annual operating cost of a large tanker. However, as tanker size increases the fuel consumption per ton of deadweight decreases, assuming a speed to be constant. This cost reduction is an important factor in the justification of large tankers (Figure 5).

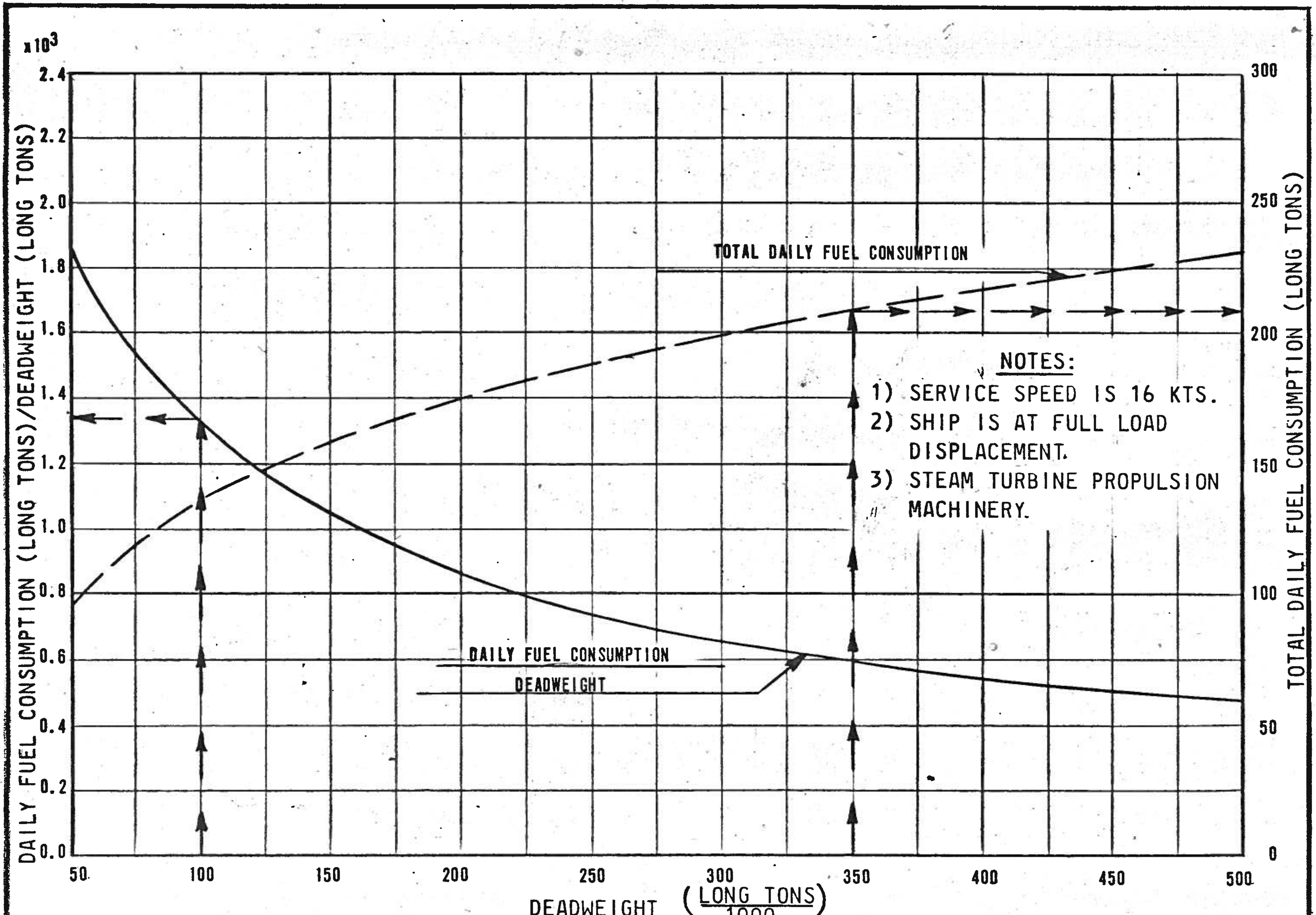


FIG 5 DAILY FUEL CONSUMPTION VS DEADWEIGHT

OVERHEAD COST

The overhead cost represents all remaining annual cost items, such as, administration, survey fees, ship supplies, communications, and crew transportation. This cost is the most difficult to estimate; however, it represents the smallest contributing segment to the annual operating cost. Thus, an error in this estimate does not appreciably affect a feasibility study (Figure 6).

