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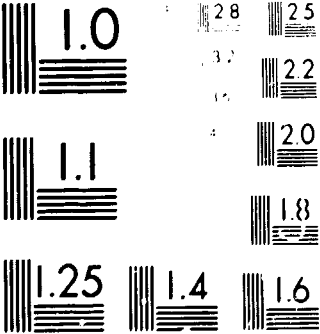


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# TRANSPORT COSTS FOR SHIPPING PETROCHEMICALS, 1975-1985*

A Study prepared for the

Negotiations Branch, Division of Policy Co-ordination**

by

H.P. Drewry (Shipping Consultants) Ltd., London***



* This document has been reproduced without formal editing.

** This Study was prepared as a contribution to the UNIDO Study of Industrial Uses of Associated Gas (UNIDO/PC.11) and the Second UNIDO World-wide Study of the Petrochemical Industry (ID/WG.336/3). It has been reproduced in response to the interest shown by readers of these studies.

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## PREFACE

UNIDO invited H.P. Drewry (Shipping Consultants) Limited to prepare this Study as a contribution to the UNIDO Study of Industrial Uses of Associated Gas and the Second World-wide Study of the Petrochemical Industry. The estimates of shipping costs contained in this Study were needed to demonstrate the ability of developing countries to produce and ship petrochemicals, LNG and LPG to selected ports in industrialized countries at competitive prices.

## INTRODUCTION BY CONSULTANTS

UNIDO (hereafter the Clients) contacted H.P. Drewry (Shipping Consultants) Ltd. (hereafter the Consultants) and requested data concerning marine transportation costs for a variety of petrochemical products on a variety of routes. The products to be reviewed were:

- (i) LNG-6,000,000 metric tonnes pa
- (ii) LPG-300,000 metric tonnes pa
- (iii) Methanol-300,000 metric tonnes pa
- (iv) Urea in bulk and bags - 500,000 metric tonnes pa
- (v) PVC powder in bulk and bags - 150,000 metric tonnes pa

and references to transportation cost differentials between these products and ethylene, propylene, ammonia, ethylene glycol and low and high density polyethylene were to be made. The loading ports to be considered were Skikda, Algeria; Doha, Qatar; Aceh, Indonesia and Veracruz, Mexico with reception facilities being situated in Genoa, Rotterdam, New Orleans and Yokohama. Cost estimates were to be provided for mid-1980 and mid-1985.

Additional Client requirements included the presenting of trends in shipping costs over the period 1975 to 1985 for a typical voyage for each product, the forecasting of shipping capacity availability for each product group in 1985 and a review of the likely terminal and storage facilities required for the commodities in question. Advice as to current shipping practice and future developments was also required.

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# STUDY OF TRANSPORT COSTS FOR SHIPPING PETROCHEMICALS

## SECTION 1

## LNG

### 1.1 THE CHARACTERISTICS OF NATURAL GAS AND LNG CARRIERS

Natural gas is a mixture of hydrocarbons of which methane ($CH_4$) predominates although ethanes ($C_2H_6$), pentanes ($C_3H_8$), and butanes ($C_4H_{10}$) occur in varying proportions depending on the nature of the gas field in question. In order to transport this commodity by sea, two processes are necessary:

(i) the seperation of the methane element from the other gas types;

(ii) the reduction in volume of the methane by liquefaction to make seaborne gas transportation an economically viable proposition.

Both these goals are achieved at the export terminal by the utilisation of specialist liquefaction plants. Methane is isolated from the other elements in the natural gas stream during the initial stages of the liquefaction process, the other elements being flared, used as an energy source within the liquefaction plant or exported, as in the case of Indonesian LPG from the Arun LNG plant. The methane is cooled to about -161.5°C to produce liquefied natural gas (LNG), a colourless, odourless, non-toxic liquid occupying less than 1/600th in volume of its gaseous equivalent. The accomplishing of this change in state is an extremely costly process requiring both large amounts of capital in the building of liquefaction plants, LNG carriers and reception facilities and a considerable input of energy. Nevertheless, LNG is a relatively cheap high energy fuel which causes few atmospheric pollution problems.

As at end-1980, 67 LNG carriers of 5,649,000 $M^3$ were in existence, and an additional 16 of 1,972,000 $M^3$ were on order. (Additional provisional orders and enquiries known by the Consultants at that date totalled 18 carriers of about 2,250,000 $M^3$). 30 of the carriers in existence, representing 70% of total delivered LNG carrying capacity, were of the 125,000-130,000 $M^3$ size, whilst 13 of the

LNG carriers on order, or almost 84% of LNG carrying capacity on order, were within this size range. It thus seems appropriate to base cost estimates on vessels of this particular size. (This is not to say that other size ranges are unimportant or will not be built in the future - Spanish builder Astano, for example, has a complete family of LNG tankers, using its Metastano - 20 system, ranging in size from 50,000 $M^3$ to 300,000 $M^3$ - but significantly smaller sized vessels have not been in demand since the delivery of a series of 75,000 $M^3$ vessels to Shell Tankers in the early to mid-1970s for operation on the Brunei to Japan route. Significantly larger vessels would be completely deprived of any operational flexibility in the event of project postponement/cancellation/breakdown. Thus, future LNG carrier orders are likely to continue to be of the 125,000 $M^3$ to 130,000 $M^3$ size).

## 1.2 LNG CARRIER NEWBUILDING PRICES

The LNG carrier is probably the most expensive commercial vessel to build. The carriage of a liquid commodity at a temperature of about - 161.5°C requires the use of specialised containment systems, expensive steels and substantial amounts of insulatory material. Moreover, the LNG carrier is unique in that it utilises a proportion of its cargo as fuel.

Such is the complexity of the LNG carrier that specialist knowledge is required in its construction. It is therefore hardly surprising that comparatively few yards have expertise in this field. Indeed, it is only relatively recently that Japan has developed an LNG carrier construction industry: up until the mid-1970s the Europeans, with France to the forefront, and the United States stood alone in the field. However, the Japanese have successfully completed a number of 125,000 to 130,000 $M^3$ LNG carriers of late and are now extremely price competitive.

### (a) Japan

LNG carrier orders in Japan for which the Consultants have price information include:

(i) the ordering in early 1975 of two 128,680 $M^3$ LNG carriers from the Kawasaki yard at a reported cost of $88.4 million each;

(ii) the ordering of a similiar vessel from the same yard at a cost of $99.0 million in early 1976;

(iii) three 125,000 $M^3$ LNG carrier orders at the Mitsui, Mitsubishi and Kawasaki yards for about $119.15 million each in May 1980.

and (iv) an additional two 125,000 $M^3$ LNG carrier orders for 1983 delivery at a reported price of $137.61 million each placed at the Kawasaki and Mitsubishi yards in mid-1980.

(b) Europe

The subsidy systems operating in Europe and applying to such tonnage make the quoting of actual price information difficult. It is suspected that the prices quoted below are net of subsidy:

(i) three 129,500 $M^3$ LNG carrier orders were placed with the Chantiers de France, Dunkerque yard in late 1976/early 1977 at a published price of $106 million each;

(ii) the French Chantiers de l'Atlantique yard at St. Nazaire secured two 129,500 $M^3$ LNG carrier orders in 1976 at a unit cost of $104 million;

(iii) Constructions Navales et Industrielles de la Mediterranee (CNIM) obtained two 129,500 $M^3$ orders in 1975 and two in 1978 at unit costs of $104 million and $106 million respectively;

(iv) the Howaldtswerke-Deutsche Werft, Hamburg yard secured orders for two 125,800 $M^3$ LNG/LPG carriers at a cost of $90 million each late in 1974.

(c) United States

Newbuilding prices in the United States are traditionally greatly in excess of comparable world price levels and, as such, massive supportive measures by way of subsidy or protected trade are normally required to ensure demand for the US shipbuilding facilities. The price disparity is, however, markedly less noticeable for sophisticated vessels and by specialised financing packages, such as leverage leasing, has to all intents and purposes been eradicated in the past. Thus, it is not surprising that US yards have enjoyed a certain amount of success in securing LNG carrier construction business. Available price data follows overleaf:

(i) in September 1972, General Dynamics obtained three orders for 125,000 $M^3$ LNG carriers at a per vessel unsubsidised price of $89.575 million;

(ii) in the same month, Newport News were awarded the contract for a further three LNG carriers at an average unsubsidised price of $96.838 million;

(iii) Avondale Shipyards, New Orleans, gained a contract for three 125,000 $M^3$ LNG carriers in June 1973 at an average price before subsidy of $103.02 million;

(iv) two 125,000 $M^3$ carriers were ordered from General Dynamics in July 1977 at an unsubsidised price of $155 million per vessel.

CONCLUSION

Capital costs are to be based upon recent deliveries. Thus, if it is assumed that the construction of an LNG carrier will be completed some two years after contract placement, the Consultants are required to estimate newbuilding prices at mid-1978. From the above data, newbuilding prices at that time in Japan would appear to be about $115 million ($920/$M^3$) for a 125,000 $M^3$ LNG carrier and perhaps $119.6 million for a 130,000 $M^3$ LNG carrier. This estimate corresponds with that published by Fearnley and Eger in their yearly review entitled "World Bulk Fleets".

## 1.3 LNG CARRIER CAPITAL COSTS PER VESSEL

The newbuilding prices displayed above have been used in conjunction with standard OECD financing terms - viz a 20% downpayment with the residual payable over 8.5 years at an annual interest rate of 8% - to calculate annual capital costs. In addition, the following assumptions have been made:

(i) the 20% cash downpayment is made on signing of the contract and the balance is accomodated by loans as various construction phases are completed (i.e. ordering of steel, keel laying, launching and delivery). Interest payments are calculated on a running loan account.

(ii) a hull life of 15 years from delivery is assumed and upon completion of this period the vessel will have no residual value. The discounted scrap value of an LNG carrier is likely to be negligible anyway.

(iii) a notional rate of return on equity of 10% has been used in conjunction with a discount rate of 10% and the resulting NPV converted into a 15 year annuity to give the average annual capital charge.

The linear relationship between the capital cost of the vessel and the annual revenue required to cover this capital cost are displayed in FIGURE 1. On the basis of this relationship, the annual capital costs associated with recently delivered 125,000 $M^3$ and 130,000 $M^3$ LNG carriers are $19.55 million and $20.33 million respectively. An example of the work-sheet showing the methodology by which these estimates were reached is displayed in TABLE 1.

## 1.4 LNG CARRIER OPERATING COSTS PER VESSEL

The annual costs associated with the regular operation of a ship which come under the heading of operating cost include:

Manning
Repairs and Maintenance
Insurance
Stores and Supplies
Administration and Management Overheads
Other Miscellaneous Costs.

### 1.4.1 Manning

LNG carriers are very sophisticated ships demanding the highest quality crews to ensure their safe operation. Because of this, manning costs tend to be high. The crew of an LNG carrier will normally consist entirely of US or West European nationals with very few, if any, less skilled and lower paid mariners from, say, South East Asia. The costs of manning include several components, some of which are crew wages, crew travelling expenses, victualling, insurance cover and the usual employers' contribution to pensions and social security.

### 1.4.2 Repairs and Maintenance

LNG carrier repair and maintenance costs tend to vary with the hull cost of the vessel, and thus with size, and will be dependant on the age of the LNG carrier.

