SSC-312

INVESTIGATION OF INTERNAL CORROSION AND CORROSION—CONTROL ALTERNATIVES IN COMMERCIAL TANKSHIPS

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1981

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An Interagency Advisory Committee
Dedicated to Improving the Structure of Ships

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SR-1269

1981

As a result of trends in tankship and bulk carrier design over the past decade, scantlings have been reduced significantly. This is attributed to a better understanding of actual service loads, improved methods of stress analysis, and the application of long-life coating systems, alone or in conjunction with sacrificial anodes. Because ship construction and repair costs have quadrupled in the past ten years and because steel repairs, renewals, or re-application of coatings or anodes in some areas of larger ships are nearly impossible or prohibitively expensive, the Ship Structure Committee felt that a re-examination of the corrosion-control alternatives should be initiated.

The results of such a review and reevaluation of the various corrosion-control philosophies, including sensitivity studies of the relative life-cycle costs of available corrosion-control techniques, are contained in this report.

Clyde T. Lusk, Jr.
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Technical Report Documentation Page

1. Report No.
SSC-312

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
INVESTIGATION OF INTERNAL CORROSION AND CORROSION-CONTROL ALTERNATIVES IN COMMERCIAL TANKSHIPS

5. Report Date
July, 1981

6. Performing Organization Code

7. Author(s)
L. C. Herring, Jr. and A. N. Titcomb

8. Performing Organization Report No.
SR-1269

9. Performing Organization Name and Address
Newport News Shipbuilding
4101 Washington Avenue
Newport News, Virginia 23607

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DOT-CG-912913-A

12. Sponsoring Agency Name and Address
U.S. Coast Guard
Office of Merchant Marine Safety
Washington, D.C. 20593

13. Type of Report and Period Covered
Final Report
January 1980 to April 1981

14. Sponsoring Agency Code
G-M

15. Supplementary Notes

16. Abstract

This report is the final product of an investigation of ballast and cargo tank corrosion and the use of corrosion control alternatives on board crude oil and refined petroleum product carriers. To obtain data, a survey of ship operators, coating and anode manufacturers, shipyards and contractors, consultants and published literature was conducted. Key factors affecting corrosion and corrosion protection costs are identified. The relative effectiveness of coatings, sacrificial anodes and full scantlings is evaluated for different tank conditions. A method of life-cycle cost analysis for various tank conditions and the results of sensitivity studies on two representative ship designs are presented. These analyses are used to examine traditional corrosion-control philosophy in light of modern day tanker developments. It was found that it is not normally advantageous to reduce scantlings in fully protected cargo tanks and that a partially coated crude oil tank will experience lower life cycle costs than one fully coated.

The main intent of this report is to provide tanker owners and designers with a rationale for selecting an optimum corrosion-control system for a specific vessel by providing a better understanding of the factors which influence both tank corrosion and the cost of corrosion protection.

17. Key Words
corrosion
pitting
corrosion prevention
tanker ships
naval architecture
shipbuilding
ballast tanks
petroleum transportation
coatings
sacrificial anodes

18. Distribution Statement
Document is available to the U.S. public through the National Technical Information Service, Springfield, Va. 22161

19. Security Classif. (of this report)
UNCLASSIFIED

20. Security Classif. (of this page)
UNCLASSIFIED

21. No. of Pages
170

22. Price

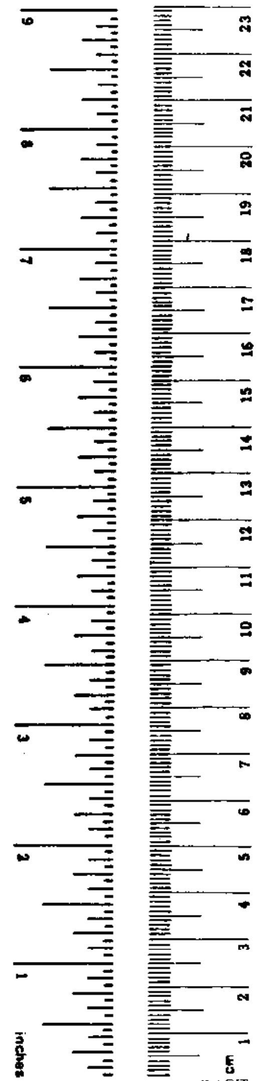
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

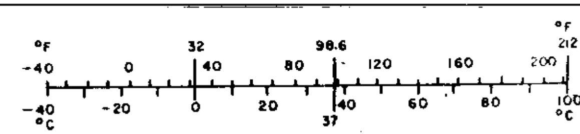
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Tankers carrying crude oil and refined petroleum products have experienced corrosion problems in cargo and ballast tanks since they first came into existence. In the 1950's, the subject started receiving widespread attention. Work done by the American Petroleum Institute, in particular, gave rise to a better understanding of the problem and its causes. As a result, more effective corrosion-control systems were developed which led to classification societies reducing the minimum scantlings required for ships. The industry trend was to use progressively lighter scantlings in an effort to minimize weight and construction cost. The philosophy was that the reduction in steel weight allowed during new construction more than offset the initial cost of corrosion-control systems and their maintenance or renewal throughout the life of a vessel. This led to increasing dependence on the ability of a corrosion-control system to prevent wastage. This basic philosophy has survived throughout the sixties and seventies.

Today, the factors on which this philosophy was predicated have changed. The size of tankers has increased so rapidly that now one tank of a modern ULCC can hold nearly as much cargo as an entire T-2 tanker did during the 1940's. Technological advances have been made in many areas of corrosion control. The cost of corrosion-control systems, ship construction and repair has increased many times over and new tanker safety and pollution regulations for tankers are in effect. In light of these changes, there exists a need to re-examine the philosophy of tank corrosion control and update it if necessary.

1.2 OBJECTIVE AND SCOPE

This project was designed to address the task of re-examining corrosion-control philosophy as it applies to today's tankers. It investigates the effectiveness of various corrosion-control systems and, by means of life-cycle cost analyses, tests the validity of the philosophy. Areas worthy of additional study are also identified. The intent of the study was to provide tanker designers and owners with a rationale for selecting the best corrosion-control system for a specific vessel by providing a better understanding of the factors influencing the corrosion experienced by a tank and the factors influencing the costs of corrosion-control systems for tankers.

The scope of the project limited the investigation to product carriers transporting refined petroleum products only (e.g. gasoline, domestic heating oil, etc.) and crude oil tankers. Chemical carriers and carriers of edible products were not included. The study was concerned with cargo tanks, cargo-ballast tanks and ballast tanks and included deep tanks only. Inner bottom tanks, slop tanks and trim tanks were excluded.

Corrosion-protection systems examined included those most widely used—full and partial coatings, increased scantlings and sacrificial anodes. Only brief mention is made of any other methods less widely used. Effort was made to report practical, representative performance results of protection systems, not the results of ideal, theoretical protection available only under optimum conditions rarely achieved. Also, corrosion related to metal stress and fatigue was not examined in this study.

The original requirements of the study as set forth by the Ship Structure Committee were the following:

a. Collect, for different areas of the structure, construction and repair costs for steel, coating and anode work in U.S. and foreign yards from published sources, owners and yards.

b. Collect existing published data, including that implied by classification rules, of corrosion rates in cargo and ballast tanks with various protection systems.

c. Develop a method or calculation procedure for taking into account life-cycle costs of various corrosion-control systems.

d. Evaluate the relative effectiveness of various corrosion-control systems based on published data and data solicited from classification societies and owners.

e. Perform sensitivity calculations of life-cycle costs of various corrosion-control systems for segregated ballast tankers as follows:

   (1) 30,000 DWT clean petroleum products tanker

   (2) 250,000 DWT crude carrier

The last requirement was later changed to allow use of a 39,300 DWT clean petroleum products tanker and a 285,000 DWT crude carrier for sensitivity studies.

1.3 LIMITATIONS

As with most research projects, there are certain limitations which must be borne in mind when using the information presented. The first is that no actual testing or detailed inspection of ships was conducted. All information was obtained by a survey of concerned groups, such as ship owners and operators, consultants, coating and anode manufacturers, shipyards, regulatory bodies, etc. and a survey of published literature on the subject.

Most ship operators and owners do not keep detailed records of tank corrosion. Most companies, especially smaller ones, are very limited by available manpower and do not have the time to devote to such activities.

In these cases, the respondee usually reported informally on their general experience with tanks. Often the information was not as detailed as ideally desired making it difficult to correlate between the type and extent of corrosion damage and the many factors that led to it.

The last limitation which should be noted concerns cost figures. Some type of cost figures was obtained from several different sources but it was soon discovered that the costs reported often depended on unquantifiable factors such as the urgency of the work, the availability of dry dock space and the volatility of the particular market. This type of response made it difficult to arrive at concensus cost figures for different types of tank work.

CHAPTER 2

METHODOLOGY

2.1 SURVEY

Two types of surveys were conducted to obtain data for use in the project. The first was a survey of published information on the subject of tank corrosion and corrosion-control technology. A comprehensive computerized literature search was first conducted by Maritime Research Information Service (MRIS). This resulted in a listing of all recent publications relating to tank corrosion, tanker repair work or the performance of corrosion-control systems. Sources of publications on the subject included technical societies such as the Society of Naval Architects and Marine Engineers (SNAME) and the National Association of Corrosion Engineers (NACE), the National Technical Information Service (NTIS) and technical libraries. A complete bibliography is located at the end of this report.

Next a survey of persons involved in the tanker and corrosion-control industry was conducted. This survey canvassed ship owners and operators, coating manufacturers, anode manufacturers, marine corrosion consultants, regulatory agencies, shipyards and independent shipyard contractors. To assist in the surveys, data sheets were developed for ship owners and operators and coating manufacturers. Contacts with other groups were conducted on a more informal basis.

Information for use in the study was received from sixteen tanker owners and operators involved in both foreign and domestic service. These responses varied significantly depending on the time and manpower available to respond and the scope of that company's experience. Small tanker companies were usually very limited in the time and manpower they could devote to tank corrosion and, as such, kept very little detailed information. Larger companies usually had on their engineering staff one or more persons whose main duties involved tank corrosion. One company had developed a comprehensive computerized tank management program to control corrosion in its ships. Most companies chose to respond on the basis of general information rather than specific ship histories. Each responded only on the tank scenarios with which they had experience. The different scenarios were based on type of cargo, type of washing, age of ship, type of corrosion protection, etc.

Ten coating companies responded to the survey. Information obtained from these contacts was very consistent due to the use of a survey data sheet which most respondees completed. All main types of coatings were represented including epoxy, inorganic zinc and soft coatings. Two major anode manufacturers were also contacted for information on zinc and aluminum sacrificial anodes.

Several marine corrosion consultants contacted provided information on corrosion-control methods for tankers and four shipyards and independent tank contractors supplied information on costs of corrosion control and repair. A great deal of tank work in shipyards is now performed by independent contractors. Foreign corrosion-control costs were obtained from publications and contacts with ship owners and coating companies.

2.2 EVALUATION

Data from the literature and industry survey were compiled, reviewed and evaluated to establish the relative effectiveness of various corrosion-control systems. Only the most widely used types of systems were evaluated. These proved to be epoxy, inorganic zinc and soft coatings, full scantlings, and zinc and aluminum sacrificial anodes. Others are mentioned in this report for completeness. There was often a great deal of disparity in performance reports for various corrosion-control systems probably due to the many affecting factors which exist. Therefore, every effort was made to disregard exceptionally high and low figures and to use the results experienced in the majority of applications. The evaluation of corrosion-control systems determined the expected lives of the systems and an estimate of the effectiveness of the system, that is, the amount of corrosion which can be expected while using a given system. This information was then used to conduct life-cycle cost analyses by computer program of the various systems to determine the total cost of corrosion protection of the ship over an assumed 20-year lifetime.

2.3 SENSITIVITY ANALYSES

Sample sensitivity analyses were performed on two representative ship designs to demonstrate how the influence of various parameters affects the life-cycle costs of corrosion-control systems used on realistic examples. One ship used was a 39,300 DWT refined petroleum product carrier with a double bottom, segregated ballast tanks and a flue gas inerting system. The other was a 285,000 DWT ultra-large crude carrier with flue gas inerting, segregated ballast tanks and a crude oil washing (COW) system. A more complete description of the two ships used and all assumptions made are found in Chapter 9.

CHAPTER 3

CORROSION CONTROL SYSTEMS

3.1 COATINGS

3.1.1 General

Coatings are the most widely used type of corrosion protection in ships' tanks today. These tank coatings include several generic types and a much greater number of proprietory brands from which the shipowner must choose. From the large number of coatings which are available, it seems evident that no one product is universally accepted as the best coating for all applications. Although covered in greater detail in other publications, discussion of some of the properties of coatings and the other factors which affect coating performance, should be a prerequisite to the descriptions of generic types which are included later in this chapter. (The term "coating" is synonymous with "paint".)

An important property of paints is the percentage of solids which is contained by volume. This figure, almost always given in coating specifications, is used to establish a relationship between the wet thickness of the paint applied and the final dry film thickness which can be used to calculate the spreading rate and coverage of paints. Part of most coatings is volatile solvent which evaporates after application. The percentage of solids by volume is the percentage of the original volume of paint which remains after these volatile solvents have evaporated.[1] The higher the percentage of solids which a coating has, the fewer the number of coats necessary to reach a required dry film thickness. The coverage of a paint determined by using the percent solids by volume is its theoretical coverage.

Practical losses of coating material also occur and must be considered in determining the actual coverage of a paint. These losses are due to mixing and application methods and vary according to many factors, the most predominant being the type of application procedure used. Losses range from 7 to 10% by brush to about 40% by conventional air spraying.

There are numerous factors which determine the protection afforded by a particular coating. The coating itself is only one of these and possibly only a minor factor at that. It has been estimated that no more than 2 or 3% of all coatings ever fail because of the paint itself.[2]

One of the most important factors is the preparation given the steel prior to application of a coating. The basic requirement for conventional coatings is that they be applied over a clean, dry surface free from water soluble materials like sodium chloride, which can cause blistering of paint, soluble ferrous salts which will, in contact with steel and moisture, initiate rusting of the steel, and oily residues which will reduce adhesion of the applied coatings.[3] The roughness of the surface, its profile, is also a consideration when coatings are used. A one to two mil profile, the distance from the bottom of pits to the top of peaks, is acceptable for most paints.

Dry abrasive blasting is currently the best and most widely used method of achieving both surface cleanliness and an acceptable profile. There are several generally accepted standards of surface preparation. These are the Steel Structures Painting Council (SSPC), the National Association of Corrosion Engineers (NACE) and the Swedish Pictorial standards. Each is in general agreement as to four main degrees of surface cleanliness. Table 3-1 describes each of these degrees along with their corresponding designations from the three organizations in decreasing order of cleanliness. The high levels of abrasive cleaning require more time and more expense than lower levels. The level of surface preparation required depends on the type of coating to be used, the severity of the environment and the length of protection desired. Manufacturers of paint are often in disagreement with each other so it is always best to consult the manufacturer of the specific coating in question for the surface preparation required.

TABLE 3.1

Surface Preparation Specifications for Abrasive Blast-Cleaned Steel[4]

Surface Finish	NACE Spec.	SSPC Spec.	SSPC/SIS Visual Std. SSPC-Vis 1	Description
White Metal Blast	1	SSPC-SP5	CSa 3	Gray-white color; 100% free of oil, grease, dirt, mill scale and paint.
Near White Blast	2	SSPC-SP10	CSa 2 1/2	Only very light shadows, streaks or discoloration; at least 98% free of above contaminants
Commercial Blast	3	SSPC-SP6	CaS2	At least two-thirds free of visible residues with slight staining or tight residues remaining
Brush-Off* Blast	4	SSPC-SP7	CaS1**	Only tight mill scale and tightly adhering rust and coating after specified pattern of blasting

* Can be used to reclean metal cleaned to a higher level on previous day or remove temporary coatings applied for protection during transit or storage.

**For rusted, unpitted steel only

It is usually desireable to remove all corrosion products before applying conventional coatings but this becomes more and more difficult as steel corrosion becomes worse. It is accomplished easiest on steel during new construction. Steel used in new construction is often sprayed with a coat of protective primer and at worst is covered with mill scale. Surface preparation of steel in ships already in service is not as easy. Steel in this case can be heavily corroded and may also have been attacked by deep corrosion pits making it hard to remove corrosion products by blasting. Some types of cargo can also have an effect on later surface preparation. Some crude oils, for instance, can leave waxy deposits on tank walls which if not cleaned prior to blasting can be driven into steel by sand blasting and retard adhesion of subsequent coatings. Badly corroded steel in tankers already in service usually takes longer to blast and is therefore more expensive to prepare than steel used in new construction.

Environmental conditions are also important factors in the successful application of a coating. Humidity must be within certain limits and, in many instances, must be controlled by dehumidification equipment. Ventilation must be adequate to allow volatile solvents to evaporate. Pockets of stagnant air not only hold up drying but, in certain cases, prevent proper curing as well. Temperature is also important, not only of the ambient air, but of the steel to be painted and the paint material itself. All should be regulated within certain limits, according to manufacturers, to ensure proper adhesion and curing. Last, the areas to be coated must be kept free of contamination by dust and moisture depending upon the recommendation of the particular paint manufacturer.

The quality of application of a coating can also be a determinant in the length of coating protection given by a coating. Application factors include the correct equipment for the job and, equally important, correct spraying procedure by painters during application. Correct equipment involves choosing the right type of spraying equipment, spray nozzle, compressors, agitators, etc. Correct spraying procedure involves many things. Spraying must result in a uniform application at a specified film thickness throughout the tank. Both too little thickness and too much can be causes of failure.[5] Weak thin spots, often called holidays, are perhaps the most prevalent cause of premature failure. Spray must be such that pinholes are not found in the coating because these pinholes allow water penetration and subsequently become initial corrosion sites. The proper type and amount of solvents for thinning must be used. Also, certain rules must be observed whenever one coat is applied over another. These are but a few of the many critical procedures involved in paint application.

Once the surface has been prepared, a suitable environment has been created and the coating material has been correctly applied, the tank is still not yet ready for use. Most conventional paints require a certain period of time for the coating to properly cure. Even after this period is over, the coating will still be in a sensitive state. Initial cargos carried should be those recommended by the manufacturer as aiding cure. Detrimental cargos should be avoided.

Paint companies often report long service lives predicated on compliance with certain conditions such as those previously stated but it should be noted that, in practice, compliance with all these conditions is rarely achieved. Often, compromises on the part of both the shipyard and the ship operator are necessary. For example, it is difficult to plan around uncontrollable factors like the weather. Often there is little incentive to wait for the right weather conditions. Shipyards attempt to maintain production schedules and avoid delays which can often result in production bottlenecks because certain facilities are being used. Shipowners, on the other hand, strive to minimize high costs incurred while a ship is in the yard as well as the revenue lost while the vessel is out of service.

This report, like many other publications, reports the life of coating in terms of a finite number of years. This should not lead one to the assumption that a tank coating is 100% intact until its life is over. Instead, a coating gradually deteriorates, slowly at first and at a faster rate with time, until it is deemed time for recoating by the shipowner.

3.1.2 Zinc-based Coatings

Zinc-based coatings have been considered a major form of tank protection for years and are one of two main types of coating used today. Zinc-based coatings are generally placed into two main categories, inorganic and organic, depending on the chemical nature of the binder used to bond the zinc particles together.[6] Organic zinc coatings provide not only cathodic protection like inorganic zinc but exhibit epoxy characteristics as well. Inorganic zinc coatings are by far the more widely used tank coatings of the two and will be the main subject of this discussion.

Corrosion resistance of inorganic zinc coatings arises principally from the galvanic protection afforded by their high loadings of zinc. These loadings in tank coatings, may represent 75% minimum weight of dried and cured linings.[7] Because zinc, whether in coatings or anodes, has a higher electromotive force than steel, its tendency to corrode is greater. This greater tendency to corrode relative to steel is the basis used for protection by zinc tank coatings. When steel tanks are coated with inorganic zinc and exposed to a suitable electrolyte the zinc becomes an anode and the steel becomes cathodic which means that the zinc will preferentially sacrifice itself thereby protecting the steel from corrosion. Minor holidays, thin areas, or pinholes in the paint do not become sites of coating failure or corrosion on the underlying steel because the steel is afforded protection against rusting by the adjacent zinc coating.

Upon initial development, inorganic zinc coatings were of a post-cured variety meaning that an acidic curing solution had to be applied over the initially applied zinc silicate film. During the past decade, however, post-cured inorganic zinc coatings have largely given way to a newer self-curing type which does not require the application of a curing solution. These coatings, which are reported to display more tolerance for variation in the thickness of the film than post-cured products, require a requisite curing time to permit chemical reactions before the coating is placed in service. Some require moisture to complete the cure. For these products, high humidity may be introduced into tank spaces by the use of steam or water atomization or the tank may be rinsed down with fresh water after application. Many ship operators prefer the post-cured inorganic zinc over its apparent successor quoting hardness and longer life as their reasons.

The self-curing products are either water-based or solvent-based coatings. Water-based coatings have liquid components composed of colloidal silica or alkali silicates such as potassium or lithium silicates.[7] Solvent-based coatings, on the other hand, are based on partially hydrolyzed alkyl silicates in a solvent medium containing alcohols or aromatic hydrocarbons. Of the two, water-based inorganic zinc linings must be applied within a narrower temperature range, 40° to 100°F, while solvent-based products can be applied in as low an ambient temperature as 0°F temperature or as high as 100°F. Surface preparation recommended for inorganic zinc coatings is commonly dry abrasive blast to white metal with only a few manufacturers recommending near white preparation. A surface profile of 1 to 2 mils is usually sufficient. Inorganic zincs are most commonly applied over prepared surfaces in a single coat of 3-5 mils film thickness resulting in perhaps the best adhesion properties of any tank coating, owing to a chemical as well as physical bond to the steel substrate. The paint consists of two components, zinc dust and a silicate solution, which are mixed together. Constant agitation of the mixture before application is required to keep the zinc in suspension for uniform distribution. Application of these coatings, which normally cost from $25 to $35 per gallon, is by conventional spray equipment. Coverage of inorganic zinc coatings ranges between 185 and 210 square feet per gallon assuming 40% wastage during spraying.

As with most coatings, there are certain limitations which must be observed when considering inorganic zinc as a tank lining. Most of these pertain to the cargo to which the coating is exposed.

All inorganic zincs have very low resistance to acids and strong alkalis and, therefore, depending on the particular manufacturer, cargoes outside a range of roughly pH 5 to 10 should be avoided. This means that service may be severely limited in some crude oils. The suitability of inorganic zinc coatings for crude oil depends upon the degree and nature of sulphur contained in the oil. This will be discussed in detail in a later part of this report.

Inorganic zinc coatings are in their most sensitive state immediately after curing. The choice of cargo during this time can be an important determinant of the life of the coating. One manufacturer recommended that solvent cargoes be avoided and that cargoes which assist curing should be sought. Unfortunately, in many instances, the ship operator is unable to do this.

Inorganic zinc coatings are suitable for the full range of petroleum products from gasolines to heavy fuel oils as long as limits of acidic content are observed to prevent contamination of the cargo by zinc. Slight zinc pick up may occur when any zinc coating is used.

Inorganic zinc tank linings can be used for both cargo and cargo tanks which intermittantly are used for saltwater ballast. They also find many uses in ballast-only tanks with some applications reported to prevent steel replacement for as long as 8 to 12 years. Use of inorganic zinc for continuous saltwater immersion service in ballast tanks is usually not recommended by many paint manufacturers. Due its sacrificial nature, a zinc coating in saltwater experiences accelerated consumption of zinc, especially in brackish and polluted waters. Inorganic zinc coatings, suitably top coated, are reported to be acceptable for continuous saltwater immersion.

Both ship operators and paint manufacturers have also found inorganic zincs to be incompatible with inert-gas systems installed onboard many ships. In certain cases, the zinc has been severely attacked in a very short time. Further discussion of the effects of inert gas will be found in Chapter 4.

3.1.3 Epoxy Coatings

The second major type of coatings used for tank protection is that of epoxy coatings. There are three main types of epoxies that are used as tank linings. These are amine catalyzed epoxies, polyamide epoxies and coal tar epoxies. The categories are by no means all inclusive. An unlimited number of combinations can be formulated that could be given the generic name epoxy.

For corrosion to occur on bare steel, two conditions must be met; both oxygen and an electrolyte must be present. It would be impossible to eliminate both oxygen and an electrolyte from a tank. But, since all three conditions must be in direct contact for corrosion, if oxygen and the electrolyte can be prevented from coming in contact with bare steel, corrosion can be averted. Epoxy coatings utilize this method of corrosion prevention by acting as such a barrier.

Amine and polyamide epoxies see widespread use in marine applications because they result in thick coatings with good adhesion and generally good resistance to most cargoes. Epoxy resin paints are supplied as two components, a base and a hardener, which must be mixed together prior to application. Curing of the paint to a tough, oil and water resistant state occurs by a chemical reaction between the epoxy resin and the curing agent, amine or polyamide, which forms the hardener. Epoxies can be applied to such a thick coat, 8 to 12 mils, because the chemical reaction does not require oxygen for its curing. Amine and polyamide cured epoxies are normally applied in 2 or 3 coats depending on the percentage of solids in the coating. In order to ensure good adhesion between coats, each successive coat should be applied before the previous one has cured.

Surface preparation for these epoxies usually consists of dry abrasive blast to near white metal condition. Coverage of these paints, which range from 45 to 55% solids by volume, is normally about 120 ft^2/gallon, assuming a 40% loss factor. Special high build epoxies with a higher percent solids by volume, as high as 80 or 90%, cover more than 200 ft^2 per gallon. Amine and polyamide epoxies form smooth, glossy surfaces and commonly cost between $16 and $20 per gallon. Recommended application temperatures range from 60°F to 90°F. Minimum acceptable temperature is commonly 50°F. The higher the ambient temperature is, the faster the curing. The application temperature range may pose a problem for many moderate-to-cold climate shipyards.

Amine and polyamide cured epoxies are suitable for cargoes of petroleum products and crude oils as well as salt water ballast. Amine-cured coatings are resistant to acids, alkalis, salts and moisture and result in a dense, hard coating. Polyamide cured coatings, on the other hand, show excellent resistance to alkalis and water but are less resistant to acids and solvents than the amine-cured type. Table 3-2 summarizes the relative properties of each of the three main types of epoxy.

TABLE 3.2

Generic Type: EPOXY[8]

Property	Epoxy Amine	Epoxy Polyamide	Epoxy Coal Tar
Physical properties	Hard	Tough	Hard
Water resistance	Good	Very Good	Excellent
Acid resistance	Good	Fair	Good
Alkali resistance	Good	Excellent	Good
Solvent resistance	Very good	Fair	Poor
Temp. resistance	Very good	Good	Good
Recoating	Difficult	Difficult	Difficult

These epoxies have two inherent properties which can contribute to premature coating failure and rust formation. The first is the epoxies' tendency to shrink which can pull paint away from sharp edges and corners. The second is the forming of pinholes in the coating which can become sites of coating failure when penetrated by water.

Coal tar epoxies, the third main type of epoxy, are considerably different from regular amine and polyamide cured products. The coating is based on epoxy resins modified with coal tar pitch. Like the other epoxies, this coating is normally applied in 2-3 coats but the total film thickness is often much greater, from 10 to 24 mils. A gallon of coal tar epoxy commonly covers 90 to 150 ft^2, assuming a 40% loss factor. Surface preparation required is normally dry abrasive blast to a commercial or near white standard. Coal tar epoxy is generally regarded as more tolerant of surface preparation imperfections than are regular epoxies. The coating usually ranges from 65 to 75% solids by volume and normally costs from $12 to $15 per gallon.

Coal tar epoxies have several advantages and disadvantages which are not shared with their regular amine or polyamide-cured counterparts. Resistance to water is exceptionally good which is why it is widely used as a ballast tank coating both domestically and abroad. This use may, however, change in the future due to health considerations at shipyards where the material is applied. Coal tar epoxies have been reported to be carcinogenic and many yards now refuse to apply the coating for that reason. Its black or dark color also has caused concern among users because it is difficult to inspect for stress cracks in a tank coated with coal tar epoxy. At least one company has now developed a light-colored coal tar epoxy that alleviates this problem.

Unlike regular epoxies, resistance to solvents is poor for coal tar epoxy. For this reason, refined products should not be carried in a tank so lined because the coal tar pitch would cause contamination of the cargo. Coal tar epoxy is also reported to be suitable for some crude oils.

3.1.4 Soft Coatings

Another form of protection for certain tanks is provided by soft or semi-permanent coatings. These are offered in many different forms by many different manufacturers. Although they have yet to receive widespread acceptance by ship owners, soft coatings do possess several properties which prove attractive.

Manufacturers report that soft coatings can be applied during new construction or to a ship already in service. When applied to existing vessels, soft coatings have the advantage of not requiring extensive surface preparation as do conventional tank coatings. The minimum surface preparation acceptable to most of these coatings amounts to little more than removing all loose scale and mucking out all silt and debris. Removal of loose scale can be accomplished by hand or by water blasting. Several soft coatings can be applied even while the tank walls are still damp. No dehumidification equipment is necessary.

Application of soft coatings to tank surfaces is by one of two methods. Some allow either. The first method is by conventional spray equipment. The second is known as floatcoating. Floating the material on involves dumping a large amount of material onto the surface of the water in a tank as it is slowly ballasted and deballasted. As the level rises and lowers, the walls are coated with the material. The process is easily done in a vessel underway and requires very little time or manpower but does require about twice as much material to coat a tank as spraying would require.

Many of the soft coatings available are a petroleum or petroleum derivative based product. They often include corrosion inhibitors and have a platelet, or fish-scale structure which prevents the transmission of moisture. These coatings are applied in a single coat to a film thickness of 4 to 6 mils and cover 100 to 400 sq ft per gallon depending on their percentage of solids. This type of coating may also possess a polar property which aids adhesion and prevents excessive loss of film from sloshing of tank contents. Another type of soft coating, composed of lanolin and applied to a film thickness of up to 80 mils, is reported to displace moisture and undermine present corrosion products until they fall from the tank surface. The film then prevents further corrosion of the steel substrate. Coverage of this type of soft coating is 20-22 sq ft per gallon.

All soft coatings are formulated for salt water immersion only and find their main application in permanent ballast tanks. They are usually delivered ready for application with no mixing required. The soft coatings range from 50 to 100% solids by volume and cost anywhere from $1.50 to $10.00 per gallon, inexpensive by normal coating standards.