Apparently, the overhead cost is not affected by the ship's size. Moreover, the very dimensions of the larger tankers restrict them to a given route between given ports. This results in fewer fleet management decisions, and possibly a reduction in the cost of administration.

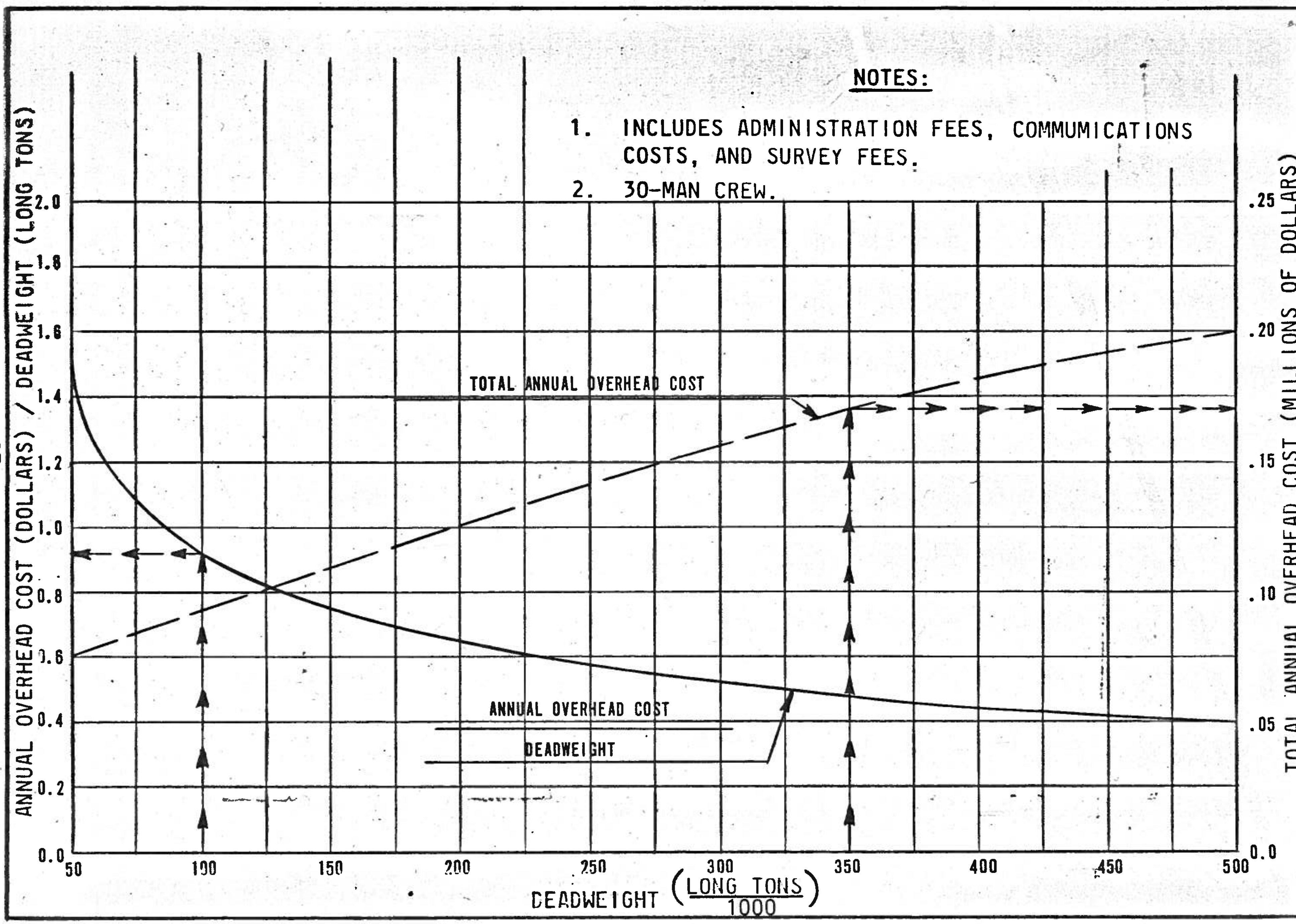


FIG. 6 ANNUAL OVERHEAD COST VS DEADWEIGHT

INVESTMENT LIMIT WITH UNEQUAL VOYAGE DISTANCES

Using procedures outlined by Professor Benford (14, 15, 16, 17), a comparison is shown between the Defender (200,000 tons DWT) and the proposed Challenger (1,000,000 tons DWT). The Defender passes through the Strait of Malacca, between the Persian Gulf and Japan, which is 68 feet deep. The Challenger (proposed megaton tanker) would not be able to pass through this shallow ocean passage and, as described in Appendices I and III, would have to travel an additional 4,940 nautical miles per round trip to carry oil between the given ports.

Estimating the construction cost of a 1,000,000-ton tanker is complicated by such factors as fabrication, availability, handling, and steel normalizing of the large structural components. Thus, only the maximum allowable construction cost (Pmax) is calculated. We start with a required freight rate derived from the Defender:

$$RFR = \frac{AAC}{C} = \frac{CR(P) + Y}{C} \qquad (1)$$

Assuming a capital recovery factor of 10 percent, and given the figures listed in Appendix I, the required freight rate of the Defender is:

$$RFR(DEFEN) = \frac{(0.10)(\$15M) + \$1.85M}{1.8M \text{ tons}} \qquad (2)$$

$$RFR = \$1.86 \text{ per ton} \qquad (3)$$

By substitution into Equation 1:

$$RFR(CHAL) = \frac{\$1.86}{\text{ton}} = \frac{(0.10)(Pmax)M + \$4.15M}{6.3M \text{ tons}} \qquad (4)$$

Then, solving for the maximum allowable construction cost,

$$P(max) = \frac{\$1.86\ (\$6.3M) - \$4.15M}{0.10} \qquad (5)$$