## TABLE 1

### CAPITAL COST RECOVERY

### ASSUMING DEPOSIT 20% - LOAN 80% - INTEREST 8% - REPAYMENT PERIOD 8.5 YEARS - RETURN ON EQUITY 10% P.A.

### 125,000 $M^3$ LNG CARRIER PRICE $142.2 MILLION

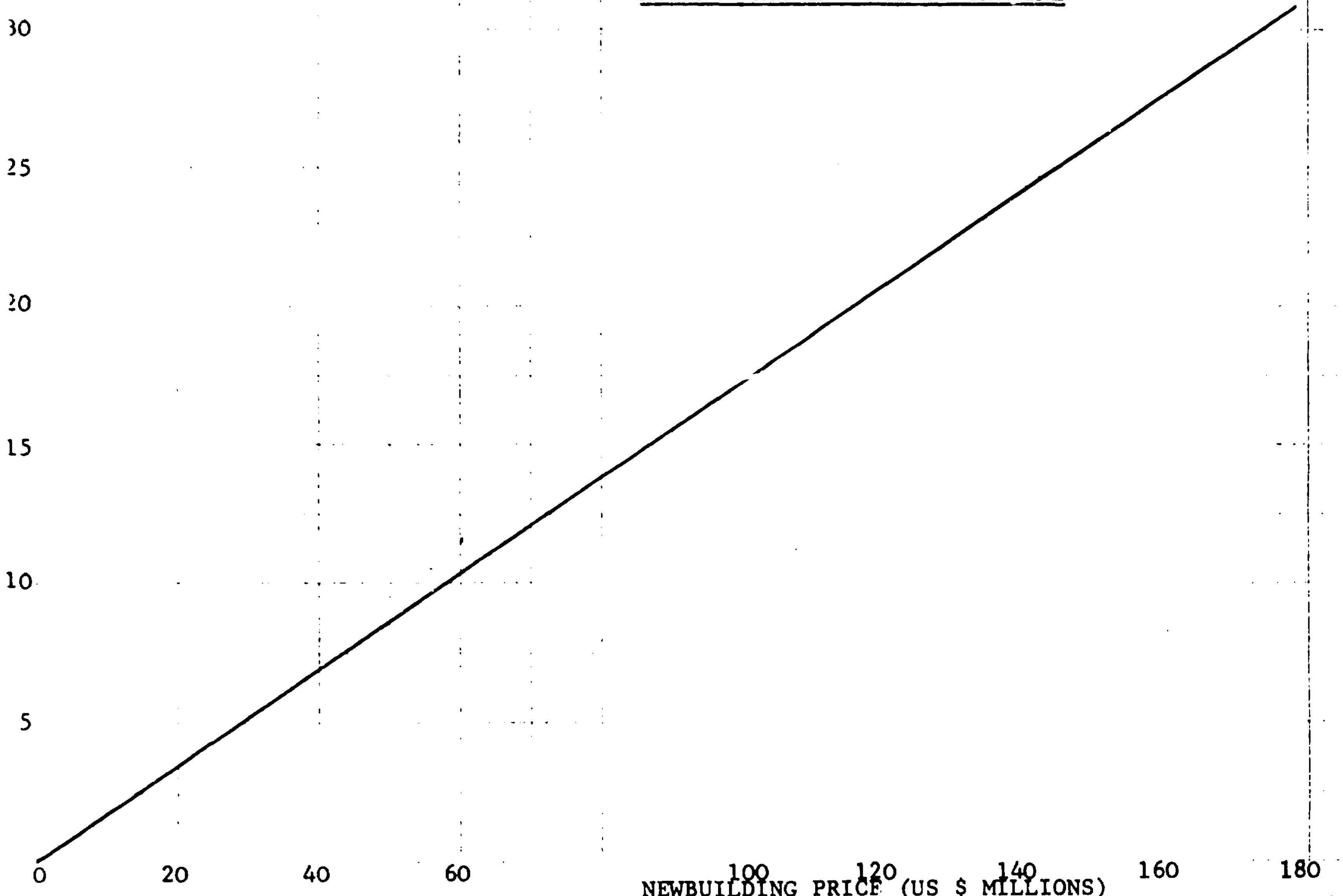
| SIX MONTHLY PERIODS | BANK PAYMENTS % | BANK PAYMENTS AMOUNT | CAPITAL EQUITY DEPOSIT | CAPITAL EQUITY LOAN REPAYMENTS | CAPITAL EQUITY DEPOSIT PLUS LOAN REPAYMENTS | CAPITAL EQUITY DEPRECIATION OVER 15 YEARS | CAPITAL EQUITY DEPRECIATED EQUITY | INTEREST ON EQUITY REQUIRED BY OWNER (10%) | BANK BALANCE | OUTGOINGS (DEPOSIT, LOAN REPAYMENTS, INTEREST ON EQUITY INTEREST ON BANK BALANCE) | NPV OF CASH OUTFLOW DISCOUNT RATE 0% | NPV OF CASH OUTFLOW DISCOUNT RATE 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | - | | 28.44 | | 28.44 | | 28.44 | | | 28.44 | 28.44 | 28.44 |
| 1 | 20 | 28.44 | | | 28.44 | | 28.44 | 1.3881 | 28.4400 | | 1.3881 | 1.3235 |
| 2 | 20 | 28.44 | | | 28.44 | | 28.44 | 1.3881 | 56.8800 | 1.1157 | 2.5038 | 2.2762 |
| 3 | 20 | 28.44 | | | 28.44 | | 28.44 | 1.3881 | 85.3200 | 2.2314 | 3.6195 | 3.1373 |
| 4 | 20 | 28.44 | | | 28.44 | | 28.44 | 1.3881 | 113.7600 | 3.3471 | 4.7352 | 3.9134 |
| 5 | | | | 6.6917 | 35.1317 | 4.740 | 30.3917 | 1.3881 | 107.06 | 4.4629 | 12.5427 | 9.8831 |
| 6 | | | | 6.6917 | 41.8234 | 9.480 | 32.3434 | 1.4834 | 100.3766 | 4.2003 | 12.3754 | 9.2978 |
| 7 | | | | 6.6917 | 48.5151 | 14.220 | 34.2951 | 1.5786 | 93.6849 | 3.9378 | 12.2081 | 8.7451 |
| 8 | | | | 6.6917 | 55.2068 | 18.960 | 36.2468 | 1.6739 | 86.9932 | 3.6753 | 12.0409 | 8.2241 |
| 9 | | | | 6.6917 | 61.8985 | 23.700 | 39.1985 | 1.7692 | 80.3015 | 3.4128 | 11.8737 | 7.7323 |
| 10 | | | | 6.6917 | 68.5902 | 28.440 | 40.1502 | 1.9132 | 73.6098 | 3.1503 | 11.7552 | 7.2991 |
| 11 | | | | 6.6918 | 75.2820 | 33.180 | 42.1020 | 1.9597 | 66.9180 | 2.8877 | 11.5392 | 6.8316 |
| 12 | | | | 6.6918 | 81.9738 | 37.920 | 44.0538 | 2.0549 | 60.2262 | 2.6252 | 11.3719 | 6.4194 |
| 13 | | | | 6.6918 | 88.6656 | 42.660 | 46.0056 | 2.1502 | 53.5344 | 2.3627 | 11.2047 | 6.0305 |
| 14 | | | | 6.6918 | 95.3574 | 47.400 | 47.9574 | 2.2455 | 46.8426 | 2.1002 | 11.0375 | 5.6540 |
| 15 | | | | 6.6918 | 102.0492 | 52.140 | 49.9092 | 2.3407 | 40.1508 | 1.8377 | 10.8702 | 5.3186 |
| 16 | | | | 6.6918 | 108.7410 | 56.880 | 51.8610 | 2.4360 | 33.4590 | 1.5751 | 10.7029 | 4.9929 |
| 17 | | | | 6.6918 | 115.4328 | 61.620 | 53.8128 | 2.5313 | 26.7672 | 1.3126 | 10.5357 | 4.6863 |
| 18 | | | | 6.6918 | 122.1246 | 66.360 | 55.7646 | 2.6265 | 20.0754 | 1.0501 | 10.3684 | 4.3973 |
| 19 | | | | 6.6918 | 128.8164 | 71.100 | 57.7164 | 2.7218 | 13.3836 | 0.7876 | 10.2012 | 4.1250 |
| 20 | | | | 6.6918 | 135.5082 | 75.840 | 59.6682 | 2.8171 | 6.6918 | 0.5250 | 10.0339 | 3.8686 |
| 21 | | | | 6.6918 | 142.2000 | 80.580 | 61.6200 | 2.9123 | | 0.2625 | 9.8666 | 3.6270 |
| 22 | | | | | 142.2000 | 85.320 | 56.8800 | 3.0076 | | | 3.0076 | 1.0542 |
| 23 | | | | | 142.2000 | 90.060 | 52.1400 | 2.7762 | | | 2.7762 | 0.9277 |
| 24 | | | | | 142.2000 | 94.800 | 47.4000 | 2.5449 | | | 2.5449 | 0.8109 |
| 25 | | | | | 142.2000 | 99.540 | 42.6600 | 2.3135 | | | 2.3135 | 0.7028 |
| 26 | | | | | 142.2000 | 104.280 | 37.9200 | 2.0822 | | | 2.0822 | 0.6031 |
| 27 | | | | | 142.2000 | 109.020 | 33.1880 | 1.8508 | | | 1.8508 | 0.51[illegible]2 |
| 28 | | | | | 142.2000 | 113.760 | 28.4400 | 1.6195 | | | 1.6195 | 0.4265 |
| 29 | | | | | 142.2000 | 118.500 | 23.7000 | 1.3881 | | | 1.3881 | 0.3485 |
| 30 | | | | | 142.2000 | 123.240 | 18.9600 | 1.1568 | | | 1.1568 | 0.2769 |
| 31 | | | | | 142.2000 | 127.980 | 14.2200 | 0.9254 | | | 0.9254 | 0.2112 |
| 32 | | | | | 142.2000 | 132.720 | 9.4800 | 0.6941 | | | 0.6941 | 0.1511 |
| 33 | | | | | 142.2000 | 137.460 | 4.7400 | 0.4627 | | | 0.4627 | 0.0960 |
| 34 | | | | | 142.2000 | 142.200 | | 0.2314 | | | 0.2314 | 0.0458 |
| TOTAL | | | | | | | | | | | 252.268 | 152.390 |

Where the NPV of a continuous stream of income of one unit discounted at 10% per annum over the lifespan of the vessel (i.e. from delivery at the start of the third year to scrappage at the end of the 17th year) equals 6.2861, the annual capital cost associated with the above vessel will be 152.39 ÷ 6.2861 or about $24.2 million. This would lead to the gradient of the annual capital cost to newbuilding cost line being 0.170 as shown in FIGURE 1.

Source : H.P.Drewry Shipping Consultants Ltd.

FIGURE 1

AVERAGE ANNUAL COST OF CAPITAL




Source: H.P.Drewry Shipping Consultants

In particular, repair and maintenance costs will be far higher during years of special survey and/or major overhaul and refit. Repair and maintenance costs will also vary with the types of cargo containment systems embodied in various LNG carrier designs. The figures arrived at in this consultancy are intended to indicate average annual repair and maintenance costs, and ignore differences in ship design.

1.4.3 Insurance

Insurance costs include:

(1) Hull and machinery premium, which covers loss or damage to ship's hull, machinery and equipment, as well as part of legal and salvage or damage costs arising from collision with other ships,

(2) Protection and indemnity, which covers owners' liabilities, not covered by hull and machinery premium, and

(3) War risk cover, which covers losses and liabilities incurred during hostilities.

Total LNG carrier insurance costs depend, in part, directly upon ship size, because they reflect the capital value of the ship. Insurance costs also tend to vary with operational risks. For LNG carriers these risks are comparatively low. The insurance premium on an LNG carrier is comparatively lower than that for, say, an oil tanker for the same amount of coverage, because the risks attaching to the operations of the much more highly sophisticated LNG carriers are less. There is virtually no environmental pollution risk associated with LNG - methane gas is non-toxic. There is, it is true, a potential explosion hazard, but because the cargo in an LNG carrier is sealed within a double hull, the possibility of cargo loss and therefore explosion in a collision is minimised. (Experiments carried out by Shell UK at Maplin Sands, Essex, in mid-1980 to discover the behaviour of potentially explosive liquefied gases following spills of up to 20 cubic metres of LNG and LPG, appear to have confirmed existing engineering models upon which designs for transportation and storage facilities for liquefied gases were based). Existing gas carriers, both LNG and LPG carriers, have had an exceptionally good operational safety record, and because present international minimum requirements in the construction, operation and maintenance of gas carriers are rigidly imposed, this record should be continued. However, three factors could lead to an escalation in LNG shipping insurance costs in the future:

(i) the $300 million insurance claim by the El Paso Corporation involving three ships, the "El Paso Columbia", "El Paso Savannah" and "El Paso Cove Point", all 125,000 $M^3$ LNG carriers, which developed cracks in the polyurethane secondary barrier insulation whilst undergoing trials at the builders' yard, Avondale Shipyards, in Louisiana. Such a claim, one of the largest marine construction claims settlements on record, seems likely to have unfavourable effects on future LNG carrier insurance premiums.

(ii) the grounding of the "El Paso Paul Kayser" off southern Spain in July 1979 and that of the "LNG Taurus" off Kitakyushu City on Japan's west coast in December 1980 may lead to a realignment of LNG carrier insurance premiums. However, the successful refloating of both vessels without loss of cargo and with comparatively minor damage to the vessels concerned may have allayed the fears of LNG carrier insurers.

(iii) rising real hull values seem likely to push up insurance premiums, assuming the hull and machinery premium covers the replacement cost of the vessel in the event of accident.

1.4.4 Stores and Supplies

Stores and supplies consist essentially of consumable deck and engine stores, such as lubricating oil, and liquid inerting gas for ships' void spaces (between stank spaces). These costs vary with ship size but are a relatively small proportion of fully built up LNG carrier costs.

1.4.5 Administration, Management Overheads and Other Miscellaneous Costs

These additional items make up the remainder of total annual LNG carrier operating costs. Costs under this head are unlikely to vary much in relation to ship size. However, considerable variations in the level of such costs can occur between owners of otherwise similar vessels.

### 1.4.6 Total Annual LNG Carrier Operating Costs

The total estimated annual LNG carrier operating costs for 1980 are shown below in TABLE 2. These are based on:

(a) in-house historical data

(b) the results of H.P. Drewry's most recent confidential operating cost return survey. As no LNG carrier owners/operators were willing to divulge details of the operating costs incurred by them during the relevant year (1979), LPG carrier operating costs have been used as a proxy and adjusted where the consultants deem it necessary to allow for differences in costs between vessel types and cost alterations since end-1979.

TABLE 2

1980 ESTIMATED ANNUAL LNG CARRIER OPERATING COSTS ($ 000)

| COST TYPE | ESTIMATED LEVEL OF COST |
|---|---|
| Manning | 1.510 |
| Repairs and Maintenance | 0.750 |
| Insurance | 0.868 |
| Stores and Supplies | C.350 |
| Administration and Other | 0.334 |
| Total per vessel | 3.812 |

## 1.5 LNG CARRIER VOYAGE COSTS

Voyage costs consist of three elements:

(i) fuel costs

(ii) port costs

(iii) canal dues (where applicable)

1.5.1 Fuel costs

Fuel costs are dependant on a number of factors:

(i) length of voyage

For the purposes of this consultancy, the voyage distances displayed in TABLE 3 have been utilised.

(ii) length of loading/discharge procedure

Turnarou ime per port visit is estimated at 2 days Such an allowance may seem rather generous given that modern LNG carriers can complete loading and discharge procedures within 15 hours but port delays, vessel manoeuvering, hose connection/disconnection activities etc. are likely to ensure that the 15 hour period is considerably extended.

(iii) time consumed using canal facilities

Time consumed utilising canal facilities (where appropriate) is estimated at two days per round trip (one day per transit). Official Suez Canal transit time, for example, is approximately 14 hours but delays caused by convoy mustering and possible cancellation suggests that an allowance of 1 day per transit may be more realistic.

(iv) bunker consumption

LNG carriers are unique in the world today in that they utilise a proportion of their cargo as a fuel for their main engine. Despite the use of insulating techniques to maintain a constant temperature within the cargo containment system and thus ensure that the commodity maintains its liquid state (unnatural at normal pressure levels and ambient temperatures), some of the liquefied gas inevitably evaporates and returns to its normal state. The reliquefaction of boil-off

## TABLE 3

## VOYAGE DISTANCE PER ROUND TRIP

| DISCHARGE PORT / LOAD PORT | GENOA (ITALY) | ROTTERDAM (NETHERLANDS) | NEW ORLEANS (US GULF COAST) | YOKOHAMA (JAPAN) |
|---|---|---|---|---|
| SKIKDA (ALGERIA) | 934 | 3,910 | 10,328 | 18,532 (SUEZ/SUEZ) |
| DOHA (QATAR) | 9,020 (SUEZ/SUEZ) | 12,730 (SUEZ/SUEZ) | 19,148 (SUEZ/SUEZ) | 13,044 |
| ACEH (INDONESIA) | 11,704 (SUEZ/SUEZ) | 15,414 (SUEZ/SUEZ) | 21,832 (SUEZ/SUEZ) | 7,034 |
| VERACRUZ (MEXICO) | 11,322 | 10,274 | 1,620 | 18,282' (PANAMA/PANAMA) 29,276' (SUEZ/SUEZ) |

' 125,000 $M^3$-130,000 $M^3$ LNG carriers cannot transit the Panama Canal due to beam restrictions. Thus, the Suez passage is employed here.

Source : H.P.Drewry Shipping Consultants Ltd.

gas on board ship would be too expensive to contemplate whilst the release of boil-off gas into the atmosphere would represent a complete loss and thus the boil-off gas is used as a supplemental fuel in the vessel's main engine. (Under the terms of the IMCO Codes relating to gas carriers viz "The Code for the Construction and Equipment of Ships carrying Liquefied Gases in Bulk" and "The Code for Existing Ships Carrying Liquefied Gases in Bulk" Chapter XVI 16.1, methane (LNG) is the only cargo whose vapour or boil-off gas may be utilised in main propelling machinery rooms and boiler rooms. Thus, combined LPG/LNG carriers must be fitted with reliquefaction plant capable of maintaining LPG cargoes in a liquid form. Such vessels are often able to reliquefy a portion of LNG boil-off - the recently delivered 126,000 M3 LPG/LNG carrier "Mourad Didouche", a product of the Chantiers de l'Atlantique (Saint-Nazaire) yard, is fitted with two reliquefaction units capable of reliquefying about 30% of the methane boil-off. Indeed, recent developments suggest that in future specialist LNG carriers could be constructed with reliquefaction units capable of handling all methane boil-off and thus obviate the need to use boil-off as a substitute for bunker fuel. Such a development would inevitably result in an increase in annual capital costs but this would be offset by lower bunker costs as fuel oil is cheaper on a cost per million BTU basis than the comparable boil-off gas cost. The incorporation as a matter of course of reliquefaction units on board specialist LNG carriers is, however, unlikely to become a feature of the market in the near future).

Newly built 125,000-130,000 $M^3$ LNG carriers consume about 200 tonnes of fuel oil equivalent at sea per day whilst attaining a speed of about 19 knots. Consumption in port will equate to about 40 tonnes of fuel oil daily, whilst consumption per day consumed transitting canals will equate to the amount of gas boil-off (0.2% of cargo capacity per day at sea) on the loaded leg and 70 tonnes of fuel oil daily on the ballast leg. Whilst at sea, in a loaded condition, about 65% of a 125,000 $M^3$ LNG carrier's fuel requirement will be met from boil-off gas, assuming a 0.2% cargo loss per day at sea, whilst, on the return leg, almost all the vessel's fuel requirements will be fulfilled via bunker fuel consumption.