These coatings are sometimes categorized as semi-permanent because their protection does not last as long as conventional coatings. Most estimates of service life are about two years although one type has been reported successful in applications as long as 10 years. Some require periodic renewing to maintain corrosion protective properties. This usually consists of adding an amount of material during normal ballasting.

As their generic name implies, soft coatings do not cure to a hard, dense film like conventional paints used in tanks. Instead, they remain soft and, as such, cannot be used in areas of high abrasion. Many ship operators and shipyards have reservations about such a slippery environment during inspections, repair, etc. but most soft coating manufacturers say that, with time, their coatings set up enough so that inspection and moving about in the tank is not a problem.

Most soft coatings can be applied after conventional coatings have experienced failure to protect the steel against further corrosion. This is of particular benefit when an owner intends to sell a ship in the forseeable future and does not want to spend the large sum of money necessary to blast and recoat and incur the accompanying out of service time. Soft coatings could also be used as a stop gap measure to delay corrosion until the ship is scheduled for major repairs.

3.2 SACRIFICIAL ANODES

3.2.1 General

Sacrificial anodes, one of two main types of cathodic protection, are commonly used to protect cargo-ballast and ballast-only tanks from corrosion. Impressed current cathodic protection systems, the other type, are not used in tanks. A sacrificial anode may be defined as a metal less noble than another metal to which it is electrically connected.[9] In the presence of a suitable electrolyte, the sacrificial or galvanic anode goes into solution at a disproportionate, accelerated rate compared to its normal rate when exposed alone to the same electrolyte under the same conditions. The anode, thereby, economically protects the metal to which it is attached.

There are several metals which make suitable anodes for steel tanks. The metals are cast into various shapes with steel cores for support and attachment and are placed by some means into a tank which contains a suitable electrolyte, salt water ballast in the case of ships. The anodes cause a current to flow between them and the steel. The longer the anode is in length, the higher the current output and the smaller the number of anodes needed to protect a tank.[10] The larger the cross sectional area an anode has, the longer its useful life.

There are three methods of attaching the anodes to the steel inside a tank that are acceptable to classification societies. These are:

1. Welding directly to the tank structure.
2. Clamping directly to the tank structure.
3. Bolting to pads welded directly to the tank structure.

Welding is the least expensive method to use on new construction.[10] This method provides the most secure attachment with the least chance of a loss of contact. Clamping is the least expensive method of initially attaching anodes on existing ships although some ship operators have reservations about the security of such an attachment. Bolting anodes onto welded pads is a compromise between welding and clamping. Although bolted anodes take longer to install initially, their replacement is easily accomplished without hot work.

Most anodes are designed for a life of three to four years under normal conditions although they can be designed for as long as ten years if desired. Replacement should occur when the anode has reached about 85% consumption. The most significant factor influencing the life of sacrificial anodes is the amount of time that the tank is in ballast. Since anodes are only active during ballast cycles the greater the amount of time the tank is in ballast, the shorter the life of the anode. Most ships spend an average of 30% to 40% of their time in a ballast condition.

The amount of time in ballast is also the most important factor in determining the effectiveness of anodes in preventing corrosion in a tank. Anodes can only reduce corrosion of steel when ballast water is present. They can afford no protection to an empty tank or to one completely full of cargo. It is, however, during times when a tank is empty that a significant amount of tank corrosion may occur. Following tank washing or deballasting, the corrosion rate due to a corrosive salt water atmosphere is considerably greater than the rate which exists when the tank is in a ballast condition. Protection by anodes is, therefore, greatest in a tank that is ballasted the largest percentage of the time and least effective in a tank that spends the least amount of its time in ballast. The quality of the ballast can also be a factor. Quality in this case refers to its salinity and the amount of contaminants it contains.

In a cargo ballast tank, the type of cargo can affect anode performance. When cargo, especially heavy crude oil, is carried in a tank equipped with anodes, the anodes tend to become covered with a thick, waxy film which affects protection. In a clean ballast tank, one which is washed of cargo before being ballasted, the washing helps clean many anodes but in a dirty ballast tank, one which is not washed prior to ballasting, the film remains on all anodes. Under these conditions, anodes take time to stabilize and polarize the area before full protection can occur. This can take anywhere from one to four days depending on the anode material and the thickness of the oil film. It is for this reason that many ships traveling short coastal routes do not use anodes. Their ballast times are so short that they either do not allow enough time for the anodes to reach potential resulting in no protection or, if they can stabilize, not enough time remains for effective economical protection.

As stated earlier, anodes must be wholly immersed in ballast water to be effective. One area of a tank that may not allow this condition to occur is the deckhead, or overhead plating and structure of a tank. Since it is almost impossible to press a tank completely full, there is usually space, the ullage space of a tank, that is not fully immersed. Anodes cannot adequately protect these overhead areas of a tank which are commonly regions of high corrosion incidence. Therefore, other protection means must be employed. The most common practice is to coat the entire overhead and about two meters down on the sides. In the case of a tank that is usually only partially ballasted, the coating should extend down to below the expected ballast waterline for optimal protection.

Another area which can need special attention is the tank bottom. There is commonly a layer of water below the cargo which may be from an inch or two to a foot in depth. This layer consists of water which remains in the bottom of the tank after deballasting or salt water washing and water which is contained in the cargo. Corrosion can occur in this layer during the cargo cycle. Anodes designed to protect the bottom are usually located at the top of longitudinal and transverse structural members and, as such, are often ineffectively immersed in the cargo above the water. Several ship operators are now positioning anodes on the vertical webs of structural members at an angle so they are immersed in the water layer instead. Another solution involves the use of strip or ribbon anodes installed on the tank bottom plating which can also provide protection to the tank bottom when a layer of water exists.

Sacrificial anodes can provide either of two main types of protection in tanks - primary and secondary. Primary protection occurs when anodes are installed on bare steel surfaces as its only means of protection. When anodes are installed for primary protection it should not be assumed that the tank will remain corrosion free. At best, corrosion will be reduced about 80% compared to a similar bare tank with no anodes installed.[11] Secondary protection exists when the anodes are installed on coated surfaces as back-up protection for the paint. In this type of service, the anodes will protect against corrosion which may occur due to pinholes, holidays or porosity in the coating. Anodes may also be used as a form of coating repair. This occurs when anodes are retrofitted in areas of significant coating failure to afford protection which the coating can no longer provide.

Anodes function by generating an electromotive force which opposes the electromotive force of the corrosion cell which exist in a tank, thus polarizing the tank area and controlling corrosion.[12] The amount of current required for protection is influenced by several factors including properties of the water such as salinity, temperature, etc.; the condition of any coatings present; and the location. Current requirements vary considerably, not only from tank to tank but from area to area within a tank. Highest current density requirements exist on the tank bottom and horizontal surfaces.[13]

Current density requirements, usually expressed in milliamps per square foot or square meter, are best estimated from past experience. Overprotecting an area does not affect the protection provided but it can be the cause of unwanted side effects such as coating damage. The degree of overprotection allowable is dependent on the likelihood of these side effects occurring.

A sacrificial anode system of any one of several materials can be designed to provide a specified current density. The difference between the use of different types of metal lies in the resulting quantity requirements, weight, dimensions and degradation rate of each anode based on its driving voltage, current output, density and efficiency. The economics of achieving desired protection in a given tank, in conjunction with applicable rules and regulations, is the major deciding factor between anodes of different materials.

The principal commercial anodes which have been used in tanks consist of alloys of magnesium, zinc and aluminum.

3.2.2 Magnesium Anodes

During the 1950's and early 60's, Magnesium anodes were used for cathodic protection in cargo/ballast and ballast tanks aboard tankers. During this time, magnesium anodes were reported to be effective in controlling not only general corrosion but also localized pitting on horizontal surfaces.[14] The situation changed, however, in 1964 upon announcement by the USCG that magnesium anodes were no longer allowed in tanks carrying volatile hydrocarbon cargoes. The ban was due to a series of tanker explosions whose origins were suspected to be due to incendive sparking by anodes. It was believed that the sparks were caused by anodes, whose connections had failed, falling and striking the metal below. Tests were conducted and, as a result, the use of magnesium was banned due to its potential explosion hazard. Although the ban concerned cargo tanks only, use of magnesium anodes in ballast tanks also declined. This was due to significant evolution of hydrogen gas by the anodes and magnesiums tendency to overprotect steel immediately adjacent to the anodes. This overprotection was evidenced by heavy calcereous salt deposits and was due to magnesium's high driving voltage and current output. Magnesium anodes do not see use in tanks today.

3.2.3 Aluminum Anodes

Although initially banned along with magnesium, aluminum anodes are now allowed with certain restrictions on their use. Aluminum anodes, first used in cargo/ballast and ballast tanks during the early sixties, are now restricted as to the height of their installation. Regulations state that they can be used in cargo oil tanks as long as their potential energy does not exceed 200 ft-lb.[15] This means that a 50-lb aluminum anode can be installed no more than four feet above the tank bottom. Recent interpretations of this restriction now permit aluminum anodes to be installed higher in the tank if "T" shaped horizontal stiffeners are used which would cradle the anode and prevent it from falling to the tank bottom if its means of connection failed. Aluminum anodes have been successfully installed in ships tanks both domestically and abroad.

Aluminum anodes are reported to possess advantageous properties. One is its self-cleaning ability. After being immersed in crude oil for days, aluminum anodes are quick to stabilize current output, an important quality for cargo/ballast tanks. Another advantage is their density. Considerably less anodes of aluminum would be required to provide the same protective current as the same size zinc anodes. Aluminum has a driving voltage similar to zinc but a current output higher than either zinc or magnesium.

3.2.4 Zinc Anodes

Unlike magnesium or aluminum, zinc anodes are not subject to any restrictions on their use or installation. Anodes of zinc have been in use since the sixties and still are probably the most widely used type of anode in tanks today. They do not generate hydrogen gas or overprotect steel like magnesium anodes and, unlike aluminum, they can be installed at any height or location but they do have two inherent disadvantages. The first is their weight. Considerably more anodes are required to provide the same protective current as magnesium or aluminum which increases the weight of the vessel. Zinc is also more susceptible to suppression by oil film than other anodes.[11]

3.3 FULL SCANTLINGS

One method of corrosion control is to simply use full scantlings alone or in conjunction with a corrosion-protection system during initial construction. All classification societies now allow a reduction in scantling requirements on new construction if an approved corrosion control system is employed. A summary of classification society rules and regulations pertaining to tanker internal corrosion control is located in Appendix A. However, once this reduction is taken a great deal more reliance must be placed on the performance of the corrosion-control system. If the system should fail or otherwise prove ineffective,there is very little allowance for corrosion before classification societies would require expensive steel renewal. Many ship operators now prefer to use full scantlings in conjunction with corrosion protection as double guarantee that steel replacement will not be required for many years. When the system fails,the ship operator has much more time to decide on his next course of action and when it should be accomplished. Several ship operators also cited maximum structural strength as an added incentive to use full scantlings.

3.4 OTHER SYSTEMS

Many other methods of internal corrosion have been tried over the years. Most came into use before coatings had received widespread acceptance. One system involved the use of inhibitors, chemicals added to cargo and ballast water to prevent tank corrosion. Oil soluble inhibitors, added to cargo oil, protected tanks when they were full and may have afforded slight protection to empty tanks. Excellent results were reported during the early 1950's[16] but due to several drawbacks their use was discontinued. The cost of water-soluble inhibitors for the treatment of ballast water was reported to exceed the cost to replace steel itself.[17] Oil-soluble inhibitors proved less expensive but still required additional apparatuses to be maintained and additional responsibilities for the crew.

Another means of corrosion control was provided by dehumidification systems which were tried experimentally on some ships to prevent atmospheric corrosion within a tank. It was claimed at the time that by holding relative humidity below 50%, corrosion could be reduced by 80%. The disadvantages of the system were the cost and required upkeep of equipment and the fact that it was not effective in ballast conditions.

A reduction in atmospheric corrosion was also the goal of spray systems. In these systems, sodium nitrate or sodium dichromate solutions were sprayed by fixed spray nozzles in each tank after unloading.[18] Often wetting agents or other additives were included in the solution to improve characteristics. Again, the cost and added work for the crew apparently proved excessive although promising results were reported.

Use of fresh water instead of salt water for tank washing or rinsing has also been reported to mitigate tank corrosion. However, use of fresh water is impractical for most ships.

Although all of these methods have been reported successful to some degree in reducing tank corrosion in the past, none were reported as still being practiced by ship owners today.

CHAPTER 4

FACTORS AFFECTING CORROSION CONTROL

4.1 TANK WASHING

Tank washing can be an important factor both in the amount of corrosion which occurs in a tank and in the performance of corrosion-control methods. Tanks are washed to prevent product contamination and to prevent excess accumulation of sediment in the bottom. Tanks, typically, are washed whenever a tank is scheduled to carry a cargo cleaner than its last cargo, whenever a ship goes into a dry dock for inspection or repair and periodically to prevent the accumulation of sediment. Tank washing may range in thoroughness from draining only the previous cargo to caustic steaming, hot-water washing and gas freeing the tank. The extent of tank washing required depends upon the likelihood of contamination of the next cargo by residual amounts of the previous cargo.

Until recent times, the only type of tank washing used on ships was salt-water washing. This was accomplished by fixed deck-mounted tank washing machines which spray high pressure streams of hot or cold water throughout a tank. These tank washing machines usually contain one or two nozzles which rotate about two planes simultaneusly. The cleansing effect on various areas of a tank depends on the distance from the nozzle and the angle of impact. The amount of tank washing required depends on the characteristics of the previous cargo carried. Tanks carrying gasoline, a light petroleum product, are relatively easy to clean. Cold-water washing may suffice in these tanks but crude oil tanks are much more difficult to wash. The tanks usually require hot-water washing, often 135° to 180°F, and may require the use of chemical detergents to sufficiently free the tank of cargo.

Salt-water washing affects tank corrosion in two ways. The first is due to the thoroughness of the washing. Cargoes of crude oil and some refined products leave an oily or waxy film on tank surfaces. This film can actually prevent corrosion of the steel. However, when the tank is washed, this film is washed away in areas that are hit by the water stream directly. Other areas, shaded by structural members or perhaps hit with less forceful spray due to their distance from the nozzle, still retain their film. This incomplete washing may cause corrosion to occur at areas of bare steel later exposed to salt water ballast or a moist salt atmosphere.

The other way salt-water washing affects corrosion is by the mere fact that salt water is being introduced into the tank. The warm, moist, salt-laden atmosphere which remains after hot, salt-water washing is ideal for corrosion to occur. Cold-water washing is reported to result in less corrosion than hot-water washing. Corrosion of refined product tankers is greatest in tanks that are washed the most. After salt-water washing, a certain amount of water, often several inches deep, usually remains in the bottom of tanks. This water is left because the tank stripping system is unable to empty the entire bottom area of water. This remaining water is left to contribute to bottom pitting corrosion.

One of the biggest advantages of protective coatings is that they allow tanks to carry a wide range of products because coated steel can be more easily cleaned between cargoes than heavily corroded bare steel. The smoother the coating surface is, the more it facilitates tank washing. But, while aiding tank cleaning, the salt-water tank washing may have detrimental effects on the protective coatings. Tank washing, to allow a tank to carry a clean product after previously carrying a dirty one, may last for days.[19] During this time, the coating in a tank is subjected to high temperature, high pressure (as high as 200 psi) bombardment by salt water and also a moist, heavy salt atmosphere. This comes at a time when the coating is weakest from heat, chemical attack, thermal stress and ionic pressures.

Different coatings react differently to this condition, but, in most cases, the end result is to cause, or at least, aggravate deterioration of the coating. Possible effects on coatings due to the high pressures, high temperatures, and chemical additives used in tank washing include depletion by chemical conversion of inorganic zinc coatings and the delamination, release from substrate, shrinkage by over curing, thermal stress, oxidation, discoloration, softening and staining of organic paints.[19]

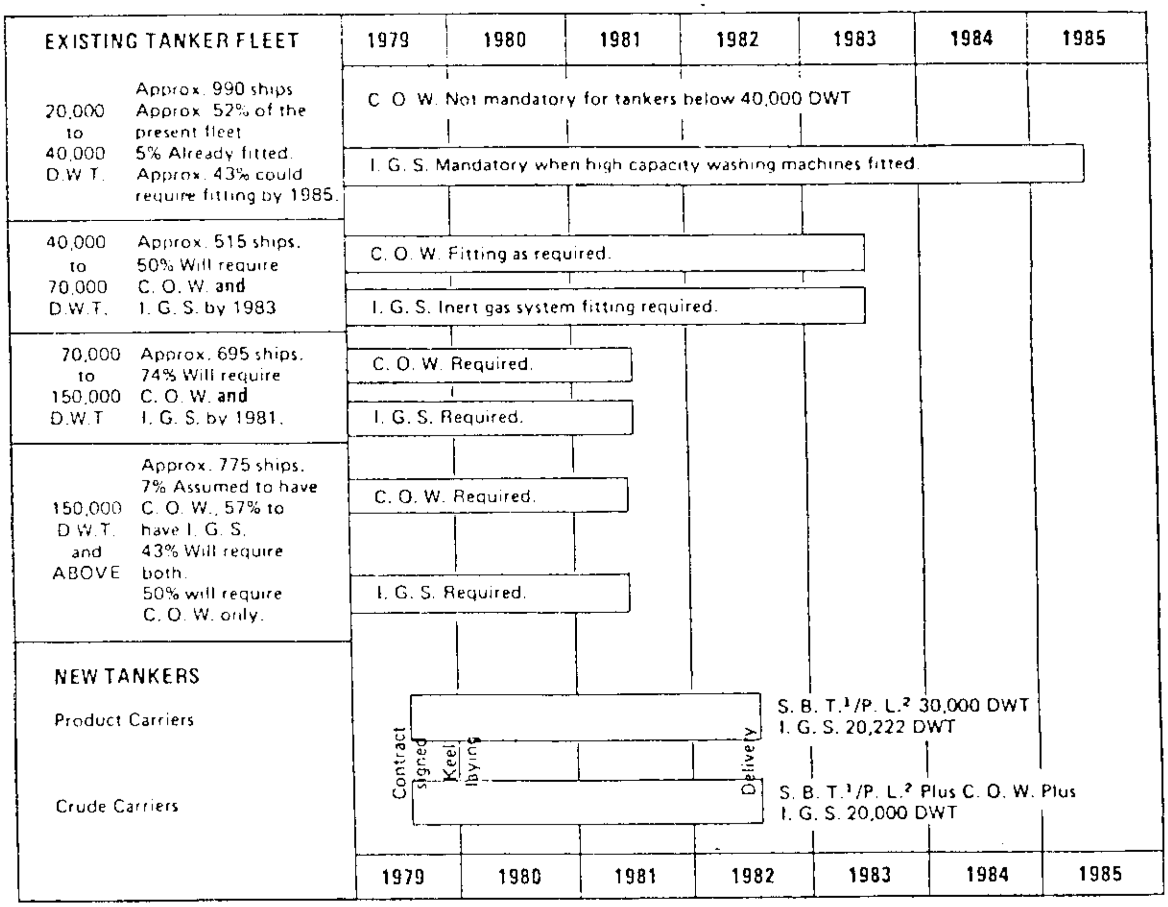
Although salt-water washing has been practiced for years, many crude oil tankers are now converting to crude oil washing (COW). A timetable listing compliance dates for crude oil washing systems and inert-gas systems (IGS) is shown in Figure 4-1. This type of tank washing is similar to salt-water washing except that crude oil is used as the washing medium. Impingement of the crude oil on tank bulkheads and internals cleans off accumulated sludge and oil residuals. COW has the effect of putting oily residues back into suspension so they can be collected by the stripping system and discharged ashore along with the rest of the cargo. Primarily a pollution prevention measure, COW eliminates the discharge of dirty ballast overboard after each tank washing. This type of tank washing is used only for crude oil carriers. No type of cargo washing system is used on board product carriers.

Crude oil washing has no direct effect on corrosion but its indirect benefit is a significant reduction in the amount of seawater a tank sees. Ships using COW should experience less tank corrosion than similar ships with salt-water washing. Under normal conditions, the only time seawater washing would be required for a cargo-only tank is when the ship goes into dry dock for inspection or repair.

Although no direct effects on corrosion have been noted, two ship operators did report instances of erosion of tank walls due to COW. The wash stream from COW apparently has sufficient force of impact to engrave visable spray patterns in steel. COW, in the case of one occurance, operated at 200 psi. As tank sizes increase, pressures must be increased to adequately clean the entire tank so that after several years of COW areas near the nozzle in the upper portions of a tank may show such effects.

FIGURE 4-1[20]

IG AND COW COMPLIANCE SCHEDULE



[1] S. B. T. Segregated Ballast Tanks. [2] P. L. Protectively Located.

4.2 Inert Gas

An inert-gas system (IGS) must be installed on all tankers over 70,000 DWT by mid-1981. Complete compliance dates for installation of inert-gas systems are shown in Figure 4-1. These systems are required to prevent explosions, but use to date indicates that they also have an effect on tank corrosion. Inert gas systems basically remove an unsafe atmosphere initially in the tank and replace it with a safe atmosphere with an oxygen content of no greater than 11% which makes it impossible for combustion to occur.

There are two main types of inert-gas systems in use today. The first is known as a flue gas system. These systems are used on board crude carriers to supply inert gas during discharge, gas freeing, purges and also for inerting of void spaces and topping off during voyages. Flue gas systems utilize scrubbed flue gas from the ships boilers. The gas is scrubbed to remove soot and other particles and then transferred to cargo tanks by a network of piping from a central blower. The other type of inert-gas system is the independent inert-gas generator common on product, LNG and chemical carriers. Gas generated by this source is cleaner than flue gas. The composition of both flue and independently generated inert gas is shown in Table 4-1.

TABLE 4.1

INERT GAS COMPARISON[21]

FLUE GAS		IND. GEN. GAS	
O_2	2-5%	O_2	1-2%
CO_2	12-14.5%	CO_2	14.5%
SO_x	250 ppm	SO_x	10 ppm
Solids	1 mg/Nm^3	Solids	0

While most ship operators agree that inert gas has an effect on tank corrosion, their opinions differ as to whether that effect is positive or negative. Still others believe its effect on corrosion deserves more study before a conclusion can be reached.

Information available from ship operators and other sources indicate that an inert-gas system can, depending on its type, application, upkeep and gas quality, either aggravate corrosion conditions or minimize them. It has long been recognized that by reducing the oxygen content of a tank, one of several elements vital to the occurrence of corrosion, corrosion can be reduced. However, while reducing oxygen content to below 5%, inert gas may also introduce corrosive elements into a tank. Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) contained in inert gas can combine with the warm moist atmosphere in a tank to form sulfuric acid which can cause accelerated corrosion of either bare or coated tank surfaces.

The inert gas can have a direct effect on inorganic zinc coatings commonly used to protect tank interiors. Most ship operators are in agreement that inert gas and inorganic zinc coating are not compatible. It is believed that this incompatibility is due to a reaction between the inorganic zinc and the sulphur oxides present in the gas. Failure rates vary greatly from total failure in six months to slow degradation of the coating lasting for several years. This may be due to the type of inert gas used. Flue gas has a much higher composition of sulphur oxides (250 ppm for flue gas compared to 10 ppm for generated gas) which may help to explain the disparity among degradation rates. Coating manufacturers do not recommend the use of inorganic zinc coatings in inerted tanks.

On the other hand, many studies have found inert gas to have a beneficial effect in reducing tank corrosion, at least in the top and upper most portions of the tank. The British Ship Research Association (BSRA) reported in 1975 that tests indicated that inert gas decreased corrosion of the deckhead, in one case, from 290 grams per annum (gpa) to 145 gpa and 115 gpa to 85 gpa at tie beams.[22] BP Tankers of London reported that their measurements show a very low corrosion rate in upper levels of inerted tanks.[12] The Ship Research Institute of Norway also made tests on a Norwegian carrier in 1976 which found a 50% reduction in corrosion of the tank top compared to a non-inerted ship, although it was not established conclusively that the reduction was due to inert gas.[23] Lloyds Register waives requirements for coating all surfaces above the normal ballast or cargo level when an inert-gas system is installed and in use on a continuous basis.[24] In this country, Sun Shipping found that, although added to ships as a safety feature, inert gas resulted in an unexpectedly advantageous variance in internal steel replacement schedules compared to non-inerted ships.[25] Most of these sources agree that inert gas has rust preventative properties only above the normal cargo level and that inert gas does not prevent localized pitting of horizontal surfaces.

The best conclusion that can be drawn from this wide range of opinions appears to be that inert gas can, under certain conditions, reduce corrosion in the upper most portions of a tank. The factor which appears to be most influential on this effect is the quality of the inert gas, in particular the amount of sulphur oxides it contains. This composition varies from system to system. Generated gas is of better quality than scrubbed flue gas. The quality of gas generated on board a single ship may also vary significantly. The ability of an inert-gas system to remove sulfur oxides depends upon many variables including the sulfur content of the fuel burned, seawater temperature, scrubber design and oxygen content. Various operational problems of the system can also affect the quality of gas generated, such as maintenance and repair of parts. Tests conducted in Germany concluded that SO_2 should be reduced to approximately 0.02% by volume in order to produce corrosion rates considerably smaller than the rates experienced in an open atmosphere.[26] To accomplish this, a cleaning grade of 88% is necessary for a cargo oil containing 3.0% sulfur by weight.

4.3 CARGO

Certain properties of a cargo have the ability to contribute to corrosion in a tank. In crude oil, the most significant corrosive component is the hydrogen sulfide which it contains. Most oils contain some hydrogen sulfide (H_2S) but oils which have especially high concentrations of it, called sour crudes, are cause for special concern. Ship operators and oil technologists, alike, usually fail to distinguish between sour crudes and high sulfur crudes. The distinction is important because many high sulfur crudes are not sour. Crude oils from Alaska are reported to be one example. Conversely, other lower total sulfur oils are sour. Crude oils which contain 6-10 ppm or more hydrogen sulfide as a liquid in solution are considered to be sour.[27,28] Sour crude oils also deserve attention because hydrogen sulfide is both poisonous to personnel and can be corrosive to steel. It is important to appreciate that the hydrogen sulfide content of crude oil refers to a liquid percentage and that the same percentage when in atmospheric conditions can increase dramatically.[27] For example, a sour crude with 300 ppm of H_2S can produce 4000 ppm or more in the ullage space of a tank. Hydrogen sulfide is often present in substantial quantities in Middle Eastern crudes.

Crudes high in sulfur also contribute to tank corrosion. The sulfur compounds present may react with water and oxygen to produce sulfuric acid which is corrosive to steel. The layer of water beneath high sulfur oil is very acidic and may lead to general and pitting corrosion of the tank bottom.[29] Similar pitting may result on any reasonably horizontal structure where acidic water is able to become trapped.

The acidic water is especially harmful to coatings. It penetrates any imperfection in the coating and initiates corrosion of the metal at that point. Inorganic zinc coatings are not resistant to acidic liquids and, therefore, are not recommended for use in tanks carrying sour and/or high sulphur crude oils by paint manufacturers.

The carriage of high sulphur oils also has other effects on a tank. After a vessel has carried several successive cargoes of high sulfur crude, scale on the sides of the tank may become impregnated with sulfur. The compound formed is pyrophoric iron sulfide.[27] The presence of iron sulphide makes surface preparation difficult when the time comes for blasting and recoating the tank.[29] Problems due to high sulfur content may be even more widespread in the future because as the world demand for oil grows it is becoming necessary to use oils with greater sulfur content to supply the demand.

The water and oxygen in a cargo tank is available to contribute to tank corrosion. Crude oils contain varying amounts of water, and gasoline has been reported to contain up to seven times as much dissolved oxygen as seawater.[29]

4.4 OTHER FACTORS

Numerous other factors can also affect tank corrosion and corrosion-control methods. Some of these that have been reported by ship operators play minor roles while others, in certain circumstances, can prove significant. One cause of coating failure is mechanical damage. This results from wear and tear caused by crew members or other personnel walking and moving about the tank. Mechanical damage is also possible when tanks are mucked out.

Condensation and sweating in tanks due to the heating and cooling of tank walls can lead to increased general corrosion. One ship operator reported a higher than normal incidence of general corrosion in wing tanks on only one side of the ship. The problem went unexplained until it was noticed that the coastal tanker, following a daily north/south route on the east coast, always had the same side of the ship toward the mid-day sun.

The amount of oxygen available is another factor determining corrosion. General corrosion of both plating and stiffeners has been reported to be worse nearest hatches and other tank opening which sometimes receive an inflow of fresh air.

The amount of maintenance performed by the ships crew can affect the life and effectiveness of protective coatings. Although few ship operators reported practicing regular maintenance, paint manufacturers recommend it to ensure long coating life. Touchup work is most easily performed on the tank bottom. Periodic inspection of anode connections guarantees the optimum protection of sacrificial anodes in a tank. One ship operator reported the increased occurance of coating deterioration on shell plating which was protected on the outside hull by an impressed current cathodic protection system. It was hypothesized that the impressed current had the effect of drawing moisture through the interior tank coating which resulted in coating failure.

In one case, pitting of the tank bottom occurred primarily under fixed salt-water tank washing machines. The ship operator suspected that the tank washing nozzles dripped constantly during long periods when the tank was empty, causing the pitting beneath them.

The last factor that was reported as affecting corrosion and corrosion-control systems is abrasion on the tank bottom which affected the tank coating in that area. Sand, sometime contained in crude oils, can settle to the bottom and cause slight erosion by constantly sloshing back and forth in bays between structural members.

CHAPTER 5

CORROSION-CONTROL SYSTEM PERFORMANCE

5.1 TYPES OF TANKS

The performance of the various corrosion-control systems is highly dependent on the use of the tank in which it is employed. Therefore, discussion of corrosion-control system performance must be categorized according to the particular type of cargo carried and/or the amount of time spent in ballast, if any. In this regard, there are numerous different classes of tanks aboard ships today. For the purposes of this study, there are three main ones. These are cargo-only tanks which see a minimum of salt-water ballast, cargo/ballast tanks which carry both cargo and ballast and ballast tanks dedicated to the carriage of salt-water ballast only.

Until recently, almost all tanks fell into the cargo/ballast tank class but under recent IMCO (Intergovernmental Maritime Consultative Organization) rules many ships have, or will be, converted to segregated ballast arrangement. Ships meeting this regulation must have tanks, separate from cargo tanks, dedicated solely to the carriage of ballast. However, this does not mean that cargo tanks will never carry ballast; some will and some may not. Certain cargo tanks can be used to carry storm ballast. Storm ballast is the additional ballast required to increase stability of a ship to a safe level during heavy seas. Most ships use the same tanks for storm ballast each time the need arises. Some ships, depending on their trade route, carry storm ballast a significant proportion of their time. The other class of tank, cargo-only, is never used for the carriage of storm ballast or normal ballast.