Therefore, the maximum construction cost of the Challenger, using a 10 percent capital recovery factor and the required freight of the Defender would be:

$$P(max) = \$75.5M = \$75{,}500{,}000 \text{ @ } CR = 10 \text{ percent} \qquad (6)$$

By repeating the procedure, now using a capital recovery factor of 20 percent (equivalent to perhaps 11 percent after tax) the maximum allowable construction cost for the Challenger would be:

$$P(max) = \$64.0M = \$64{,}000{,}000 \text{ @ } CR = 20 \text{ percent} \qquad (7)$$

INVESTMENT LIMIT WITH EQUAL VOYAGE DISTANCES

A feasibility study is now presented for the Defender (200,000 tons DWT) and the proposed Challenger (1,000,000 tons DWT), both plying between the Persian Gulf and New York City. Unlike the determination in Appendix I, both tankers travel the same distance as described in Appendix II and Appendix III.

The maximum allowable construction cost is calculated by again first finding the required freight rate for the Defender. Assuming a capital recovery factor of 10 percent and given the figures listed in Appendix II, the required freight rate for the Defender is:

$$\text{RFR(DEFEN)} = \frac{(0.10)(\$15M) + \$1.87M}{1.1M \text{ tons}} \qquad (8)$$

$$\text{RFR} = \$3.06 \text{ per ton} \qquad (9)$$

By substituting into Equation 1:

$$\text{RFR(CHAL)} = \frac{\$3.06}{\text{ton}} = \frac{(0.10)(\text{Pmax})M + \$4.20M}{4.95M \text{ tons}} \qquad (10)$$

Then, solving for the maximum allowable construction cost:

$$P(max) = \frac{\$3.06(\$4.95M) - \$4.20M}{0.10} \qquad (11)$$

Therefore, the maximum construction cost for the proposed Challenger, using a 10 percent capital recovery factor and the required freight rate of the Defender, would be:

$$P(max) = \$109.5M = \$109,500,000 \text{ @ } CR = 10 \text{ percent} \qquad (12)$$