(v) <u>bunker costs</u>

The price of boil-off gas has been estimated thus:

(a) Indonesian gas on the Japanese market cost $5.39 per million BTU in June 1980 and thus this figure has been used for all shipments originating in Aceh;

(b) The price of gas originating in the United Arab Emirates on the Japanese market in June 1980 was $5.59 per million BTU and thus this figure has been used for boil-off gas valuation on all shipments out of Doha;

(c) Boil-off gas originating in Skikda and Veracruz has been estimated to cost $5.00 per million BTU as at mid-1980. Such a figure would appear to be fairly reasonable in the light of

(i) the gas prices indicated in (a) and (b) above;

(ii) the breakdown in Algerian-US negotiations concerning the "El Paso" contract. Upon cessation of supply, El Paso was paying $1.95 per million BTU whilst Algeria was demanding $6.11 per million BTU. Recently, negotiations recommenced and some industry analysts believe a compromise solution with a price of about $4.50 per million BTU may result;

## TABLE 4

### BUNKER COSTS AS AT MID-1980 (US DOLLARS PER TONNE)

| GRADE \ AREA | ARABIAN GULF | NORTH EUROPE | CARIBBEAN | US GULF | SINGAPORE | JAPAN | ITALY | NORTH AFRICA |
|---|---|---|---|---|---|---|---|---|
| FUEL OIL (180 cst) | 176 | 164 | 169 | 131 | 182 | 179 | 179 | 181 |
| MARINE DIESEL | 346 | 303 | 292 | 241 | 339 | 340 | 349 | 350 |

## TABLE 5

### BUNKER COSTS PER ROUND TRIP AS AT MID-1980

(US DOLLARS)

| DISCHARGE PORT \ LOADING PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| GENOA | 107,140 | 696,753 | 1,088,259 | 896,805 |
| ROTTERDAM | 346,860 | 1,148,058 | 1,368,361 | 788,325 |
| NEW ORLEANS | 819,115 | 1,596,838 | 1,801,585 | 134,129 |
| YOKOHAMA | 1,626,945 | 1,166,287 | 637,160 | 2,315,585 |

Source : H.P.Drewry Shipping Consultants Ltd.

(iii) Mid-1980 Canadian and Mexican natural gas pipeline supply prices on exports to the US of $4.47 per million BTU.

In addition, bunker prices as at mid-1980 are displayed in TABLE 4. This information is drawn from the H.P. Drewry "Quarterly Tanker Market Report" for July 1980 and on data published by Marine Oil Consultants Ltd.

(vi) cargo boil-off/residual

5% of total cargo capacity is anticipated to be returned on the ballast leg as cargo residual (or cargo heel) and used as a refrigerating agent to keep the cargo tanks cold. 0.2% of cargo capacity per day at sea is assumed to be lost as cargo boil-off.

Using these assumptions, the Consultants have formulated TABLE 5 showing total bunker costs incurred per round trip by 125,000-130,000 $M^3$ LNG carriers operating on the routes under investigation.

### 1.5.2 Port Disbursements

Port disbursements include the cost of terminalling operations, pilotage, tug hire etc. For the purposes of this consultancy, port charges have been estimated from actual disbursement accounts associated with similar sized tankers calling at the ports in question, or, in the absense of such data, neighbouring ports, as reported by the Consultant's confidential sources. These port charges are shown below in TABLE 6.

TABLE 6

PORT CHARGES PER VISIT AS AT MID-1980
(US DOLLARS)

| PORT | SKIKDA | DOHA | ACEH | VERACRUZ | GENOA | ROTTERDAM | NEW ORLEANS | YOKOHAMA |
|---|---|---|---|---|---|---|---|---|
| PORT CHARGES | 60,750 | 15,775 | 20,250 | 24,300 | 27,000 | 92,000 | 45,900 | 40,000 |

### 1.5.3 Suez Canal Tolls

From July 1979, Suez Canal tolls have been fixed on the following basis:

(i) 2.084 SDRs for the first 5,000 Suez Net Registered Tonnes (SCNRT) loaded;

(ii) 1.6672 SDRS for the first 5,000 SCNRT ballast;

(iii) 1.611 SDRs for the excess over 5,000 SCNRT loaded;

(iv) 1.289 SDRS for the excess over 5,000 SCNRT ballast.

Assuming that 1 SDR = $1.30 and that a 125,000-130,000 $M^3$ LNG carrier will have a SCNRT equivalent of 64,125, the cost per round trip will be $247,301.

### 1.5.4 Total LNG Carrier Voyage Costs per round trip

By simply combining bunker costs with port disbursements and Suez Canal tolls, where applicable, total voyage costs per round trip can be estimated. This exercise is accomplished in TABLE 7.

TABLE 7

TOTAL VOYAGE COSTS PER ROUND TRIP AS AT MID-1980
(US DOLLARS)

| ROUTE | BUNKER COSTS | PORT CHARGES | CANAL TOLLS | TOTAL |
|---|---|---|---|---|
| SKIKDA-GENOA | 107,140 | 87,750 | - | 194,890 |
| SKIKDA-ROTTERDAM | 346,860 | 152,750 | - | 499,610 |
| SKIKDA-NEW ORLEANS | 819,115 | 106,650 | - | 925,765 |
| SKIKDA-YOKOHAMA | 1,626,945 | 100,750 | 247,301 | 1,974,996 |
| DOHA-GENOA | 696,753 | 42,725 | 247,301 | 986,829 |
| DOHA-ROTTERDAM | 1,148,058 | 107,775 | 247,301 | 1,503,134 |
| DOHA-NEW ORLEANS | 1,596,838 | 61,675 | 247,301 | 1,905,814 |
| DOHA-YOKOHAMA | 1,166,287 | 55,775 | - | 1,222,062 |
| ACEH-GENOA | 1,088,259 | 47,250 | 247,301 | 1,382,810 |
| ACEH-ROTTERDAM | 1,360,361 | 112,250 | 247,301 | 1,727,912 |
| ACEH-NEW ORLEANS | 1,801,585 | 66,150 | 247,301 | 2,115,036 |
| ACEH-YOKOHAMA | 637,160 | 60,250 | - | 697,410 |
| VERACRUZ-GENOA | 896,805 | 51,300 | - | 948,105 |
| VERACRUZ-ROTTERDAM | 788,325 | 116,300 | - | 904,625 |
| VERACRUZ-NEW ORLEANS | 134,129 | 70,200 | - | 204,[illegible] |
| VERACRUZ-YOKOHAMA | 2,315,585 | 64,300 | 247,301 | 2,627,186 |

## 1.6 TRANSPORT COSTS PER TONNE DELIVERED

To enable the calculation of transport cost per metric tonne delivered, the Clients asked the Consultants to assume an annual volume per route of 6,000,000 metric tonnes would be traded (for the purposes of this study, it has been assumed that 6,000,000 metric tonnes is the amount delivered per annum, that is net of boil-off and cargo heel allowance). This figure has been used in conjunction with the earlier assumptions concerning speed, port time, canal time and operating year (viz 19 knots, 2 days per pot visit, 2 days canal time per round trip and a 345 day operating year) to calculate the number of LNG carriers required on each route.

This enables the calculation of total capital, operating and voyage costs associated with a particular route in 1980 and thus transport costs per tonne based upon the given trade volume.

TABLE 8

CALCULATION OF TRANSPORT COSTS PER TONNE DELIVERED AS AT MID-1980

| ROUTE | NO. OF UNITS REQUIRED | TOTAL ANNUAL CAPITAL COSTS ($) | TOTAL ANNUAL OPERATING COSTS ($) | NO. OF ROUND TRIPS REQUIRED | TOTAL ANNUAL VOYAGE COSTS ($) | TOTAL ANNUAL FULLY BUILT UP COSTS ($) | FULLY BUILT UP COSTS PER TONNE DELIVERED ($) |
|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 2 x 125,000 | 39,100,000 | 7,624,000 | 106.59 | 20,773,325 | 67,497,325 | 11.25 |
| SKIKDA-ROTTERDAM | 4 x 125,000 | 78,200,000 | 15,248,000 | 107.33 | 53,623,141 | 147,071,141 | 24.51 |
| SKIKDA-NEW ORLEANS | 9 x 125,000 | 17,595,000 | 34,308,000 | 108.96 | 100,871,354 | 311,129,354 | 51.85 |
| SKIKDA-YOKOHAMA | 15 x 130,000 | 304,950,000 | 57,180,000 | 107.07 | 211,462,822 | 573,592,822 | 95.60 |
| DOHA-GENOA | 7 x 125,000 | 136 850,000 | 26,684,000 | 108.39 | 106,962,395 | 270,496,395 | 45.08 |
| DOHA-ROTTERDAM | 11 x 125,000 | 215,050,000 | 41,932,000 | 109.82 | 165,074,176 | 422,056,176 | 70.34 |
| DOHA-NEW ORLEANS | 16 x 125,000 | 312,800,000 | 60,992,000 | 111.52 | 212,536,377 | 586,328,377 | 97.72 |
| DOHA-YOKOHAMA | 10 x 130,000 | 203,300,000 | 38,120,000 | 105.44 | 128,854,217 | 370,274,217 | 61.71 |
| ACEH-GENOA | 10 x 130,000 | 203,300,000 | 38,120,000 | 105.34 | 145,665,205 | 387,085,205 | 64.51 |
| ACEH-ROTTERDAM | 13 x 125,000 | 254,150,000 | 49,556,000 | 110.52 | 190,968,834 | 494,674,834 | 82.45 |
| ACEH-NEW ORLEANS | 18 x 125,000 | 351,900,000 | 68,616,000 | 112.25 | 237,412,791 | 657,928,791 | 109.65 |
| ACEH-YOKOHAMA | 6 x 130,000 | 121,980,000 | 22,872,000 | 103.96 | 72,502,744 | 217,354,744 | 36.23 |
| VERACRUZ-GENOA | 9 x 130,000 | 182,970,000 | 34,308,000 | 105.02 | 99,569,987 | 316,847,987 | 52.81 |
| VERACRUZ-ROTTERDAM | 9 x 125,000 | 175,950,000 | 34,308,000 | 108.94 | 98,549,848 | 308,807,848 | 51.47 |
| VERACRUZ-NEW ORLEANS | 3 x 125,000 | 58,650,000 | 11,436,000 | 106.76 | 21,814,164 | 91,900,164 | 15.32 |
| VERACRUZ-ROTTERDAM | 23 x 130,000 | 467,590,000 | 87,676,000 | 109.94 | 288,832,829 | 844,098,829 | 140.68 |

Source : H.P.Drewry Shipping Consultants Ltd.

Using this methodology, TABLE 8 has been constructed and costs per metric tonne delivered calculated.

## 1.7 TRANSPORT COSTS PER TONNE DELIVERED - ALTERNATIVE METHODOLOGY

The costs displayed in TABLE 8 relate to LNG carriers ordered in mid-1978 for mid-1980 delivery : this brief section presents our alternative methodology which revises the capital element of the costs involved. For the purposes of this exercise it has been assumed that LNG carriers have been ordered and delivered in mid-1980 and thus contemporary pricing data is utilised.

Japanese LNG carrier newbuilding prices at mid-1980 are estimated at $142.2 million per 125,000 $M^3$ unit and $147.9 million per 130,000 $M^3$ unit i.e. annual capital charges of $24.173 million and $25.143 million respectively. These prices appear reasonable given the mid-year signing of contracts for two 125,000 $M^3$ LNG carriers building at the Mitsubishi and Kawasaki yards for NYK, Mitsui OSK, 'K' Line and Japan Line joint ownership of a rumoured cost of ¥30,000 million each ($137.61 million at ¥218 = $1). These prices were reached after protracted negotiations so additional LNG carriers of this size would probably have cost ¥31,000 million each or $142.2 million.

Using these alternative capital costs, fully built up trading costs per tonne delivered as expressed in TABLE 8 may be amended, as displayed in TABLE 9.

TABLE 9

TRANSPORT COSTS PER TONNE DELIVERED - MID-1980 ORDERED AND DELIVERED TONNAGE

($)

| DISCHARGE PORT \ LOADING PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| GENOA | 12.79 | 50.48 | 72.57 | 59.86 |
| ROTTERDAM | 27.59 | 78.82 | 92.46 | 58.40 |
| NEW ORLEANS | 58.79 | 110.05 | 123.53 | 17.63 |
| YOKOHAMA | 107.68 | 69.77 | 41.04 | 159.13 |

Source : H.P.Drewry Shipping Consultants Ltd.

## 1.8 MID-1985 LNG TRANSPORTATION COSTS

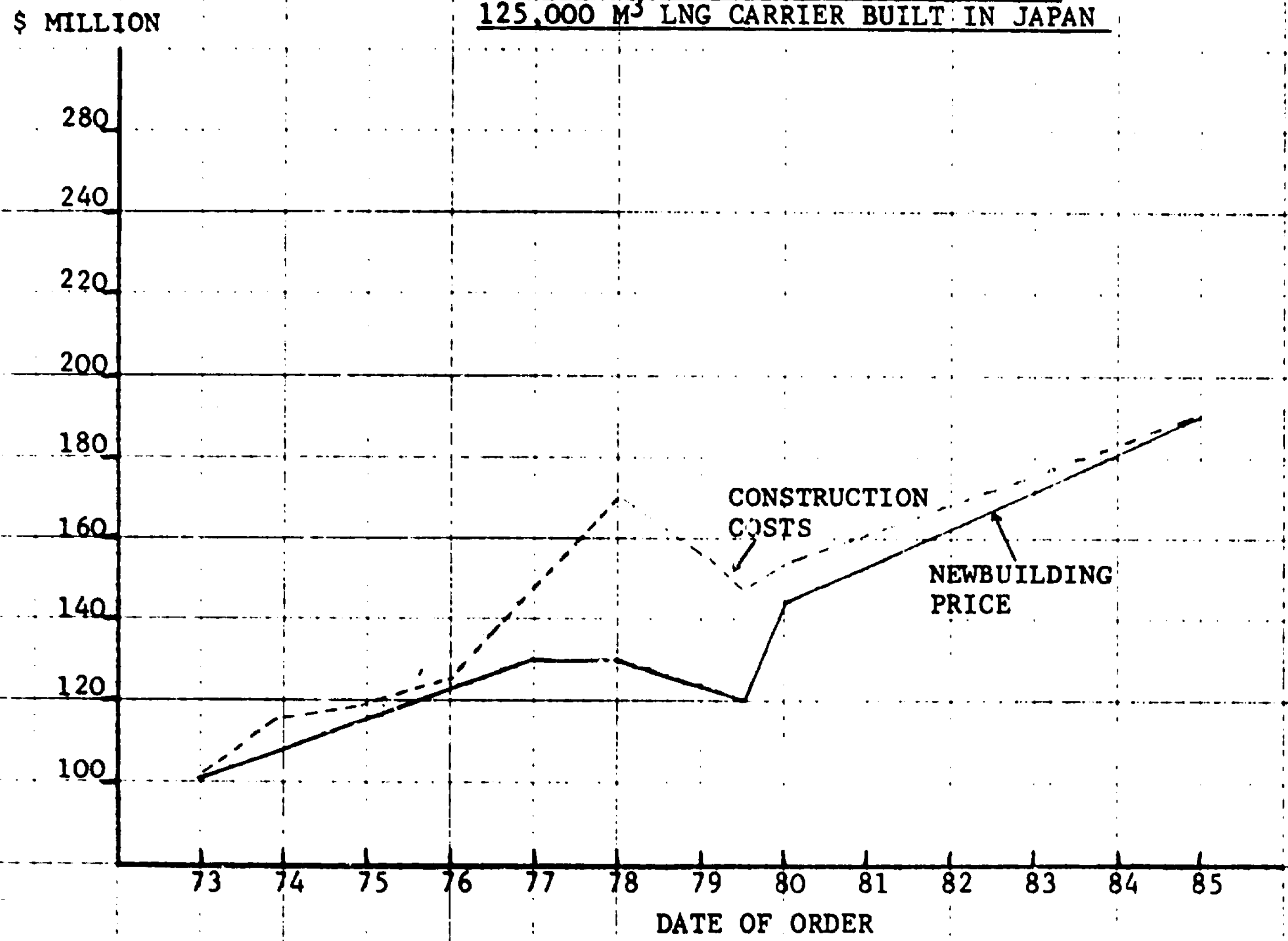
The cost elements have been outlined in SECTIONS 1.2 to 1.5 above. These elements have been altered to take account of upward inflationary pressure on the following assumptions:

(i) Newbuilding prices - newbuilding order prices are assumed to equate to construction costs (including normal profits) when the employment market for LNG carriers reaches equilibrium (see SECTION 1.13). Unfortunately construction cost data is extremely limited and of doubtful validity when available. (Indeed, even newbuilding price information must be treated with an element of caution). However, the Consultants believe that construction costs for LNG carriers are likely to rise by about 7% per annum between 1980 and 1985. Construction cost increases for such vessels building in Japanese yards are likely to be minimised as economies of scale are reaped following the expansion of the Japanese LNG carrier construction industry from its current relatively small base. Thus, 125,000 $M^3$ unit prices are likely to approximate to $170 million for 1983 orders and $190 million for 1985 orders whilst 130,000 $M^3$ LNG carriers are likely to cost $176.8 million and $197.6 million respectively if ordered at those dates. These newbuilding price levels would be consistent with annual capital costs of $28.9 million, $32.3 million, $30.06 million and $33.59 million respectively. (The approximate relationship between construction costs and newbuilding order prices for 125,000 $M^3$ Japanese built LNG carriers is portrayed in FIGURE 2).