In this evaluation, five types from the three classes of tanks will be considered. These are:

1. Crude oil cargo-only tanks
2. Crude oil cargo/ballast tanks
3. Refined product cargo-only tanks
4. Refined product cargo/ballast tanks
5. Ballast-only tanks

5.2 TYPES OF CORROSION

In general, there are two main types of corrosion which control systems must deal with in tanks. The first is known as classical, or general, corrosion. General corrosion is surface rust which appears uniformly on tank internal surfaces. The second type of tank corrosion, deep pitting, refers to cavities, or pits, which develop on horizontal surfaces. Pitting is a localized form of tank corrosion.

5.3 CORROSION-CONTROL PERFORMANCE IN TANKS

5.3.1 Crude Oil Cargo Only Tanks

Crude oil cargo-only tanks see a minimum of salt water since the tanks are usually crude oil washed. They can be expected to see salt-water washing only before they need to return to dry dock for inspection or repair. The tanks should not see any normal or storm ballast except in extreme emergency. Because the amount of salt water seen by a tank is the major factor in tank corrosion, crude oil cargo-only tanks experience the least corrosion of all tanks. The tanks are usually covered internally with a protective film of oil and are often inerted.

General corrosion may occur in the uppermost regions of the tank, the deckhead plating and structure. This corrosion is reported to be less in tanks which are inerted. Vertical bulkheads and shell plating experience mild general corrosion, at worst.

Pitting is most frequent in the lower portions of the tank. It is common on the tank bottom and upper horizontal flat surfaces of internal structure, especially in tanks carrying sour crude which are high in hydrogen sulfide content. In crude oil cargo-only tanks, pits are usually larger in area than they are deep. Pitting is usually associated with salt water. In these tanks, there are two sources - the infrequent tank washing and the water found in the crude oil itself. Any salt water in a tank will either be trapped on the horizontal surfaces of tank structure or collect on the tank bottom.

Ship owners usually leave such tanks bare or coat the tank overhead and six feet down on the sides and/or the bottom and six feet up on the sides. Inorganic zinc coatings are recommended only if it is ascertained that the cargo will be sweet, that is, relatively free of hydrogen sulfide and that the tank is not to be inerted. The life of properly applied inorganic zinc coatings can reach twelve years or more in tanks that meet these conditions.

Epoxy or coal tar epoxy coatings are also used in crude oil cargo-only tanks. They can withstand the occasional salt water that the tanks see as well as resist inert gas and sour cargoes. Life of these coatings ranges from approximately seven years to a maximum of ten to twelve years with 5 to 30% wastage.

Still other owners prefer not to coat the tank at all. Instead, they leave the steel bare and rely on the fact that due to its low corrosion rate the tank will go many years, possibly the life of the ship, before steel replacement will be required. Because a true cargo-only tank will see salt water such a small percentage of its life, the use of anodes is not common.

5.3.2 Crude Oil Cargo/Ballast Tanks

Crude oil/ballast tanks are of two types, dirty ballast and clean, and corrosion-control performance varies according to each. Traditionally, dirty ballast tanks have been prevalent. Dirty ballast refers to the fact that cargo tanks are not salt water washed before ballast is introduced. But now, due to stricter environmental pollution regulations, ships are, or soon will be, required to wash cargo tanks before carrying normal or storm ballast. This way, the ballast, which will later be discharged overboard, will not be contaminated by the cargo oil previously carried.

In crude oil cargo/ballast tanks, crude oils tend to coat tank internal surfaces with an oily, waxy film which can effectively protect the steel from corrosion. In clean ballast tank, the integrity of this film is broken when the tank is cleaned by high pressure washing machines. The surface of the tank is washed clean in some areas while others still remain covered. This situation causes a corrosion cell to occur between the bare areas which act as anodes and the coated areas which act as cathodes on a local scale. As a result of this, and the fact that areas washed clean of film are now vulnerable to atmospheric corrosion, clean ballast tanks tend to suffer more from corrosion than a dirty ballast tank. Dirty ballast tanks are afforded better protection from their oil films.

The underdeck area of a crude oil/ballast tank is subject to corrosion both when it is empty and when it is full of either cargo or ballast water. When it is empty, the area is subject to a highly corrosive, moist, salt-laden atmosphere. Oxygen is readily available high in the tank from hatches, vents and deck openings. An inert-gas system can reduce deckhead corrosion in tanks so equipped. When the tank is full of cargo, corrosion results from the same causes in this area because the deckhead is not protected by an oil film. The situation is aggravated when the cargo is sour crude because hydrogen sulfide emanating from the cargo causes an even more corrosive atmosphere in the ullage space. The deckhead of most cargo/ballast tanks is subject to severe general corrosion. Without protection, much of the underdeck plating and structure will require replacement in six to twelve years. The actual time before replacement is dependent on the allowance for corrosion built into the scantlings, the H_2S content of the oil, the frequency of tank washing and the amount of time in ballast. Vertical bulkheads and shell plating usually experience mild general corrosion.

When the tank is full, corrosion is relatively inactive below the level of the cargo surface. The only exception to this is the bottom of the tank which is highly susceptible to deep pitting corrosion in the thin water phase commonly found beneath the cargo. Pitting may also occur on horizontal surfaces of structure where ballast and wash water may become trapped. Deep pits in cargo ballast tanks vary in size and density but may be 3/4" deep in unprotected sour crude/ballast tanks after seven years.

If the tanks are washed with crude oil rather than salt water, a general decrease in the tank steel corrosion rates will be experienced. Crude-oil washing ensures that after washing most surfaces will remain covered in oil, without standing water, before the tank is ballasted. However, if the tank was not completely stripped prior to cleaning, water previously introduced into the tank will remain standing on the bottom and the tank bottom will continue to experience pitting corrosion during all tank loading conditions. Some reduction in the general corrosion on the underdeck steel will be realized when washing with crude oil because the ullage space will not be subject to a salt water spray during cleaning. Conversely, if crude-oil washing is introduced in a tank that was normally in a crude oil/dirty ballast condition (no salt-water washing) the protective oil film would be thinned and consequently the steel below the cargo level would be more susceptible to corrosion during the ballast condition.

The protection systems most frequently employed in crude oil/dirty ballast tanks are as follows:

1. Coat deckhead area and 6 ft down the sides
2. Repeat 1. and coat tank bottom and sides to 6 ft up.
3. Repeat 2. and coat all upward facing horizontal steel surfaces.
4. Repeat 1. and install anodes near bottom to protect bottom plating.
5. Repeat 2. and install anodes near bottom to protect bottom plating.

Those most commonly used in crude oil/clean ballast tanks are:

1. Coat deckhead area and 6 ft down the sides. Install anodes on bottom and up to ballast level.
2. Repeat 1. and coat tank bottom and sides to six feet up.
3. Repeat 2. and coat all upward facing horizontal surfaces.

As with cargo-only tanks, inorganic zinc coatings are not recommended when either sour crude is to be carried or the tank is to be inerted. Inorganic zinc coatings in recommended service last from six to nine years in crude oil cargo/ballast tanks depending on the frequency of ballasting and tank washing. Two coats of epoxy or coal tar epoxy commonly last seven to ten years.

Anodes used may be either zinc or aluminum or a combination of aluminum anodes low in the tank and zinc anodes throughout the remainder of the tank. Many ship owners prefer aluminum over zinc because aluminum provides more economical protection.

5.3.3 Refined Product Cargo-Only Tanks

The term refined petroleum products refers to a wide range of cargoes, for example gasoline, kerosene, jet fuel, heating oil and lube oils. The corrosion problems associated with these products are different from those encountered in crude oil tanks and the performance of corrosion systems also varies accordingly.

Unprotected refined product tanks suffer most from severe general corrosion. This is due to the fact that most products are less viscous than crude oil and do not provide the protective film of crude oils. When light cargoes such as gasoline and solvent are pumped from tanks, the liquid remaining on tank surfaces quickly evaporates leaving the metal vulnerable to atmospheric corrosion.

Some refined products are more viscous than gasoline and do leave a protective film on tank internals. Home heating fuel is reported to be one example. In these cases, corrosion more closely resembles that found in crude oil tanks. As in crude oil tanks, areas most exposed to the washing stream are relatively clean while other areas remain covered by the protective film. In moist air, the washed areas experience general corrosion. General corrosion in a refined product tank is greatest in a tank carrying gasoline and least in a tank whose main cargo is heating oil.

Refined product tanks are usually exposed to much more salt-water washing than crude oil tanks which further aggravates the incidence of corrosion. The products are very susceptible to contamination. Therefore, each time a cleaner cargo is carried the tank must be salt-water washed. Due to the wide range of products which may be carried, this can be relatively often. Salt-water washing is the only available means of cleaning the tank. No form of cargo washing, analogous to COW, exists.

Atmospheric corrosion in unprotected non-ballast tanks results in thick rust scale which soon falls, often in large sheets, to the tank bottom exposing more metal to atmospheric corrosion caused by moist air. Condensation and sweating due to heating and cooling of the tank steel have a significant effect on tank corrosion. An unprotected tank is likely to require major steel replacement in six to eight years. The use of inert gas in tanks is expected to reduce corrosion in refined product tanks but sufficient data is not yet available to quantify the reduction.

The most common practice among ship owners today is to coat the entire tank. This is done to prevent corrosion, to facilitate and hasten tank cleaning and to lessen the probability of cargo contamination. Both inorganic zinc and epoxy coatings are commonly used. Coal tar epoxies are not compatible with solvent cargoes and should be avoided. One coat of inorganic zinc will last seven to ten years in cold-water washed tanks. Post-cured inorganic zincs, popular until the self-cured coating was introduced, were reported to have a longer life of eight to fourteen years. Epoxy coatings will usually last eight to ten years in refined product cargo-only tanks.

5.3.4 Refined Product Cargo/Ballast Tanks

The carriage of ballast in refined product tanks on either a normal or storm basis further increases the corrosion in a tank. In unprotected refined product/ballast tanks, a thick rust scale develops as in non-ballast tanks but is shed more frequently than non-ballast tanks. It is also softer and comes off in smaller sections. Pitting may also be a problem. Pits usually begin when blisters form in the rust and then break open. The most severe corrosion in these tanks is general corrosion often reported to occur at more than twice the rate observed in a crude oil tank. Pitting, although reported significant in a few cases, is not as much a problem in refined product ballast tanks.

Like refined product non-ballast tanks, ship operators usually coat the tank throughout. Both inorganic zinc and epoxy coatings see use in refined product/ballast tanks. Inorganic zinc self-cured coatings usually last from seven to nine years while epoxy paints last from seven to ten years.

A second option followed by some is to install anodes in addition to coating. The decision to install anodes depends a great deal on the trade route of the vessel in question. Many product carriers are used in coastal routes of short duration. For anodes to be economically effective, tanks should be in ballast at least 30% of the time for a minimum of four or five days. Often product carrier routes are so short that anodes cannot be justified.

5.3.5 Ballast Tanks

Tanks dedicated solely to carrying salt-water ballast suffer corrosion both when the tank is full and empty. General corrosion is serious on the deckhead which is exposed to the moist salt-laden atmosphere present in the ullage space. Corrosion is also severe on bulkhead plating and stiffeners and is further aggravated adjacent to tanks carrying high temperature cargoes. The heat from crude oil or fuel bunkers can be transmitted from one side of the steel to the other and contribute to increased general corrosion in moist ballast tanks. General corrosion is reported to be worse in the upper regions of the tank due to an increased availability of oxygen. Some pitting is likely to occur on horizontal surfaces low in the tank and on the tank bottom. Unprotected ballast tanks usually require steel replacement in six to ten years.

The protection systems most often used by ship operators are:

1. Coat entire tank.
2. Repeat 1. and add anodes for secondary protection.
3. Coat overhead and 6 ft down the sides and install anodes.

The first two systems seem to be the most preferred by ship operators today. Anodes alone are unlikely to result in adequate protection because a significant amount of corrosion occurs during empty periods when anodes are ineffective.

Coatings most often used in ballast tanks are epoxy and coal tar epoxy. These coatings usually last from eight to ten years. Inorganic zincs are also used in ballast tanks; however, their degradation rate in salt water is high. A single coat of inorganic zinc can be expected to last six to ten years. Post-cured inorganic zincs were reported to last longer, eight to fourteen years.

5.4 SUMMARY

Tables 5.1 and 5.2 summarize the performance of corrosion-protection systems reported during the study. Table 5.1 summarizes the performance of coatings for various tank conditions. Table 5.2 reports the performance of anodes for various tank conditions.

TABLE 5.1

PERFORMANCE OF COATINGS

Tank Condition	Type Coating and Number of Coats	Average Life (Yrs.)	Remarks
Crude oil only tank cold salt water washed	Inorganic zinc (one coat)	8-10	Sweet crudes only, not recommended for sour crude (2-6 yrs). Hot-water wash reduces life to 6-8 yrs. Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.
	Epoxy or coal tar Epoxy (2 coats)	8-10	Hot-water wash reduces life to 6-8 yrs. Three coats coal tar epoxy will extend life to 9-14 yrs. Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.
Crude oil only tank Inerted with flue gas Infrequent water wash	Inorganic zinc 1 (one coat) Epoxy or coal tar Epoxy (2 coats)	2-6 8-10	Inorganic zinc is not recommended with flue gas. Coating in ullage space rapidly attacked by inert gas. With inert gas and sour crudes life reduced to 6 mo. - 2 yrs. 3 coats coal tar epoxy will extend life to 9-14 yrs.
Crude oil/ballast tank Cold salt water washed	Inorganic zinc (one coat)	7-9	Sweet crudes only, not recommended for sour crudes (2-6 yrs.). Post-cured inorganic zinc has life of 8-14 yrs. Hot water wash reduces life to 6-7 yrs. Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.
	Epoxy or coal tar Epoxy (2 coats)	7-9	Hot-water wash reduces life to 6-8 yrs. 3 coats coal tar epoxy will extend life to 8-12 yrs. Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.
Crude oil/ballast tank Inerted with flue gas infrequent water wash	Inorganic zinc (one coat)	2-8	Inorganic zinc is not recommended with flue gas. Coating in ullage space will last 2-4 yrs. Coating below cargo level will last 6-8 yrs. Can be used with sweet crudes only, not recommended for use with sour crudes (2-6 yrs). Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.
	Epoxy or coal Tar Epoxy (2 coats)	7-10	3 coats coal tar epoxy will extend life to 9-14 yrs. Numerous small paint failures may be experienced on upper horizontal surfaces where deep pitting corrosion occurs, especially with sour crudes.

PERFORMANCE OF COATINGS (Cont'd)

Tank Conditions	Type Coating and Number of Coats	Average Life (Yrs.)	Remarks
Refined product only tank Cold salt-water washed	Inorganic zinc (one coat)	7-10	Post-cured inorganic zincs have a longer life (8-14 yrs.) than self cured inorganic zincs. Hot salt-water washing will reduce life of coating by 1-2 yrs.
	Epoxy (2 coats)	8-10	Hot salt-water washing will reduce life of coating by 1-2 yrs.
Refined product/ballast tank - cold salt-water washed	Inorganic zinc (one coat)	7-9	Post-cured inorganic zincs have a longer life (8-14yrs) than self cured inorganic zincs. Hot salt-water washing will reduce life of coating by 1-2 yrs.
	Epoxy (2 coats)	7-10	Hot salt-water washing will reduce life of coating 1-2 yrs.
	Coal tar epoxy	-	Not recommended - will contaminate many refined products.
Refined product only tank Inerted, infrequently washed	Inorganic zinc (one coat)	2-6	Not recommended for use with inert gas. Little information available to determine whether generated gas is less harmful than flue gas to inorganic zinc. If tank inerted with flue gas life of coating reduced to 2-4 yrs. with coating in ullage space being severely attacked.
	Epoxy (2 coats)	9-10	
Ballast only tank	Inorganic zinc (one coat)	6-10	Post-cured inorganic zincs have a longer life (8-14 yrs.) than self-cured inorganic zincs.
	Epoxy or coal Tar epoxy (two coats)	8-10	3 coats of coal tar epoxy will extend life to 10-14 yrs.

TABLE 5.2

PERFORMANCE OF ANODES

PERCENT REDUCTION OF BARE STEEL GENERAL CORROSION EXPERIENCED DURING BALLASTED CONDITION(1)(2)

Area of Tank	TANK DESCRIPTION				
	Ballast[14]	Cargo/Clean Ballast[14]		Cargo/Dirty Ballast[8]	
		Product	Crude	Product	Crude
Upper Half(4)	80	75(3)	60	70(3)	55
Lower Half	95	90(3)	75	85(3)	70

PERCENT REDUCTION OF BARE STEEL GENERAL CORROSION EXPERIENCED UNDER ALL CONDITIONS(1)(2)

Area of Tank	TANK DESCRIPTION					
	Ballast [14]	Cargo/Clean Ballast[14]			Cargo/Dirty Ballast[8]	
		Product (Water Wash)	Crude (C.O.W.)	Crude (Water Wash)	Product	Crude
Upper Half(4)	35	65(3)	55	50	60(3)	50
Lower Half	45	75(3)	65	60	70(3)	60

(1) Assumes voyages of moderate to long duration, ballast tanks ballasted 50% of time and cargo/ballast tanks ballasted 45% of time.

(2) Effectiveness of anodes based on 12 milliamps/ft^2 for uncoated tanks and 1 milliamp/ft^2 for coated tanks.

(3) Performance of anodes based on gasoline type cargoes. Effectiveness of anodes would approach those shown for crudes if heating oils are

CHAPTER 6

STEEL CORROSION RATES

The rate at which steel corrodes is a major determinant of the time before steel replacement or other corrective action is needed. Information on the rate at which steel corrodes was obtained from published sources and by a survey of ship operators using protection systems under many different tank conditions. The rate of steel corrosion varies according to many factors. A summary of the main factors, described in other chapters, which affect the rate of steel degradation follows:

A. Tank Washing

1. Water Pressure - temperature, spray pattern, salinity
2. Crude Oil - pressure, temperature, spray pattern
3. None

B. Tank Contents

1. Light Oils - Refined products
2. Heavy Oils - Refined products, crude
3. H_2S content of crude oil
4. Oxygen content of cargo
5. Water content of cargo
6. pH level
7. Temperature of cargo
8. Dirty ballast
9. Clean ballast

C. Tank Atmosphere When Empty

1. After unloading cargo
2. After dirty ballast
3. After clean ballast
4. After salt-water washing
5. After fresh-water washing
6. After crude oil washing

D. Inert Gas System

1. Flue gas - moisture, oxygen, SO_2 content
2. Generated gas - moisture, oxygen, SO_2 content
3. None

E. Other

1. Temperature of cargo in adjacent tank
2. Structural complexity of tank
3. Voyage length and route

From this list of factors and conditions which affect corrosion, it is obvious that there are thousands of combinations for which a corrosion rate exists. Understandably, most corrosion-rate data are far from being fully qualified with respect to all possible factors and conditions.

The rate at which steel corrodes is a function of both types of corrosion, general and pitting. A schedule of steel renewal or other corrective action is easily calculated when the wastage is due to general corrosion. However, when deep pitting is present the schedule is not as readily determined. The strength of steel plating and structural members is dependent not only on the depth and diameter of pits, but equally important on the locations and frequency of pits. The limit to which pitting can occur before corrective action must be taken is often subjective and best determined on a case basis.

Estimated corrosion rates for unprotected steel subject to general corrosion and pitting corrosion are presented in Tables 6-1 and 6-2, respectively. Rates are reported for both an average and worst case. The data are useful in determining the approximate time frame in which corrective action would be required for bare steel tanks and tanks whose original means of protection has totally failed. The user of this data should realize that many conditions may exist in a tank other than those described in the tables. Therefore, the user must ultimately decide the proper interpolation to be applied to the data to suit other known or anticipated tank conditions. Table 6.3 shows ABS allowance guidelines for allowable steel degradation.

TABLE 6.1

GENERAL WASTAGE(1) FOR UNCOATED TANKS

IN CRUDE OIL AND PRODUCT CARRIERS

STEEL DESCRIPTION	SEVERITY OF CORROSION FOR GIVEN TANK CONDITIONS					
	Maximum Corrosion(2)		Average Corrosion(2)(3)		Minimum Corrosion(2)	
	Ballast Only Tk.(3) or Cargo Only Tank With Freq. Washing(4)		Cargo/Ballast Tk. With Moderate Washing(4)		Cargo Only Tank Seldom Washed(4)	
	Ballast Only Tk. or Refnd. Product	Crude	Refined Product	Crude(5)	Refined Produce	Crude (5)
Deck Plating	.018	.015	.014	.009	.008	.005
Deck Structure	.011	.006	.008	.004	.005	.003
Horizontal Webs, Stringers, Girders	.015	.006	.008	.004	.004	.003
Upper Side Shell	.012	.006	.009	.005	.004	.003
Upper Bulkheads	.010	.006	.007	.003	.003	.002
Upper Stiffeners	.010	.006	.007	.003	.003	.002
Lower Side Shell	.010	.005	.007	.003	.003	.002
Lower Bulkheads	.008	.004	.005	.002	.002	.001
Lower Stiffeners	.008	.004	.005	.002	.002	.001
Bottom Plating	.017	.013	.013	.008	.005	.004
Bottom Structure	.012	.006	.007	.004	.004	.002

NOTES: (1) One side corrosion rates expressed in inches per year.
(2) No tank inerting.
(3) No cathodic protection
(4) Salt-water wash
(5) Corrosion rates would be approximately the same for a crude/ballast tank that was frequently crude oil washed.

TABLE 6.2

PITTING CORROSION TABLE FOR UPPER FACING

HORRIZONTAL FLAT SURFACES LOCATED BELOW THE CARGO LEVEL

Location in Tank	Pitting Rates, Diameters, Frequencies	TANK CONDITION						
		Crude Oil Only No Ballasting No Washing (2) Water Remains on Bottom (1)		Sweet Crude/Ballast Infrequent Ballasting Infrequent Washing (2) Water Remains on Bottom (1)		Sweet Crude/Ballast Frequent Ballasting Frequent Washing (2) Water Remains on Bottom (1)		So Fr Water
		Average	Maximum	Average	Maximum	Average (3)	Maximum (3)	Av
Upper half of Tank	Pitting rate (in/yr)	Negligible	Negligible	.015	.030	.040	.080	.060
	Pit dia. in 5 yrs. (in)	-	-	3/4	7	1-1/2	8	2
	Frequency Pits/ft^2 in 5 yrs.	-	-	3	10 to 15	3	10 to 15	3
Lower half of Tank	Pitting rate (in/yr)	Negligible	Negligible	.020	.040	.050	0.100	.080
	Pit diam. in 5 yrs. (in)	-	-	1	7	2	8	2-1/
	Frequency Pits/ft^2 in 5 yrs.	-	-	5	10 to 15	5	10 to 15	5
Tank Bottom	Pitting rate (in/yr)	.015	.030	.020	.040	.050	0.100	.080
	Pit dia. in 5 yrs. (in)	2 to 4	Pits run together	2 to 4	Pits run together	3 to 6	Pits run together	3 to
	Frequency Pits/ft^2 in 5 yrs.	7	10 to 15	7	10 to 15	7	10 to 15	7

(1) Cargo tanks are seldom completely stripped. A few inches of water usually
the tank bottom after the tank is emptied.

(2) Washing refers to salt water washing.

(3) A tank condition which would result in a similar corrosion pattern is sour
moderate washing, moderate ballasting.

TABLE 6.3

ABS GUIDELINES FOR ALLOWABLE STEEL DEGRADATION IN TANKS

DESCRIPTION OF STEEL	PERCENT REDUCTION IN ORIGINAL STEEL THICKNESS(1) (For ships built since 1962 which are longitudinally framed and whose longitudinals contribute at least 30% to the strength of the vessel)	
	Overall Allowance	Local Allowance
Deck Plating	15%	20 to 25%
Internal Longitudinal Stiff. Contributing to Strength	25	30 to 35
Side Shell	25	30
Hull Girders, Stringers	15	20 to 25
Transverse Webs	15	20 to 25
Bulkheads	30	35
Bottom Plating	15	20 to 25
Deep Tank Bottom Plating in Double Bottom Ships	20	25

1. These are only guidelines for the amount of steel degradation allowed before steel replacement is required. The determination of when and the extent to which corrective action is required remains the responsibility of the local ABS surveyor.

CHAPTER 7

COSTS OF CORROSION CONTROL

7.1 GENERAL

There are many different costs which may be incurred by a ship owner for corrosion work in cargo and ballast tanks. Estimates of these costs are presented in this chapter. The costs were estimated on the basis of information reported in published sources and responses from ship operators, coating and anode manufacturers, shipyards, and independent contractors. These costs form a foundation for performing economic analyses on the various means of corrosion control (Chapter 8) and performing sensitivity studies on representative ships (Chapter 9).

Costs associated with corrosion-control work include surface preparation, staging, coatings, anodes, steel replacement work and the cost of lost revenue. Most of these involve both material and labor charges. Cost figures reported include overhead charges, profit, service charges and docking fees. They are reported for domestic shipyards and foreign yards. Unless otherwise designated, all costs are based on 1980 dollars and are for large-scale work. Small-scale work can cost up to several times the unit charge of large-scale work. Distinctions in cost are also made between new construction and repair work on existing ships.

7.2 SURFACE PREPARATION AND COATING COSTS

In the United States, blasting and coating of complete tanks on existing ships is very often subcontracted to independent contractors who specialize in this type of work. The cost of blasting and coating by independent specialists is usually significantly less than if the work was performed by shipyard personnel. Since most yards employ these contractors, the cost of performing large-scale, corrosion-control work is fairly uniform among U.S. shipyards. Costs for performing the same work in various foreign yards will vary from 15 to 25% above domestic costs. However, in some cases, costs may be as much as 40% below, depending on the volatility of the particular market involved.

The cost of blasting and coating during new construction of tankers is 70 to 80% of the cost of coating and blasting for an existing ship. This is because both coating and blasting are more quickly and easily performed on new steel than old. Also, most shipyards perform much tank work while the structure is still in the preassembly module stage of construction. This results in easier access and better environmental conditions.

The costs of blasting to a near-white metal condition (see Table 3.1 for a description of this degree of surface preparation) and the cost of coating application are summed up in Table 7.1. A further breakdown of these costs into their various labor and material components was not possible due to wide variation in costs, accounting procedures and the inclusion of the ancillary costs of overhead, supervision and profit into arbitrarily selected components of the cost. Total costs charged for performing these activities was, however, uniform. Table 7.2 shows paint material costs. These figures are the same for both new construction and repair work. For determination of total blasting and painting cost the information from Table 7.1 must be used in conjunction with Table 7.2.

7.3 ANODES

Costs associated with sacrificial anodes are the material costs of the anode itself including steel core and any accompanying hardware and the cost of labor for their installation or replacement in tanks. These costs are shown in Table 7.3 for both zinc and aluminum anodes of commonly used sizes. Costs for anodes of sizes other than those shown may be estimated by determining the unit cost per weight ($/lb) of the examples and multiplying by the anode weight desired. All costs given in Table 7.3 are on a per-anode basis.

7.4 STEEL RENEWAL

There are two ways for steel to fail inspection by a classification society surveyor. The first is by exceeding the overall steel corrosion allowance. In this case, steel must be replaced outright. Costs of steel replacement at both U.S. yards and foreign shipyards are provided in Table 7.4. The foreign costs represent an average of costs reported by Far Eastern and European shipyards.

The other way for steel to fail is by exceeding local steel thickness limits while overall steel thickness is sufficient. This is often the case with deep pitting corrosion. When local limits are exceeded due to deep pitting, they must be filled with weld material. Cost for this repair in the U.S. is about $8.00 for each pit filled for 100 or more pits of 2" diameter and 1/4" depth. Pits 4" in diameter and 1/2" deep cost $35.00 a piece. Costs at foreign shipyards average 50% of the U.S. costs. No charge for staging of any type is included in these figures because most pit repair work is performed on the tank bottom.

TABLE 7.1

TANK BLASTING AND COATING COSTS

Number of Coats	EXISTING SHIP (REPAIR)	
	U.S. (Avg.) ($ U.S./ft^2)	Foreign (Avg.) ($ U.S./ft^2)
1	2.60	3.50
2	3.25	3.90

1. Costs reflect those applicable to large contracts. Costs may increase up to 300% for small contracts.
2. Costs include staging and removal of blast material.
3. Surface finish blasted to SA 2-1/2 using 16 lb. Grit/Ft^2.
4. Costs include removal of moderate amounts of heavy scale build-up by means other than blasting.
5. Excludes paint material costs.
6. Excludes costs for cleaning tank, removing sludge and gas freeing.

TABLE 7.2

PAINT MATERIAL COSTS

General Description of Coatings	Number of Coats	Total Thickness	Total Material Costs[1] (Dollars/Ft^2)	
			U.S.	FOREIGN
Inorganic Zinc	1	3 mil	0.14 to 0.20	Material Costs 10-20% higher in Europe and 15-40% higher in Far East
Epoxy	2	8 mil	0.30 to 0.36	
Coal Tar Epoxy	2	12 mil	0.18 to 0.30	

1. Material costs based on paint loss of 35%.

TABLE 7.3

SACRIFICIAL ANODE COSTS

Description of Anodes	Avg. U.S. Costs ($ U.S.)		Avg. Foreign Costs(5) ($ U.S.)	
	Install	Replace	Install	Replace
24 lb Zinc - Mat'l(2)	23	23	23	23
- Labor(3)	42	58(4)	21	32(4)
- Total	65	81	44	55
70 lb Zinc - Mat'l(2)	55	55	55	55
- Labor(3)	52	72(4)	25	35(4)
- Total	107	127	80	90
42 lb Alum - Mat'l(2)	68	68	68	68
- Labor(3)	52	72(4)	25	35(4)
- Total	120	140	93	103

(1) Excludes staging costs. For new construction, assuming anodes installed in modules, staging costs/anode are 10% to 20% of labor costs for installing anodes. For existing vessels, staging costs/anode are 80% to 150% of labor costs for installing anodes.

(2) Material costs are for welded anodes. Clamped and bolted anodes cost 5% to 7% more than welded anodes.

(3) Labor costs are for welded anodes. Increase labor rate by 12% for clamped anodes and by 35% for first installation of bolted anodes.

(4) Decrease labor rate by 40% for replacing bolted anodes if bolting pads were previously installed.

(5) Material cost advantage alternated in 1980 between U.S. and foreign yards. Material costs are shown as identical for U.S. and foreign.