By repeating the procedure, now using a capital recovery factor of 20 percent, the maximum allowable construction cost for the Challenger would be:

$$P(max) = \$88.7M = \$88,700,000 \text{ @ } CR = 20 \text{ percent} \qquad (13)$$

CONCLUSIONS

The acquisition of a 300,000-ton deadweight tanker involves a capital investment of over $20,000,000. This is of particular concern to the independent owner when any return must be dependent upon a long-term charter to a specified oil company. With larger tankers, the independent owner has less flexibility in the spot charter market and in short-term contracts, because the dimension of these ships can restrict their operation to a given trade route. Likewise, before an oil company can commit itself to large tankers, it must have an ample supply of crude oil at a suitable loading port. This crude oil must be the type required over a long period of time, and the refineries must also be located at suitable ports.

A cargo lot of 300,000 long tons has a considerable effect on the operation of a refinery. Extensive shore tankage, representing a large capital investment, is required; variations between estimated and actual ship arrival times are critical, and production is limited to long processing periods on one type of crude oil.

Therefore, the tanker subsystem cannot be considered alone, but rather, the entire system, including the investment and maintenance cost of shore facilities, must be analyzed in detail.

It must be remembered that the cost of providing terminals and cargo-handling stations for large tankers may outweigh any freighting advantage.

The construction of the 300,000-ton deadweight tankers to be operated by National Bulk Carriers under charter by Gulf Oil Company is an excellent example of investigating the entire system. The tankers will transport crude oil from the Persian Gulf to a central terminal in Northern Europe via the Cape of Good Hope (principal dimensions of the tanker are listed on page 2). The oil will be discharged at an offshore cargo-handling facility on Bantry Bay off the southwest coast of Ireland. A similar central terminal station is being considered as a joint project by Sinclair, Cities Service, and Gulf, and would be constructed inside the Delaware breakwaters. Large tankers may discharge all of their cargo at the offshore terminal and then depart in the ballast condition or, they may discharge only a part of their cargo offshore and then continue up river at a reduced draft, to discharge the remainder of their oil at a shore facility. The oil discharged at the offshore terminal will be barged to the refineries until a pipeline becomes economical.

Although this paper deals only with the tanker subsystem, it must be emphasized that the tanker and terminals must be considered as an integral unit. Thus, this study represents only the tanker portion of that integral unit.

Figure 7 illustrates oil transportation cost versus deadweight, using a capital recovery factor of 10 percent. After having calculated the required freight rates, using Figures 1 through 6 of this paper, the results are expressed here as a percentage of the 50,000-ton deadweight tanker costs.