(ii) Operating costs - total operating costs are assumed to increase at an annual rate of 10% per annum. This is approximately in line with historical experience.

FIGURE 2

FORECAST NEWBUILDING ORDER PRICES
125,000 $M^3$ LNG CARRIER BUILT IN JAPAN




Source : H.P.Drewry Shipping Consultants Ltd.

(iii) Bunker prices - the Consultants were asked to assume that, by 1985, crude oil prices would have reached either $40 or $80 a barrel. The Consultants have interpeted this request in the following manner:

(a) as crude has been given a uniform cost per barrel, irrespective of quality differences, area of production or market considerations, the Consultants have assumed that, for each level of price, a single fuel oil and marine diesel cost will be applicable irrespective of route.

(b) actual fuel oil/marine diesel costs have been calculated thus: the price of marker crude as at mid-1980 stood at $28 a barrel and this price has been used in conjunction with the prices quoted by the Clients to inflate mid-1980 Arabian Gulf bunker prices to their likely mid-1985 levels. The resulting bunker prices have been used throughout this exercise.

(iv) Boil-off gas prices - boil-off gas prices have been increased on a similar basis, with a cost of $7.14 per MMBTU of gas being associated with a bunker cost of $40 a barrel and one of $14.28 per MMBTU being associated with a bunker cost of $80 a barrel.

(v) Port costs - these normally form a relatively minor part of overall voyage costs, and thus of total costs. Port disbursements will vary considerably between ports and thus it is likely that rises in port costs will also vary, depending upon port management policy, competition from other ports in the vicinity etc. A year-on-year increase of 8.5% has been incorporated into future cost projections for the purposes of this consultancy.

(vi) Canal dues - (a) Suez Canal. Tolls were revised late in 1980 following the deepening operations. The new tariff is as presented below in TABLE 10. This new tariff structure has been utilised in the calculation of mid-1985 costs.

TABLE 10

NEW SUEZ CANAL TARIFF STRUCTURE

| | RATE - SPECIAL DRAWING RIGHTS PER SUEZ CANAL NET REGISTERED TON | | | |
|---|---|---|---|---|
| | LADEN | | BALLAST | |
| | SDR | $ | SDR | $ |
| First 5,000 tons | 3.50 | 4.55 | 2.80 | 3.64 |
| Next 15,000 tons | 2.10 | 2.73 | 1.68 | 2.18 |
| Additional Tons: | | | | |
| (i) tankers (petroleum), bulk carriers combined carriers | 1.30 | 1.69 | 1.04 | 1.35 |
| (ii) all other vessels | 2.10 | 2.73 | 1.68 | 2.18 |

Assumes 1 SDR = $1.30

Thus, Suez Canal charges in mid-1985 for a 125,000 $M^3$ LNG carrier has been taken as $248,740 per round trip.

(b) Panama Canal. The last increase in the level of Panama Canal charges was in 1976 when a hike of 20% occurred. Previous to that, tolls had been increased in 1974, the only other increase experienced in the life of the canal. Thus, rate increases are irregular and do not keep pace with inflation. Tolls are, however, likely to increase over the period and thus a nominal increase of 5% per annum has been incorporated into the calculations.

Based on these assumptions, mid-1985 LNG transportation costs have been calculated, as shown overleaf in TABLE 11.

TABLE 11

TRANSPORT COST PER TONNE OF LNG DELIVERED AS AT MID-1985
(US DOLLARS)

| ROUTE \ COST BASIS | MID-1983 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1983 ORDER/ CRUDE OIL COST $80 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $80 PER BARREL |
|---|---|---|---|---|
| SKIKDA-GENOA | 16.70 | 19.37 | 17.08 | 19.76 |
| SKIKDA-ROTTERDAM | 36.44 | 45.41 | 37.21 | 46.18 |
| SKIKDA-NEW ORLEANS | 78.32 | 101.18 | 80.06 | 102.92 |
| SKIKDA-YOKOHAMA | 143.97 | 184.70 | 147.20 | 187.93 |
| DOHA-GENOA | 63.62 | 80.70 | 64.97 | 82.05 |
| DOHA-ROTTERDAM | 101.01 | 130.26 | 103.14 | 132.39 |
| DOHA-NEW ORLEANS | 143.56 | 187.34 | 146.65 | 190.43 |
| DOHA-YOKOHAMA | 93.28 | 121.03 | 95.43 | 123.18 |
| ACEH-GENOA | 95.63 | 121.58 | 97.28 | 123.73 |
| ACEH-ROTTERDAM | 118.88 | 154.14 | 121.39 | 156.65 |
| ACEH-NEW ORLEANS | 161.61 | 211.58 | 165.09 | 215.06 |
| ACEH-YOKOHAMA | 55.08 | 70.16 | 56.37 | 71.45 |
| VERACRUZ-GENOA | 81.45 | 103.91 | 83.39 | 105.85 |
| VERACRUZ-ROTTERDAM | 76.84 | 97.95 | 78.58 | 99.69 |
| VERACRUZ-NEW ORLEANS | 23.17 | 26.93 | 23.75 | 27.51 |
| VERACRUZ-YOKOHAMA | 214.33 | 274.98 | 219.28 | 279.93 |

Source : H.P.Drewry Shipping Consultants Ltd.

## 1.9 LNG TRANSPORTATION COSTS - CHANGES OVER THE PERIOD 1975 TO 1980 COMPARED WITH 1980 TO 1985

The Clients have asked the Consultants to compare the increases in costs between 1975 and 1980 with those anticipated over the period 1980-85 for the typical voyage for each product. The nature of the LNG transportation industry facilitates an easy choice of typical route. For the purposes of this consultancy, the costs of transporting LNG between Brunei and Japan will be reviewed.

### 1.9.1 Capital Costs

It is common practice for LNG carrying tonnage to be constructed to fulfil the specific requirements of a particular trade for the duration of that trade. (Contracts normally last 15 to 25 years). Such was the case with the Brunei to Japan trade: five c.75,000 $M^3$ LNG carriers were constructed initially to enable the transportation of a contracted volume of 525 million cubic feet of gas per day and an additional two vessels of 77,731 $M^3$, costing $31.5 million each, entered service in 1975 following an expansion of trade volume to 750 million cubic feet of gas per day. These vessels should remain in operation until project cessation in 1995 and thus, capital costs will remain unaltered throughout contract length. At current OECD terms, such a capital cost would be consistent with an annual capital cost of $5.355 million per annum. Mid-1980 prices for such vessels are difficult to estimate due to the lack of recent orders for vessels of this size but perhaps a unit cost of about $100 million could be anticipated.

### 1.9.2 Operating Costs

Operating costs for tankers have increased by 13.8% per annum over the period 1975 to 1979 according to the confidential operating cost surveys carried out by the Consultants. It has been assumed here that annual LNG carrier operating costs will have increased at a similar annual rate. Thus, if annual operating costs for a 75,000 $M^3$ LNG carrier in mid-1980 totalled $3.254 million comprising:

| | |
|---|---|
| Manning Costs | $1.31 million |
| Repair and Maintenance Costs | $0.60 million |
| Insurance Costs | $0.65 million |
| Stores and Supplies Costs | $0.35 million |
| Administration Costs | $0.344 million |

then operating costs in 1975 would have equated to $1.705 million per unit.

Operating costs from 1980 to 1985 have been escalated at 10% per annum, however. This is less than that observed for tankers over the period 1975 to 1979 but is more in line with that experienced by dry cargo vessels during the earlier period. As operating costs for all vessel types should increase at similar rates in general, a lower rate of increase in LNG carrier operating costs may be anticipa..d over the forecast period. Thus, operating costs for 75,000 $M^3$ LNG carriers may rise to $5.241 million in 1985.

### 1.9.3 Voyage Costs

The main element of voyage costs, bunker prices, has changed dramatically over the period 1975 to 1980 and is likely to do so between 1980 and 1985. (Port costs form a very small proportion of voyage costs and thus a lengthy discussion will not be attempted here). Estimated bunker prices in the relevant areas are as shown in TABLE 12.

TABLE 12

APPROXIMATE BUNKER PRICE LEVELS AT MID-YEAR

($ per ton)

| | | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| Japan | Fo | 66.0C | 67.50 | 78.50 | 81.00 | 159.00 | 179.00 |
| | Do | 99.00 | 117.00 | 126.00 | 126.00 | 270.00 | 340.00 |
| Singapore | Fo | 58.50 | 63.50 | 73.00 | 79.00 | 135.00 | 182.00 |
| | Do | 99.00 | 117.00 | 124.00 | 124.00 | 232.00 | 339.00 |

Similarly, boil-off gas prices have increased considerably over the period, as shown in TABLE 13.

TABLE 13

CIF PRICE OF BRUNEI GAS

($/MMBTU)

| YEAR | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|
| BRUNEI PRICE | 1.73 | 1.83 | 1.98 | 2.12 | 2.59 | 5.36 |

The Clients anticipate that crude oil in 1985 will cost either $40 a barrel or $80 a barrel. Assuming a crude oil price at mid-1980 of $28 a barrel and using contemporary Arabian Gulf bunker prices viz fuel oil at $176 a tonne and marine diesel at $346 a tonne as a benchmark, bunker prices will increase to:

TABLE 14

COMPARISON OF DELIVERED TRANSPORT COST OF LNG MOVEMENTS 1975 to 1980 AND 1980 TO 1985

($)

| YEAR | ANNUAL CAPITAL COSTS | ANNUAL OPERATING COSTS | ANNUAL BUNKER COSTS | ANNUAL PORT CHARGES | TOTAL ANNUAL COSTS | COSTS PER ROUND TRIP | COSTS PER TONNE DELIVERED | CHANGE IN COSTS OVER PERIOD |
|---|---|---|---|---|---|---|---|---|
| 1975 | 5,355,000 | 1,705,000 | 1,915,208 | 914,564 | 9,889,712 | 406,649 | 11.72 | |
| 1980 | 5,355,000 | 3,254,000 | 5,715,131 | 1,375,190 | 15,699,321 | 645,531 | 18.61 | 58.8% |
| 1985 (a) | 5,355,000 | 5,241,000 | 7,799,768 | 2,067,814 | 20,463,582 | 841,430 | 24.25 | 30.3% |
| (b) | 5,355 000 | 5,241,000 | 15,599,534 | 2,067,814 | 28,263,348 | 1,162,144 | 33.50 | 80.0% |

Source : H.P.Drewry Shipping Consultants Ltd.

(a) $251 a tonne for fuel oil and $494 a tonne for marine diesel assuming a crude oil price of $40 a barrel in 1985;

(b) $502 a tonne for fuel oil and $988 a tonne for marine diesel assuming a crude oil price of $80 a barrel in 1985.

Similarly, if it is assumed that boil-off gas prices will increase in line with rises in the price of crude, gas in 1985 will be priced at either $7.14 or $14.28 per million British Thermal Unit (MMBTU).

1.9.4 Changes in Overall Cost Levels

Using the above figures, estimates of costs incurred per voyage can be calculated. (It has been assumed that port costs will have increased at a rate of 8.5% per annum throughout the period).

Costs per round trip and costs per tonne delivered are estimated in TABLE 14 and have been calculated on the assumptions that

(i) a 75,000 $M^3$ LNG carrier will complete 24.32 round trips annually, steaming at 18 knots and consuming 110 tons of fuel daily;

(ii) such a vessel will deliver 843,932 tonnes of LNG annually.

1.10 SPECIFIC HAZARDS/SPECIALISED SHIPPING REQUIREMENTS OF LNG TRADING

The extremely low temperatures involved in the carriage of LNG (about-161.5°C) and the potential volatility of the cargo in the event of spillage provide potential hazards for the seaborne LNG trader. These have been minimised extremely well by the construction of highly specialised, extremely sophisticated LNG carriers complying with a plethora of regulations i.e. IMCO Codes, US Coastguard, classification society requirements etc. As a result, such vessels have suffered due to:

(i) high construction costs - speculative LNG carrier construction is almost unknown, owners preferring to secure lifetime employments for LNG carriers prior to vessel ordering due to the heavy capital expenditure implied in the acquisition of such tonnage.

(ii) LNG carrier unemployment - delays in the commissioning of LNG liquefaction trains, administrative problems i.e. the siting of reception facilities in the importing country, disagreements over price of product etc. have resulted in the delivery of LNG carrying capacity ahead of trade commencement. The vertically integrated nature of the LNG trade, the highly specialised character of LNG carriers and the non-existence of a sizeable spot market for LNG shipments have resulted in such capacity sustaining periods of lay-up.

(iii) absence of backhaul cargoes - as LNG carriers are designed specifically for the carriage of liquefied methane, no prospect of backhaul cargoes exists. (Some carriers have the ability to carry LPG in addition to LNG but the carriage of such a commodity to the loading terminal or environs would seem rather unlikely).

## 1.11 CURRENT SHIPPING PRACTICE AND POSSIBLE FUTURE REVISIONS

As stated above, at end-1980 70% of the LNG carriers in existence had a carrying capacity of between 125,000 $M^3$ and 130,000 $M^3$, this being the typical cargo size carried. (This equates to between about 59,000 and 62,000 metric tonnes). Given that 84% of LNG carrying capacity on order is of a similar size it is unlikely that, despite the availability of designs for LNG carriers of 300,000 $M^3$, significantly larger vessels will be ordered in the foreseeable future in great numbers.

## 1.12 TERMINAL AND STORAGE FACILITIES

The seaborne LNG trade is a highly specialised trade requiring not only specific carriers but also distinctive facilities in both country of origin and importing nation. This section will briefly examine the facilities required to enable seaborne LNG trading to flourish.

### (i) Facilities in the exporting country

Natural gas is transported by pipeline from a single gas field (as in Brunei where the offshore Southwest Ampa field provides the natural gas for liquefaction at the Lummut plant) or from several fields (as will shortly be the case with the existing Abu Dhabi plant) to the liquefaction plant, generally sited at the export terminal. The liquefaction plant, normally consisting of more than one production train, isolates the methane from the other elements within the natural gas stream prior to sending the gas through a series of heat exchangers (cooled by liquefied gases such as propane, ethylene and methane) and compressors. The end product, LNG,

## TABLE 15

## INTERNATIONAL BASE LOAD LNG PLANT STORAGE CAPACITY

| PROJECT | DISTANCE (nautical miles per round trip) | CONTRACTED TRADE VOLUME (million cubic feet/day) | STORAGE CAPACITY ($10^6$ scf) | TANK NUMBERS |
|---|---|---|---|---|
| ALGERIA-US | 7,440/7,840 | 1,100 | 7,000 | 3 |
| BRUNEI -JAPAN | 4,400 | 750 | 4,050 | 3 |
| ALGERIA-FRANCE | 800 | 450 | 2,500 | 2 |
| US | 7,360 | | | |
| SPAIN | 800 | | | |
| INDONESIA (ARUN) -JAPAN | 6,440 | 1,200 | 8,350 | 4 |
| US | 16,000 | | | |
| INDONESIA (BADAK) -JAPAN | 5,200 | 450 | 6,250 | 3 |

Source : H.P.Drewry Shipping Consultants Ltd.

is then pumped into the storage facilities to await carrier arrival. The storage tanks are generally above ground, are double-walled metal tanks with the inner metal being 9% nickel or aluminium.