TABLE 7.4

TANK STEEL CONSTRUCTION AND REPLACEMENT COSTS
(Dollars/100 lb)

TYPE STEEL WORK	U.S.		FOREIGN	
	Product[1] Tanker	VLCC[2]	Product[1] Tanker	VLCC[2]
New Construction	110	90	60	50
Repair (Large Contracts)	450	400	240	220
Repair (Small Contracts)	Up to 1200		Up to 800	

1. Assume 40,000 DWT.
2. Assume 300,000 DWT.

7.5 LOST REVENUE

Each time a ship is taken out of service it ceases to generate revenue. This results in a loss of income to the ship owners. All ship owners plan on a certain number of days out of service each year for maintenance and inspection by regulatory bodies. It is assumed in this report that a ship is normally out of service for 12 days each year and a total of 40 days every fourth year. In an attempt to reduce lost revenue, all corrosion work should be scheduled during planned out of service periods if possible. If these days are exceeded due to corrosion control work, the revenue lost should be considered a cost of corrosion control.

Both blasting and coating and steel replacement work may take long enough to cause additional days out of service if work is not regularly performed during maintenance and inspection periods. The time required for blasting and coating is largely dependent on the number of blasters used on a ship. Independent contractors can reportedly supply a maximum of 32 qualified blasters. If these men are assigned to shifts covering a 24-hour day, they can blast about 20,000 ft^2. When shipyard blasting crews are used, the blasting rate is somewhat lower. In determining the total blasting and coating time, several days should be added to allow for painting after the last tank is vacated by blasting and cleaning crews. Painting for the other tanks is accomplished right after it is blasted and while the blasting crew is working on another tank.

The time required for steel replacement is governed by the number of pounds of steel to be replaced, the number of men assigned to the job and the rate at which steel can be replaced. Assuming that an average of 150 men are available for steel replacement during each of three daily shifts and that 15 man-hours are needed to replace 100 lbs. of steel, 24,000 lbs. of steel can be replaced daily.

Actual lost revenue is determined by estimating the number of days out of service and applying the correct revenue rate for that particular vessel.

CHAPTER 8

ECONOMIC ANALYSIS PROGRAM

The economic value of a corrosion-control system depends on many factors. Although initial cost is the most obvious of these, it should not be used as the sole criterion for evaluation. Often other factors such as effectiveness of performance, useful life, maintenance and replacement costs prove to be more important. Because some of these factors have no effect until the ship has been in service a number of years, a complete economic analysis should be conducted to determine life-cycle cost.

Numerous different computer programs are used throughout the marine industry for the economic evaluation of both costs and effects on cargo-carrying capability of ships. It is expected that each tanker owner has his own method of economic analysis tailored to his particular operation and will conduct his own economic investigations. Therefore, the main purpose of this report is to identify the key cost parameters which should be included in any economic analyses to account for the life-cycle costs of corrosion control systems. A sample economic analysis computer program has been developed to illustrate one possible method of economic analysis of the effects of corrosion control on a given vessel.

The program used is called GENeralized EConomic analysis program (GENEC1). This discounted cash-flow life-cycle-cost analysis method evaluates the economic effect of corrosion-control systems on both cost and cargo carried. Given various vessel particulars and operational characteristics, the program generates a consistent measure of merit for each case investigated. Required corrosion-control system inputs to the program are the costs due to corrosion protection by a particular system and the point in time at which they are incurred.

The measure of merit reported by GENEC1 is the required freight rate (RFR) commonly used in the economic analysis of ships of all types. RFR is the freight rate, based on life-cycle costs, which must be obtained to make the return on money invested in the ship equal to the return that could be obtained elsewhere at a prescribed interest or "discount" rate. It is not intended to be used as a minimum acceptable freight rate, but rather as a standard for comparison of the same ship with several different corrosion control systems. Since a large portion of the petroleum tanker industry is more used to dealing with time charter rates, the RFR is also stated as a comparable time charter rate ($/DWT/month) adjusted to exclude fuel, manning provisions and port charges. Reporting the results of the analyses in either of these manners is an indication of the life-cycle cost of a ship. The spot and world scale charter rates are dependent on the often volatile demand of the petroleum transportation market and as such are not suited for use in economic analyses of this type. The yearly cost of the use of each alternative system is also reported to illustrate the significance of small differences in rates.

A complete description and listing of the GENEC1 computer program is presented in Appendix B. This program will be used in Chapter 9 to conduct sensitivity studies on two representative ship designs employing various means of corrosion control.

CHAPTER 9

SENSITIVITY STUDIES

9.1 GENERAL

Sensitivity studies are conducted to demonstrate the use of performance data (Chapter 5), corrosion rates and allowable limits (Chapter 6) and key cost parameters (Chapter 7). The studies involve two representative base ships, a 39,300 DWT product carrier and a 285,000 DWT crude carrier. In the analyses, given specific ship and operational data, the effect of corrosion-control systems over the life of the vessels is assessed. The computer program GENEC1 is used to evaluate a variety of corrosion-control alternatives for the two ships. It is described in Chapter 8 and Appendix B.

9.2 INPUT ASSUMPTIONS AND PARAMETERS

The sensitivity studies are limited to considering only the primary variable costs of corrosion control. These are considered to be capital costs, repair costs, days out of service and differences in annual cargo tonnage.

In order to conduct realistic sensitivity studies, numerous parameters were determined and assumptions made. Both ships were assumed to be of segregated ballast design with cargo tanks protected by inert gas. A crude oil washing (COW) system is in use on board the crude carrier. No costs for tank cleaning or gas freeing were included in the analyses. Summaries of Ship and Operational Data and Economic Data used in the studies are shown in Tables 9.1 and 9.2, respectively.

It was assumed that each ship spends 12 days out of service each year and 40 days each fourth year. When the time required for corrosion-control work exceeds these figures, the cost associated with additional days out of service cost was considered attributable to corrosion control.

The sensitivity studies assume that the vessels have a residual salvage or resale value at the end of their twenty-year economic life. This figure plays an important role in the life-cycle economic evaluation of the two vessels. To demonstrate this effect, sensitivity studies were conducted by two methods. One method assumed that the resale value of all ships was 10% and the other considered the resale value to be a function of the effectiveness of corrosion protection. Ships with full scantlings and maximum protection were assigned highest values. The actual resale of a ship is difficult to predict due to unquantifiable factors such as the market demand for a certain type and size of vessel.

TABLE 9.1

SUMMARY OF SHIP AND OPERATIONAL DATA

Ship Type	Crude Carrier	Product Carrier
Length B.P. (ft)	1,063.00	640.50
Beam, Mld. (ft)	175.52	105.83
Depth, Mld. (ft)	91.86	54.0
Design Displacement (LT)	319,015	51,470
Segr. Ballast Capacity (LT)	87,307	20,400
Cargo Tank Volume, 98% (ft^3)	9,880,284	1,763,546
Ballast Tank Volume, 100% (ft^3)	3,055,778	714,000
Fuel Tank Capacity (LT)	13,000	1,100
Shaft Horsepower, max. (English)	36,000	12,000
Max. Range (Naut. Miles)	28,100	7,000
One-Way Voyage Length (Naut. Miles)	11,169	1,775
Speed, Cargo (knots)	15.0	15.0
Speed, Ballast (knots)	17.5	16.2
Complement	56	28
Total Deadweight (LT)	282,900	39,300
Loading Port	Ras Tanura	Curacao
Discharge Port	Rotterdam	New York
Port Time, Loading (Days)	2	2
Port Time, Discharge (Days)	2	2
Crew and Stores (LT)	500	250
Fresh Water (LT)	150	100
Reserve Fuel (LT)	833	300
Fuel Consumption in Port (LT/day)	42.10	14.2
Fuel Consumption at Sea (LT/day)	166.52	56.70

TABLE 9.2

SUMMARY OF ECONOMIC DATA

Ship Type	Crude Carrier	Product Carrier
Ships Life (Years)	20	20
Fuel Cost ($/LT)	171.87	171.87
H&M Insurance (% of New Ship)	0.01125	0.01125
Escalation of H&M Insurance (%/Year)	0	0
P&I Insurance ($/DWT)	1.25	1.25
Escalation of P&I Ins. (%/Year)	0	0
Manning Cost ($/Year/Man)	37,640	37,640
Escalation of Manning Cost (%/Year)	8.5	8.5
Provisions and Stores ($/Year)	312,500	156,250
Escal. of Prov. & Stores (%/Year)	7.5	7.5
Port Charges ($/Voyage)	140,800	19,410
Escal. of Port Charges (%/Year)	6.0	6.0
Repair Costs ($/Year), Average	200,000	100,000
Escal. of Rep. Costs (%/Year)	7.5	7.5

For steel replacement, the time before wastage limits were reached for both unprotected and anodically protected tanks was determined by using applicable general corrosion rates for the particular conditions which exist. For the purpose of applying these corrosion rates, each tank was divided horizontally into sections (see Figure 9.1). Descriptions of all steel in a tank were then recorded on data sheets specifically developed for that purpose. The sheets describe the thickness, weight, surface area, allowable wastage and the number of years before the wastage is reached for each basic structural component. A tank plan and midship section for each ship is shown in Figure 9.1. Descriptions are included for both protected tanks with reduced scantlings and unprotected tanks with full steel scantlings. A sample data sheet is included in Appendix C.

Inorganic zinc coating schemes were not evaluated for the crude carrier because the cargo was assumed to be sour. Epoxy coating schemes were based on two coats of straight epoxy, not coal tar epoxy. It was assumed that no maintenance of coatings was performed annually for either ship and that coatings suffered 2% failure after two years. When blasting and recoating due to failure of initially applied coating, it was always assumed that the work was accomplished during the next scheduled out of service period.

All anodes were assumed to be designed for a useful life of four years. Aluminum anodes were used in dedicated ballast tanks and a combination of zinc and aluminum anodes was used in cargo/storm ballast tanks. Cargo/storm ballast tanks were assumed to be in ballast 45% of the time.

Using these assumptions, sensitivity studies were conducted for various corrosion-control systems. They include full and partial epoxy and inorganic zinc coatings, aluminum and zinc anodes and full and reduced scantlings. A complete listing of the corrosion-protection systems evaluated is shown in Table 9.3 for the crude carrier and 9.4 for the product carrier. Corrosion-control costs which served as inputs to the economic analysis program are shown in Tables 9.5 and 9.6. These tables define the year in which the costs were incurred.

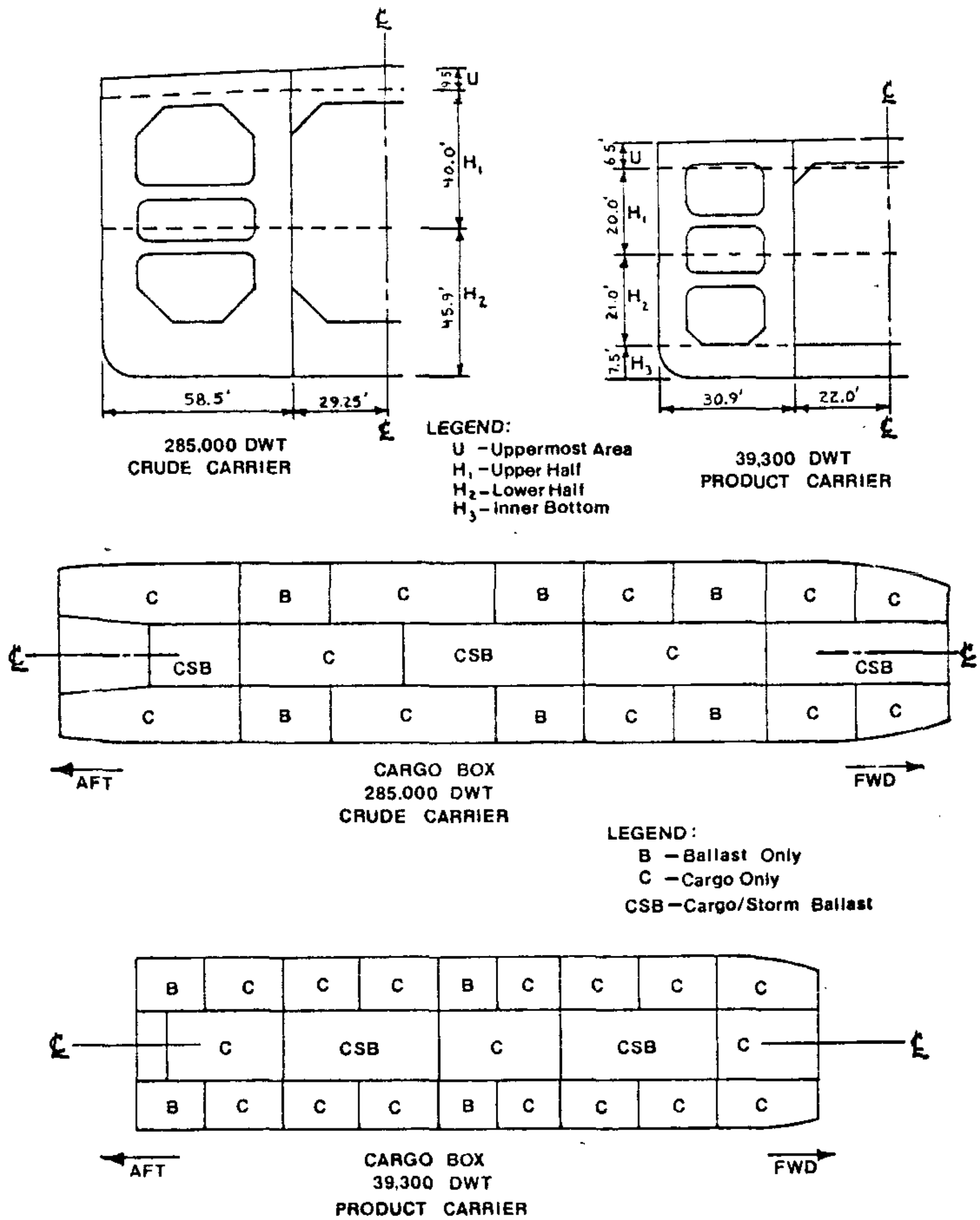


FIGURE 9.1

TANK PLANS AND MIDSHIP SECTIONS

TABLE 9.3

SYSTEM DESCRIPTIONS - CRUDE CARRIER

SYSTEM	COATINGS	REDUCTION IN SCANTLINGS	CATHODIC PROTECTION
A	Full (2 coats, epoxy)	None	None
B	Full (2 coats, epoxy)	Yes	None
C	Full (2 coats, epoxy)	Yes	Aluminum anodes (1 ma/ft^2, 4 yr) supplement coatings in ballast only tanks. Aluminum and zinc anodes (1 ma/ft^2, 4 yr) supplement coatings in cargo/storm ballast tanks.
D	Partial - Coatings (2 coats epoxy) applied to underdeck and 6 ft down in cargo only and cargo/ballast tanks. Ballast only tanks fully coated (2 coats epoxy)	None	Aluminum and zinc anodes (12 ma/ft^2, 4 yr) installed in cargo/storm ballast tanks.
D Mod.	Partial - same as system D except no coatings in ullage space of cargo only tanks	None	Same as system D except aluminum anodes (1 ma/ft^2, 4 yr) are installed in ballast only tanks to supplement coatings.
E	None for life of vessel	None	None for life of vessel

TABLE 9.4

SYSTEM DESCRIPTIONS - PRODUCT CARRIER

SYSTEM	COATINGS	REDUCTION IN SCANTLINGS	CATHODIC PROTECTION
A	Full (2 coats, epoxy)	None	None
A Mod.	Full (1 coat, inorganic zinc)	None	None
B	Full (2 coats, epoxy)	Yes, except for inner bottoms	None
C	Full (2 coats epoxy)	Yes, except for inner bottoms	Aluminum anodes (1 ma/ft^2, 4 yr) supplement coatings in ballast only tanks. Aluminum and zinc anodes (1 ma/ft^2, 4 yr) supplement coatings in cargo/storm ballast tanks.
D	None for life of vessel	None	None for life of vessel

TABLE 9.5

CORROSION-CONTROL COSTS - CRUDE CARRIER

SYSTEM	YEAR													
	INITIAL COSTS				2	4	6	8	10	12	14	16	18	20
	Base Ship[1]	Coatings	Reduced Scant.	Anodes										
A Costs ($000.)	181,200	8,300	0	0		103	670	206		3,330		206	670	-
Days Out of Service[2]	-	-	-	-	-	-	8	-	-	25	-	-	8	-
B Costs ($000.)	181,200	8,300	-4,500	0	-	103	670	206	3,035	2,733	-	3,100	206	-
Days Out of Service	-	-	-	-	-	-	8	-	33	10	-	20	-	-
C Costs ($000.)	181,200	8,300	-4,500	93	-	136	553	136	3,241	2,326	-	3,339	-	-
Days Out of Service	-	-	-	-	-	-	8	-	48	-	-	25	-	-
D Costs ($000.)	181,200	2,995	0	325	-	473	876	473	323	3,508	350	548	773	-
Days Out of Service	-	-	-	-	-	-	13	-	-	15	-	-	8	-
D Mod. Costs ($000.)	181,200	2,345	0	389	-	565	270	565	323	4,600	350	640	167	-
Days Out of Service	-	-	-	-	-	-	-	-	-	15	-	-	-	-
E Costs ($000.)	181,200	0	0	0	0	0	16,800	8,460	16,335	17,060	-	13,572	4,000	-
Days Out of Service	-	-	-	-	-	-	128	40	124	101	-	74	21	-

1. No coatings in cargo box - full steel scantlings.
2. These are additional days beyond normal 12 and 40 day out of service periods.

TABLE 9.6

CORROSION-CONTROL COSTS - PRODUCT CARRIER

SYSTEM	YEAR													
	INITIAL COSTS				2	4	6	8	10	12	14	16	18	20
	Base Ship(1)	Coatings	Reduced Scant.	Anodes										
A Costs ($000.)	69,800	2,700	0	0	-	-	537	-	715	2,254	-	253	-	-
Days Out of Service(2)	-	-	-	-	-	-	8	-	8	-	-	-	-	-
A Mod. Cost ($000.)	69,800	2,128	0	20	-	-	423	-	563	1,897	-	199	-	-
Days Out of Service	-	-	-	-	-	-	8	-	8	-	-	-	-	-
B Costs ($000.)	69,800	2,700	-710	0	-	170	367	618	570	1,951	315	386	-	-
Days Out of Service	-	-	-	-	-	-	4	-	8	-	-	-	-	-
C Costs ($000.)	69,800	2,700	-710	20	-	28	537	28	1,018	1,979	-	335	-	-
Days Out of Service	-	-	-	-	-	-	8	-	8	-	-	-	-	-
D Costs ($000.)	69,800	0	0	0	-	1116	10,123	5,726	3,499	14,802	5,565	8,209	-	-
Days Out of Service	-	-	-	-	-	-	85	8	17	84	34	27	-	-

1. No coatings in cargo box - full steel scantlings.
2. These are additional days out of service beyond normal 12 and 40 day out of service periods.

9.3 RESULTS

9.3.1 Crude Carrier

Economic analyses were first performed on the fully coated systems A, B, and C. Using resale values of 11, 8, and 9%, respectively for these systems, the full scantling system A was found to be the most cost effective. However, using a resale value of 10% for each of the three systems, system C ranked first economically. In either comparison, system C costs were less than those of system B and proved the cost effectiveness of installing supplementary anodes in fully coated, ballasted tanks.

An economic analysis of system D, a system similar to that employed in many recently constructed crude carriers, showed that lower costs could be achieved with a partially coated cargo box. In system D, all cargo tanks were coated under deck and 6 ft down; the ballast-only tanks were fully coated and the cargo/storm ballast tanks were cathodically protected with anodes.

Noting that corrective action was not required during the ship's life for uncoated steel in the ullage space of cargo only tanks and that anodes were previously found economically effective in supplementing coatings in cargo ballast tanks, system D was modified accordingly.

Of the systems studied, system D modified proved to be the most cost effective. Like system D, its economic ranking among the systems was not affected by the resale value of the ship.

System E was the least cost effective and reflects the high costs required for steel repair work if corrosion-control systems are not employed during the life of the ship.

A complete summary of the results of the economic analysis of the crude carrier is provided in Table 9.7.

9.3.2 Product Carrier

Using resale values of 22, 18 and 20% for systems A, B, and C, the full scantling, fully coated system A proved to be the most cost effective. For constant resale values, system C ranked first. Regardless of resale value, system C is the most cost effective of the fully coated, reduced scantling systems, B and C. System C, unlike system B, provides supplementary cathodic protection for the ballasted tanks.

Though it is recognized that product tankers are generally fully coated, system D was evaluated for purposes of comparison to indicate the high repair costs experienced when no protection is provided for the tank steel.

Two coats of epoxy were used in the fully coated systems A, B, and C. The cost differences between system A and system A modified, indicate the savings,

TABLE 9.7

PROGRAM RESULTS - CRUDE CARRIER

SYSTEM	RESALE VALUE AT END OF 20 YRS (% of Initial Costs)	CARGO DWT (Lt)	NO. TRIPS PER YEAR	REQUIRED FREIGHT RATE ($/Ton)	RELATIVE DIFF. IN COSTS ($/Yr)	REQUIRED CHARTER RATE ($/DWT/Mo)
A	11	271,738	5.605	23.546	0	5.009
B	8	273,524	5.572	23.621	137,000	5.076
C	9	273,524	5.572	23.542	17,000	5.041
D	10	271,738	5.619	23.391	-147,000	4.956
D mod.	10	271,738	5.615	23.351	-234,000	4.930
E	5	271,738	5.250	27.612	3,529,000	6.329
	Constant Resale Value = 10%					
A	10	271,738	5.605	23.618	0	5.042
B	10	273,524	5.572	23.481	-186,000	5.014
C	10	273,524	5.572	23.472	-200,000	5.010
D	10	271,738	5.619	23.391	-257,000	4.956
D mod.	10	271,738	5.615	23.351	-343,000	4.930
E	10	271,738	5.250	27.246	2,897,000	6.176

primarily that of labor, realized when the tanks are coated with a one coat system of inorganic zinc in place of a two coat system of epoxy. The full savings, however, can only be realized on product carriers which have independent inert gas generators because the sulfur oxides in flue gas readily attack inorganic zinc coatings. Therefore, only the savings attributable to coating the ballast tanks with inorganic zinc can be realized when the cargo tanks are inerted with flue gas.

A complete summary of the results of the economic analysis of the product carrier is provided in Table 9.8.

TABLE 9.8

PROGRAM RESULTS - PRODUCT CARRIER

SYSTEM	RESALE VALUE AT END OF 20 YRS (% of Initial Costs)	CARGO DWT (Lt)	NO. TRIPS PER YEAR	REQUIRED FREIGHT RATE ($/Ton)	RELATIVE DIFF. IN COSTS ($/Yr)	REQUIRED CHARTER RATE ($/DWT/Mo)
A	22	38,083	25.682	12.794	0	13.115
A mod.	22	38,083	25.682	12.694	-98,000	12.908
B	18	38,373	25.697	12.844	152,000	13.432
C	20	38,373	25.682	12.740	42,000	13.207
D	9	38,083	24.945	16.418	3,084,000	19.958
	Constant Resale Value = 10%					
A	10	38,083	25.682	13.308	0	14.181
A mod.	10	38,083	25.682	13.204	-102,000	13.966
B	10	38,373	25.697	13.181	-18,000	14.049
C	10	38,373	25.682	13.161	-46,000	14.116
D	10	38,083	24.945	16.376	2,541,022	19.874

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

The traditional philosophy of tanker internal corrosion control was valid during the early years of widespread tanker construction but many developments have occurred in the tanker industry since then which affect this philosophy. These developments include the rapid increase in the size of tankers since the days of the T-2 tanker, the significant increase in the cost of ship construction and repair work, new and improved corrosion control techniques and hardware, and new safety and pollution regulations. All of these have had an impact on corrosion and corrosion control in crude oil, refined product and ballast tanks. The results of this study indicate that some widely used practices of the past may no longer be viable for the modern tanker industry.

It was common during the last several decades for ship owners to reduce scantlings used in initial tank construction owing to the belief that the reduction in steel weight and cost would be justified by the performance of the corrosion-control systems employed. One conclusion of this report is that, on the basis of two vessels studied and the assumptions made, the use of reduced steel scantlings does not offer any significant economic advantage to a vessel over a 20-year life. Full scantlings in several cases examined proved to have roughly equivalent or lower life cycle costs and provide valuable insurance against unexpected coating failure.

For years, the most effective way to protect crude oil carriers was believed to be full coating throughout. Based on the results of this study, partial coatings used in conjunction with full scantlings appear to be more economical than coating an entire crude oil cargo tank. Partially coating a tank instead of fully coating can result in a considerable cost saving over the life of a ship.

Next, it was found that every effort should be made by shipowners to avoid steel replacement, which is both expensive and time consuming. It is more economical in the long run to maintain and renew corrosion-protection systems. For each ship investigated, the highest life cycle costs were experienced when all tanks had full scantlings and no other means of protection during a 20-year life. This was due to the high cost of steel replacement.

Last, the use of secondary anodes acting to supplement coatings is often more economical than coatings alone in ballast and cargo-ballast tanks. They act to extend the useful life of the tank coating.

The results of this study identified, within the limits stated in the report, the most economical of the corrosion control systems evaluated. The repair costs used in the study generally give precedence to coating repair over the higher cost of steel replacement. When an owner does not obtain accurate and current data on the condition of tank steel and plan tank work accordingly, repair costs may differ significantly from those given in this report. Corrosion-control systems must be maintained to prevent high steel repair costs.

The recent advent of IMCO rules involving segregated ballast tanks and inert gas systems as explosion preventatives and COW as a pollution-control measure all stand to have significant impact on the internal corrosion of tankers. At the time of this report, most ship operators have not had more than a couple of years experience with these systems and are unable to report conclusive results at this time. It does appear that the overall effect will be favorable in reducing corrosion.

Inert gas, in particular, has been reported by foreign sources to be especially effective in mitigating tank corrosion. However, very little work has been done to determine the degree to which inert gas is effective in controlling corrosion and under what conditions this effectiveness can be realized. It is recommended that work be undertaken to quantify these unknowns and investigate the full use of inert gas in both cargo and ballast tanks on board tankers.

Another area that needs further investigation is deep pitting corrosion in tanks. This type of corrosion is highly detrimental to tank steel and is often the sole cause of the necessity to replace steel. Although it has been a problem on board tankers for many years, there has been little work undertaken to find ways of reducing or controlling pitting corrosion. One aspect of the problem, in particular, which warrants further investigation is the effect of anodes in preventing pitting, particularly in tanks carrying sour crude cargo.

Several ship owner/operators contacted during the project survey recommended that an investigation of the corrosion of tank piping be conducted. The piping was reported to experience a high corrosion rate and to require frequent replacement.

Corrosion on board a ship is a subject of major importance to most shipowners. Choosing and maintaining the best corrosion control system for each application is essential to efficient, economical ship operation. This project provides the tools to enable tanker owners and designers to more accurately plan for the protection of new vessels and to assess the condition of existing ships in order to chose the best means of protection. However, this study should not be considered an end in itself. This area of marine technology is constantly changing as are the economic factors which affect it. Instead, the subject of internal corrosion and corrosion control alternatives in tankers is one which deserves periodic updates and renewals as time goes on. It is hoped that this study will be the beginning of a continuing effort to minimize the serious effects of internal corrosion on the tanker industry.

APPENDIX A

SUMMARY OF CLASSIFICATION SOCIETY RULES AND REGULATIONS PERTAINING TO TANKER INTERNAL CORROSION CONTROL

CONTENTS

1. AMERICAN BUREAU OF SHIPPING

Reference: ABS Rules for Building and Classing Steel Vessels, 1979

In order to receive reduced scantlings plans must be submitted which show corrosion protection particulars. These plans are to show both required and proposed reduced scantlings.

Longitudinal Frames, Beams and Bulkhead Stiffeners

The required section modulus of longitudinal frames, beams, or bulkhead stiffeners, in association with the plating to which it is attached, may be reduced 10% when an effective method of protection against corrosion is employed.

Bulkhead Plating

When special protective coatings are adopted for corrosion control the required thickness may be reduced by 3 mm (.125 in.) except where the required thickness of plating is less than 12.5 mm (.50 in.). In this case the reduction shall not exceed 20%. In no case shall the thickness of plating be less than 6.5 mm (.25 in.). Swash bulkheads, where coated, may be reduced 1.5 mm (.0625 in.) provided this thickness is not less than 6.5 mm (.25 in.).

Deck Plating

Where special protective coatings are adopted for corrosion control and after all minimum thicknesses and longitudinal hull-girder requirements have been satisfied the thickness may be reduced by 10% but not more than 3 mm (.125 in.). Where special protective coatings are to be applied to the exterior surfaces of weather decks as a means of corrosion control and after all minimum thickness and longitudinal hull-girder requirements have been satisfied the thickness of deck plating may be reduced by 10% but not more than 3.5 mm (.125 in.).

Transverse Frames

Where special protective coatings or other effective methods are adopted for corrosion control the web plate thickness may be reduced 10% from the required thickness, in which case the required section mod. of the members may be reduced as result.

Shell Plating

Where special protective coatings are adopted for corrosion control and after all minimum thickness and longitudinal hull-girder requirements have been satisfied the thickness of shell plating may be reduced by 10% but not more than 3 mm (.125 in.).

Anodes

In general, magnesium anodes are not to be used. Where other sacrificial anodes are fitted in cargo or adjacent ballast tanks, their disposition and details of attachment are to be submitted for approval.

2. BUREAU VERITAS

Reference: Rules and Regulations for the Construction and Classification of Steel Vessels - Bureau Veritas - 1977

At the shipyard's request, and with the owner's written agreement, reductions in scantlings may be granted for certain elements of the ship hull for taking into consideration the effective protection against corrosion by means of special coatings or other means that the shipyard or owner intends to use.

The class of ships benefiting from such reductions is complemented by the notation "CL" (limited corrosion). In such case, the shipyard is to furnish the Head Office complete details on the nature of the product used for protective purposes, details on the method of application and drawings to indicate the areas where the product is applied.