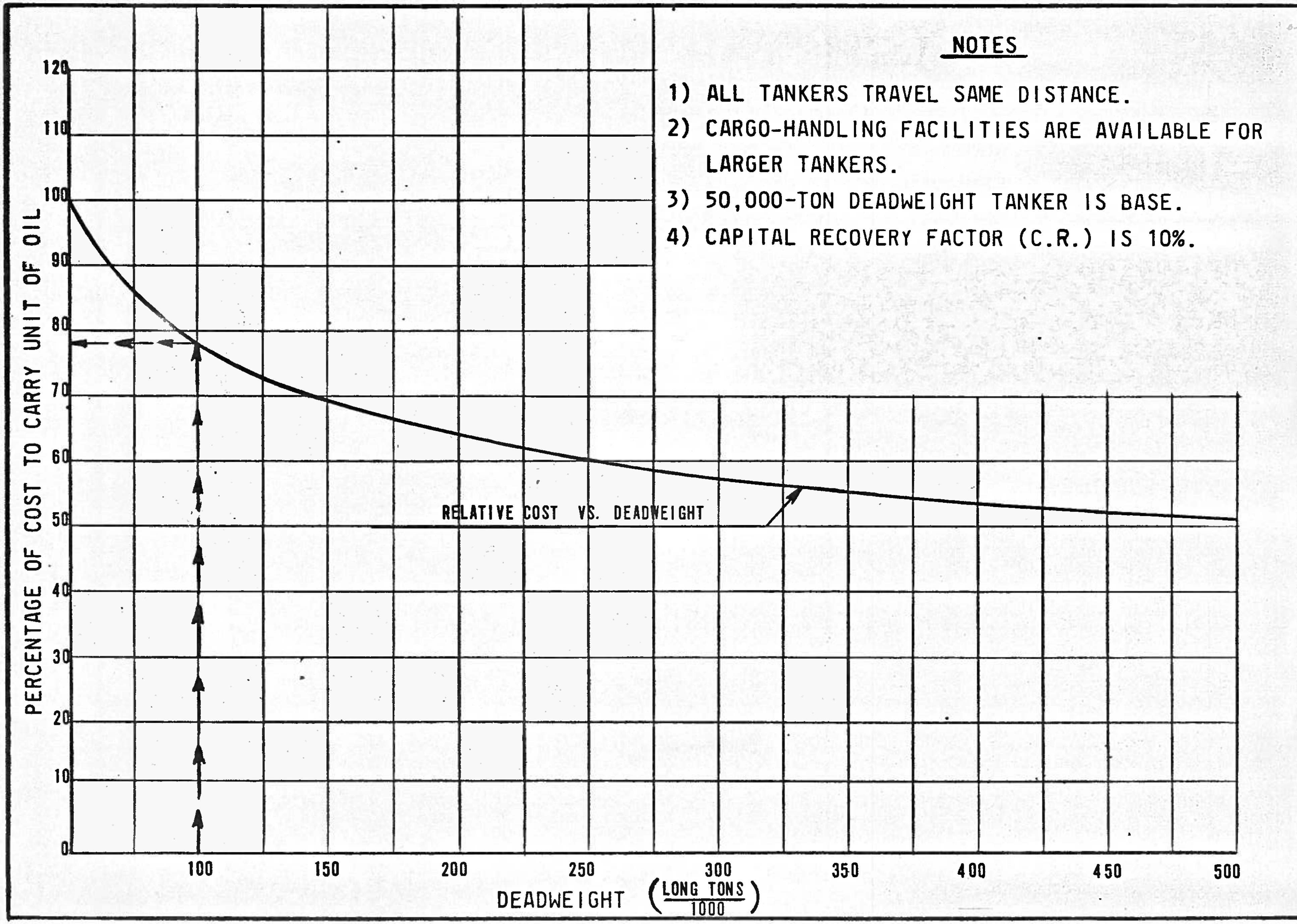


FIG. 7 RELATIVE TRANSPORTATION COST VS DEADWEIGHT

APPENDIX I

SUMMARY: PERSIAN GULF TO JAPAN

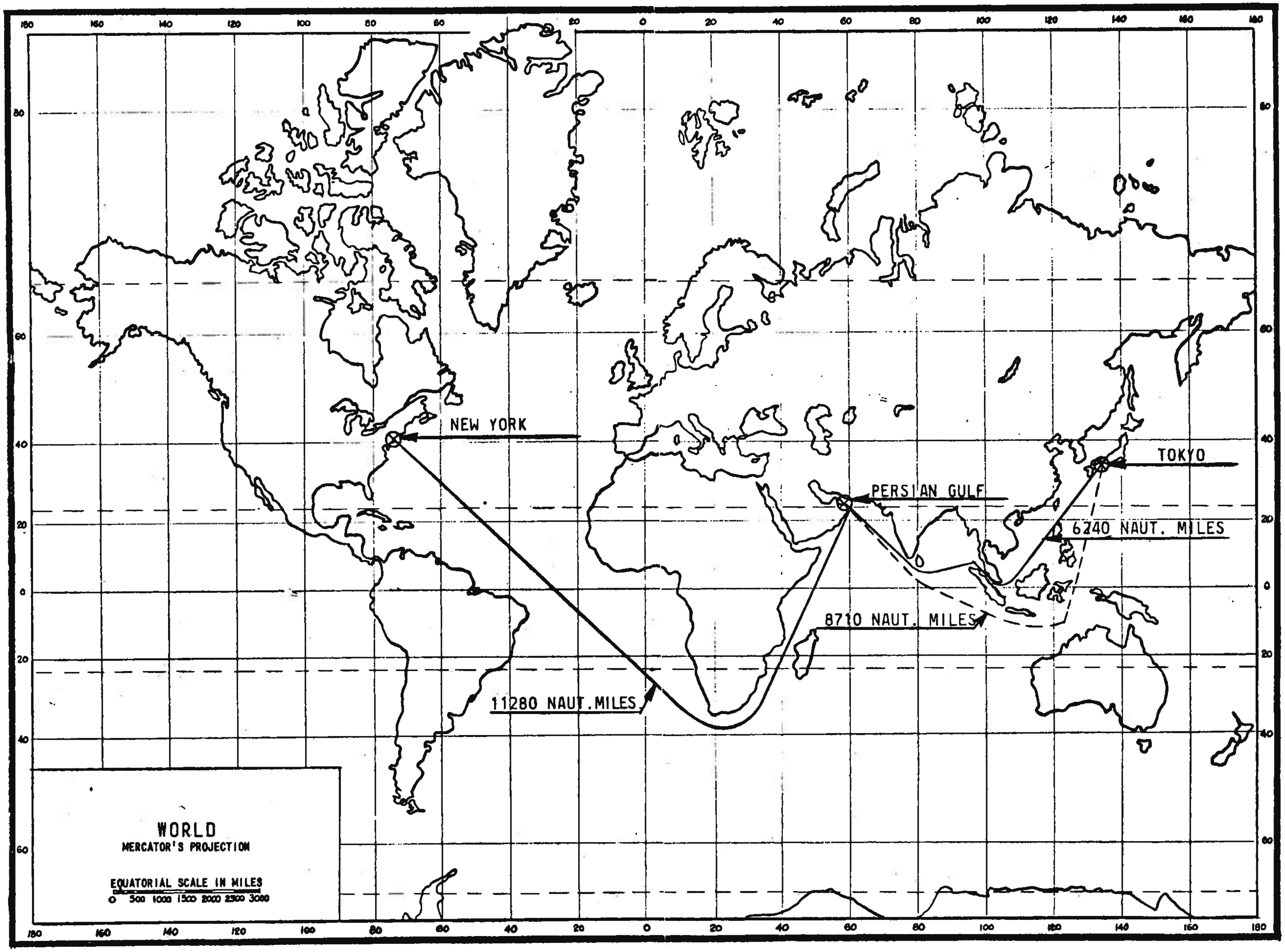
	Defender	Challenger
Ship Characteristics		
Length (bp)	1,070 ft	1,650 ft
Beam	163 ft	300 ft
Draft	58 ft	100 ft
Depth	76 ft	150 ft
Deadweight	206,000 lt	1,000,000 lt
Speed	16 kt	16 kt
Power	32,000 shp	120,000 shp
Voyage Data		
Total distance	12,480 naut. miles	17,420 naut. miles
Trips per year	9 round trips	6.5 round trips
Annual cargo	1,800,000 lt	6,300,000 lt
Construction Cost		
Investment	$15,000,000	To be determined
Annual Operating Costs		
Crew cost	$ 430,000	$690,000
Insurance cost	$ 140,000	$580,000
Maintenance and repair cost	$ 360,000	$800,000
Fuel cost	$ 770,000	$1,780,000
Overhead cost	$ 150,000	$300,000
Total annual operating cost	$ 1,850,000	$4,150,000

APPENDIX II

SUMMARY: PERSIAN GULF TO NEW YORK

	Defender	Challenger
Ship Characteristics		
Length (bp)	1,070 ft	1,650 ft
Beam	163 ft	300 ft
Draft	58 ft	100 ft
Depth	76 ft	150 ft
Deadweight	206,000 lt	1,000,000 lt
Speed	16 kt	16 kt
Power	32,000 shp	120,000 shp
Voyage Data		
Total distance	22,560 naut. miles	22,560 naut. miles
Trips per year	5.5 round trips	5.1 round trips
Annual cargo	1,100,000 lt	4,950,000 lt
Construction Cost		
Investment	$15,000,000	To be determined
Annual Operating Cost		
Crew cost	$430,000	$690,000
Insurance cost	$140,000	$580,000
Maintenance and repair cost	$360,000	$800,000
Fuel cost	$790,000	$1,830,000
Overhead cost	$150,000	$300,000
Total annual operating cost	$1,870,000	$4,200,000

APPENDIX III WORLD CHART



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