The amount of storage capacity required at the exporting terminal will be a function of a number of factors such as trade size, voyage distance, plant throughput, vessel carrying capacity and numbers. However, an indication of storage capacity requirements for an annual trade of 6,000,000 tonnes can be gained by reviewing existing storage capacity levels associated with trades of a similar size i.e. with a contracted trade volume of about 750 million cubic feet per day of gas. The results are shown in TABLE 15 overleaf.

During the loading procedure, the LNG is pumped from the storage facilities to the loading jetty and into the awaiting LNG carrier. As the liquid is loaded into the tanks, gas will be displaced which must be returned to the shore facilities via vapour return lines. The loading jetty must be able to accomodate vessels of up to about 11.6 metres in draught, 300 metres LOA and 44 metres in beam. (The dimensions of individual vessels of 125,000 $M^3$-130,000 $M^3$ will vary considerably with design, particularly containment system, differences).

(ii) reception facilities

Upon arrival at the importation terminal, gas and liquid shore connections are made and the cargo pumps started. As the volume of liquid in the tanks diminishes, pressure within the tanks will fall unless gas is pumped from the shore installations into the cargo tanks. The liquid is transported via pipeline to the storage tanks to await regasification. (As the volume delivered is less than the volume of cargo loaded, it would appear that requirements for storage capacity at the reception facility is less than at the production centre). This process is achieved by using submerged combustion, ambient air, intermediate fluid or direct-fired vapourisers. The resulting gas is then fed into the local (national) gas grid.

In addition to the specialist facilities required to enable the seaborne transportation of LNG, a number of other facilities must be available to LNG carriers, or any other vessel, at either the reception or dispatch centre or at intermediate ports:

(i) bunker loading facilities

(ii) water loading facilities

(iii) cranage to enable the loading of foodstuffs, lubricating oil, spares, equipment etc.

(iv) tugs and pilots to facilitate port entry/departure and the docking/undocking procedure.

## 1.13 THE AVAILABILITY OF LNG CARRYING CAPACITY IN 1985

In June 1980, the Consultants published a study, No.82, entitled "LNG Shipping in the Eighties". The following LNG carrier supply and demand predictions are based on this study and the conclusions amended to take into account the events of the past 6 months.

FIGURE 3 shows that LNG carrier supply and demand is likely to be in balance in 1985 and thus new orders will have to be placed to meet the demand for additional capacity in the event of the projects under discussion coming to fruition. This figure has been based upon the following assumptions:

(i) Supply

(a) no expansion in the end-1980 orderbook;

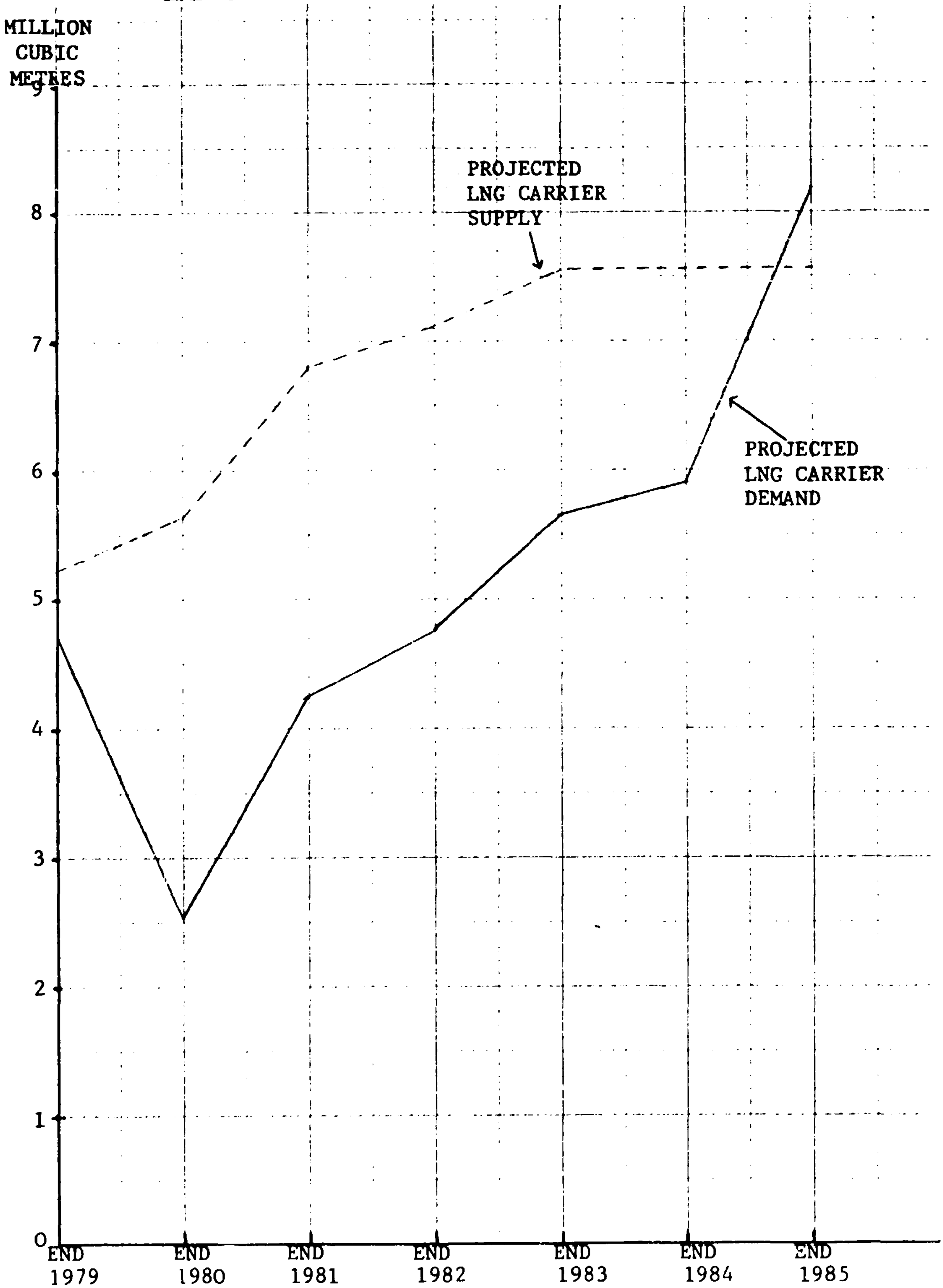
(b) carriers scheduled for delivery in 1980 (or earlier) not delivered by end-1980 will enter service in 1981. Otherwise, delivery will be as scheduled.

(c) only the 23,400 $M^3$ sisterships "Methane Princess" and "Methane Progress", currently trading Algeria to UK, will be scrapped when the present contract runs out. All other LNG carriers will continue in service. (As no LNG carriers have yet been scrapped, such an assumption appears reasonable).

(d) a nominal 80,000 $M^3$ of shipping capacity has been deducted to allow for small combined LNG/LPG/ethylene carriers trading on non-LNG trades.

FIGURE 3

PROJECTED LNG CARRIER SUPPLY/DEMAND BALANCE




Source : H.P.Drewry Shipping Consultants Ltd.

(ii) Demand

Projects currently in existence (apart from the Algeria to UK project) and those under construction or, in the Consultants'opinion, that will come to fruition prior to 1986 have been reviewed and the shipping demand that each project generates added to enable an estimate of world LNG shipping demand to be made for the period end 1979 to end 1985.

# STUDY OF TRANSPORT COSTS FOR SHIPPING PETROCHEMICALS

## SECTION 2

## LPG

### 2.1 CARGO CHARACTERISTICS

Liquefied petroleum gas (LPG) is a term used by the oil industry for propane and butane or a mixture of the two petroleum hydrocarbons. (As such the term is badly chosen given that any petroleum gas can be liquefied under the correct conditions). LPG can be derived either by the processing of sour "wet" natural gas retrieved from gas or oil fields or by the fractionation of crude oil at petroleum refineries. Brief descriptions of the properties of propane and butane are given below:

(i) Butane

(a) Properties

1. Formula $C_4H_{10}$
2. Colourless, virtually odourless
3. Boiling point at atmospheric pressure - 0.5°C.
4. Specific gravity 0.602
5. Coefficient of cubic expansion 0.002 per °C at 15°C.
6. Relative vapour density 2.01

(b) Conditions of Carriage

1. Normal carriage conditions pressurised, semi refrigerated or fully refrigerated.
2. Ship type 2G/2PG
3. Gauging restricted, closed or indirect
4. Vapour detection flammable

(c) Materials of Construction

1. Certain plastics are unsuitable.
2. Mild Steel, stainless steel and most normal metals are suitable.

(ii) Propane

(a) Properties

1. Formula $C_3 H_8$
2. Colourless, odourless
3. Boiling point at atmospheric pressure - 42.8°C
4. Specific gravity 0.583
5. Coefficient of cubic expansion 0.003 per °C at 15°C.
6. Relative vapour density 1.55

(b) Conditions of Carriage

1. Normal carriage conditions pressurised, semi refrigerated or fully refrigerated
2. Ship type 2G/2PG
3. Gauging restricted closed or indirect
4. Vapour detection flammable

(c) Materials of Construction

1. Mild steel (below 0°C) is unsuitable
2. Mild steel (above 0°C), stainless steel and aluminium is suitable.

SOURCE : Tanker Safety Guide (Liquefied Gas) - International Chamber of Shipping.
Liquid Gas Carrier Register 1980 - H.Clarkson & Co.

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## 2.2 THE LPG CARRIER

As with LNG, seaborne LPG carriage requires vessels of a specialist nature. LPG carriers are designed to transport liquefied gases either at subzero temperatures at atmospheric pressure (generally at c. -50°C), in mild steel pressure vessels designed to withstand pressures of perhaps $17kg/cm^2$ or use a combination of low temperature and pressurised containment. The fully pressurised vessel is generally very small (below 1,000 cubic metres) and thus is confined largely to coastal trading. Despite simple design and ease of operation, with little or no cargo supervision required during the voyage due to the absence of cargo boil-off, the fully pressurised vessel has not increased in size as LPG/chemical gas trading has grown due to:

(i) the high tank weights involved in pressurised containment systems;

(ii) the poor utilisation of available cargo space made by pressure vessel tanks;

(iii) the absence, until recently, of welding and material technologies enabling the easy construction of pressurised tanks with a carrying capacity of over 600 cubic metres.

As a result, designers have found it more economical to install refrigerating plants on LPG carriers with over 1,000 $M^3$ carrying capacity and thus enable cargoes to be carried at reduced pressure.

Semi-pressurised carriers are considerably larger, being competitive with fully refrigerated non-pressurised ships up to 12,000 cubic metres. Such vessels can normally handle two grades of cargo at the same time, i.e. propane, butane and ammonia. These vessels typically operate on short-haul international trades or in the carriage of chemical gases e.g. 12,000 $M^3$ LPG carriers have recently been in demand for the carriage of vinyl chloride monomer to the Far East.

Fully refrigerated LPG carriers are by far the largest, being up to about 100,000 cubic metres in size. Such carriers are a relatively recent development (the first purpose-built fully refrigerated LPG carrier, the 28,875 $M^3$ "Bridgestone Maru" being completed at the Yokohama yard of Mitsubishi Heavy Industries in Japan in 1962). The advantages that refrigeration holds over pressurisation have ensured that the fully refrigerated fleet has grown dramatically, both in numbers and average size, over the past 20 years and is now largely responsible for the transportation of internationally traded LPG on deep-sea routes.

Thus, LPG can be carried in a variety of parcel sizes, depending largely on trade volume and distance. The Consultants thus propose to estimate costs on two bases :

(i) by selecting the vessel size, as governed by distance, best suited to fulfil the requirements of a particular trade. (It has been assumed that 12,000 $M^3$ LPG carriers will fulfil vessel demand on short haul trades whilst c.50,000 $M^3$ and c.75,000 $M^3$ vessels will provide capacity on deep-sea routes).

(ii) by assuming that standard 75,000 $M^3$ LPG carriers will be utilised on each route.

## 2.3 LPG CARRIER NEWBUILDING PRICES

The Japanese have tended to specialise in either very small or very large LPG carrier construction and thus have failed to produce LPG carriers with cargo capacities of 12,000 M3 and 50,000 $M^3$. As a result, the following costs have been developed by using European newbuilding prices. (The Japanese have considerable experience in constructing LPG carriers of about 75,000 $M^3$ at prices, in mid-1978, some 20% below European levels. However, these vessels have been purchased almost exclusively by Japanese buyers intending to import large quantities of LPG to their energy-hungry homeland and have attracted little international custom. This may suggest that the considerable price differential could at least in part be due to Japanese vessels being built to lower specifications).

### (a) 12,000 $M^3$ LPG carriers

Two yards have specialised, in the past, in the construction of series built c.12,000 $M^3$ LPG carriers - Jos.L Meyer of Papenburg, West Germany and the Moss Rosenberg Verft yard at Moss, Norway. Meyer contracted to construct six 12,000 $M^3$ units in 1974 at a cost of $13.6 million each ($1,133/$M^3$). Since that date, the popularity of the 12,000 $M^3$ unit has waned so it seems unlikely that a 12,000 $M^3$ vessel would have cost more than about $1,300/$M^3$, to order in 1978, or $15.6 million. Interest revived in 1979, and in 1980 three 15,000 $M^3$ LPG/Ammonia/Chemical Gas carriers were reported to have been ordered from the Odense Steel Shipyard Ltd. by A.P. Moller for a staggering $48.65 million each. The terms of the contract, however, were rather complex involving a 40% discount on price in the event of swift payment and thus can hardly be considered representative.

Given a $15.6 million newbuilding cost, annual capital cost will equate to $2.652 million. (The methodology leading to this result is outlined in SECTION 1.3).

### (b) 50,000 $M^3$ LPG carriers

Rheinstahl Nordseewerke Emden, West Germany, received orders in 1974 for four 53,000 $M^3$ LPG/$NH_3$/naphtha carriers from P & O Steam Navigation at a cost of $41.2 million each.

However, mid-1978 order prices are possibly better reflected in the sale of two completed but untr. ded 57,000 $M^3$ LPG carriers by the Boelwerf yard of Belgium in 1980 at a cost of $50 million per vessel. Assuming similar costs per $M^3$ for a 50,000 $M^3$ LPG carrier, a price of $43.9 million would seem appropriate. Such a price is consistent with a capital cost of $7.463 million per vessel.

(c) 75,000 $M^3$ LPG carrier

Four 71,650 $M^3$ LPG carriers were ordered from the French La Ciotat yard in 1975 at $52.0 million each. With the market for 75,000 $M^3$ LPG carriers in a depressed state over the period 1975-8, prices remained relatively stable so that in mid-1978 a new order could have been placed for perhaps only $53.0 million ($740/$M^3$). This would suggest a 75,000 $M^3$ LPG carrier cost of $55.5 million, corresponding to an annual capital cost of $9.435 million.

## 2.4 LPG CARRIER OPERATING COSTS

The annual costs associated with the regular operation of a ship, which come under the heading of operating costs are as outlined in SECTION 1.4 viz

Manning
Repairs and Maintenance
Insurance
Stores and Supplies
Administration and Management Overheads
Other Miscellaneous Costs

Annual LPG carrier operating costs have been based upon the results of the Consultants' 1979 confidential operating costs survey and are shown in TABLE 16 overleaf. The general level of LPG carrier operating costs is likely to be below that of the LNG carrier due to:

(i) fewer, possibly less skilled personnel being used;

(ii) lower hull values being reflected in lower repairs and maintenance and insurance costs;

(iii) the use of smaller vessels.