Where the notation CL is assigned, reduction in scantlings with respect to the rule values may be granted for certain members of the hull. The following may be reduced by 10%:

- the minimum thickness, 12.5 mm, in the case of large size members, such as platings, transverse bulkheads, web frames, stringers and, generally speaking, all members stiffened by secondary stiffeners

- the thickness of the plating and stiffeners of longitudinal and transverse bulkheads

- the thicknesses of side shell stringers and transverses, of deck transverses, of bottom transverses and of cross ties

The following may be reduced by 5%:

- the thickness of bottom and side shell plating, including the keel and bilge

- the thickness of deck plating

- the thicknesses of keelsons and deck girders

- the section moduli of bottom, side shell and deck longitudinals

3. DET NORSKE VERITAS

Reference: Rules for the Construction and Classification of Steel Ships - 1977 - Det norske Veritas

Unprotected steel (plate, stiffeners and girders) in tanks for water ballast and/or cargo oil are generally to be given a corrosion addition as stated in Table D401:

TABLE D 401

Tank Area	Tank Type	Ballast/Cargo Oil Tank or Ballast Tank Only	Ballast Tank/Dry Cargo Hold or Cargo Oil Tank Only
Within 1,5 m below top of tank in weather deck	One side unprotected	2,0 mm	1,0 mm
	Both sides unprotected	3,0 mm	1,5 mm
Elsewhere	One side unprotected	1,0 mm	0,5 mm
	Both sides unprotected	1,5 mm	1,0 mm

If a system approved by the Society is applied for corrosion protection of steel structures in tanks for water ballast and/or cargo oil the corrosion additions may be dispensed with. In such cases, the notation CORR will be entered in the Register of Ships for that vessel.

For longitudinal strength members any dispensing with the corrosion additions will be accepted only if the members are protected over the total cargo tank area of the ship.

The section modules of the hull girder is not to be reduced by more than 5% as compared to the modulus based on scantlings including the corrosion addition. Plans of steel structure submitted for approval must show net scantlings as well as scantlings with the corrosion additions included.

There are two systems which are approved and for which the corrosion addition may be dispensed with. These are coatings and cathodic protection systems. Complete particulars for all systems must be submitted to the Society for approval. Systems of protection other than the coatings and cathodic protection systems, to be described, will be specially considered.

Coating Systems

Coatings must be suitable for use on any previously applied ship primer. All surfaces are to be coated in tanks where the corrosion additions are dispensed with. Aluminum paint is not acceptable in tanks for liquid cargo with a flash point below 60°C or in adjacent tanks.

Systems for Cathodic Protection

All surfaces in the upper part of tanks down to a level not less than 1.5 m below the top of the tank are to be protected by a coating. The coating and any previously applied ship primer are to be suitable for use in combination with a cathodic protection system. Sacrificial anodes are to be fitted for protection of the remaining parts of the tank. In tanks for liquid cargo with a flash point below 60°C and in adjacent ballast tanks, magnesium or magnesium alloy anodes are not acceptable. Aluminum anodes may be accepted provided they are located such that their potential energy does not exceed 275 joules (203 ft. lbs.). Tanks in which anodes are installed are to have sufficient holes for circulation of air to prevent gas from collecting in pockets. In tanks for water ballast only and in top wing tanks cathodic protection will not be accepted as basis for the register notation CORR and dispensing with corrosion additions.

4. GERMANISCHER LLOYD

Reference: Germanischer Lloyd Rules for the Classification and Construction of Seagoing Steel Ships Vol. 1, 1980 edition.

For tanks, where an effective protection against corrosion is employed approval may be given for the reduction of material thickness. If both sides of the steel are protected, thickness may be reduced 1.5 mm and if only one side is protected 1.0 mm reduction is permitted. When this reduction in material is granted the class notation KORR will be assigned.

Drawing submitted for approval must contain both the required material thicknesses and the proposed thicknesses. A description of the envisaged corrosion protection system complete with all particulars is also required.

For structural elements also subjected to compression, the thickness may be reduced only upon proof of adequate buckling strength.

5. LLOYD'S REGISTER OF SHIPPING

Reference: Rules and Regulations for the Classification of Ships-1978 Lloyd's Register of Shipping

All steelwork, except inside tanks intended for the carriage of oil or bitumen, is to be suitably protected against corrosion. This may be by coatings or, where applicable, by a system of cathodic protection or by any other approved method.

Where a coating system is proposed, the coating must have been approved by the Society for the type of cargo to be contained in the particular space. The coating must be compatible with any previously applied primer. Complete particulars for paint, surface preparation, method of application and cargo must be submitted.

Where a cathodic protection system is to be fitted in tanks a plan showing details of the locations and attachment of anodes is to be submitted. Impressed current cathodic protection systems are not allowed in tanks. Magnesium anodes are not permitted in oil tanks but are permitted in ballast tanks. Aluminum or aluminum alloy anodes are permitted in oil tanks but only at locations where their potential energy does not exceed 275 joules (203 ft. lbs.). Aluminum anodes may not be located under tank hatches or butterworth openings unless protected by adjacent structure.

For ships engaged solely in the carriage of crude oil with defined ballasting arrangements a modified corrosion-control system will be permitted in association with the Register Book notation "(cc) crude oil defined ballasting". Modified corrosion-control systems which are acceptable are shown in Table 2.3.1. Combinations of these or other systems of corrosion control will be specially considered on the basis of equivalent protection.

Where an inert gas system is installed and tested and the notation "IGS" is entered in the register book, the requirements for coatings at the top of cargo or cargo/ballast tanks may be omitted on the understanding that the system will be operated on a continuous basis. Where the notation "(cc)" is assigned scantlings in tanks may be reduced in accordance with Table 2.5.1.

TABLE 2.3.1 CORROSION-CONTROL SYSTEM FOR CRUDE OIL CARRIERS WITH DEFINED BALLASTING

ITEM	COATINGS	CATHODIC PROTECTION
Ballast tanks	All surfaces	Anodes below normal liquid level plus coating of all surfaces above normal liquid level (see Note 1)
Crude oil/ ballast tanks	All surfaces above the normal ballast or cargo level (see Notes 1 and 2) plus the upper surface of all horizontal items in remainder of the tank, also the bottom shell, bottom longitudinals and girders up to the level of the top of the longitudinals.	Anodes below normal ballast or cargo level plus coating of all surfaces above normal liquid level (see Notes 1 and 2)
Crude oil only tanks	All surfaces above the normal liquid level (see Notes 1 and 2), bottom shell, bottom longitudinals and girders up to the level of the top of the longitudinals.	Not applicable
Dry spaces	All surfacs	Not applicable

NOTES
1. The minimum coating is to be all the surfaces in the top 1,5 mm of the tank.
2. For inert gas systems, see 3.8.

Where the notation "(cc)" is assigned scantlings in tanks may be reduced in accordance with Table 2.5.1.

TABLE 2.5.1 PERMISSIBLE SCANTLING REDUCTIONS FOR CORROSION CONTROL

Item	Permissible Reduction in Thickness
Keel, bottom and side shell, deck plating Bottom and deck longitudinals	5 per cent
Bottom and deck girders Bulkhead plating protected on one side only	5 per cent
Structural items of tank minimum thickness within oil cargo tanks where protected on both sides	1 mm or 10 per cent whichever is the lesser
Side longitudinals, bulkhead stiffeners (where within a protected tank), and all other structural items wholly within the tank, or forming the boundary between two protected tanks, except as listed above	10 per cent

NOTES

1. The hull midship section modulus and the scantling requirements for longitudinal strength are to be determined before reductions for corrosion control are applied.

2. Where the inner bottom and the lower strakes of bulkheads and hopper side plating are liable to grab or bulldozer damage, the reduction is limited to 5 per cent even though both sides are protected.

3. Reductions to shell plating are not affected by the fitting of external cathodic protection.

4. Reductions of scantlings of longitudinal items contributing to the hull girder strength will be permitted only if the items are protected throughout the full range of the cargo spaces.

6. NIPPON KAISI KYOKAI

Reference: Rules and Regulations for the Construction and Classification of Ships, 1979

When an approved measure of corrosion control is applied to tanks the required scantlings of structural members may be reduced at the discretion of the society.

Where an approved method of corrosion control is adopted and an appropriate reduction in scantlings have been approved by the Committee the notation "CoC" will be entered in the Register Book.

APPENDIX B

ECONOMIC EVALUATION

COMPUTER PROGRAM

GENEC1

CONTENTS

1. INTRODUCTION

Computer program "GENEC1" is a mathematical model for evaluating the economic worth of a merchant ship or of a component system of that ship. It is written in timesharing BASIC for the NNS Honeywell 6080 computer.

The Measure of Merit developed by this program can be either Required Freight Rate (RFR) or Net Present Value (NPV). In either case, the resulting number should be compared only with other Measures of Merit calculated by this or a similar program. RFR or NPV can vary as much as 40 or 50% if different (but equally reasonable and valid) assumptions are used for such things as frequency and timing of cost payments or income receipts, escalation, taxes, etc.

No provision is made in this program for the effects of taxes, or of such tax related stratagems as leveraged leasing, because these effects depend on owner-related circumstances which are not governed by ship design. Each prospective owner must, therefore, evaluate his own tax situation.

2. PROGRAM DESCRIPTION

GENEC1 is a GENeralized EConomic analysis program in which the input data define the mathematical model to be analyzed. These data are prepared and stored in a separate data file. Any number of such files can be used, one at a time. Input data subdivided into "Accounts", with the number of accounts dependent on the complexity of the model. Currently the dimension statements of the program limit the total number of accounts to 50, but this can easily be changed.

Three different types of accounts can be used. Figure B1 is the input data sheet for the "GENERAL" account. This sheet includes ship data, economic data, and program control data. One such account is used for each data file.

Figure B2 is the input data sheet for the "PORTS" accounts. This sheet includes data on the port, on the route to the next port, on fuel consumption in port and enroute, and on fuel and cargo loading, off-loading and costs in the port. At least one such account must be used; there is no upper limit on the number of these accounts.

Figure B3 is the input data sheet for the "COSTS" accounts. This sheet includes data on the acquisition or operating costs to be considered, one account for each cost. No cost accounts are required; there is no upper limit on the number of such accounts. Figure B4 is a supplementary table of payment schedules which is sometimes used in conjunction with a cost account. Currently the dimension statements of the program limit the number of such tables to 5 and the number of entries per table to 100, but this can easily be changed.

These input data sheets permit each data file to establish any desired set of conditions. An analysis can cover the total cost of owning and operating the

PROGRAM "GENEC1" INPUT DATA

"GENERAL" ACCOUNT # 1

ALPHANUMERIC DATA (Enclose in Quotation Marks)

FILE IDENT.	F I L E S A V E D A T ... O N ... / ... /
SHIP IDENT.	

LINE	DESCRIPTION	UNITS	NUMERICAL DATA
1	NUMBER OF "PORT" ACCOUNTS (1 or more)	INTEGER	
2	NUMBER OF CAPITALIZED "COST" ACCOUNTS	INTEGER	
3	NUMBER OF OPERATING "COST" ACCOUNTS	INTEGER	
4	DISCOUNT RATE	%/YEAR	
5	MONTHS FROM CONTRACT TO DELIVERY	MONTHS	
6	SHIP LIFE	YEARS	
7	NUMBER OF MEN IN CREW	INTEGER	
8	OPERATING DAYS PER YEAR	(Note 1)	
9	MAXIMUM DEADWEIGHT (fully loaded)	TONS	
10	MINIMUM DEADWEIGHT (ballasted)	TONS	
11	WEIGHT - CREW & STORES	TONS	
12	- FRESH WATER	TONS	
13	- RESERVE FUEL OIL	TONS	
14	MAXIMUM CAPACITY OF FUEL OIL TANKS	TONS	
15	FIRST YEAR (after deliv.) OF PERIOD ANALYZED	INTEGER	
16	LAST YEAR (after deliv.) OF PERIOD ANALYZED	INTEGER	

TABLE A - OPERATING DAYS / YEAR (See Note 2)

YEAR	OPER. DAYS	YEAR	OPER. DAYS	YEAR	OPER. DAYS	YEAR	OPER. DAYS	YEAR	OPER. DAYS	YEAR	OPER. DAYS
1		6		11		16		21		26	
2		7		12		17		22		27	
3		8		13		18		23		28	
4		9		14		19		24		29	
5		10		15		20		25		30	

NOTES:

1. Values given in Line 8 mean:
   (D) = Uniform number of operating days (D) each year.
   (-1) = Variable number of operating days per year as shown in Table A.

2. Table A follows Line 16. It is not to be used unless Line 8 is -1.
   Only (N) Lines of Table A are used. (N) is the value given in Line 6.

FIGURE B1

PROGRAM "GENEC1" INPUT DATA			
"PORTS"			ACCOUNT #
ALPHANUMERIC DATA (Enclose in Quotation Marks)			
NAME OF PORT			
LINE	DESCRIPTION	UNITS	NUMERICAL DATA
1	DAYS IN PORT	DAYS	
2	DISTANCE TO NEXT PORT	N. MILES	
3	SPEED TO NEXT PORT	KNOTS	
4	FUEL CONSUMPTION - IN PORT	TONS/DAY	
5	- AT SEA	TONS/DAY	
6	FUEL - LOADED AT THIS PORT	(Note 1)	
7	- COST	$/TON	
8	- ESCALATION	%/YEAR	
9	CARGO - LOADED AT THIS PORT	(Note 2)	
10	--OFFLOADED AT THIS PORT	(Note 2)	
11	- FREIGHT RATE	(Note 3)	
12	- ESCALATION	%/YEAR	

NOTES:

1. Values given for Line 6 mean:
   (F) = Amount of fuel to be loaded (tons).
   (-1) = Fuel needed for entire round trip is to be loaded (calculated by the program).

2. Values given for Lines 9 & 10 mean:
   (C) = Amount of cargo to be loaded/offloaded (tons).
   (-1) = Maximum amount of cargo is to be loaded/offloaded (calculated by the program).

3. Values given for Line 11 mean:
   (R) = Freight rate for cargo offloaded ($/ton).
   (-1) = RFR is to be calculated by the program.

FIGURE B2

PROGRAM "GENEC1" INPUT DATA

"COSTS" ACCOUNT #

ALPHANUMERIC DATA (Enclose in Quotation Marks)

NAME OF COST

LINE	DESCRIPTION	UNITS	NUMERICAL DATA
1	AMOUNT	(Note 1)	
2	ESCALATION	%/YEAR	
3	MULTIPLYING FACTOR	(Note 2)	
4			
5	MULTIPLYING FACTOR	(Note 2)	
6			
7	MULTIPLYING FACTOR	(Note 2)	
8			
9	TIME OF PAYMENT	(Note 4)	
10			

NOTES:

1. Line 1 may be given in "dollars" or in any other units, depending on the multiplying factors given in lines 3/4, 5/6, & 7/8.

2. Values given in lines 3/4, 5/6, & 7/8 mean:
(-1,F) = Divide Line 1 by (F).
(0,F) = Multiply Line 1 by (F).
(J,L) = Multiply Line 1 by the value of Account (J) Line (L).

3. Factors 3/4, 5/6, & 7/8 are applied sequentially so that:
Basic cost = (Line 1)*f(3/4)*f(5/6)*f(7/8).
Basic cost can be "per voyage" or "per payment".

4. Values given in lines 9/10 mean:
(1,M) = A single payment at the end of (M) months after contract (for capitalized costs) or after delivery (for operating costs).
(2,M) = Cost is per voyage (operating costs only). The total cost (before escalation) of all voyages is divided into equal payments made at the beginning of each (M) month period after delivery. Each payment is escalated at the rate specified in Line 2.
(3,M) = Cost is per voyage (operating costs only). The total cost (before escalation) of all voyages is divided into equal payments made at the end of each (M) month period after delivery. Each payment is escalated at the rate specified in Line 2.
(4,M) = Cost is per payment. Each payment is made at the beginning of every (M) month period from contract to delivery (for capitalized costs) or after delivery (for operating costs).
(5,M) = Cost is per payment. Each payment is made at the end of every (M) month period from contract to delivery (for capitalized costs) or after delivery (for operating costs).
(6,N) = (N) payments made in accordance with Table B.

FIGURE B3

PROGRAM "GENEC1" INPUT DATA

TABLE B FOR USE WITH "COSTS" ACCOUNT #___

LINE	MONTH	%	LINE	MONTH	%	LINE	MONTH	%	LINE	MONTH	%
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		

NOTES:

1. Table B follows Line 10 of the corresponding cost account. It is not to be used unless Line 9 of that account is 6.

2. Only (N) lines of Table B are used. (N) is the value given in Line 10 of the associated cost account.

3. "Month" is the month after contract for capitalized costs and after delivery for operating costs.

4. "%" is the percent of the basic cost (see Note 3 of the Cost Account Data Sheet) which is paid at the end of the corresponding month.

FIGURE B4

ship, or it can be limited to the costs associated with one or several components of that ship. It can cover the entire ship life, or it can be limited to one or several years of that life. It can include the effect of escalation on any or all of the costs and income being considered, with a different escalation rate applied to each, or it can assume that these values will not change.

The program will accept a round voyage touching at any number of ports, with fueling and cargo loading or off-loading at any of them. The amount of fuel to be loaded at any port can be specified, or the program will calculate the amount needed for the total voyage or for the trip to the next port. The amount of cargo to be handled at any port can be specified, or the program will calculate the maximum that can be loaded or off-loaded. The freight rate for cargo off-loaded at any port can be specified; the program will calculate RFR for any cargo which does not have a specified freight rate.

The number of operating days can be varied from year to year. The program will calculate the average number of days per year for the operating period being analyzed.

The average number of round trips per year is determined by adding the number of days in port and the number of days at sea for all legs of the voyage to get the total days per trip. This number divided into the average number of operating days per year gives the average number of trips per year. These trips, together with the associated income and costs, are assumed to be distributed uniformly among the twelve months of the year.

Fuel oil (F.O.) consumed per trip is determined by adding the fuel used in port and the fuel used at sea for all legs of the voyage. The program checks to be sure that there always is enough service fuel on board to reach the next port, and that the amount of fuel on board (including reserve F.O.) never exceeds the capacity of the F.O. tanks.

The maximum amount of cargo that can be transported on any leg of the voyage is equal to the total deadweight minus the weight of crew and stores, fresh water, service F.O. when leaving port, and reserve F.O. The program will add ballast as necessary to permit safe operation in light condition.

Each cost account can be tailored to any desired conditions by appropriate choices of input data. The amount of the cost is the product of four factors which may be individually specified or may be referenced to other accounts and line numbers. Payments may be made "regularly" at the start (or end) of specified periods before or after delivery, or "irregularly" at any number of specified dates.

3. PROGRAM THEORY

This math model is based on a Discounted Cash Flow (DCF) analysis of all the costs and income involved in acquiring, owning and operating a merchant ship over its total life, or over any selected portion of that life. It can also be used to evaluate the economic merit of any selected part of that ship. Figure B5 is a listing of the program, and Figure 6 is an index of the symbols used.

Income and costs are collected by months, with all transactions in a given month assumed to occur at the end of the month. Transactions which occur on known dates (such as construction payments or insurance premiums) are included with other costs for the month in which they occur; transactions which occur at unpredictable times (such as fuel costs, port charges, income, repair costs, etc.) are distributed uniformly over the months of the year in which they occur.

3.1 Escalation and Present Value

Escalation is defined as "the steady increase in cost of materials or services, usually as a result of inflation". Every dollar value used in this math model can be escalated, with a different annual rate for each. Each rate remains constant for the life of the ship. Date of contract is the base date for calculating escalation, using the formula:

$$E = V \; 1 + \frac{e}{100}^{(m/12)}$$

where;

E = Escalated value ($)

V = Value at date of contract ($)

e = Escalation rate (%)

m = Months from date of contract

Present value is defined as "the worth, on a specified date, of a payment made on some other date". Money paid or received today is worth more than the same amount of money paid or received at a future date because money-in-hand today can accumulate interest until that future date and will, therefore, have grown to a larger amount at that time. (This is completely independent of any change in the value of the money itself because of inflation or other factors.) All payments, then, must be "discounted" to establish their worth at some common date before they can be compared with each other in an economic study.

Date of contract is the base date for calculating present value, using the formula:

$$P = \frac{F}{1 + \frac{d}{100}^{(m/12)}}$$

(Text continues on B-21)