TABLE 16

1980 ESTIMATED ANNUAL LPG CARRIER OPERATING COSTS
($ 000)

| COST TYPE | LEVEL OF COST | | |
|---|---|---|---|
| | 12,000 $M^3$ | 50,000 $M^3$ | 75,000 $M^3$ |
| Manning | 0.600 | 0.950 | 1.075 |
| Repairs and Maintenance | 0.325 | 0.390 | 0.450 |
| Insurance | 0.250 | 0.283 | 0.340 |
| Stores and Supplies | 0.250 | 0.300 | 0.325 |
| Administration and Other | 0.425 | 0.334 | 0.334 |
| Total per Vessel | 1.850 | 2.257 | 2.524 |

## 2.5 LPG CARRIER VOYAGE COSTS

LPG carrier voyage costs, as with LNG carriers consist of three elements

(i) fuel costs

(ii) port costs

(iii) canal dues (where applicable)

### 2.5.1 Fuel Costs

Fuel costs are dependant on a number of factors:

(i) length of voyage

The voyage distances used are as displayed in SECTION 1.5 TABLE 3.

(ii) length of loading/discharge procedure

Turnaround time per port visit is estimated at 2 days. Normal discharge time, even of the largest LPG carriers, is generally below about 20 hours, so port time includes an allowance for port delays, vessel manoeuvering, hose connection/disconnection activities etc.

(iii) time consumed using canal facilities

Each canal transit has been assumed to take one day. This exceeds advertised transit times but makes allowances for mustering activities and cancellation due to bad weather.

(iv) bunker consumption

The statutory installation of reliquefaction plants aboard LPG carriers with refrigeration capacity precludes the use of boil-off gases as a supplementary fuel in the main engines. Thus, LPG carriers exclusively consume bunker fuel of varying qualities. For the purposes of this consultancy, it has been assumed that all LPG carriers will steam at 16.5 knots in open water and that a 12,000 $M^3$ LPG carrier will consume 35 tonnes of fuel oil and 1 tonne of diesel oil daily whilst at sea and that 50,000 $M^3$ LPG carriers and 75,000 $M^3$ LPG carriers will consume 65 and 1.5 tonnes and 80 and 2 tonnes respectively. Fuel utilisation in port will be 25% of sea-going consumption, whilst usage in the Canal will be 60% of consumption at sea.

(v) bunker costs

Bunker costs will be as displayed in SECTION 1.5 TABLE 4. Using these assumptions, the Consultants have constructed TABLE 17 showing total bunker costs incurred on an annual basis by LPG carriers operating on the routes under investigation.

### 2.5.2 Port Disbursements

Port disbursements include the cost of terminalling operations, pilotage, tug hire etc. Such charges are likely to vary considerably from port to port and even, due to the variable cost elements involved (i.e. charges based on time spent in dock) vary with successive visits to a particular port by the same vessel. Port charges, however, normally form only a small proportion of total voyage costs. For the purposes of this consultancy, port charges have been derived using port disbursement accounts of tankers reported by the Consultant's confidential sources. The Consultants' estimates of LPG carrier port charges are displayed in TABLE 18.

### 2.5.3 Canal Charges

(i) Suez Canal Tolls

Using the rate structure and SDR/exchange rate shown in SECTION 1.5.3 in conjunction with

(a) an SCNRT equivalent of 35,000 for a 75,000 $M^3$ LPG carrier,

TABLE 17

ANNUAL BUNKER COSTS
(US DOLLARS)

| LOADING PORT / DISCHARGE PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| GENOA | 1,268.978[1] | 3,635,575[2] | 3,792,541[2] | 3,710,079[2] |
| ROTTERDAM | 1,744,339[1] | 2,858,017[2] | 4,591,989[3] | 3,512.613[2] |
| NEW ORLEANS | 3,302,709[2] | 4,144,689[3] | 3,444.177[2] | 1,231,643[1] |
| YOKOHAMA | 4,845,165[3] | 3,835.062[2] | 3,664,046[2] | 4.675,888[3] |

1 12,000 $M^3$ LPG carrier base
2 50,000 $M^3$ LPG carrier base
3 75,000 $M^3$ LPG carrier base

TABLE 18

PORT CHARGES PER VISIT AS AT MID-1980
(US DOLLARS)

| PORT / VESSEL SIZE | SKIKDA | DOHA | ACEH | VERACRUZ | GENOA | ROTTERDAM | NEW ORLEANS | YOKOHAMA |
|---|---|---|---|---|---|---|---|---|
| 12,000 $M^3$ | 5,400 | 5,294 | 3,840 | 2,160 | 2,280 | 8,300 | 10,000 | 8,400 |
| 50,000 $M^3$ | 30,600 | 10,214 | 11,265 | 12,240 | 13,000 | 47,000 | 23,000 | 24,500 |
| 75,000 $M^3$ | 36,000 | 11,768 | 12,602 | 14,400 | 15,000 | 55,000 | 27,200 | 28,000 |

Source : H.P.Drewry Shipping Consultants Ltd.

(b) an SCNRT equivalent of 30,000 for a 50,000 $M^3$ LPG carrier,

Suez Canal tolls of $137,500 per round trip for a 75,000 $M^3$ LPG carrier and of $118,650 per round trip for a 50,000 $M^3$ LPG carrier have been calculated.

(ii) Panama Canal Tolls

LPG carriers of 75,000 $M^3$ can be designed to trade on routes utilising the Panama Canal. For this exercise, it is assumed that such tonnage will fulfil demand on the Veracruz to Yokohama route.

Panama Canal tolls as at mid-1980 were $1.29 per Panama Canal Net Registered Ton (PCNRT) laden and $1.03 PCNRT ballast. In addition, an allowance of $2,000 has been made to account for possible tug usage costs. If it is assumed that an LPG carrier of 75,000 $M^3$ has a PCNRT of 31,000, then canal charges per round trip will equate to $73,920.

2.5.4 Total LPG carrier voyage costs per annum

By converting bunker costs and canal tolls into annual outflows and adding to annual port costs, total voyage costs per annum per vessel can be estimated as is shown in TABLE 19. For the purposes of this exercise it has been assumed that a single vessel of the required size will operate exclusively on the chosen trade.

## 2.6 TRANSPORT COSTS PER TONNE DELIVERED - VARYING VESSEL SIZES

To enable the calculation of transport costs per metric tonne delivered, the Clients estimated annual trade per route at 300,000 tons of LPG. This figure has been used in conjunction with the earlier assumptions concerning speed, port time, canal time and operating year (viz 16.5 knots, 2 days per port visit, 2 days canal time per round trip and a 345 day operating year) to calculate the number of LPG carriers required on each route. The market for LPG carriers is different from that of LNG carriers in that a spot/short-term timecharter market has developed over time. As a result, LPG carriers have been constructed without employment guarantees upon

TABLE 19

TOTAL VOYAGE COSTS PER ANNUM PER VESSEL AS AT MID-1980
(US DOLLARS)

| ROUTE | ROUND TRIPS PER VESSEL | BUNKER COSTS | PORT CHARGES | CANAL TOLLS | TOTAL |
|---|---|---|---|---|---|
| SKIKDA-GENOA | 54.25 | 1,268,978 | 416,640 | - | 1,685,618 |
| SKIKDA-ROTTERDAM | 24.87 | 1,744,339 | 340,719 | - | 2,085,058 |
| SKIKDA-NEW ORLEANS | 11.47 | 3,302,709 | 614,792 | - | 3,917,501 |
| SKIKDA-YOKOHAMA | 6.53 | 4,845,165 | 417,920 | 897,875 | 6,160,960 |
| DOHA-GENOA | 11.99 | 3,675,575 | 155,870 | 1,422,614 | 5,254,059 |
| DOHA-ROTTERDAM | 9.04 | 2,858,017 | 517,215 | 1,072,596 | 4,447,828 |
| DOHA-NEW ORLEANS | 6.35 | 4,144,689 | 247,447 | 873,125 | 5,265,261 |
| DOHA-YOKOHAMA | 9.34 | 3,835,062 | 324,229 | - | 4,159,291 |
| ACEH-GENOA | 9.70 | 3,792,541 | 235,371 | 1,150,905 | 5,178,817 |
| ACEH-ROTTERDAM | 7.68 | 4,591,989 | 519,183 | 1,056,000 | 6,167,172 |
| ACEH-NEW ORLEANS | 5.64 | 3,444,177 | 193,255 | 669,186 | 4,306,618 |
| ACEH-YOKOHAMA | 15.85 | 3,664,046 | 566,875 | - | 4,230,921 |
| VERACRUZ-GENOA | 10.58 | 3,710,079 | 137,540 | - | 3,847,619 |
| VERACRUZ-ROTTERDAM | 11.52 | 3,512,613 | 682,445 | - | 3,895,058 |
| VERACRUZ-NEW ORLEANS | 42.65 | 1,231,643 | 518,624 | - | 1,750,267 |
| VERACRUZ-YOKOHAMA | 6.62 | 4,675,888 | 280,688 | 489,350 | 5,445,926 |

Source : H.P.Drewry Shipping Consultants Ltd.

TABLE 20

CALCULATION OF TRANSPORT COSTS PER TONNE DELIVERED AS AT MID-1980 - VARYING VESSEL SIZES

| ROUTE | UNIT SIZE ($M^3$) | ANNUAL CAPITAL COSTS PER VESSEL | ANNUAL OPERATING COSTS PER VESSEL | ANNUAL VOYAGE COSTS PER VESSEL | ANNUAL FULLY BUILT-UP COSTS PER VESSEL | UTILISATION FACTOR | ANNUAL FULLY BUILT-UP COSTS PER ROUTE | ANNUAL FULLY BUILT-UP COSTS ($/METRIC TONNE) |
|---|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 12,000 | 2,620,000 | 1,850,000 | 1,685,618 | 6,155,618 | 0.7777 | 4,787,224 | 15.96 |
| SKIKDA-ROTTERDAM | 12,000 | 2,620,000 | 1,850,000 | 2,085,058 | 6,555,058 | 1.6964 | 11,120,000 | 37.07 |
| SKIKDA-NEW ORLEANS | 50,000 | 7,463,000 | 2,257,000 | 3,917,501 | 13,637,501 | 0.8831 | 12,043,277 | 40.14 |
| SKIKDA-YOKOHAMA | 77,539 | 9,754,000 | 2,524,000 | 6,160,960 | 18,438,690 | 1 | 18,438,690 | 61.46 |
| DOHA-GENOA | 50,000 | 7,463,000 | 2,257,000 | 5,254,059 | 14,974,059 | 0.8449 | 12,651,582 | 42.17 |
| DOHA-ROTTERDAM | 56,010 | 8,360,000 | 2,257,000 | 4,447,828 | 15,064,828 | 1 | 15,064,828 | 50.22 |
| DOHA-NEW ORLEANS | 79,740 | 10,030,000 | 2,524,000 | 5,265,261 | 17,819,261 | 1 | 17,819,261 | 59.40 |
| DOHA-YOKOHAMA | 54,215 | 8,092,000 | 2,257,000 | 4,159,291 | 14,508,291 | 1 | 14,508,291 | 48.36 |
| ACEH-GENOA | 52,200 | 7,791,000 | 2,257,000 | 5,178,817 | 15,226,817 | 1 | 15,226,817 | 50.76 |
| ACEH-ROTTERDAM | [illegible],000 | 9,435,000 | 2,524,000 | 6,167,172 | 18,126,172 | 0.8620 | 15,624,760 | 53.10 |
| ACEH-NEW ORLEANS | 50,000 | 7,463,000 | 2,257,000 | 4,306,618 | 14,026,618 | 1.7961 | 25,193,209 | 83.98 |
| ACEH-YOKOHAMA | 50,000 | 7,463,000 | 2,257,000 | 4,230,921 | 13,950,921 | 0.6361 | 8,916,034 | 29.72 |
| VERACRUZ-GENOA | 50,000 | 7,463,000 | 2,257,000 | 3,847,619 | 13,567,619 | 0.9575 | 12,990,995 | 43.30 |
| VERACRUZ-ROTTERDAM | 50,000 | 7,463,000 | 2,257,000 | 3,895,058 | 13,615,058 | 0.8793 | 11,971,720 | 39.91 |
| VERACRUZ-NEW ORLEANS | 12,000 | 2,620,000 | 1,850,000 | 1,750,267 | 6,220,267 | 0.9892 | 6,153,088 | 20.51 |
| VERACRUZ-YOKOHAMA | 76,600 | 9,636,000 | 2,524,000 | 5,445,926 | 17,605,926 | 1 | 17,605,926 | 58.69 |

Source : H.P.Drewry Shipping Consultants Ltd.

delivery or of a size greater than that required by the tied trade upon which they operate. It would seem reasonable, therefore, to treat all three cost elements as continuous variables, implying that employment opportunities for unutilised capacity on a single route is available elsewhere.

Using this methodology, TABLE 20 has been constructed and transport costs per metric tonne delivered calculated.

## 2.7 TRANSPORT COSTS PER TONNE DELIVERED - STANDARD 75,000 $M^3$ UNIT SIZE

The above exercise (in TABLE 20) examines the costs associated with the transportation of 300,000 metric tonnes of LPG in units of a size perhaps best suited to LPG carriage over the distances under investigation. TABLE 21 uses a similar methodology to estimate costs associated with the single most cost effective size, the standard 75,000 $M^3$ unit. By using this vessel size and chartering out unutilised capacity for part of the year, considerable savings in transportation costs may be available i.e. a $20 reduction per tonne delivered on the Skikda to Rotterdam route. Conversely, spot/short-term timechartered tonnage could be used on the shorter routes. The use of vessels of this size may require additional capital expenditure in other areas, however. (For example, the onshore storage facilities required to maintain the 12,000 $M^3$ unit plying the Skikda to Genoa trade is likely to be significantly smaller than that required by 75,000 $M^3$ spot market carriers on the same route).

## 2.8 TRANSPORT COSTS PER TONNE DELIVERED - MID-1980 ORDER AND DELIVERY

SECTIONS 2.6 and 2.7 reviewed the cost of delivering 300,000 metric tonnes of LPG in varying vessel sizes and in standard 75,000 $M^3$ units based on mid-1980 deliveries from European yards. This section reviews these costs in the light of mid-1980 order prices (or, where unavailable, the Consultants' assessments of these prices).

### (a) 12,000 $M^3$ LPG carriers

Little information concerning mid-1980 12,000 $M^3$ LPG carrier prices is available. The only recent orders, despite considerable spot market activity for such vessels, were placed by A.P. Moller at the Odense yard at $48.65 million or $29.2 million each after allowing for a reduction in contract price of 40%. Such a price, however, seems extremely high and may reflect set-up costs at the yard and even government pressure on a domestic owner to maintain the local

**TABLE 21**

**CALCULATION OF TRANSPORT COSTS PER TONNE DELIVERED AS AT MID-1980 - STANDARD 75,000 $M^3$ UNITS**
**($)**

| ROUTE | ANNUAL VOYAGE COSTS PER VESSEL | ANNUAL FULLY BUILT-UP[1] COSTS PER VESSEL | UTILISATION FACTOR | ANNUAL FULLY BUILT-UP COSTS PER TRADE | ANNUAL FULLY BUILT-UP COSTS PER TRADE ($/METRIC TONNE) |
|---|---|---|---|---|---|
| SKIKDA-GENOA | 5,632,666 | 17,591,666 | 0.1244 | 2,188,403 | 7.29 |
| SKIKDA-ROTTERDAM | 6,219,113 | 18,178,113 | 0.2714 | 4,933,540 | 16.45 |
| SKIKDA-NEW ORLEANS | 4,810,243 | 16,769,243 | 0.5885 | 9,868,700 | 32.90 |
| SKIKDA-YOKOHAMA | 6,160,960 | 18,119,960 | 1.0337 | 18,813,299 | 62.71 |
| DOHA-GENOA | 6,353,546 | 18,312,546 | 0.5630 | 10,309,963 | 34.37 |
| DOHA-ROTTERDAM | 6,320,348 | 18,279,348 | 0.7467 | 13,649,189 | 45.50 |
| DOHA-NEW ORLEANS | 5,265,261 | 17,224,261 | 1.0283 | 17,711,708 | 59.04 |
| DOHA-YOKOHAMA | 5,110,213 | 17,069,213 | 0.7227 | 12,335,920 | 41.12 |
| ACEH-GENOA | 6,271,582 | 18,230,582 | 0.6959 | 12,686,662 | 42.29 |
| ACEH-ROTTERDAM | 6,167,172 | 18,126,172 | 0.8789 | 15,931,093 | 53.10 |
| ACEH-NEW ORLEANS | 5,282,424 | 17,241,424 | 1.1968 | 20,634,536 | 68.78 |
| ACEH-YOKOHAMA | 5,158,421 | 17,117,421 | 0.4259 | 7,290,310 | 24.30 |
| VERACRUZ-GENOA | 4,878,507 | 16,837,507 | 0.6380 | 16,837,509 | 56.13 |
| VERACRUZ-ROTTERDAM | 5,117,235 | 17,076,235 | 0.5859 | 10,004,966 | 33.35 |
| VERACRUZ-NEW ORLEANS | 5,014,138 | 16,973,138 | 0.1583 | 2,686,848 | 8.96 |
| VERACRUZ-YOKOHAMA | 5,445,926 | 17,404,926 | 1.0196 | 17,746,063 | 59.16 |

1 Annual Capital plus Operating costs per vessel constant at $11,959,000.

Source : H.P.Drewry Shipping Consultants Ltd.

TABLE 22

**TRANSPORT COSTS PER TONNE DELIVERED USING MID-1980 ORDER PRICES ($)**

| LOADING PORT / DISCHARGE PORT | SKIKDA | | DOHA | | ACEH | | VERACRUZ | |
|---|---|---|---|---|---|---|---|---|
| | VARYING VESSEL SIZES | STANDARD 75,000 $M^3$ UNIT | VARYING VESSEL SIZES | STANDARD 75,000 $M^3$ UNIT | VARYING VESSEL SIZES | STANDARD 75,000 $M^3$ UNIT | VARYING VESSEL SIZES | STANDARD 75,000 $M^3$ UNIT |
| GENOA | 18.16 | 8.30 | 47.49 | 38.91 | 56.59 | 47.91 | 49.33 | 61.28 |
| ROTTERDAM | 41.87 | 18.64 | 56.46 | 51.53 | 60.20 | 60.20 | 45.44 | 38.08 |
| NEW ORLEANS | 45.70 | 37.65 | 67.98 | 67.34 | 95.27 | 78.44 | 23.31 | 10.23 |
| YOKOHAMA | 69.81 | 71.06 | 54.41 | 46.95 | 33.74 | 27.74 | 66.93 | 67.39 |

Source : H.P.Drewry Shipping Consultants Ltd.

shipbuilding industry. More competitive prices would probably be available at the traditional builders of such tonnage, Jos L Meyer and Moss Rosenberg. The latter yard did receive an order for a 30,000 $M^3$ LPG carrier in early 1980 at $40.6 million ($1,353/DWT) which suggests a lower price would be available at that yard for 12,000 $M^3$ carriers. The yard also obtained an order for a 24,000 $M^3$ LPG carrier in the third quarter of 1979 at $27.6 million ($1,150/$M^3$). These prices would probably indicate a mid-1980 price level of about $1,750/$M^3$ for 12,000 $M^3$ LPG carriers giving a unit cost of $21 million. That price would be consistent with an annual capital cost of $3.57 million.

(b) 75,000 $M^3$ LPG carriers

The only order placed in a European yard at about mid-1980 was that for an 85,000 $M^3$ LPG carrier building at the French yard of Chantiers Nav. de La Ciotat at a cost of $77.0 million ($906/$M^3$). This would suggest a cost per 75,000 $M^3$ unit of perhaps $69.75 million ($930/$M^3$) and an annual capital cost of $11.857 million.

(c) 50,000 $M^3$ LPG carriers

No new orders for 50,000 $M^3$ LPG carriers have been placed. However, a price of $55.0 million per 50,000 $M^3$ unit or $1,100/$M^3$, consistent with an annual capital cost of $9.35 million, has been estimated based on :

(i) the early 1980 ordering at Moss Rosenberg of a 30,000 $M^3$ LPG carrier for $40.6 million ($1,353/$M^3$).

and (ii) the third quarter 1980 order placed at Chantiers Nav. de La Ciotat for a 85,000 $M^3$ LPG carrier at a cost of $77 million ($906/$M^3$).

Based on these revised capital costs, and assuming that operating and voyage costs will remain at the levels shown in SECTIONS 2.4 and 2.5, transport costs per metric tonne delivered have been calculated, as shown in TABLE 22.

## 2.9 MID-1985 LPG TRANSPORTATION COSTS

The assumptions utilised in the construction of mid-1985 LNG transportation costs (see SECTION 1.8), have been used in connection with the forecasting of mid-1985 LPG transportation costs with the following exception:

> Newbuilding prices - the absence of a reasonable historical time series of data for 12,000 $M^3$ and 50,000 $M^3$ LPG carriers (and of European construction cost information) makes the forecasting of future newbuilding prices problematical. Thus, this analysis will concentrate on 75,000 $M^3$ LPG carriers and the Consultants will use the resulting rates of increase to calculate future prices associated with the smaller, European built, LPG carriers under review.
>
> Approximate contracting prices for 75,000 $M^3$ LPG carriers built at European yards are shown in FIGURE 4. Prices increased rapidly between 1972 and 1974 from an estimated $33 million to about $52 million before stagnating. The upturn came in 1978 and by 1980 prices had reached about $933/$M^3$. The rise over the period as a whole averaged $4.625 million per annum, equivalent to an annual rate of about 10%. European prices may cease to rise at such a rapid rate in the future, however, due to the need to maintain their competitive relationship with Japan. For this reason, a rate of increase of about 8% per annum has been used for this exercise. The price of a 75,000 $M^3$ LPG carrier will thus rise to around $88.5 million ($1180/$M^3$) in 1983 and $101 million ($1347/$M^3$) in 1985, consistent with annual capital costs per vessel of $15.045 million and $17.17 million respectively. Such a level of newbuilding price would point to 50,000 $M^3$ LPG carriers being priced at $69.6 million ($1,392/DWT) in 1983 and $79.45 million in 1985 ($1,589/DWT) whilst 12,000 $M^3$ LPG carriers could be contracted for $26.556 million ($2,213/DWT) and $30.324 million ($2,527/DWT) in those years. These newbuilding prices would be consistent with an annual capital cost level of $11.832 million, $13.507 million, $4.515 million and $5.155 million respectively.

Based on the assumptions laid out in SECTION 1.8 and on the above newbuilding prices, mid-1985 LPG transportation costs, based on differing vessel sizes and on standardised 75,000 $M^3$ units, have been calculated, as shown in TABLE 23.

**TABLE 23**

**TRANSPORT COST PER TONNE OF LPG DELIVERED AS AT MID-1985**
(US Dollars)

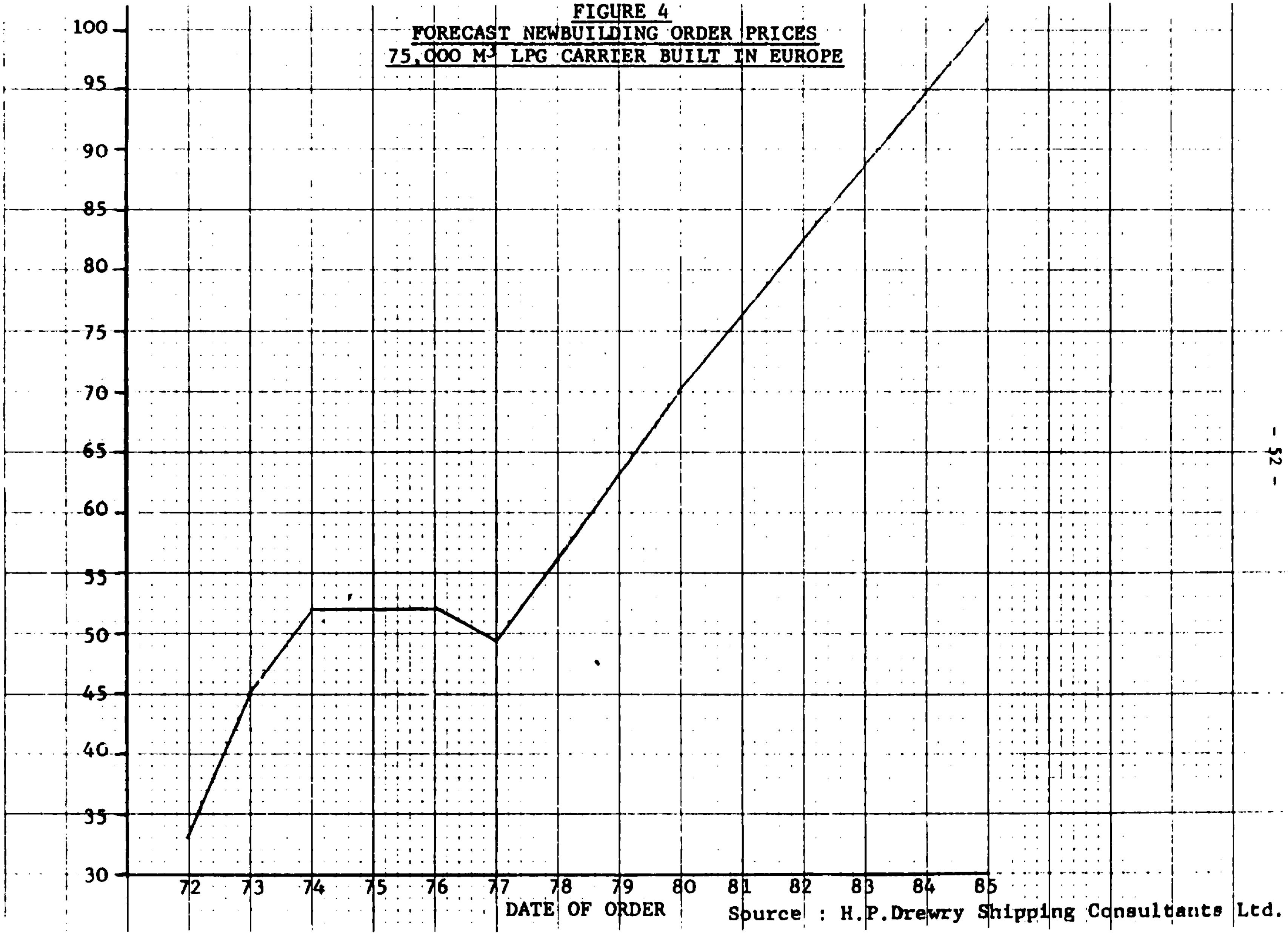
(i) Differing Vessel Sizes

| COST BASIS / ROUTE | MID-1983 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1983 ORDER/ CRUDE OIL COST $80 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $80 PER BARREL |
|---|---|---|---|---|
| SKIKDA-GENOA | 25.10 | 29.56 | 26.76 | 31.22 |
| SKIKDA-ROTTERDAM | 58.75 | 73.14 | 62.37 | 76.76 |
| SKIKDA-NEW ORLEANS | 63.92 | 90.13 | 68.85 | 95.06 |
| SKIKDA-YOKOHAMA | 93.51 | 116.05 | 100.85 | 123.39 |
| DOHA-GENOA | 63.60 | 78.08 | 68.32 | 82.80 |
| DOHA-ROTTERDAM | 77.35 | 91.44 | 83.60 | 97.69 |
| DOHA-NEW ORLEANS | 94.12 | 116.75 | 101.67 | 124.30 |
| DOHA-YOKOHAMA | 74.59 | 92.68 | 80.64 | 98.73 |
| ACEH-GENOA | 76.77 | 94.37 | 82.60 | 100.20 |
| ACEH-ROTTERDAM | 81.45 | 101.03 | 87.68 | 107.25 |
| ACEH-NEW ORLEANS | 132.40 | 165.56 | 142.43 | 175.59 |
| ACEH-YOKOHAMA | 47.11 | 56.52 | 50.68 | 60.09 |
| VERACRUZ-GENOA | 67.16 | 84.29 | 72.71 | 89.64 |
| VERACRUZ-ROTTERDAM | 63.93 | 79.52 | 68.84 | 84.43 |
| VERACRUZ-NEW ORLEANS | 33.60 | 40.45 | 35.71 | 42.56 |
| VERACRUZ-YOKOHAMA | 90.83 | 113.40 | 98.08 | 120.65 |

(ii) Standard 75,000 $M^3$ UNITS

| COST BASIS / ROUTE | MID-1983 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1983 ORDER/ CRUDE OIL COST $80 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $40 PER BARREL | MID-1985 ORDER/ CRUDE OIL COST $80 PER BARREL |
|---|---|---|---|---|
| SKIKDA-GENOA | 11.31 | 12.97 | 12.19 | 13.85 |
| SKIKDA-ROTTERDAM | 25.59 | 30.80 | 27.51 | 32.72 |
| SKIKDA-NEW ORLEANS | 52.55 | 65.47 | 56.72 | 69.64 |
| SKIKDA-YOKOHAMA | 94.91 | 118.21 | 102.23 | 125.63 |
| DOHA-GENOA | 52.02 | 63.65 | 56.01 | 67.64 |
| DOHA-ROTTERDAM | 69.89 | 86.63 | 75.18 | 91.65 |
| DOHA-NEW ORLEANS | 96.75 | 120.02 | 104.03 | 127.30 |
| DOHA-YOKOHAMA | 63.54 | 79.70 | 68.66 | 84.82 |
| ACEH-GENOA | 63.95 | 79.04 | 68.88 | 83.97 |
| ACEH-ROTTERDAM | 81.45 | 101.03 | 87.68 | 107.26 |
| ACEH-NEW ORLEANS | 108.68 | 136.17 | 117.16 | 144.65 |
| ACEH-YOKOHAMA | 37.44 | 46.37 | 40.46 | 49.39 |
| VERACRUZ-GENOA | 55.69 | 69.74 | 60.21 | 74.26 |
| VERACRUZ-ROTTERDAM | 52.44 | 65.20 | 56.59 | 69.35 |
| VERACRUZ-NEW ORLEANS | 14.37 | 17.25 | 15.49 | 18.37 |
| VERACRUZ-YOKOHAMA | 91.52 | 114.53 | 98.74 | 121.75 |

**FIGURE 4**
**FORECAST NEWBUILDING ORDER PRICES**
**75,000 M$^3$ LPG CARRIER BUILT IN EUROPE**




Source : H.P.Drewry Shipping Consultants Ltd.

## 2.10 LPG TRANSPORTATION COSTS - CHANGES OVER THE PERIOD 1975 TO 1980 COMPARED WITH 1980 TO 1985

The Clients have requested that the Consultants compare cost increases over the period 1975 to 1980 with those anticipated over the period 1980 to 1985 for one typical voyage. Japan has been, is and could remain the largest single importer of long-haul LPG, and the Arabian Gulf has consistently been a major supplier of Japanese demands, a position likely to be maintained given the growth of productive capacity anticipated for the 1980s. Thus, the Arabian Gulf to Japan route would seem an obvious choice for the exercise in hand.

Although LPG carriers are sophisticated, expensive vessels, speculative ordering of such tonnage without employment guarantees has been a feature of the market. (Exceptions to this rule are not uncommon, however, and the increase in LPG trading may lead to the signing of longer-term trade contracts and the ordering of more tied tonnage). Thus, it seems reasonable to adopt a slightly different approach to that indicated in SECTION 1.9.

### 2.10.1 Capital Costs

For the purposes of this consultancy, the capital costs associated with newly delivered European built 75,000 $M^3$ LPG carriers will be utilised. (Japanese built vessel prices will be below the level of capital costs shown, a discount of perhaps 20% being available. Costs for Japanese built vessels will thus also be estimated, based on the assumption that this level of discount is constant throughout the period under investigation). European order prices for 75,000 $M^3$ LPG carriers in 1973 (for 1975 delivery) were approximately $45 million (equivalent to an annual capital charge of $7.65 million), had risen to about $56 million in 1978 (equivalent to an annual capital charge of $9.52 million) and could increase to $88.5 million in 1983 (or $15.045 million on an annual basis). (This would suggest Japanese capital values of $36 million in 1973, $44.8 million in 1978 and $70.8 million in 1983, corresponding to annual capital charges of $6.12 million, $7.616 million and $12.036 million respectively).