FIGURE B5

"GENEC 1" PROGRAM LISTING

```
10 DIM C1(50),C3(50),C4(5),D(50),D2(50),D3(50),E(50),F1(50),F2(50)
20 DIM F3(50),F4(50),F5(50),K3(5),K4(5),M(5,100),N$(50),P(5,100)
30 DIM P1(50),R(50),W1(50),W2(50),W3(50),W4(50),Z(50,16)
40 DIM D6(30),K5(50),V3(10),V4(10)
50 FILES *
60 DEF FNE(X)=(1+X/100)↑((K-1)/12)
70 DEF FNP(X)=D(J)+C*(1+X/100)↑((1-K)/12)
80 PRINT "OUTPUT OPTION 8 WILL LIST ALL OUTPUT OPTIONS"
90 REM+++++++++++++++++++++++++ DATA INPUT +++++++++++++++++++++++++
100 PRINT "DATA FILE ";
110 INPUT F$
120 IF F$<>"STOP" THEN 140
130 STOP
140 FILE #1,F$
150 M1=0
160 P1(1)=0
170 READ #1,F1$,N1$
180 FOR I=1 TO 16
190 READ #1,Z(1,I)
200 NEXT I
210 IF Z(1,8)=>0 THEN 250
220 FOR Y=1 TO Z(1,6)
230 READ #1,D6(Y)
240 NEXT Y
250 FOR J=2 TO Z(1,1)+1
260 P1(J)=0
270 READ #1,N$(J)
280 FOR I=1 TO 12
290 READ #1,Z(J,I)
300 NEXT I
310 NEXT J
320 T1=0
330 FOR J=Z(1,1)+2 TO Z(1,1)+Z(1,2)+Z(1,3)+1
340 P1(J)=0
350 READ #1,N$(J)
360 FOR I=1 TO 10
370 READ #1,Z(J,I)
380 NEXT I
390 IF Z(J,9)<6 THEN 480
400 T1=T1+1
410 IF T1<6 THEN 440
420 PRINT "TOO MANY IRREGULAR PAYMENT SCHEDULES"
430 GO TO 100
440 P1(J)=T1
450 FOR I=1 TO Z(J,10)
460 READ #1,M(P1(J),I),P(P1(J),I)
470 NEXT I
480 NEXT J
490 RESTORE #1
500 REM+++++++++++++++++++++++++++ DATA MODIFICATION ++++++++++++++++
510 PRINT F1$
520 IF M1=0 THEN 540
```

```
530 PRINT "FILE MODIFIED AT ";T$;" ON ";D$
540 LET T$=CLK$
550 LET D$=DAT$
560 PRINT "NEW DATA",T$,D$
570 INPUT T1,T2,T3
580 IF T1=0 THEN 840
590 M1=1
600 IF T1>1 THEN 720
610 IF T2<>6 THEN 650
620 IF T3<=Z(1,6) THEN 720
630 Z(1,6)=T3
640 GO TO 670
650 IF T2<>8 THEN 720
660 Z(1,8)=T3
670 IF Z(1,8)=>0 THEN 730
680 PRINT "INPUT OPERATING DAYS/YEAR FOR";Z(1,6);"YEARS"
690 FOR Y=1 TO Z(1,6)
700 INPUT D6(Y)
710 NEXT Y
720 Z(T1,T2)=T3
730 IF T1<Z(1,1)+2 THEN 570
740 IF T2<>9 THEN 570
750 IF T3<6 THEN 570
760 PRINT "HOW MANY CHANGES";
770 INPUT T4
780 FOR I=1 TO T4
790 INPUT T5,T6,T7
800 M(P1(T1),T5)=T6
810 P(P1(T1),T5)=T7
820 NEXT I
830 GO TO 570
840 REM++++++++++++++++++++++++ DAYS/VOYAGE +++++++++++++++++++++
850 IF Z(1,8)<0 THEN 890
860 FOR Y=1 TO Z(1,6)
870 D6(Y)=Z(1,8)
880 NEXT Y
890 D4=0
900 FOR J=2 TO Z(1,1)+1
910 D2(J)=Z(J,1)
920 D3(J)=Z(J,2)/(24*Z(J,3))
930 D4=D4+D2(J)+D3(J)
940 NEXT J
950 T1=0
960 T2=0
970 FOR Y=Z(1,15) TO Z(1,16)
980 T1=T1+D6(Y)
990 T2=T2+1
1000 NEXT Y
1010 V1=T1/(T2*D4)
1020 REM++++++++++++++++++++++++ FUEL ++++++++++++++++++++++++++++
1030 F=0
1040 FOR J=2 TO Z(1,1)+1
1050 F2(J)=Z(J,1)*Z(J,4)
1060 F5(J)=D3(J)*Z(J,5)
```

```
1070 F=F+F2(J)+F5(J)
1080 NEXT J
1090 F1(2)=0
1100 FOR I=1 TO 2
1110 FOR J=2 TO Z(1,1)+1
1120 IF Z(J,6)<0 THEN 1170
1130 F3(J)=Z(J,6)
1140 IF F1(J)+F3(J)=>F2(J)+F5(J) THEN 1180
1150 F3(J)=F2(J)+F5(J)-F1(J)
1160 GO TO 1180
1170 F3(J)=F-F1(J)
1180 F4(J)=F1(J)+F3(J)-F2(J)
1190 IF F4(J)<Z(1,14)-Z(1,13)+.1 THEN 1270
1200 F4(J)=Z(1,14)-Z(1,13)
1210 F3(J)=F4(J)+F2(J)-F1(J)
1220 IF I=1 THEN 1240
1230 PRINT "SHIP CAN ONLY LOAD";F3(J);"TONS OF FUEL AT ";N$(J)
1240 IF F4(J)>F5(J)-.1 THEN 1270
1250 PRINT "OUT OF FUEL AFTER ";N$(J)
1260 GO TO 2920
1270 F1(J+1)=F4(J)-F5(J)
1280 IF I=1 THEN 1370
1290 IF F3(J)<.1 THEN 1360
1300 IF Z(J,6)<0 THEN 1330
1310 IF F3(J)<Z(J,6)+.1 THEN 1330
1320 PRINT "SHIP MUST LOAD";F3(J);"TONS OF FUEL AT ";N$(J)
1330 IF Z(J,7)>0 THEN 1360
1340 PRINT "NO COST DATA FOR FUEL AT ";N$(J)
1350 GO TO 2920
1360 C1(J)=F3(J)*Z(J,7)
1370 NEXT J
1380 F1(2)=F1(Z(1,1)+2)
1390 NEXT I
1400 REM+++++++++++++++++++++++++ CARGO & BALLAST +++++++++++++++++
1410 T1=Z(1,11)+Z(1,12)+Z(1,13)
1420 W3(1)=0
1430 FOR I=1 TO 2
1440 FOR J=2 TO Z(1,1)+1
1450 IF Z(J,10)<0 THEN 1510
1460 IF Z(J,10)>W3(J-1)+.1 THEN 1490
1470 W2(J)=Z(J,10)
1480 GO TO 1520
1490 IF I=1 THEN 1510
1500 PRINT "SHIP CAN ONLY OFFLOAD";W3(J-1);"TONS OF CARGO AT ";N$(J)
1510 W2(J)=W3(J-1)
1520 T2=Z(1,9)-T1-F4(J)-W3(J-1)+W2(J)
1530 IF Z(J,9)<0 THEN 1590
1540 IF Z(J,9)>T2+.1 THEN 1570
1550 W1(J)=Z(J,9)
1560 GO TO 1600
1570 IF I=1 THEN 1590
1580 PRINT "SHIP CAN ONLY LOAD";T2;"TONS OF CARGO AT ";N$(J)
1590 W1(J)=T2
1600 W3(J)=W3(J-1)-W2(J)+W1(J)
```

```
1610 W4(J)=0
1620 IF Z(1,10)<F4(J)+W3(J)+T1 THEN 1640
1630 W4(J)=Z(1,10)-T1-F4(J)-W3(J)
1640 NEXT J
1650 W3(1)=W3(Z(1,1)+1)
1660 NEXT I
1670 REM+++++++++++++++++++++++++ CASH FLOW +++++++++++++++++++++++
1680 D1=0
1690 D5=0
1700 E1=0
1710 E2=0
1720 K1=Z(1,5)+12*(Z(1,15)-1)+2
1730 K2=Z(1,5)+12*Z(1,16)+1
1740 REM......................... PORT ACCOUNTS ....................
1750 FOR J=2 TO Z(1,1)+1
1760 D(J)=0
1770 E(J)=0
1780 FOR K=K1 TO K2
1790 Y=INT((K-Z(1,5)-2)/12+1)
1800 C=C1(J)*D6(Y)*FNE(Z(J,8))/(12*D4)
1810 D(J)=FNP(Z(1,4))
1820 C2=W2(J)*D6(Y)*FNE(Z(J,12))/(12*D4)
1830 E(J)=E(J)+C2*(1+Z(1,4)/100)↑((1-K)/12)
1840 NEXT K
1850 D1=D1+D(J)
1860 IF Z(J,11)<0 THEN 1900
1870 E1=E1+E(J)*Z(J,11)
1880 R(J)=Z(J,11)
1890 GO TO 1910
1900 E2=E2+E(J)
1910 NEXT J
1920 REM........................ CAPITAL COST ACCOUNTS ...........
1930 IF Z(1,2)=0 THEN 2270
1940 FOR J=Z(1,1)+2 TO Z(1,1)+Z(1,2)+1
1950 D(J)=0
1960 C3(J)=Z(J,1)
1970 FOR I=3 TO 7 STEP 2
1980 IF Z(J,I)<>1 THEN 2000
1990 IF Z(J,I+1)=8 THEN 2130
2000 IF Z(J,I)=>0 THEN 2030
2010 C3(J)=C3(J)/Z(J,I+1)
2020 GO TO 2070
2030 IF Z(J,I)>0 THEN 2060
2040 C3(J)=C3(J)*Z(J,I+1)
2050 GO TO 2070
2060 C3(J)=C3(J)*Z(Z(J,I),Z(J,I+1))
2070 NEXT I
2080 ON Z(J,9) GO TO 2090,2130,2130,2150,2150,2200
2090 K=Z(J,10)+1
2100 C=C3(J)*FNE(Z(J,2))
2110 D(J)=FNP(Z(1,4))
2120 GO TO 2250
2130 PRINT "ACCT.";J;"CAPITAL COSTS CANNOT DEPEND ON OPER. DAYS"
2140 GO TO 2920
```

```
2150 FOR K=1+(Z(J,9)-4)*Z(J,10) TO Z(1,5)+(Z(J,9)-4) STEP Z(J,10)
2160 C=C3(J)*FNE(Z(J,2))
2170 D(J)=FNP(Z(1,4))
2180 NEXT K
2190 GO TO 2250
2200 FOR I=1 TO Z(J,10)
2210 K=1+M(P1(J),I)
2220 C=C3(J)*FNE(Z(J,2))*P(P1(J),I)/100
2230 D(J)=FNP(Z(1,4))
2240 NEXT I
2250 D5=D5+D(J)
2260 NEXT J
2270 REM.......................... OPERATING COST ACCOUNTS .........
2280 IF Z(1,3)=0 THEN 2760
2290 FOR J=Z(1,1)+Z(1,2)+2 TO Z(1,1)+Z(1,2)+Z(1,3)+1
2300 D(J)=0
2310 C3(J)=Z(J,1)
2320 K5(J)=0
2330 FOR I=3 TO 7 STEP 2
2340 IF Z(J,I)<>1 THEN 2380
2350 IF Z(J,I+1)<>8 THEN 2380
2360 K5(J)=1
2370 GO TO 2450
2380 IF Z(J,I)=>0 THEN 2410
2390 C3(J)=C3(J)/Z(J,I+1)
2400 GO TO 2450
2410 IF Z(J,I)>0 THEN 2440
2420 C3(J)=C3(J)*Z(J,I+1)
2430 GO TO 2450
2440 C3(J)=C3(J)*Z(Z(J,I),Z(J,I+1))
2450 NEXT I
2460 ON Z(J,9) GO TO 2470,2530,2530,2570,2570,2670
2470 K=Z(1,5)+Z(J,10)+1
2480 IF K<K1 THEN 2750
2490 IF K>K2 THEN 2750
2500 C=C3(J)*FNE(Z(J,2))
2510 D(J)=FNP(Z(1,4))
2520 GO TO 2740
2530 T1=Z(J,9)-2
2540 C3(J)=C3(J)/(D4*12)
2550 K5(J)=1
2560 GO TO 2580
2570 T1=Z(J,9)-4
2580 FOR K=K1+T1*Z(J,10)-1 TO K2+T1-1 STEP Z(J,10)
2590 Y=INT((K-Z(1,5)-2)/12+1)
2600 IF K5(J)=0 THEN 2630
2610 C=C3(J)*D6(Y)*FNE(Z(J,2))
2620 GO TO 2640
2630 C=C3(J)*FNE(Z(J,2))
2640 D(J)=FNP(Z(1,4))
2650 NEXT K
2660 GO TO 2740
2670 FOR I=1 TO Z(J,10)
2680 K=Z(1,5)+M(P1(J),I)+1
```

```
2690 IF K<K1 THEN 2730
2700 IF K>K2 THEN 2730
2710 C=C3(J)*FNE(Z(J,2))*P(P1(J),I)/100
2720 D(J)=FNP(Z(1,4))
2730 NEXT I
2740 D1=D1+D(J)
2750 NEXT J
2760 REM......................... SUMMATION .........................
2770 R1=0
2780 T1=1+Z(1,4)/100
2790 A1=12*T1↑((Z(1,5)+1)/12)*((1/T1)↑(1/12)-1)/((1/T1)↑Z(1,6)-1)
2800 A2=12*T1↑((Z(1,5)+12*(Z(1,15)-1)+1)/12)*((1/T1)↑(1/12)-1)
2810 A2=A2/((1/T1)↑(Z(1,16)-Z(1,15)+1)-1)
2820 V2=E1-D1-D5*A1/A2
2830 IF E2=0 THEN 2850
2840 R1=-V2/E2
2850 IF Q1=7 THEN 4920
2860 REM+++++++++++++++++++++++++ OUTPUT +++++++++++++++++++++++++
2870 PRINT
2880 PRINT "OUTPUT ";
2890 INPUT Q1
2900 PRINT
2910 ON Q1 GO TO 90,500,3060,3420,3940,4010,4730,4980
2920 PRINT "OUTPUT (MUST BE 1, 2 OR 8) ";
2930 INPUT Q1
2940 PRINT
2950 ON Q1 GO TO 90,500,2920,2920,2920,2920,2920,5100
2960 REM+++++++++++++++++++++++++ SUBROUTINE FOR HEADINGS ++++++++++
2970 PRINT N1$
2980 PRINT "      DATA FILE: ";F$
2990 PRINT "      ";F1$
3000 IF M1=0 THEN 3020
3010 PRINT "      FILE MODIFIED AT ";T$;" ON ";D$
3020 PRINT USING 3030,Z(1,15),Z(1,16)
3030:EXPENSES FOR YEARS ## THRU ## AFTER DELIVERY USED IN THIS ANALYSIS
3040 PRINT
3050 RETURN
3060 REM+++++++++++++++++++++++++ VOYAGE DATA ++++++++++++++++++++
3070 GOSUB 2970
3080 FOR J=2 TO Z(1,1)+1
3090 PRINT "<<<<< ";N$(J);" >>>>>"
3100 PRINT USING 3150,Z(J,2),Z(J,3)
3110 PRINT USING 3160,D2(J),F2(J)
3120 PRINT USING 3170,D3(J),F5(J)
3130 PRINT USING 3180,F3(J)
3140 PRINT USING 3190,W1(J),W2(J)
3150:NEXT LEG OF VOYAGE=######## MILES AT ##.## KNOTS
3160:TIME IN PORT      =#####.## DAYS, USING ######## TONS OF FUEL
3170:TIME AT SEA       =#####.## DAYS, USING ######## TONS OF FUEL
3180:FUEL LOADED       =######## TONS
3190:CARGO LOADED      =######## TONS, OFFLOADED=######## TONS
3200 PRINT "DEPARTURE WEIGHTS"
3210:      CREW & STORES=######## TONS
3220:      FRESH WATER  =######## TONS
```

```
3230:      BALLAST       ######### TONS
3240:      SERVICE FUEL ######### TONS
3250:      RESERVE FUEL ######### TONS
3260:      CARGO         ######### TONS
3270:         TOTAL      ######### TONS
3280:MAXIMUM DEADWEIGHT=######## TONS
3290 PRINT USING 3210,Z(1,11)
3300 PRINT USING 3220,Z(1,12)
3310 PRINT USING 3230,W4(J)
3320 PRINT USING 3240,F4(J)
3330 PRINT USING 3250,Z(1,13)
3340 PRINT USING 3260,W3(J)
3350 PRINT USING 3270,Z(1,11)+Z(1,12)+W4(J)+F4(J)+Z(1,13)+W3(J)
3360 PRINT USING 3280,Z(1,9)
3370 PRINT
3380 NEXT J
3390 PRINT "TOTAL DAYS, ROUND TRIP=";D4
3400 PRINT "AVERAGE NUMBER OF TRIPS PER YEAR=";V1
3410 GO TO 2860
3420 REM+++++++++++++++++++++++++ PRESENT VALUES +++++++++++++++++
3430 GOSUB 2970
3440:<<<<< INCOME >>>>>     TONS DELIV.   $/TON    ESCAL.   PRES.VAL.
3450:                        PER YEAR                %       ($1000)
3460:'LLLLLLLLLLLLLLLLLLLLLL ########     ###.##   ##.##    ########
3470:              TOTAL    ##########                     ############
3480:<<<<< EXPENSES >>>>>       AVG.ANN.  ESCAL.   % OF   PRES.VAL.    RFR
3490:                           ($1000)    (%)    TOTAL   ($1000)      ($)
3500:.....FUEL.....
3510:'LLLLLLLLLLLLLLLLLLLLLL    ########  ##.##  ###.##   ########   ###.##
3520:.....CAPITALIZED.....
3530:.....OPERATING.....
3540:              TOTAL       ###########            ###########   ###.##
3550 PRINT USING 3440
3560 PRINT USING 3450
3570 T1=0
3580 T2=0
3590 FOR J=2 TO Z(1,1)+1
3600 IF Z(J,11)=>0 THEN 3620
3610 R(J)=R1
3620 PRINT USING 3460,N$(J),W2(J)*V1,R(J),Z(J,12),E(J)*R(J)/1000
3630 T1=T1+W2(J)*V1
3640 T2=T2+E(J)*R(J)
3650 NEXT J
3660 PRINT USING 3470,T1,T2/1000
3670 PRINT
3680 PRINT USING 3480
3690 PRINT USING 3490
3700 T1=0
3710 PRINT USING 3500
3720 FOR J=2 TO Z(1,1)+1
3730 T4=100*A2*D(J)/(A2*D1+A1*D5)
3740 PRINT USING 3510,N$(J),A2*D(J)/1000,Z(J,8),T4,D(J)/1000,T4*R1/100
3750 T1=T1+A2*D(J)
3760 NEXT J
```

```
3870 FOR J=Z(1,1)+Z(1,2)+2 TO Z(1,1)+Z(1,2)+Z(1,3)+1
3880 T4=100*A2*D(J)/(A2*D1+A1*D5)
3890 PRINT USING 3510,N$(J),A2*D(J)/1000,Z(J,2),T4,D(J)/1000,T4*R1/100
3900 T1=T1+A2*D(J)
3910 NEXT J
3920 PRINT USING 3540,T1/1000,(D1+A1*D5/A2)/1000,R1
3930 PRINT
3940 REM+++++++++++++++++++++++++ RFR OR NPV +++++++++++++++++++++
3950 IF E2<>0 THEN 3990
3960:NET PRESENT VALUE=#######000 $
3970 PRINT USING 3960,V2/1000
3980 GO TO 2860
3990 PRINT "CALCULATED RFR=";R1;"$/TON AT DATE OF CONTRACT"
4000 GO TO 2860
4010 REM+++++++++++++++++++++++++ COSTS BY MONTHS ++++++++++++++++
4020 PRINT "WHAT ACCOUNTS ";
4030 INPUT T1,T2,T3,T4,T5
4040 PRINT "WHAT MONTHS ";
4050 INPUT T6,T7
4060 PRINT
4070 GOSUB 2970
4080 PRINT "<<<<< COSTS BY MONTHS >>>>>"
4090 PRINT USING 4100,N$(T1),N$(T2),N$(T3),N$(T4),N$(T5)
4100:MONTH 'RRRRRRRRRRR 'RRRRRRRRRRR 'RRRRRRRRRRR 'RRRRRRRRRRR 'RRRRRRRRRRR
4110:####  ############ ############ ############ ############ ############
4120 IF T6>0 THEN 4140
4130 T6=0
4140 IF T7<Z(1,5)+12*Z(1,6) THEN 4160
4150 T7=Z(1,5)+12*Z(1,6)
4160 FOR K=T6+1 TO T7+1
4170 Y=INT((K-Z(1,5)-2)/12+1)
4180 J=T1
4190 I=1
4200 GOSUB 4400
4210 J=T2
4220 I=2
4230 GOSUB 4400
4240 J=T3
4250 I=3
4260 GOSUB 4400
4270 J=T4
4280 I=4
4290 GOSUB 4400
4300 J=T5
```

```
4310 I=5
4320 GOSUB 4400
4330 PRINT USING 4110,K-1,C4(1),C4(2),C4(3),C4(4),C4(5)
4340 IF K<>K1-1 THEN 4360
4350 PRINT "+++++FIRST MONTH OF OPERATING EXPENSES INCLUDED IN ANALYSIS
4360 IF K<>K2 THEN 4380
4370 PRINT "+++++LAST MONTH OF OPERATING EXPENSES INCLUDED IN ANALYSIS"
4380 NEXT K
4390 GO TO 2860
4400 REM+++++++++++++++++++++++++ SUBROUTINE FOR MONTHLY COSTS +++++
4410 C4(I)=0
4420 IF J>Z(1,1)+1 THEN 4460
4430 IF K<Z(1,5)+2 THEN 4450
4440 C4(I)=C1(J)*D6(Y)*FNE(Z(J,8))/(D4*12)
4450 RETURN
4460 IF K>T6+1 THEN 4510
4470 K3(I)=1
4480 K4(I)=1
4490 IF J<Z(1,1)+Z(1,2)+2 THEN 4510
4500 K3(I)=Z(1,5)+1
4510 ON Z(J,9) GO TO 4520,4550,4550,4570,4570,4650
4520 IF K<>Z(J,10)+1 THEN 4540
4530 C4(I)=C3(J)*FNE(Z(J,2))
4540 RETURN
4550 IF K<>K3(I)+Z(J,9)-2 THEN 4640
4560 GO TO 4580
4570 IF K<>K3(I)+Z(J,9)-4 THEN 4640
4580 IF J>Z(1,1)+Z(1,2)+1 THEN 4600
4590 IF K>Z(1,5)+1 THEN 4640
4600 C4(I)=C3(J)*FNE(Z(J,2))
4610 IF K5(J)=0 THEN 4630
4620 C4(I)=C4(I)*D6(Y)
4630 K3(I)=K3(I)+Z(J,10)
4640 RETURN
4650 IF K4(I)>Z(J,10) THEN 4700
4660 IF K<M(P1(J),K4(I))+K3(I) THEN 4700
4670 IF K>M(P1(J),K4(I))+K3(I) THEN 4710
4680 C4(I)=C3(J)*FNE(Z(J,2))*P(P1(J),K4(I))/100
4690 K4(I)=K4(I)+1
4700 RETURN
4710 K4(I)=K4(I)+1
4720 GO TO 4650
4730 REM+++++++++++++++++++++++++++ PARAMETRIC STUDY ++++++++++++++++
4740 PRINT "---------- PARAMETRIC STUDY-----------"
4750 GOSUB 2970
4760 PRINT "NAME OF PARAMETER ";
4770 INPUT P$
4780 PRINT "RANGE - LOW, HIGH, STEP ";
4790 INPUT L,H,S
4800 PRINT "NUMBER OF ACCOUNTS AFFECTED ";
4810 INPUT N
4820 FOR I=1 TO N
4830 PRINT "ACCOUNT, LINE ";
4840 INPUT V3(I),V4(I)
```

```
4850 NEXT I
4860 PRINT
4870 FOR I1=L TO H STEP S
4880 FOR I=1 TO N
4890 Z(V3(I),V4(I))=I1
4900 NEXT I
4910 GO TO 840
4920 IF E2=0 THEN 4950
4930 PRINT "RFR=";R1;"$/TON WHEN PARAMETER=";I1
4940 GO TO 4960
4950 PRINT "NPV=";V2;"$ WHEN PARAMETER=";I1
4960 NEXT I1
4970 GO TO 2860
4980 REM+++++++++++++++++++++++++ OUTPUT OPTIONS ++++++++++++++++++
4990 PRINT "<<<<< OUTPUT OPTIONS >>>>>"
5000 PRINT "1 = (ENTER NEW DATA FILE)"
5010 PRINT "2 = (MODIFY CURRENT DATA FILE)"
5020 PRINT "3 = VOYAGE DATA"
5030 PRINT "4 = PRESENT VALUE DATA"
5040 PRINT "5 = RFR OR NPV"
5050 PRINT "6 = COSTS BY MONTHS"
5060 PRINT "7 = PARAMETRIC STUDY"
5070 PRINT "8 = LIST OF OUTPUT OPTIONS"
5080 PRINT "STOP = TERMINATE PROGRAM EXECUTION"
5090 GO TO 2860
5100 PRINT "<<<<< OUTPUT OPTIONS >>>>>"
5110 PRINT "1 = (ENTER NEW DATA FILE)"
5120 PRINT "2 = (MODIFY CURRENT DATA FILE)"
5130 PRINT "8 = LIST OF OUTPUT OPTIONS"
5140 PRINT "STOP = TERMINATE PROGRAM EXECUTION"
5150 GO TO 2920
```

FIGURE B6
<u>PROGRAM "GENEC1"</u>

A1	Average annual cost coefficient (capitalized costs)
A2	Average annual cost coefficient (operating costs)
C	Escalated cost
C1(J)	Cost of fuel per voyage, not escalated, port (J)
C2	Escalated value of tons of cargo off-loaded
C3(J)	Basic monthly cost, account (J)
C4(I)	Monthly cost, output column (I)
D(J)	Discounted value of cost, account (J)
D$	Date of program execution
D1	Total discounted value of all operating cost accounts
D2(J)	Days in port (J)
D3(J)	Days at sea after port (J)
D4	Days per round trip
D5	Total discounted value of all capitalized cost accounts
D6(Y)	Operating days, year (Y)
E(J)	Discounted value of tons of cargo off-loaded at port (J)
E1	Total discounted dollar value of cargo off-loaded at ports with specified freight rates
E2	Total discounted value of tons of cargo off-loaded at ports with unspecified freight rates
F	Total tons of fuel used for round trip
F$	Name of data file
F1(J)	Tons of fuel on board, arriving port (J)
F1$	Identification of data file
F2(J)	Tons of fuel burned in port (J)
F3(J)	Tons of fuel loaded, port (J)
F4(J)	Tons of fuel on board, leaving port (J)
F5(J)	Tons of fuel burned at sea after port (J)
H	High value for parametric study range
I	Index
I1	Index for parametric variation
J	Account
K	Month (date of contract = 1)
K1	First month for cost calculation
K2	Last month for cost calculation

LIST OF SYMBOLS (Cont'd)

K3(I)	Index for monthly cost subroutine, column (I)
K4(I)	Index for monthly cost subroutine, column (I)
K5(J)	Index to show when "operating days" are used as a multiplier for account (J)
L	Low value for parametric study range
M(J,I)	Month cost is incurred, account (J), Table B line (I)
M1	Index for modifications to data file
N	Number of accounts affected by parametric variation
N$(J)	Name of account (J)
N1$	Name of ship
P(J,I)	Percentage of total cost, account (J), Table B line (I)
P$	Name of parametric variable
P1(J)	Index for irregular payment schedule, account (J)
Q1	Index for output option
R(J)	Freight rate (not escalated), port (J)
R1	Required Freight Rate (RFR), not escalated
S	Step value for parametric study range
T$	Time of program execution
T1/T7	Temporary variables
V1	Average round trips per year of period being analyzed
V2	Net present value
V3(N)	Account number affected by parametric variation, case (N)
V4(N)	Line number affected by parametric variation, case (N)
W1(J)	Tons of cargo loaded, port (J)
W2(J)	Tons of cargo off-loaded, port (J)
W3(J)	Tons of cargo on board, leaving port (J)
W4(J)	Tons of ballast on board, leaving port (J)
Y	Year (first year after delivery = 1)
Z(J,I)	Input data, account (J), input data sheet line (I)

where;

P = Present value ($)

F = Future value ($)

d = Discount rate (%)

m = Months from date of contract

Both "escalation" and "present value" normally refer to the dollar value of a transaction. When the RFR is unknown, however, it is convenient to apply these formulas to the tons of cargo off-loaded. The resulting numbers are then multiplied by RFR (when it is determined) to get the corresponding values for income. Mathematically, this has the same result as applying the formulas directly to income, but it makes the calculation of RFR much simpler.

3.2 Costs and Scrap Value

Cost accounts are identified as "operating" or "capitalized". This distinction has no effect when the economic study covers the entire life of the ship, but it is needed when the study is limited to only a part of that life. Operating costs which occur during the period being studied are included in the analysis; operating costs which do not occur during that period are ignored. All capitalized costs are included regardless of when they occur. The expected scrap or resale payment is treated as a (negative) capitalized cost.

Average annual cost for an operating account is defined as "the uniform annual cost, payable in equal monthly installments over a specified period of the life of the ship, which would have the same present value as all expenses incurred during that period by the operating cost account." It is calculated by the formula:

$$A = P\left\{\frac{12\left[\left(1+\frac{d}{100}\right)^{\left(\frac{m+1}{12}+Y1-1\right)}\right]\left[\frac{1}{\left(1+\frac{d}{100}\right)^{(1/12)}}-1\right]}{\left[\frac{1}{\left(1+\frac{d}{100}\right)^{(Y2-Y1+1)}}-1\right]}\right\}$$

where;

A = Average annual cost ($)

P = Present value of account ($)

d = Discount rate (%)

m = Months from contract to delivery

Y1 = First year (after delivery) of period being studied

Y2 = Last year (after delivery) of period being studied

Capitalized costs are amortized over the total ship life, regardless of the period of time being analyzed. When this period is shorter than the total ship life, only the amortization payments made during the shorter period are included in the analysis. The present value of such a capitalized cost is the present value of these amortization payments, not of the actual cost payments. This permits the remaining amortization to be accomplished during the portion of ship life excluded from the study.

Average annual cost (amortization payment) for a capitalized expense is defined as "the uniform annual cost, payable in equal monthly installments over the operating life of the ship, which would have the same present value as all expenses of the capitalized cost account." It is calculated by the formula:

$$A = P \left\{ \frac{12 \left[\left(1 + \frac{d}{100}\right)^{\left(\frac{m+1}{12}\right)} \right] \left[\frac{1}{\left(1 + \frac{d}{100}\right)^{(1/12)}} - 1 \right]}{\left[\frac{1}{\left(1 + \frac{d}{100}\right)^{(Y)}} - 1 \right]} \right\}$$

where;

A = Average annual cost ($)

P = Present value of account ($)

d = Discount rate (%)

m = Months from contract to delivery

Y = Years of ship life

3.3 Measures of Merit

Required Freight Rate (RFR) is defined as "that freight rate which makes the present value of all income equal to the present value of all expenses". It can be calculated for all the cargo delivered in a round voyage, or for some of that cargo (which may be delivered at one or more ports of a multi-leg voyage) when freight rates are specified for the remaining cargo, using the formula:

$$RFR = \frac{P_c - P_i}{P_d}$$

where;

RFR = Required Freight Rate ($/ton)

P_c = Present value of all costs ($)

P_i = Present value of specified income ($)

P_d = Present value of all cargo delivered with unspecified freight rate (tons)

Net Present Value (NPV) is defined as "the difference between the present value of all income and the present value of all expenses." It is calculated only when freight rates are specified for all the cargo delivered in a round voyage. The formula is:

$$NPV = P_c - P_i$$

where;

NPV = Net Present Value ($)

P_c = Present value of all costs ($)

P_i = Present value of specified income ($)

4. INPUT

Program "GENEC1" requires a separate data file. Figures B1 - B4 are the input sheets used for this file, and Figure B7 is a listing of a sample file. Any number of such data files may be prepared and saved. They are used one at a time and are called for as needed during program execution.

Each data file has line numbers separated by one blank space from the succeeding data items (these line numbers are not used by the program). Data items are separated by commas, with a comma at the end of each line, and alphanumeric items are enclosed in quotation marks. Line numbers on the input sheets are not used in the data file, but are used when modifying data during program execution.

5. OUTPUT

Program "GENEC1" can produce any or all of the six sets of output shown in Figures B8 - B14 (identified as Type 3, Type 4, Type 5, Type 6, Type 7 and Type 8), as selected during program execution.

Type 3 output (Voyage Data) is shown in Figure B8. This output contains four blocks of data. The first block identifies the data file used. The next two blocks give information on each port visited, and on the sea trip to the next port. (If the data file had held information on more or less than two ports then there would have been more or less than two such blocks of output.) The final block gives the total time per round trip and the average number of trips per year.

Type 4 output (Present Value Data) is shown in Figures B9 and B10. This output also contains four blocks of data. The first block identifies the data file used. The second block, "INCOME," shows the amount of cargo off-loaded at each port, its freight rate, escalation, and present value. It also gives the total present value of all income. The third block, "EXPENSES," gives the average annual cost, escalation rate, and present value of each expense account. It also gives the total present value of all expenses, the percentage share of that total which is attributable to each account, and the amount of RFR which is attributable to each account. If RFR was calculated, the fourth block gives its value, RFR, as shown in Figure B9. If a freight rate was specified at every

FIGURE B7

SAMPLE DATA FILE

```
*LIST SAMPLE

1 "FILE SAVED AT 10.414 ON 09/05/80",
10 "EXAMPLE SHIP",2,3,8,9,36,20,30,-1,250000,100000,
11 100,150,850,12000,1,20,
12 360,350,360,340,360,350,360,340,360,350,
13 360,340,360,350,360,340,360,350,360,365,
20 "LOADING PORT",2,12000,15.3,38,165.3,-1,87.19,5,-1,0,0,0,
30 "DISCHARGE PORT",2,12000,17.82,138.8,165.3,0,0,0,0,-1,-1,0,
40 "ACQUISITION",120000000,6,0,1,0,1,0,1,6,6,
41 6,1,12,5,18,14,24,28,30,35,36,17,
50 "CONSTR. ADMIN.",7000,8,0,1,0,1,0,1,5,1,
60 "SCRAP VALUE",5000000,6,0,-1,0,1,0,1,1,276,
70 "MANNING",50000,8.5,1,7,-1,12,0,1,5,1,
80 "SUBSISTENCE",5.15,8,1,7,1,8,-1,12,5,1,
90 "H & M INSURANCE",1.125,0,4,1,-1,100,0,1,4,12,
100 "P & I INSURANCE",1.25,4,1,9,0,1,0,1,4,12,
110 "STORES & SUPPLIES",150000,7.5,-1,12,0,1,0,1,5,1,
120 "PORT CHARGES",140000,6,0,1,0,1,0,1,3,1,
130 "ROUTINE MAINT.",300000,8,-1,12,0,1,0,1,5,1,
140 "REPAIR/OVERHAUL",1000000,8,0,1,0,1,0,1,6,19,
141 12,15,24,25,36,15,48,50,60,15,72,25,84,15,96,100,
142 108,15,120,25,132,15,144,50,156,15,168,25,180,15,192,100,
143 204,15,216,25,228,15,
```

FIGURE B8

SAMPLE OUTPUT, TYPE 3

```
OUTPUT ?3

EXAMPLE SHIP
     DATA FILE: SAMPLE
     FILE SAVED AT 10.414 ON 09/05/80
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< LOADING PORT >>>>>
NEXT LEG OF VOYAGE=   12000 MILES AT 15.30 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        76 TONS OF FUEL
TIME AT SEA       =   32.68 DAYS, USING      5402 TONS OF FUEL
FUEL LOADED       =   10394 TONS
CARGO LOADED      =  238582 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     100 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =   10318 TONS
     RESERVE FUEL =     850 TONS
     CARGO        =  238582 TONS
        TOTAL     =  250000 TONS
MAXIMUM DEADWEIGHT=  250000 TONS

<<<<< DISCHARGE PORT >>>>>
NEXT LEG OF VOYAGE=   12000 MILES AT 17.82 KNOTS
TIME IN PORT      =    2.00 DAYS, USING       278 TONS OF FUEL
TIME AT SEA       =   28.06 DAYS, USING      4638 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=  238582 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     100 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =   94262 TONS
     SERVICE FUEL =    4638 TONS
     RESERVE FUEL =     850 TONS
     CARGO        =       0 TONS
        TOTAL     =  100000 TONS
MAXIMUM DEADWEIGHT=  250000 TONS

TOTAL DAYS, ROUND TRIP= 64.7381
AVERAGE NUMBER OF TRIPS PER YEAR=   5.464325
```

FIGURE B9

SAMPLE OUTPUT, TYPE 4 (RFR)

OUTPUT ?4

EXAMPLE SHIP
DATA FILE: SAMPLE
FILE SAVED AT 10.414 ON 09/05/80
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
LOADING PORT	0	.00	.00	0
DISCHARGE PORT	1303692	25.07	.00	239578
TOTAL	1303692			239578

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
LOADING PORT	8482	5.00	25.97	62217	6.51
DISCHARGE PORT	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	15383	6.00	47.10	112836	11.81
CONSTR. ADMIN.	34	8.00	.10	248	.03
SCRAP VALUE	-359	6.00	-1.10	-2631	-.28
.....OPERATING.....					
MANNING	3853	8.50	11.80	28264	2.96
SUBSISTENCE	132	8.00	.41	971	.10
H & M INSURANCE	1414	.00	4.33	10372	1.09
P & I INSURANCE	491	4.00	1.50	3604	.38
STORES & SUPPLIES	342	7.50	1.05	2512	.26
PORT CHARGES	1468	6.00	4.49	10767	1.13
ROUTINE MAINT.	726	8.00	2.22	5328	.56
REPAIR/OVERHAUL	694	8.00	2.12	5090	.53
TOTAL	32662			239578	25.07

CALCULATED RFR= 25.06971 $/TON AT DATE OF CONTRACT

FIGURE B-10

SAMPLE OUTPUT, TYPE $ (NPV)

```
OUTPUT 74

EXAMPLE SHIP
     DATA FILE: SAMPLE
     FILE SAVED AT 10.414 ON 09/05/80
     FILE MODIFIED AT  9.955 ON 09/09/80
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS
```

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
LOADING PORT	0	.00	.00	0
DISCHARGE PORT	1412978	25.00	.00	258940
TOTAL	1412978			258940

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
LOADING PORT	8482	5.00	25.94	62217	.00
DISCHARGE PORT	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	15383	6.00	47.04	112836	.00
CONSTR. ADMIN.	34	8.00	.10	248	.00
SCRAP VALUE	-359	6.00	-1.10	-2631	.00
.....OPERATING.....					
MANNING	3853	8.50	11.78	28264	.00
SUBSISTENCE	132	8.00	.40	971	.00
H & M INSURANCE	1414	.00	4.32	10372	.00
P & I INSURANCE	531	4.00	1.62	3892	.00
STORES & SUPPLIES	342	7.50	1.05	2512	.00
PORT CHARGES	1468	6.00	4.49	10767	.00
ROUTINE MAINT.	726	8.00	2.22	5328	.00
REPAIR/OVERHAUL	694	8.00	2.12	5090	.00
TOTAL	32701			239867	.00

NET PRESENT VALUE= 19073000 $

FIGURE B11

SAMPLE OUTPUT, TYPE 1, 2, & 5

```
•OLD GENEC1
•RUN


OUTPUT OPTION 8 WILL LIST ALL OUTPUT OPTIONS
DATA FILE ?SAMPLE
FILE SAVED AT 10.414 ON 09/05/80
NEW DATA          9.821          09/09/80
?0,0,0

OUTPUT ?5

CALCULATED RFR=   25.06971 $/TON AT DATE OF CONTRACT

OUTPUT ?2

FILE SAVED AT 10.414 ON 09/05/80
NEW DATA          9.826          09/09/80
?3,11,25
?0,0,0

OUTPUT ?5

NET PRESENT VALUE=   -666000 $

OUTPUT ?2

FILE SAVED AT 10.414 ON 09/05/80
FILE MODIFIED AT  9.826 ON 09/09/80
NEW DATA          9.833          09/09/80
?1,9,270000
?0,0,0

OUTPUT ?5

NET PRESENT VALUE=  19073000 $

OUTPUT ?1

DATA FILE ?SAMPLE
FILE SAVED AT 10.414 ON 09/05/80
NEW DATA          9.843          09/09/80
?0,0,0

OUTPUT ?5

CALCULATED RFR=   25.06971 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

READY
```

FIGURE B12

SAMPLE OUTPUT, TYPE 6

```
OUTPUT ?6

WHAT ACCOUNTS ?2,4,8,9,14
WHAT MONTHS ?35,62

EXAMPLE SHIP
     DATA FILE: SAMPLE
     FILE SAVED AT 10.414 ON 09/05/80
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< COSTS BY MONTHS >>>>>
MONTH LOADING PORT  ACQUISITION  SUBSISTENCE H & M INSURA REPAIR/OVERH
  35             0            0            0            0            0
  36             0     24296725            0      1350000            0
+++++FIRST MONTH OF OPERATING EXPENSES INCLUDED IN ANALYSIS
  37        488122            0         5876            0            0
  38        490110            0         5914            0            0
  39        492107            0         5952            0            0
  40        494112            0         5990            0            0
  41        496125            0         6029            0            0
  42        498146            0         6068            0            0
  43        500176            0         6107            0            0
  44        502214            0         6146            0            0
  45        504260            0         6186            0            0
  46        506314            0         6225            0            0
  47        508377            0         6266            0            0
  48        510448            0         6306      1350000       204073
  49        498291            0         6170            0            0
  50        500321            0         6210            0            0
  51        502359            0         6250            0            0
  52        504406            0         6290            0            0
  53        506461            0         6330            0            0
  54        508524            0         6371            0            0
  55        510596            0         6412            0            0
  56        512676            0         6453            0            0
  57        514765            0         6495            0            0
  58        516862            0         6537            0            0
  59        518968            0         6579            0            0
  60        521082            0         6621      1350000       367332
  61        538154            0         6854            0            0
  62        540346            0         6898            0            0
```

FIGURE B13

SAMPLE OUTPUT, TYPE 7

```
OUTPUT ?7

---------- PARAMETRIC STUDY ----------
EXAMPLE SHIP
      DATA FILE: SAMPLE
      FILE SAVED AT 10.414 ON 09/05/80
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

NAME OF PARAMETER ?DEADWEIGHT
RANGE - LOW, HIGH, STEP ?230000,270000,20000
NUMBER OF ACCOUNTS AFFECTED ?1
ACCOUNT, LINE ?1,9

RFR=   27.33062 $/TON WHEN PARAMETER=  230000
RFR=   25.06971 $/TON WHEN PARAMETER=  250000
RFR=   23.15853 $/TON WHEN PARAMETER=  270000

OUTPUT ?2

FILE SAVED AT 10.414 ON 09/05/80
NEW DATA        9.955          09/09/80
?3,11,25
?0,0,0

OUTPUT ?7

---------- PARAMETRIC STUDY ----------
EXAMPLE SHIP
      DATA FILE: SAMPLE
      FILE SAVED AT 10.414 ON 09/05/80
      FILE MODIFIED AT  9.955 ON 09/09/80
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

NAME OF PARAMETER ?DEADWEIGHT
RANGE - LOW, HIGH, STEP ?230000,270000,20000
NUMBER OF ACCOUNTS AFFECTED ?1
ACCOUNT, LINE ?1,9

NPV=-2.04055E 07    $ WHEN PARAMETER=  230000
NPV= -666170 $ WHEN PARAMETER=  250000
NPV= 1.90732E 07    $ WHEN PARAMETER=  270000
```

FIGURE B14

SAMPLE OUTPUT, TYPE 8

```
OUTPUT ?8

<<<<< OUTPUT OPTIONS >>>>>
1 = <ENTER NEW DATA FILE>
2 = <MODIFY CURRENT DATA FILE>
3 = VOYAGE DATA
4 = PRESENT VALUE DATA
5 = RFR OR NPV
6 = COSTS BY MONTHS
7 = PARAMETRIC STUDY
8 = LIST OF OUTPUT OPTIONS
STOP = TERMINATE PROGRAM EXECUTION
```

port where cargo was off-loaded, the present value of income will not necessarily equal the present value of expenses and the difference is NPV. In this case, the fourth block gives NPV, and RFR in the third block is set equal to zero, as shown in Figure B10.

Type 5 output (RFR or NPV Data) is shown in Figure B11. This is a single line which shows RFR (if that was calculated) or NPV (if all the freight rates were given).

Type 6 output (Costs by Months) is shown in Figure B12. It contains three blocks of data. The first block identifies the account numbers and months for which output is desired. The second block identifies the data file used. The third block gives the actual cost for each specified account for each specified month. These costs include escalation but have not been "present valued." (In Figure B12 the account labeled "LOADING PORT" refers to fuel purchased at that port.)

Type 7 output (Parametric Study) is shown in Figure B13. It contains three blocks of data. The first block identifies the data file used. The second block identifies the parameter being varied and its range. The third block shows the RFR (if that was calculated) or NPV (if all the freight rates were given) for each value of the parameter.

Type 8 output (List of Output Options) is shown in Figure B14. It gives a list of the titles of all output options for ready reference.

There also are a number of program-generated messages which may appear with any of this output. These messages are described in Section 6.3.

6. OPERATION

6.1 Input Selection and Modification

Figure B11 illustrates the operation of this program. When the command "RUN" is given, the computer will print "OUTPUT OPTION 8 WILL LIST ALL OUTPUT OPTIONS" as a reminder of how to obtain a list of these options. It will then ask "DATA FILE?". The response is the name of a previously saved data file. The computer then prints the file identification (input sheet Account 1), and a time-of-run identification: "NEW DATA (time)(date)." Next it asks for input by printing "?". The response is three numbers (X, Y, Z) separated by commas. The first of these numbers tells the computer what to do. It has the following meanings:

X = 0: Execute program with current data

X > 0: Substitute Z for the number currently given in Account X, Line Y.

When X refers to Account 1 and Y refers to Line 6 or 8, the change may involve Table A of Figure B1. If this happens, the computer will print "INPUT OPERATING DAYS/YEAR FOR (N) YEARS", where (N) is the number of years of ship life (Line 6). It will then ask for input N times. Each response is the number of operating days in the corresponding year (arranged sequentially from 1 to N).

When X refers to a "cost" account and Y refers to Line 9 of that account and Z is "6", the change will involve Table B (Figure B4). In this case, the computer will ask "HOW MANY CHANGES?". The response is (N), the number of changes to Table B. The computer will then ask for input (N) times. Each time the response is three numbers (A, B, C) separated by commas. These numbers have the following meanings:

A = Line number of Table B

B = "Month" for Line (A)

C = "Percentage" for Line (A)

6.2 Output Selection

The computer will continue to ask for data changes until it is directed to execute the program as described above (this command is usually given as "0,0,0"). It will then ask "OUTPUT?". The response is a number from 1 to 8 with the following meanings:

1 = No output. The computer will print "DATA FILE?" and will accept the name of a new data file as shown in Figure B11.

2 = No output. The computer will print "NEW DATA (time)(date)" and will accept new data as shown in Figures B11 and B13.

3 = Print "Voyage Data" as shown in Figure B8.

4 = Print "Present Value Data" as shown in Figures B9 and B10.

5 = Print RFR or NPV as shown in Figure B11.

6 = Print "Costs by Months" as shown in Figure B12.

7 = Execute a parametric study and print results as shown in Figure B13.

8 = Print a list of the output options as shown in Figure B14.

If output option "6" is selected (Figure B12), the computer will ask "WHAT ACCOUNTS?". The response is five numbers separated by commas. These are the numbers of the cost accounts to be printed. If this number refers to a "port" account, the values printed will be the cost of fuel at that port. (There is no cost account #1.) The computer will then ask "WHAT MONTHS?". The response is two numbers separated by a comma. These are the earliest and latest of the series of months (after contract) to be printed.

If output option "7" is selected (Figure B13), the computer will print a block of identification data and then will ask "NAME OF PARAMETER?" The response is an alphanumeric description of the parameter. The computer will then ask "RANGE - LOW, HIGH, STEP?" The response is three numbers separated by commas. It will then ask "NUMBER OF ACCOUNTS AFFECTED?" The response is the number of places (P) where the parametric variable occurs. Most variables occur only once, but some (escalation, for example) may occur in several places. Currently, the dimension statements of the program limit the number of occurrences to 10, but this can easily be changed. The computer will then ask "ACCOUNT, LINE?" and wait for input P times. Each time the response is two numbers separated by a comma.

After the desired output has been printed, the computer will again ask "OUTPUT?" so that program execution can continue with as many data files, data changes and sets of output as needed. Any data changes which are input in response to the question "NEW DATA?" remain in the program for the duration of that run. Subsequent responses to this question may modify that data again, or may modify other data, but the original numbers are not restored unless the entire file is reloaded in response to the question "DATA FILE?". This is illustrated in Figure B11.

When no further runs are desired, the response "STOP" will terminate the program.

6.3 Computer Generated Messages

There are several computer-generated information messages, not described above, which may appear during program execution. These are:

6.3.1 "FILE MODIFIED AT (time) ON (date)"

This message appears as a fourth line in the block of output which identifies the data file used (output options "2", "3", "4", "6", and "7"). It appears when changes have been made to that data file during program execution.

6.3.2 "SHIP CAN ONLY LOAD (xxx) TONS OF FUEL AT (port)"

This message appears when the amount of fuel specified by the input data file to be loaded at this port, plus the fuel already on board, is greater than the capacity of the F.O. tanks. The program continues with the reduced amount of fuel on board.

6.3.3 "SHIP MUST LOAD (xxx) TONS OF FUEL AT (port)"

This message appears when the amount of service fuel on board is less than the amount needed to reach the next port and the input data file does not call for fuel to be loaded. The program continues with the increased amount of fuel on board.

6.3.4 "OUT OF FUEL AFTER (port)"

This message appears when the amount of service fuel on board (with all F.O. tanks full) is not sufficient to reach the next port. It terminates execution of the run; the computer will ask "OUTPUT (MUST BE 1, 2 OR 8)?" and will proceed accordingly.

6.3.5 "NO COST DATA FOR FUEL AT (port)"

This message appears when fuel is loaded at a port but the input data file does not include cost data for that fuel. It terminates execution of the run; the computer will ask "OUTPUT (MUST BE 1, 2 OR 8)?" and will proceed accordingly.

6.3.6 "SHIP CAN ONLY OFFLOAD (xxx) TONS OF CARGO AT (port)"

This message appears when the input data file specifies an amount of cargo to be off-loaded which is greater than the amount of cargo on board. The program continues with the reduced amount of cargo off-loaded.

6.3.7 "SHIP CAN ONLY LOAD (xxx) TONS OF CARGO AT (port)"

This message appears when the input data file specifies an amount of cargo to be loaded which would make the total deadweight on board (crew and stores, fresh water, service fuel, reserve fuel and cargo) greater than the maximum allowable deadweight. The program continues with the reduced amount of cargo loaded.

6.3.8 "TOO MANY IRREGULAR PAYMENT SCHEDULES"

This message appears when the input data file has more than five cost accounts with irregular payment schedules (input data sheet Line 9 = 6). It terminates execution of the run; the computer will ask "DATA FILE?" and will accept the name of a new data file as described above.

6.3.9 "ACCT. (number) CAPITAL COSTS CANNOT DEPEND ON OPER. DAYS"

This message appears when a capitalized cost account uses operating days (Account 1 Line 8) as a multiplier, or when it distributes the cost on a "per voyage" basis (Line 9 = 2 or 3). It terminates execution of the run; the computer will ask "OUTPUT (MUST BE 1, 2 OR 8)?" and will proceed accordingly.

6.3.10 "+++++ FIRST MONTH OF OPERATING EXPENSES INCLUDED IN ANALYSIS" "+++++ LAST MONTH OF OPERATING EXPENSES INCLUDED IN ANALYSIS"

These messages may appear as part of output 6, Costs by Months. They indicate the beginning and end of the period being analyzed. One of them is shown in Figure B12.

APPENDIX C

SENSITIVITY ANALYSES

CONTENTS

1. EXAMPLE COST CALCULATIONS USING CORROSION DATA SHEET

Tank Description - Product carrier inerted center tanks used for cargo only, full scantlings, fully coated with two coats epoxy.

Assumptions: Coating lasts 9 years (30% failure) and suffers a 2% failure after 2 years in service.

New construction costs for coating = $\$3.00/ft^2$

Repair costs for recoating = $\$3.55/ft^2$

Total surface area of cargo only center tanks (from data sheets) = $95,900\ ft^2$

Initial costs of coating = $\$3.00/ft^2 \times 95,900\ ft^2 = \$287,700$

Using Data Sheet attached (Figure C-1) and assuming 2% coating failures after 2 years, no steel reaches local wastage limits within life of coating.

Assuming coating lasts 9 years, the overall wastage limit is reached in 18 to 19 years on the transverse web plating in space "U", and the girder plates in the upper and lower tank sections, H_1 and H_2. However, tanks have to be recoated after 10 or 12 years to prevent contamination of cargo.

Recoat tanks in 12th year:

Cost - $\$3.55/ft^2 \times 95,900 = \$340,445$

CORROSION DATA SHEET
Sheet 1

Area of Tank	Steel Description	Thickness (in.) Reduced Scant.	Thickness (in.) Full Scant.	Weight (lb) Reduced	Weight (lb) Full	Surf. Area Ft^2	Upper Surf. Area Ft^2	Allow. Wastage (In.) Reduced Over All	Allow. Wastage (In.) Reduced Local	Allow. Wastage (In.) Full Over All	Allow. Wastage (In.) Full Local
UPPERMOST SPACE - U_1	Deck Plt.	0.625	0.625	257,000	257,000	10,000		0.031	0.094	0.094	0.156
	Deck Long'l.	0.6875	0.750	72,300	78,800	5,200		0.113	0.198	0.188	0.263
	Transv. Web Plt.	0.500 1.00	0.500 1.00	85,200 15,400	95,400 15,400	9,400 200		0.025 0.050	0.075 0.150	0.075 0.150	0.125 0.250
	Transv. Web Stiff.	0.375	0.375	1,600	1,600	200		0.018	0.056	0.056	0.084
	Swash Bhd. Plt.		NOT APPLICABLE								
	Swash Bhd. Stiff.		N.A.				N.A.				
	Long'l. Bhd. Plt.	← ASSIGNED TO WING TANKS →				2,900					
	Long'l. Bhd. Stiff.		N.A.								
	Transv. Bhd. Plt.	0.500	0.500	11,700	11,700	1,700		0.100	0.125	0.150	0.175
	Transv. Bhd. Stiff.	0.375	0.375	5,500	5,500	900		0.075	0.094	0.113	0.131
	Side Shell Plt.		N.A.								
	Side Shell Stiff.		N.A.								
	U_1 Totals			448,700	465,400	30,500	N.A.				
UPPER HALF - H_1	Horiz. Gird. Plt.	0.4375 1.00	0.500 1.00	44,500 13,000	50,200 13,000	4,900 600		0.025 0.050	0.075 0.150	0.075 0.150	0.125 0.250
	Horiz. Gird. Stiff	0.625 0.500	0.625 0.500	900 4000	900 4000	100 400		0.031 0.025	0.094 0.075	0.094 0.075	0.156 0.125
	Transv. Web Plt.	0.4375 0.750	0.500 0.750	7,600 4,500	8,600 4,500	300 300		0.025 0.038	0.075 0.113	0.075 0.113	0.125 0.188
	Transv. Web Stiff.		N.A.								
	Swash Bhd. Plt.		N.A.								
	Swash Bhd. Stiff.		N.A.				N.A.				
	Long'l. Bhd. Plt.	← ASSIGNED TO WING TANKS →				9,200					
	Long'l. Bhd. Stiff.		N.A.								
	Transv. Bhd. Plt.	0.500	0.500	38,300	38,300	3,600		0.100	0.125	0.150	0.175
	Transv. Bhd. Stiff.	0.375	0.375	19,100	19,100	3,100		0.075	0.094	0.113	0.131
	Side Shell Plt.		N.A.								
	Side Shell Stiff.		N.A.								
	H_1 Totals			131,900	138,600	25,000	N.A.				
LOWER HALF - H_2	Horiz. Gird. Plt.	0.4375	0.500	60,000	66,000	5,600		0.025	0.075	0.075	0.120
	Horiz. Gird. Stiff.	0.500	0.500	5,400	5,400	600		0.025	0.075	0.075	0.125
	Transv. Web Plt.		N.A.								
	Transv. Web Stiff.		N.A.								
	Swash Bhd. Plt.		N.A.								
	Swash Bhd. Stiff.		N.A.								
	Long'l. Bhd. Plt.	← ASSIGNED TO WING TANKS →				4,800	N.A.				
	Long'l. Bhd. Stiff.		N.A.								
	Transv. Bhd. Plt.	0.500	0.5625	40,200	47,700	6,000		0.113	0.141	0.169	0.197
	Transv. Bhd. Stiff.	0.375	0.375	23,300	23,300	3,300		0.075	0.094	0.113	0.131
	Side Shell Plt.		N.A.								
	Side Shell Stiff.		N.A.								
	Bottom Long'l.		N.A.								
	H_2 Totals			128,900	144,400	20,300	N.A.				
B	Inner Bottom Plt.	0.500	0.625	205,500	257,000	20,100	N.A.	0.063	0.094	0.125	0.156
	GRAND TOTALS			915,000	1,005,400	95,900					

CORROSION DATA SHEET
Sheet 2

Area of Tank	Steel Description	No. of Sides Corr.	Corr. Rate In/Yr	Wastage Limit Reached (Yrs.) Reduced Over All	Reduced Local	Full Over All	Full Local	Cathodic Protect. (Anodes) Corr. Rate In/Yr	Wast. Limit Reachd (Yrs) Reduced Over All	Reduced Local	Full Over All	Full Local
UPPERMOST SPACE - U_1	Deck Plt.	1	0.007			13.4	20+					
	Deck Longit.	2	0.004			20+	20+					
	Transv. Web Plt.	2	0.003			12.7 20+	20+ 20+					
	Transv. Web Stiff.	2				9.3	14.0					
	Swash Bhd. Plt.	N.A.										
	Swash Bhd. Stiff.	N.A.							NOT	APPLICABLE		
	Long'l. Bhd. Plt.	N.A.										
	Long'l. Bhd. Stiff.	N.A.										
	Transv. Bhd. Plt.	1				20+	20+					
	Transv. Bhd. Stiff.	2				19.0	20+					
	Side Shell Plt.	N.A.										
	Side Shell Stiff.	N.A.										
	U_1 Totals											
UPPER HALF - H_2	Horiz. Gird. Plt.	2	0.004			9.5 18.8	15.8 20+					
	Horiz. Gird. Stiff.	2	0.003			15.7 12.7	20+ 20+					
	Transv. Web Plt.	2				12.7 19.0	20+ 20+					
	Transv. Web Stiff.	N.A.										
	Swash Bhd. Plt.	N.A.										
	Swash Bhd. Stiff.	N.A.								N.A.		
	Long'l. Bhd. Plt.	N.A.										
	Long'l. Bhd. Stiff.	N.A.										
	Transv. Bhd. Plt.	1				20+	20+					
	Transv. Bhd. Stiff.	2				19.0	20+					
	Side Shell Plt.	N.A.										
	Side Shell Stiff.	N.A.										
	H_1 Totals											
LOWER HALF - H_2	Horiz. Gird. Plt.	2	0.004			9.5	20+					
	Horiz. Gird. Stiff.	2	0.002			19.0	20+					
	Transv. Web Plt.	N.A.										
	Transv. Web Stiff.	N.A.										
	Swash Bhd. Plt.	N.A.										
	Swash Bhd. Stiff.	N.A.										
	Long'l. Bhd. Plt.	N.A.								N.A.		
	Long'l. Bhd. Stiff.	N.A.										
	Transv. Bhd. Plt.	1				20+	20+					
	Transv. Bhd. Stiff.	2				20+	20+					
	Side Shell Plt.	N.A.										
	Side Shell Stiff.	N.A.										
	Bottom Long'l.	N.A.										
	H_2 Totals					-						
B	Inner Bottom Plt.	1	0.005			20+	20+			N.A.		

2. PROGRAM OUTPUT

OUTPUT ?3

```
285000 DWT CRUDE CARRIER A
     DATA FILE: CRUDEA
     FILE SAVED AT 11.045 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  271738 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =     9679 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =   271738 TONS
        TOTAL     =   282900 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =    77289 TONS
     SERVICE FUEL =     4428 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =        0 TONS
        TOTAL     =    83200 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   [illegible]
```

FIGURE C-2 CRUDE CARRIER, SYSTEM A, RESALE 11%

OUTPUT 14

285000 DWT CRUDE CARRIER A
DATA FILE: CRUDEA
FILE SAVED AT 11.045 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1523013	23.55	4.00	430331
TOTAL	1523013			430331

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19315	9.00	39.93	171849	9.40
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	21299	.00	44.04	189500	10.37
RESALE VALUE	-1623	8.00	-3.36	-14442	-.79
.....OPERATING.....					
H & M INSURANCE	2244	.00	4.64	19965	1.09
P & I INSURANCE	372	.00	.77	3312	.18
MANNING	4141	8.50	8.56	36843	2.02
PROVISIONS & STORES	563	7.50	1.16	5005	.27
PORT CHARGES	1251	6.00	2.59	11134	.61
REPAIRS	360	7.50	.74	3203	.18
CORROSION CONTROL	445	7.50	.92	3962	.22
TOTAL	48368			430331	23.55

CALCULATED RFR= 23.54596 $/TON AT DATE OF CONTRACT

OUTPUT [illegible]

FIGURE C2 (Continued)

```
OUTPUT 03

285000 DWT CRUDE CARRIER B
     DATA FILE: CRUDEB
     FILE SAVED AT 11.300 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=    11169 MILES AT 15.00 KNOTS
TIME IN PORT       =     2.00 DAYS, USING         84 TONS OF FUEL
TIME AT SEA        =    31.02 DAYS, USING       5166 TONS OF FUEL
FUEL LOADED        =     9763 TONS
CARGO LOADED       =   273524 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=       500 TONS
     FRESH WATER  =       150 TONS
     BALLAST  .   =         0 TONS
     SERVICE FUEL =      9679 TONS
     RESERVE FUEL =       833 TONS
     CARGO        =    273524 TONS
        TOTAL     =    284686 TONS
MAXIMUM DEADWEIGHT=    284686 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=    11169 MILES AT 17.50 KNOTS
TIME IN PORT       =     2.00 DAYS, USING         84 TONS OF FUEL
TIME AT SEA        =    26.59 DAYS, USING       4428 TONS OF FUEL
FUEL LOADED        =        0 TONS
CARGO LOADED       =        0 TONS, OFFLOADED=   273524 TONS
DEPARTURE WEIGHTS
     CREW & STORES=       500 TONS
     FRESH WATER  =       150 TONS
     BALLAST      =     77289 TONS
     SERVICE FUEL =      4428 TONS
     RESERVE FUEL =       833 TONS
     CARGO        =         0 TONS
        TOTAL     =     83200 TONS
MAXIMUM DEADWEIGHT=    284686 TONS

TOTAL DAYS, ROUND TRIP=    61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=    5.5722[illegible]
```

FIGURE C-3 CRUDE CARRIER, SYSTEM B, RESALE 8%

OUTPUT 24

285000 DWT CRUDE CARRIER B
DATA FILE: CRUDEB
FILE SAVED AT 11.300 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1524145	23.62	4.00	432166
TOTAL	1524145			432166

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19204	9.00	39.53	170857	9.34
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20793	.00	42.81	185000	10.11
RESALE VALUE	-1152	8.00	-2.37	-10254	-.56
.....OPERATING.....					
H & M INSURANCE	2191	.00	4.51	19491	1.07
P & I INSURANCE	375	.00	.77	3333	.18
MANNING	4141	8.50	8.53	36843	2.01
PROVISIONS & STORES	563	7.50	1.16	5005	.27
PORT CHARGES	1244	6.00	2.56	11071	.61
REPAIRS	360	7.50	.74	3203	.18
CORROSION CONTROL	856	7.50	1.76	7617	.42
TOTAL	48574			432166	23.62

CALCULATED RFR= 23.62136 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-3 (Continued)

```
OUTPUT ?3

285000 DWT CRUDE CARRIER C
     DATA FILE: CRUDEC
     FILE SAVED AT 11.440 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING         84 TONS OF FUEL
TIME AT SEA       =   31.02 DAYS, USING       5166 TONS OF FUEL
FUEL LOADED       =    9763 TONS
CARGO LOADED      =  273524 TONS, OFFLOADED=         0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =    9679 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =  273524 TONS
        TOTAL     =  284686 TONS
MAXIMUM DEADWEIGHT=  284686 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT      =    2.00 DAYS, USING         84 TONS OF FUEL
TIME AT SEA       =   26.59 DAYS, USING       4428 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=  273524 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =   77289 TONS
     SERVICE FUEL =    4428 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =       0 TONS
        TOTAL     =   83200 TONS
MAXIMUM DEADWEIGHT=  284686 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.572248
```

FIGURE C-4 CRUDE CARRIER, SYSTEM C, RESALE 9%

OUTPUT ?4

285000 DWT CRUDE CARRIER C
DATA FILE: CRUDEC
FILE SAVED AT 11.440 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1524145	23.54	4.00	430738
TOTAL	1524145			430738

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19204	9.00	39.67	170859	9.34
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20804	.00	42.97	185093	10.12
RESALE VALUE	-1297	8.00	-2.68	-11541	-.63
.....OPERATING.....					
H & M INSURANCE	2192	.00	4.53	19501	1.07
P & I INSURANCE	375	.00	.77	3333	.18
MANNING	4141	8.50	8.55	36843	2.01
PROVISIONS & STORES	563	7.50	1.16	5005	.27
PORT CHARGES	1244	6.00	2.57	11071	.61
REPAIRS	360	7.50	.74	3203	.18
CORROSION CONTROL	828	7.50	1.71	7371	.40
TOTAL	48414			430738	23.54

CALCULATED RFR= 23.54207 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-4 (Continued)

OUTPUT 13

```
285000 DWT CRUDE CARRIER D
     DATA FILE: CRUDED
     FILE SAVED AT 11.560 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  271738 TONS, OFFLOADED=       0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =     9679 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =   271738 TONS
        TOTAL     =   282900 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =    77289 TONS
     SERVICE FUEL =     4428 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =        0 TONS
        TOTAL     =    83200 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

TOTAL DAYS- ROUND TRIP=    61.61796
AVERAGE NUMBER OF TRIPS PER YEAR=    [illegible]
```

FIGURE C-5 CRUDE CARRIER, SYSTEM D, RESALE 10%

OUTPUT ?4

285000 DWT CRUDE CARRIER D

DATA FILE: CRUDED

FILE SAVED AT 11.560 ON 04/03/81

EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1526982	23.39	4.00	428635
TOTAL	1526982			428635

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19366	9.00	40.20	172301	9.40
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20737	.00	43.04	184500	10.07
RESALE VALUE	-1437	8.00	-2.98	-12783	-.70
.....OPERATING.....					
H & M INSURANCE	2185	.00	4.53	19438	1.06
P & I INSURANCE	372	.00	.77	3312	.18
MANNING	4141	8.50	8.60	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1255	6.00	2.60	11163	.61
REPAIRS	360	7.50	.75	3203	.17
CORROSION CONTROL	635	7.50	1.32	5651	.31
TOTAL	48177			428635	23.39

CALCULATED RFR= 23.39051 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-5 (Continued)

```
OUTPUT ?3

285000 DWT CRUDE CARRIER E
      DATA FILE: CRUDEE
      FILE SAVED AT 8.045 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING       84 TONS OF FUEL
TIME AT SEA       =   31.02 DAYS, USING     5166 TONS OF FUEL
FUEL LOADED       =    9763 TONS
CARGO LOADED      =  271738 TONS, OFFLOADED=       0 TONS
DEPARTURE WEIGHTS
      CREW & STORES=     500 TONS
      FRESH WATER  =     150 TONS
      BALLAST   -  =       0 TONS
      SERVICE FUEL =    9679 TONS
      RESERVE FUEL =     833 TONS
      CARGO        =  271738 TONS
         TOTAL     =  282900 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT      =    2.00 DAYS, USING       84 TONS OF FUEL
TIME AT SEA       =   26.59 DAYS, USING     4428 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
      CREW & STORES=     500 TONS
      FRESH WATER  =     150 TONS
      BALLAST      =   77289 TONS
      SERVICE FUEL =    4428 TONS
      RESERVE FUEL =     833 TONS
      CARGO        =       0 TONS
         TOTAL     =   83200 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.250102
```

FIGURE C-6 CRUDE CARRIER, SYSTEM D Modified, RESALE 10%

OUTPUT ?4

285000 DWT CRUDE CARRIER E
DATA FILE: CRUDEE
FILE SAVED AT 8.045 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1426654	27.61	4.00	473495
TOTAL	1426654			473495

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	18093	9.00	34.00	160973	9.39
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20366	.00	38.27	181200	10.57
RESALE VALUE	-706	8.00	-1.33	-6277	-.37
.....OPERATING.....					
H & M INSURANCE	2146	.00	4.03	19090	1.11
P & I INSURANCE	372	.00	.70	3312	.19
MANNING	4141	8.50	7.78	36843	2.15
PROVISIONS & STORES	563	7.50	1.06	5005	.29
PORT CHARGES	1173	6.00	2.20	10436	.61
REPAIRS	360	7.50	.68	3203	.19
CORROSION CONTROL	6711	7.50	12.61	59710	3.48
TOTAL	53219			473495	27.61

CALCULATED RFR= 27.61223 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-6 (Continued)

```
OUTPUT ?3

285000 DWT CRUDE CARRIER D MOD.
      DATA FILE: CRUDEDMO
      FILE SAVED AT 11.560 ON 04/06/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  271738 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
      CREW & STORES=     500 TONS
      FRESH WATER  =     150 TONS
      BALLAST      =       0 TONS
      SERVICE FUEL =    9679 TONS
      RESERVE FUEL =     833 TONS
      CARGO        =  271738 TONS
         TOTAL     =  282900 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
      CREW & STORES=     500 TONS
      FRESH WATER  =     150 TONS
      BALLAST      =   77289 TONS
      SERVICE FUEL =    4428 TONS
      RESERVE FUEL =     833 TONS
      CARGO        =       0 TONS
         TOTAL     =   83200 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.615255
```

FIGURE C-7, CRUDE CARRIER, SYSTEM E, RESALE 5%

OUTPUT ?4

285000 DWT CRUDE CARRIER D MOD.
DATA FILE: CRUDEDMD
FILE SAVED AT 11.560 ON 04/06/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1525880	23.35	4.00	427228
TOTAL	1525880			427228

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19349	9.00	40.29	172151	9.41
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20671	.00	43.05	183914	10.05
RESALE VALUE	-1432	8.00	-2.98	-12742	-.70
.....OPERATING.....					
H & M INSURANCE	2178	.00	4.54	19376	1.06
P & I INSURANCE	372	.00	.78	3312	.18
MANNING	4141	8.50	8.62	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1253	6.00	2.61	11149	.61
REPAIRS	360	7.50	.75	3203	.18
CORROSION CONTROL	564	7.50	1.17	5017	.27
TOTAL	48019			427228	23.35

CALCULATED RFR= 23.35045 $/TON AT DATE OF CONTRACT

FIGURE C-7 (Continued)

```
OUTPUT 73

285000 DWT CRUDE CARRIER A
     DATA FILE: CRUDEA
     FILE SAVED AT 14.045 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  271738 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =     9679 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =   271738 TONS
        TOTAL     =   282900 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =    77289 TONS
     SERVICE FUEL =     4428 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =        0 TONS
        TOTAL     =    83200 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

TOTAL DAYS, ROUND TRIP=    61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=    5.604707
```

FIGURE C-8 CRUDE CARRIER, SYSTEM A, RESALE 10%

OUTPUT *A

285000 DWT CRUDE CARRIER A
DATA FILE: CRUDEA
FILE SAVED AT 14.045 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1523013	23.62	4.00	431644
TOTAL	1523013			431644

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19315	9.00	39.81	171849	9.40
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	21299	.00	43.90	189500	10.37
RESALE VALUE	-1476	8.00	-3.04	-13129	-.72
.....OPERATING.....					
H & M INSURANCE	2244	.00	4.63	19965	1.09
P & I INSURANCE	372	.00	.77	3312	.18
MANNING	4141	8.50	8.54	36843	2.02
PROVISIONS & STORES	563	7.50	1.16	5005	.27
PORT CHARGES	1251	6.00	2.58	11134	.61
REPAIRS	360	7.50	.74	3203	.18
CORROSION CONTROL	445	7.50	.92	3962	.22
TOTAL	48515			431644	23.62

CALCULATED RFR= 23.6178 $/TON AT DATE OF CONTRACT

OUTPUT *STOP

FIGURE C-8 (Continued)

```
OUTPUT 73

285000 DWT CRUDE CARRIER B
     DATA FILE: CRUDEB
     FILE SAVED AT 14.300 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA       =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED       =    9763 TONS
CARGO LOADED      =  273524 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =    9679 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =  273524 TONS
        TOTAL     =  284686 TONS
MAXIMUM DEADWEIGHT=  284686 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA       =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=  273524 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =   77289 TONS
     SERVICE FUEL =    4428 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =       0 TONS
        TOTAL     =   83200 TONS
MAXIMUM DEADWEIGHT=  284686 TONS

TOTAL DAYS, ROUND TRIP=    61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=    5.572248
```

FIGURE C-9 CRUDE CARRIER, SYSTEM B, RESALE 10%

OUTPUT 74

285000 DWT CRUDE CARRIER B
DATA FILE: CRUDEB
FILE SAVED AT 14.300 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1524145	23.48	4.00	429602
TOTAL	1524145			429602

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19204	9.00	39.77	170857	9.34
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20793	.00	43.06	185000	10.11
RESALE VALUE	-1441	8.00	-2.98	-12817	-.70
.....OPERATING.....					
H & M INSURANCE	2191	.00	4.54	19491	1.07
P & I INSURANCE	375	.00	.78	3333	.18
MANNING	4141	8.50	8.58	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1244	6.00	2.58	11071	.61
REPAIRS	360	7.50	.75	3203	.18
CORROSION CONTROL	856	7.50	1.77	7617	.42
TOTAL	48286			429602	23.48

CALCULATED RFR= 23.48124 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-9 (Continued)

```
OUTPUT ?3

285000 DWT CRUDE CARRIER C
     DATA FILE: CRUDEC
     FILE SAVED AT 14.440 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  273524 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =     9679 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =   273524 TONS
        TOTAL     =   284686 TONS
MAXIMUM DEADWEIGHT=   284686 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  273524 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =    77289 TONS
     SERVICE FUEL =     4428 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =        0 TONS
        TOTAL     =    83200 TONS
MAXIMUM DEADWEIGHT=   284686 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.572248
```

FIGURE C-10 CRUDE CARRIER, SYSTEM C, RESALE 10%

OUTPUT ?4

285000 DWT CRUDE CARRIER C
DATA FILE: CRUDEC
FILE SAVED AT 14.440 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1524145	23.47	4.00	429455
TOTAL	1524145			429455

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19204	9.00	39.79	170859	9.34
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20804	.00	43.10	185093	10.12
RESALE VALUE	-1441	8.00	-2.99	-12824	-.70
.....OPERATING.....					
H & M INSURANCE	2192	.00	4.54	19501	1.07
P & I INSURANCE	375	.00	.78	3333	.18
MANNING	4141	8.50	8.58	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1244	6.00	2.58	11071	.61
REPAIRS	360	7.50	.75	3203	.18
CORROSION CONTROL	828	7.50	1.72	7371	.40
TOTAL	48269			429455	23.47

CALCULATED RFR= 23.47198 $/TON AT DATE OF CONTRACT

FIGURE C-10 (Continued)

```
OUTPUT 73

285000 DWT CRUDE CARRIER D
     DATA FILE: CRUDED
     FILE SAVED AT 14.560 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT     =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA      =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED      =    9763 TONS
CARGO LOADED     =  271738 TONS, OFFLOADED=       0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =    9679 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =  271738 TONS
        TOTAL     =  282900 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT     =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA      =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED      =       0 TONS
CARGO LOADED     =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     500 TONS
     FRESH WATER  =     150 TONS
     BALLAST      =   77289 TONS
     SERVICE FUEL =    4428 TONS
     RESERVE FUEL =     833 TONS
     CARGO        =       0 TONS
        TOTAL     =   83200 TONS
MAXIMUM DEADWEIGHT=  282900 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.81931[illegible]
```

FIGURE C-11 CRUDE CARRIER, SYSTEM D, RESALE 10%

OUTPUT [illegible]

225000 DWT CRUDE CARRIER D
DATA FILE: CRUDED
FILE SAVED AT 14.560 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1526982	23.39	4.00	428635
TOTAL	1526982			428635

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19366	9.00	40.20	172301	9.40
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20737	.00	43.04	184500	10.07
RESALE VALUE	-1437	8.00	-2.98	-12783	-.70
.....OPERATING.....					
H & M INSURANCE	2185	.00	4.53	19438	1.06
P & I INSURANCE	372	.00	.77	3312	.18
MANNING	4141	8.50	8.60	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1255	6.00	2.60	11163	.61
REPAIRS	360	7.50	.75	3203	.17
CORROSION CONTROL	635	7.50	1.32	5651	.31
TOTAL	48177			428635	23.39

CALCULATED RFR= 23.39851 $/TON AT DATE OF CONTRACT

OUTPUT STOP

FIGURE C-11 (Continued)

```
OUTPUT 13

285000 DWT CRUDE CARRIER E
     DATA FILE: CRUDEE
     FILE SAVED AT 14.045 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED        =    9763 TONS
CARGO LOADED       =  271738 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =     9679 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =   271738 TONS
        TOTAL     =   282900 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA        =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED        =      .0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      500 TONS
     FRESH WATER  =      150 TONS
     BALLAST      =    77289 TONS
     SERVICE FUEL =     4428 TONS
     RESERVE FUEL =      833 TONS
     CARGO        =        0 TONS
        TOTAL     =    83200 TONS
MAXIMUM DEADWEIGHT=   282900 TONS

TOTAL DAYS, ROUND TRIP=    61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=    5.250103
```

FIGURE C-12 CRUDE CARRIER, SYSTEM D MODIFIED, RESALE 10%

OUTPUT ?4

285000 DWT CRUDE CARRIER E
DATA FILE: CRUDEE
FILE SAVED AT 14.045 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1426654	27.25	4.00	467218
TOTAL	1426654			467218

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	18093	9.00	34.45	160973	9.39
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20366	.00	38.78	181200	10.57
RESALE VALUE	-1411	8.00	-2.69	-12554	-.73
.....OPERATING.....					
H & M INSURANCE	2146	.00	4.09	19090	1.11
P & I INSURANCE	372	.00	.71	3312	.19
MANNING	4141	8.50	7.89	36843	2.15
PROVISIONS & STORES	563	7.50	1.07	5005	.29
PORT CHARGES	1173	6.00	2.23	10436	.61
REPAIRS	360	7.50	.69	3203	.19
CORROSION CONTROL	6711	7.50	12.78	59710	3.48
TOTAL	52514			467218	27.25

CALCULATED RFR= 27.24618 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-12 (Continued)

```
OUTPUT 73
285000 DWT CRUDE CARRIER D MOD.
      DATA FILE: CRUDEDMO
      FILE SAVED AT 11.560 ON 04/06/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< RAS TANURA >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA       =   31.02 DAYS, USING      5166 TONS OF FUEL
FUEL LOADED       =    9763 TONS
CARGO LOADED      =  271738 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
      CREW & STORES=    500 TONS
      FRESH WATER  =    150 TONS
      BALLAST      =      0 TONS
      SERVICE FUEL =   9679 TONS
      RESERVE FUEL =    833 TONS
      CARGO        = 271738 TONS
         TOTAL     = 282900 TONS
MAXIMUM DEADWEIGHT= 282900 TONS

<<<<< ROTTERDAM >>>>>
NEXT LEG OF VOYAGE=   11169 MILES AT 17.50 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        84 TONS OF FUEL
TIME AT SEA       =   26.59 DAYS, USING      4428 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=  271738 TONS
DEPARTURE WEIGHTS
      CREW & STORES=    500 TONS
      FRESH WATER  =    150 TONS
      BALLAST      =  77289 TONS
      SERVICE FUEL =   4428 TONS
      RESERVE FUEL =    833 TONS
      CARGO        =      0 TONS
         TOTAL     =  83200 TONS
MAXIMUM DEADWEIGHT= 282900 TONS

TOTAL DAYS, ROUND TRIP=   61.61786
AVERAGE NUMBER OF TRIPS PER YEAR=   5.615255
```

FIGUREC-12 PRODUCT CARRIER, SYSTEM E, RESALE 10%

OUTPUT ?4

285000 DWT CRUDE CARRIER D MOD.
DATA FILE: CRUDEDMD
FILE SAVED AT 11.560 ON 04/06/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
RAS TANURA	0	.00	.00	0
ROTTERDAM	1525880	23.35	4.00	427228
TOTAL	1525880			427228

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
RAS TANURA	19349	9.00	40.29	172151	9.41
ROTTERDAM	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	20671	.00	43.05	183914	10.05
RESALE VALUE	-1432	8.00	-2.98	-12742	-.70
.....OPERATING.....					
H & M INSURANCE	2178	.00	4.54	19376	1.06
P & I INSURANCE	372	.00	.78	3312	.18
MANNING	4141	8.50	8.62	36843	2.01
PROVISIONS & STORES	563	7.50	1.17	5005	.27
PORT CHARGES	1253	6.00	2.61	11149	.61
REPAIRS	360	7.50	.75	3203	.18
CORROSION CONTROL	564	7.50	1.17	5017	.27
TOTAL	48019			427228	23.35

CALCULATED RFR= 23.35045 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER A MOD.
DATA FILE: PRODAMOD
FILE SAVED AT 10.470 ON 04/06/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	978049	13.20	4.00	154839
TOTAL	978049			154839

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5395	9.00	31.00	48002	4.09
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8084	.00	46.45	71928	6.13
RESALE VALUE	-560	8.00	-3.22	-4983	-.42
.....OPERATING.....					
H & M INSURANCE	852	.00	4.89	7578	.65
P & I INSURANCE	52	.00	.30	460	.04
MANNING	2071	8.50	11.90	18421	1.57
PROVISIONS & STORES	281	7.50	1.62	2503	.21
PORT CHARGES	790	6.00	4.54	7029	.60
REPAIRS	180	7.50	1.03	1602	.14
CORROSION CONTROL	259	7.50	1.49	2300	.20
TOTAL	17403			154839	13.20

CALCULATED RFR= 13.20429 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-14 PRODUCT CARRIER, SYSTEM A, RESALE 22%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER A MOD.
     DATA FILE: PRODAMOD
     FILE SAVED AT 10.470 ON 04/06/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =    4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED       =     595 TONS
CARGO LOADED      =   38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =     567 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =   38083 TONS
        TOTAL     =   39300 TONS
MAXIMUM DEADWEIGHT=   39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 16.20 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =    4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=   38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =   14091 TONS
     SERVICE FUEL =     259 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =       0 TONS
        TOTAL     =   15000 TONS
MAXIMUM DEADWEIGHT=   39300 TONS

TOTAL DAYS, ROUND TRIP=   13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
```

FIGURE C-14 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER D
DATA FILE: PRODD
FILE SAVED AT 15.470 ON 04/3/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	949971	16.38	4.00	187116
TOTAL	949971			187116

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5242	9.00	24.93	46641	4.08
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	7845	.00	37.30	69800	6.11
RESALE VALUE	-544	8.00	-2.58	-4836	-.42
.....OPERATING.....					
H & M INSURANCE	827	.00	3.93	7354	.64
P & I INSURANCE	52	.00	.25	460	.04
MANNING	2071	8.50	9.84	18421	1.61
PROVISIONS & STORES	281	7.50	1.34	2503	.22
PORT CHARGES	769	6.00	3.66	6840	.60
REPAIRS	180	7.50	.86	1602	.14
CORROSION CONTROL	4308	7.50	20.48	38331	3.35
TOTAL	21031			187116	16.38

CALCULATED RFR= 16.37592 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-15 PRODUCT CARRIER, SYSTEM A MODIFIED, RESALE 22%

```
OUTPUT 23

39300 DWT PRODUCT CARRIER D
     DATA FILE: PRODD
     FILE SAVED AT 15.470 ON 04/3/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =    4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED        =     595 TONS
CARGO LOADED       =   38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER   =     100 TONS
     BALLAST       =       0 TONS
     SERVICE FUEL  =     567 TONS
     RESERVE FUEL  =     300 TONS
     CARGO         =   38083 TONS
        TOTAL      =   39300 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 16.20 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =    4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=    38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER   =     100 TONS
     BALLAST       =   14091 TONS
     SERVICE FUEL  =     259 TONS
     RESERVE FUEL  =     300 TONS
     CARGO         =       0 TONS
        TOTAL      =   15000 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

TOTAL DAYS, ROUND TRIP=    13.49588
AVERAGE NUMBER OF TRIPS PER YEAR=    24.94464
```

FIGURE C-15 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER C
DATA FILE: PRODC
FILE SAVED AT 15.180 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	985496	13.16	4.00	155509
TOTAL	985496			155509

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5395	9.00	30.87	48002	4.06
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8069	.00	46.16	71790	6.08
RESALE VALUE	-559	8.00	-3.20	-4974	-.42
.....OPERATING.....					
H & M INSURANCE	850	.00	4.86	7563	.64
P & I INSURANCE	52	.00	.30	463	.04
MANNING	2071	8.50	11.85	18421	1.56
PROVISIONS & STORES	281	7.50	1.61	2503	.21
PORT CHARGES	790	6.00	4.52	7029	.59
REPAIRS	180	7.50	1.03	1602	.14
CORROSION CONTROL	349	7.50	2.00	3110	.26
TOTAL	17479			155509	13.16

CALCULATED RFR= 13.1612 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-16 PRODUCT CARRIER, SYSTEM B, RESALE 18%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER C
     DATA FILE: PRODC
     FILE SAVED AT 15.180 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.93 DAYS, USING      280 TONS OF FUEL
FUEL LOADED        =     595 TONS
CARGO LOADED       =   38373 TONS, OFFLOADED=       0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =      567 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =    38373 TONS
        TOTAL     =    39590 TONS
MAXIMUM DEADWEIGHT=    39590 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 16.20 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.57 DAYS, USING      259 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=   38373 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =    14091 TONS
     SERVICE FUEL =      259 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =        0 TONS
        TOTAL     =    15000 TONS
MAXIMUM DEADWEIGHT=    39590 TONS

TOTAL DAYS, ROUND TRIP=   13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
```

FIGURE C-16 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER B
DATA FILE: PRODB
FILE SAVED AT 15.580 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	986065	13.18	4.00	155851
TOTAL	986065			155851

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5398	9.00	30.82	48031	4.06
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8069	.00	46.06	71790	6.07
RESALE VALUE	-559	8.00	-3.19	-4974	-.42
.....OPERATING.....					
H & M INSURANCE	850	.00	4.85	7563	.64
P & I INSURANCE	52	.00	.30	463	.04
MANNING	2071	8.50	11.82	18421	1.56
PROVISIONS & STORES	281	7.50	1.61	2503	.21
PORT CHARGES	791	6.00	4.51	7034	.59
REPAIRS	180	7.50	1.03	1602	.14
CORROSION CONTROL	384	7.50	2.19	3418	.29
TOTAL	17517			155851	13.18

CALCULATED RFR= 13.18085 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-17 PRODUCT CARRIER, SYSTEM C, RESALE 20%

```
OUTPUT [illegible]

39300 DWT PRODUCT CARRIER B
     DATA FILE: PRODB
     FILE SAVED AT 15.580 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =    4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED       =     595 TONS
CARGO LOADED      =   38373 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =     567 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =   38373 TONS
        TOTAL     =   39590 TONS
MAXIMUM DEADWEIGHT=   39590 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 16.20 KNOTS
TIME IN PORT      =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =    4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=    38373 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =   14091 TONS
     SERVICE FUEL =     259 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =       0 TONS
        TOTAL     =   15000 TONS
MAXIMUM DEADWEIGHT=   39590 TONS

TOTAL DAYS, ROUND TRIP=    13.49588
AVERAGE NUMBER OF TRIPS PER YEAR=    35.98578
```

FIGURE C-17 (Continued)

```
OUTPUT ?4

39300 DWT PRODUCT CARRIER A
     DATA FILE: PRODA
     FILE SAVED AT 15.470 ON 04/3/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>       TONS DELIV.    $/TON     ESCAL.    PRES.VAL.
                          PER YEAR                  %        ($1000)
CURACAO                         0         .00       .00           0
NEW YORK                   978049       13.31      4.00      156054
          TOTAL            978049                            156054

<<<<< EXPENSES >>>>>        AVG.ANN.   ESCAL.    % OF    PRES.VAL.     RFR
                            ($1000)     (%)      TOTAL    ($1000)      ($)
.....FUEL.....
CURACAO                        5395    9.00     30.76       48002     4.09
NEW YORK                          0     .00       .00           0      .00
.....CAPITALIZED.....
ACQUISITION                    8149     .00     46.46       72500     6.18
RESALE VALUE                   -565    8.00     -3.22       -5023     -.43
.....OPERATING.....
H & M INSURANCE                 859     .00      4.89        7638      .65
P & I INSURANCE                  52     .00       .29         460      .04
MANNING                        2071    8.50     11.80       18421     1.57
PROVISIONS & STORES             281    7.50      1.60        2503      .21
PORT CHARGES                    790    6.00      4.50        7029      .60
REPAIRS                         180    7.50      1.03        1602      .14
CORROSION CONTROL               328    7.50      1.87        2922      .25
          TOTAL               17540                        156054    13.31

CALCULATED RFR=   13.30785 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP
```

FIGURE C-18 PRODUCT CARRIER, SYSTEM D, RESALE 9%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER A
     DATA FILE: PRODA
     FILE SAVED AT 15.470 ON 04/3/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.93 DAYS, USING      280 TONS OF FUEL
FUEL LOADED        =     595 TONS
CARGO LOADED       =   38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =      567 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =    38083 TONS
        TOTAL     =    39300 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 16.20 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.57 DAYS, USING      259 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=   38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =    14091 TONS
     SERVICE FUEL =      259 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =        0 TONS
        TOTAL     =    15000 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

TOTAL DAYS, ROUND TRIP=    13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
```

FIGURE C-18 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER A MOD.
DATA FILE: PRODAMOD
FILE SAVED AT 9.470 ON 04/06/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	978049	12.69	4.00	148859
TOTAL	978049			148859

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5395	9.00	32.25	48002	4.09
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8084	.00	48.32	71928	6.13
RESALE VALUE	-1232	8.00	-7.36	-10963	-.93
.....OPERATING.....					
H & M INSURANCE	852	.00	5.09	7578	.65
P & I INSURANCE	52	.00	.31	460	.04
MANNING	2071	8.50	12.38	18421	1.57
PROVISIONS & STORES	281	7.50	1.68	2503	.21
PORT CHARGES	790	6.00	4.72	7029	.60
REPAIRS	180	7.50	1.08	1602	.14
CORROSION CONTROL	259	7.50	1.55	2300	.20
TOTAL	16731			148859	12.69

CALCULATED RFR= 12.69433 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-19 PRODUCT CARRIER, SYSTEM A, RESALE 10%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER A MOD.
     DATA FILE: PRODAMOD
     FILE SAVED AT 9.470 ON 04/06/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =    4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED        =     595 TONS
CARGO LOADED       =   38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =      567 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =    38083 TONS
        TOTAL     =    39300 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 16.20 KNOTS
TIME IN PORT       =    2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =    4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=    38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =    14091 TONS
     SERVICE FUEL =      259 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =        0 TONS
        TOTAL     =    15000 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

TOTAL DAYS, ROUND TRIP=    13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
```

FIGURE C-19 (Continued)

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER D
     DATA FILE: PRODD
     FILE SAVED AT 9.470 ON 04/3/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 15.00 KNOTS
TIME IN PORT      =     2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =     4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED       =      595 TONS
CARGO LOADED      =    38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =      567 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =    38083 TONS
        TOTAL     =    39300 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 16.20 KNOTS
TIME IN PORT      =     2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA       =     4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED       =        0 TONS
CARGO LOADED      =        0 TONS, OFFLOADED=   38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =    14091 TONS
     SERVICE FUEL =      259 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =        0 TONS
        TOTAL     =    15000 TONS
MAXIMUM DEADWEIGHT=    39300 TONS

TOTAL DAYS, ROUND TRIP=   13.49588
AVERAGE NUMBER OF TRIPS PER YEAR=   24.94464
```

FIGURE C-20 PRODUCT CARRIER, SYSTEM A MODIFIED, RESALE 10%

OUTPUT ?4

39300 DWT PRODUCT CARRIER D
DATA FILE: PRODD
FILE SAVED AT 9.470 ON 04/3/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	949971	16.42	4.00	187599
TOTAL	949971			187599

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5242	9.00	24.86	46641	4.08
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	7845	.00	37.21	69800	6.11
RESALE VALUE	-489	8.00	-2.32	-4352	-.38
.....OPERATING.....					
H & M INSURANCE	827	.00	3.92	7354	.64
P & I INSURANCE	52	.00	.25	460	.04
MANNING	2071	8.50	9.82	18421	1.61
PROVISIONS & STORES	281	7.50	1.33	2503	.22
PORT CHARGES	769	6.00	3.65	6840	.60
REPAIRS	180	7.50	.85	1602	.14
CORROSION CONTROL	4308	7.50	20.43	38331	3.35
TOTAL	21086			187599	16.42

CALCULATED RFR= 16.41825 $/TON AT DATE OF CONTRACT

OUTPUT ?SO@TOP

FIGURE C-20 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER C
DATA FILE: PRODC
FILE SAVED AT 10.180 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	985496	12.74	4.00	150536
TOTAL	985496			150536

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5395	9.00	31.89	48002	4.06
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8069	.00	47.69	71790	6.08
RESALE VALUE	-1118	8.00	-6.61	-9948	-.84
.....OPERATING.....					
H & M INSURANCE	850	.00	5.02	7563	.64
P & I INSURANCE	52	.00	.31	463	.04
MANNING	2071	8.50	12.24	18421	1.56
PROVISIONS & STORES	281	7.50	1.66	2503	.21
PORT CHARGES	790	6.00	4.67	7029	.59
REPAIRS	180	7.50	1.06	1602	.14
CORROSION CONTROL	349	7.50	2.07	3110	.26
TOTAL	16920			150536	12.74

CALCULATED RFR= 12.74026 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-21 PRODUCT CARRIER, SYSTEM B, RESALE 10%

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OUTPUT ?3

39300 DWT PRODUCT CARRIER C
     DATA FILE: PRODC
     FILE SAVED AT 10.180 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 15.00 KNOTS
TIME IN PORT      =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA       =    4.93 DAYS, USING      280 TONS OF FUEL
FUEL LOADED       =     595 TONS
CARGO LOADED      =   38373 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =     567 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =   38373 TONS
        TOTAL     =   39590 TONS
MAXIMUM DEADWEIGHT=   39590 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 16.20 KNOTS
TIME IN PORT      =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA       =    4.57 DAYS, USING      259 TONS OF FUEL
FUEL LOADED       =       0 TONS
CARGO LOADED      =       0 TONS, OFFLOADED=   38373 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =   14091 TONS
     SERVICE FUEL =     259 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =       0 TONS
        TOTAL     =   15000 TONS
MAXIMUM DEADWEIGHT=   39590 TONS

TOTAL DAYS, ROUND TRIP=   13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
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FIGURE C-21 (Continued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER B
DATA FILE: PRODB
FILE SAVED AT 9.580 ON 04/03/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	986065	12.84	4.00	151872
TOTAL	986065			151872

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5398	9.00	31.63	48031	4.06
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8069	.00	47.27	71790	6.07
RESALE VALUE	-1006	8.00	-5.89	-8953	-.76
.....OPERATING.....					
H & M INSURANCE	850	.00	4.98	7563	.64
P & I INSURANCE	52	.00	.31	463	.04
MANNING	2071	8.50	12.13	18421	1.56
PROVISIONS & STORES	281	7.50	1.65	2503	.21
PORT CHARGES	791	6.00	4.63	7034	.59
REPAIRS	180	7.50	1.05	1602	.14
CORROSION CONTROL	384	7.50	2.25	3418	.29
TOTAL	17070			151872	12.84

CALCULATED RFR= 12.84433 $/TON AT DATE OF CONTRACT

OUTPUT ?STOP

FIGURE C-22 PRODUCT CARRIER, SYSTEM C, RESALE 10%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER B
     DATA FILE: PRODB
     FILE SAVED AT 9.580 ON 04/03/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 15.00 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.93 DAYS, USING      280 TONS OF FUEL
FUEL LOADED        =     595 TONS
CARGO LOADED       =   38373 TONS, OFFLOADED=       0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =        0 TONS
     SERVICE FUEL =      567 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =    38373 TONS
        TOTAL     =    39590 TONS
MAXIMUM DEADWEIGHT=    39590 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=     1775 MILES AT 16.20 KNOTS
TIME IN PORT       =    2.00 DAYS, USING       28 TONS OF FUEL
TIME AT SEA        =    4.57 DAYS, USING      259 TONS OF FUEL
FUEL LOADED        =       0 TONS
CARGO LOADED       =       0 TONS, OFFLOADED=   38373 TONS
DEPARTURE WEIGHTS
     CREW & STORES=      250 TONS
     FRESH WATER  =      100 TONS
     BALLAST      =    14091 TONS
     SERVICE FUEL =      259 TONS
     RESERVE FUEL =      300 TONS
     CARGO        =        0 TONS
        TOTAL     =    15000 TONS
MAXIMUM DEADWEIGHT=    39590 TONS

TOTAL DAYS, ROUND TRIP=   13.49588
AVERAGE NUMBER OF TRIPS PER YEAR=   25.69672
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FIGURE C-22 (Ctoninued)

OUTPUT ?4

39300 DWT PRODUCT CARRIER A
DATA FILE: PRODA
FILE SAVED AT 9.470 ON 04/3/81
EXPENSES FOR YEARS 1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< INCOME >>>>>	TONS DELIV. PER YEAR	$/TON	ESCAL. %	PRES.VAL. ($1000)
CURACAO	0	.00	.00	0
NEW YORK	978049	12.79	4.00	150026
TOTAL	978049			150026

<<<<< EXPENSES >>>>>	AVG.ANN. ($1000)	ESCAL. (%)	% OF TOTAL	PRES.VAL. ($1000)	RFR ($)
.....FUEL.....					
CURACAO	5395	9.00	32.00	48002	4.09
NEW YORK	0	.00	.00	0	.00
.....CAPITALIZED.....					
ACQUISITION	8149	.00	48.32	72500	6.18
RESALE VALUE	-1242	8.00	-7.37	-11051	-.94
.....OPERATING.....					
H & M INSURANCE	859	.00	5.09	7638	.65
P & I INSURANCE	52	.00	.31	460	.04
MANNING	2071	8.50	12.28	18421	1.57
PROVISIONS & STORES	281	7.50	1.67	2503	.21
PORT CHARGES	790	6.00	4.69	7029	.60
REPAIRS	180	7.50	1.07	1602	.14
CORROSION CONTROL	328	7.50	1.95	2922	.25
TOTAL	16862			150026	12.79

CALCULATED RFR= 12.79383 $/TON AT DATE OF CONTRACT

FIGURE C-23 PRODUCT CARRIER, SYSTEM D, RESALE 10%

```
OUTPUT ?3

39300 DWT PRODUCT CARRIER A
     DATA FILE: PRODA
     FILE SAVED AT 9.470 ON 04/3/81
EXPENSES FOR YEARS  1 THRU 20 AFTER DELIVERY USED IN THIS ANALYSIS

<<<<< CURACAO >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 15.00 KNOTS
TIME IN PORT       =   2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =   4.93 DAYS, USING       280 TONS OF FUEL
FUEL LOADED        =    595 TONS
CARGO LOADED       =  38083 TONS, OFFLOADED=        0 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =       0 TONS
     SERVICE FUEL =     567 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =   38083 TONS
        TOTAL     =   39300 TONS
MAXIMUM DEADWEIGHT=   39300 TONS

<<<<< NEW YORK >>>>>
NEXT LEG OF VOYAGE=    1775 MILES AT 16.20 KNOTS
TIME IN PORT       =   2.00 DAYS, USING        28 TONS OF FUEL
TIME AT SEA        =   4.57 DAYS, USING       259 TONS OF FUEL
FUEL LOADED        =      0 TONS
CARGO LOADED       =      0 TONS, OFFLOADED=   38083 TONS
DEPARTURE WEIGHTS
     CREW & STORES=     250 TONS
     FRESH WATER  =     100 TONS
     BALLAST      =   14091 TONS
     SERVICE FUEL =     259 TONS
     RESERVE FUEL =     300 TONS
     CARGO        =       0 TONS
        TOTAL     =   15000 TONS
MAXIMUM DEADWEIGHT=   39300 TONS

TOTAL DAYS, ROUND TRIP=    13.49588
AVERAGE NUMBER OF TRIPS PER YEAR= 25.6819
```

FIGURE C-23 (Continued)

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