### 2.10.2 Operating Costs

As with LNG carrier operating costs, LPG carrier operating costs are taken to have increased by 13.8% between 1975 and 1979 and by 10% between 1980 and 1985. Given a base year annual operating cost level of $2.524 million, operating costs of $1.567 million would be associated with a 75,000 $M^3$ LPG carrier in 1975 whilst the level in 1985 would equate to $4.065 million for the same vessel size.

2.10.3 Voyage Costs

Bunker prices have risen considerably as crude oil prices have increased. The extent of the increases experienced are shown in TABLE 24. Moreover, the Clients anticipate this rise will continue with crude oil reaching $40 or $80 a barrel, suggesting bunker fuel prices of either $251 or $402 a tonne for fuel oil and either $494 or $988 a tonne for marine diesel in 1985.

TABLE 24

APPROXIMATE BUNKER PRICES AS AT MID-YEAR
($ per tonne)

| | | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| ARABIAN GULF | FO | 59.00 | 64.00 | 73.50 | 79.50 | 139.00 | 176.00 |
| | DO | 90.00 | 106.50 | 113.00 | 113.00 | 307.00 | 346.00 |
| JAPAN | FO | 66.00 | 63.50 | 73.00 | 79.00 | 135.00 | 182.00 |
| | DO | 99.00 | 117.00 | 124.00 | 124.00 | 232.00 | 339.00 |

2.10.4 Changes in Overall Cost Levels

The above data has been utilised, in conjunction with port charges estimated to have increased at an annual rate of 8.5%, to indicate how the shipping costs associated with LPG have changed over the period 1975 to 1985. The results are shown in TABLE 25. A speed of 16.5 knots has been assumed for this exercise in conjunction with a round trip distance of 13,000 miles and average port time of two days per visit. This is consistent with 9.34 round trips being completed per annum and the delivery of 415,000 tonnes of LPG approximately by a single 75,000 $M^3$ LPG carrier in a given year.

## 2.11 OTHER PRODUCTS TRANSPORTED IN LPG CARRIERS

### 2.11.1 Ammonia

(a) Properties

1. Formula $NH_3$
2. Colourless. Pungent, suffocating odour
3. Boiling point at atmospheric - 33.4°C
4. Specific gravity 0.683
5. Coefficient of cubic expansion 0.0028 per °C at 0°C

(b) Conditions of Carriage

1. Normal carriage conditions pressurised, semi-refrigerated or fully refrigerated

TABLE 25

COMPARISON OF DELIVERED TRANSPORT COST OF LPG MOVEMENTS 1975 TO 1980 AND 1980 TO 1985

ARABIAN GULF TO JAPAN

(US Dollars)

(i) European Build

| YEAR | ANNUAL CAPITAL COSTS | ANNUAL OPERATING COSTS | ANNUAL BUNKER COSTS | ANNUAL PORT CHARGES | TOTAL ANNUAL COSTS | COSTS PER ROUND TRIP | COSTS PER TONNE DELIVERED | CHANGES IN COSTS OVER PERIOD |
|---|---|---|---|---|---|---|---|---|
| 1975 | 7,650,000 | 1,567,000 | 1,650,205 | 268,017 | 11,135,222 | 1,192,208 | 2.87 | |
| 1980 | 9,520,000 | 2,524,000 | 4,738,760 | 371,433 | 17,154,193 | 1,836,637 | 4.43 | 54.4% |
| 1985 (a) | 15,045,000 | 4,065,000 | 6,707,276 | 558,538 | 26,375,014 | 2,838,877 | 6.84 | 54.4% |
| (b) | 15,045,000 | 4,065,000 | 13,414,552 | 558,538 | 33,083,090 | 3,542,087 | 8.53 | 92.6% |
| | | | (ii) Japanese Build | | | | | |
| 1975 | 6,120,000 | 1,567,000 | 1,650,205 | 268,017 | 9,605,222 | 1,028,396 | 2.48 | |
| 1980 | 7,616,000 | 2,524,000 | 4,738,760 | 371,433 | 15,250,193 | 1,632,783 | 3.93 | 58.5% |
| 1985 (a) | 12,036,000 | 4,065,000 | 6,707,276 | 558,538 | 23,366,814 | 2,501,800 | 6.03 | 53.4% |
| (b) | 12,036,000 | 4,065,000 | 13,414,552 | 558,538 | 30,074,090 | 3,219,924 | 7.76 | 97.5% |

Source : H.P.Drewry Shipping Consultants Ltd.

2. Ship type 2G/2PG
3. Gauging closed or indirect
4. Vapour detection toxic

(c) Materials of Construction

1. Mercury, zinc, copper alloys, aluminium or its alloys, galvanised surfaces, phenolic resins, PVC, polyester, viton rubber are unsuitable
2. Mild steel, stainless steel, neoptene and polythene are suitable.

Sources : Tanker Safety Guide (Liquefied Gas) - International. Chamber of Shipping.
Liquid Gas Carrier Register - H.Clarkson & Co.

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Anhydrous ammonia ($NH_3$), the third highest volume chemical produced in the US in the mid-1970s, is derived from natural gas and coal. It has a wide variety of uses including the production of fertilisers, synthetic fibre and rocket fuel, is often a chemical intermediary and can be used as a refrigerant.

Liquefied ammonia is a relatively widely traded commodity, cargoes being carried in all sizes and types of LPG carriers (Few LPG carriers of 75,000 $M^3$ have been trading in ammonia, carriers of this size unable to gain employment in LPG trading have recently reverted to clean oil/naphtha trading. However, the 1979/1980 75,000 $M^3$ Soviet deliveries from the Italian C.N. Breda shipyard "Mossovet" and "Lensovet" are now apparently carrying ammonia on the USSR to USA trade). Examples of typical cargo size/route combinations experienced of late are given below in TABLE 26.

TABLE 26

TYPICAL SEABORNE AMMONIA PARCEL SIZES

| ROUTE | PARCEL SIZE (Tonnes) | VESSEL SIZE ($M^3$) |
|---|---|---|
| Arabian Gulf to India | 10,000 | 15,300 |
| Arabian Gulf to Europe | 15,000 to 25,000 | 30,000-53,000 |
| Cork to Bilbao | 3,000 | 4,500 |
| Mexico/US Gulf to Brazil | 10,000 to 15,000 | 15,500-22,500 |
| Mexico/US Gulf to Carthagena/Castellon | 7,000 to 10,000 | 11,750-15,500 |
| Odessa to US Gulf | 12,000 to 50,000 | 18,400-75,000 |
| US Gulf to Turkey | 15,000 to 20,000 | 30,000-40,000 |
| USWC to UK/Cont | 20,000 | 54,000 |

The transportation costs associated with anhydrous ammonia will obviously be dependent upon parcel/vessel size : as shown in the calculation of LPG transportation costs, large economies of scale can be reaped by the utilisation of larger vessels. As a generalisation, however, the costs associated with transporting ammonia should be lower than those associated with LPG transportation on a cost per tonne delivered basis assuming the use of vessels of the same size. This is because the specific gravity of ammonia is higher than that of LPG and thus a particular vessel can deliver a larger cargo, in terms of tonnes,of ammonia than LPG. The differences in the amounts delivered by vessels of a specific size are shown below in TABLE 27.

TABLE 27

DIFFERENCES IN AMOUNTS OF LPG AND AMMONIA DELIVERED PER ROUND TRIP[1]

| VESSEL SIZE | LPG DELIVERED[2] (Tonnes) | AMMONIA DELIVERED[3] (Tonnes) |
|---|---|---|
| 12,000 $M^3$ | 7,100 | 8,200 |
| 50,000 $M^3$ | 29,650 | 34,150 |
| 75,000 $M^3$ | 44,475 | 51,225 |

1. Assumes full cargoes of either commodity can be carried
2. Assumes propane/butane mix with a specific gravity of 0.593
3. Assumes ammonia has a specific gravity of 0.683.

The above figures would indicate that ammonia transportation costs should equate to 86-87% of LPG transportation costs, assuming similar parcel and vessels sizes are employed.

2.11.2 Ethylene

(a) Properties

1. Formula $C_2H_4$
2. Colourless. Faintly sweet odour
3. Boiling point at atmospheric - 104°C
4. Specific gravity 0.570
5. Coefficient of cubic expansion 0.0026 per °C at 100°C

(b) Conditions of Carriage

1. Normal carriage conditions fully refrigerated
2. Ship type 2G
3. Gauging restricted closed or indirect
4. Vapour detection flammable

(c) Materials of Construction

1. Steel is unsuitable
2. Stainless steel, aluminium and copper are suitable.

Sources : Tanker Safety Guide (Liquefied Gas) - International Chamber of Shipping
Liquid Gas Carrier Register - H. Clarkson & CO.

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Ethylene, the fifth highest volume chemical produced in the US in the mid-1970s, is derived from the thermal cracking of propane, butane, ethane, naphtha and refinery off-gases. It is primarily a chemical feedstock but is also used as a refrigerant, an anaesthetic and in the cutting and welding of metals.

Unlike ammonia, which can be carried in most LPG carriers with little difficulty (problems have arisen on occasion, the pumps installed in certain carriers being unsuited to a product with a specific gravity exceeding that of butane/propane), ethylene requires fully refrigerated carriage conditions at temperature below that associated with LPG carriage. As such, the costs associated with constructing gas carriers with ethylene carrying capacity are likely to exceed LPG carrier construction costs. This, plus the relatively small size of existing ethylene carriers, will push ethylene transportation costs above those associated with LPG carriage.

As at end 1979, the total world ethylene carrying fleet, excluding carriers with a capacity of below 1,000 $M^3$, consisted of 33 vessels with a total capacity of only 239,500 M3 and thus an average vessel size of only about 7,250 $M^3$. All but six vessels were of below mean size, half being of less than 5,000 $M^3$. Moreover, many of those above 5,000 $M^3$ were finding employment in alternative areas, most notably in LPG carriage.

It would appear, therefore, that ethylene parcel sizes are relatively small. Examples of parcel sizes for ethylene are given overleaf in TABLE 28.

**TABLE 28**

**ETHYLENE PARCEL SIZES BASED ON RECENT MARKET REPORTS**

| DATE OF REPORT | ROUTE | CARGO SIZE (Tonnes) | VESSEL SIZE ($M^3$) |
|---|---|---|---|
| 1/79 | Terneuzen to Tarragona | 3,300 | 6,150 |
| 4/79 | Mexico to South Spain | 6,800 | 12,058 |
| 7/79 | Skikda to Barcelona | 3,700 | 6,100 |
| 8/79 | Moerdijk to Rafnes | 1,500 | 2,700 |
| 9/79 | Pajaritus to Tarragona | 6,700 | 12,060 |
| 12/79 | Dunkirk to Maceio | 6,700 | 12,058 |
| 1/80 | Terneuzen to West | 5,200 | 12,058 |
| 1/80 | Rotterdam to New York or Columbia | 2,250 | 4,100 |
| 1/80 | UK/Cont to Spanish Med | 5,200 | 12,058 |
| 4/80 | Moerdijk to Columbia | 4,200 | 7,418 |
| 9/80 | Venezuela to Italy | 4,200 | 7,418 |

2.11.3 Propylene

(a) Properties

1. Formula $C_3H_6$
2. Colourless. Slightly characteristic odour
3. Boiling point at atmospheric - 47.7°C
4. Specific gravity 0.522
5. Coefficient of cubic expansion 0.0027 per °C at -47°C

(b) Conditions of Carriage

1. Normal carriage conditions pressurised, semi-refrigerated or fully refrigerated
2. Ship type 2C/2PG
3. Gauging restricted, closed or indirect
4. Vapour detection flammable

(c) Materials of Construction

1. Mild steel (below 0°C) is unsuitable
2. Mild steel (above 0°C), stainless steel and aluminium is suitable.

Sources : Tanker Safety Guide (Liquefied Gas) - International Chamber of Shipping
Liquid Gas Carrier Register - H. Clarkson & Co.

Propylene, the fourteenth highest volume chemical produced in the US in the mid-1970s, is derived from ethylene and naphtha and is used in the production of a variety of chemicals and vinyl resins.

Propylene is the least traded liquefied gas of those under scrutiny and thus, despite the fact that it does not present the temperature problem of ethylene nor the occasional pump problems associated with ammonia carriage, propylene is normally carried in relatively small cargo lots, in smaller vessels than LPG and thus transportation costs are normally higher. Moreover, the relatively low specific gravity of propylene would suggest a higher level of cargo tonne transportation costs (between 13 and 14% higher) than those associated with LPG, given delivery in vessels with a similar cubic capacity.

The Consultants have found little information concerning recent propylene fixtures but a few examples are given below in TABLE 29.

TABLE 29

PROPYLENE PARCEL SIZES BASED ON RECENT MARKET REPORTS

| DATE OF REPORT | ROUTE | CARGO SIZE (Tonne) | VESSEL SIZE ($M^3$) |
|---|---|---|---|
| 4/79 | UK Cont to West Med | 6,800 | 12,058 |
| 10/79 | Dunkirk to Priolo/Brindisi | 6,000 | 12,060 |
| 3/80 | Moerdijk to Carrington | 1,300 | 2,481 |
| 4/80 | Moerdijk to Carrington | 1,100 | 2,109 |
| 4/80 | Tees to Shellhaven | 2,150 | 4,100 |
| 4/80 | Tees to Carrington | 1,100 | 2,109 |
| 5/80 | Porvoo to Tees | 1,940 | 3,723 |
| 10/80 | Rafnes to Moerdijk | 1,300 | 2,500 |

## 2.12 TERMINAL AND STORAGE FACILITIES FOR LPG AND CHEMICAL GASES

### 2.12.1 Facilities at Export Terminals

As with LNG, the production of LPG is a highly complex, capital intensive industry requiring investment in pipeline facilities connecting the export terminal, where most of the production facilities are normally centred, to the gas sources(s), the construction of LPG plant and storage facilities and finally the construction of a terminal capable of handling the product. A brief description of two export terminals may clarify the picture somewhat.

(i) The Ju'Aymah Refrigerated LPG Terminal

The Ju'Aymah LPG terminal is an Aramco-operated facility designed to load refrigerated liquid petroleum gas (RLPG) aboard LPG carriers ranging in size from 25,000 $M^3$ to about 200,000 $M^3$ and is situated just south of the recently opened Ju'Aymah crude oil terminal.

The onshore complex consists of fractionation, refrigeration, compression and storage facilities. Natural gas liquids (NGL'S) are received from two NGL production units at Shedgum (currently open and designed to produce 305,000 barrels a day (b/d) of NGLS from the associated gas of the Ghawar field) and Uthmaniyah (with a design capacity of 445,000 b/d of NGLS) by pipeline and processed at the Ju'Aymah plant. This facility is capable of processing 397,000 b/d of mixed NGLS into 195,000 $ft^3$/day of ethane, 156,000 b/d of propane, 73,000 b/d of butane and 58,000 b/d of natural gasoline. The propane and butane is stored in seven insulated dome-roof tanks of 500,000 barrel capacity each. Booster and shipper pumps are located in the onshore tankage area. The terminal has two 50,000 barrel bunker fuel oil tanks and one 30,000 barrel black diesel tank. A six mile long trestle, along which runs an access roadway and a pipeway for the product and bunker lines, connects the onshore facilities to a 2 berth offshore loading platform. There are 4 breasting dolphins at each berth and 6 mooring dolphins for safely securing a ship at berth. A tower crane is located in the middle of the platform. Loading facilities at each berth consist of four 16 inch LPG loading arms, all capable of either the propane or butane loading service or vapour return. Bunker fuel or black diesel can be loaded through both of the eight inch loading arms located on either side of the LPG loading station.

(ii) <u>The Mina Al-Ahmadi LPG Terminal</u>

Mina-Al-Ahmadi is a crude/LPG loading terminal owned by the Kuwait Oil Company (KOC). The facility is capable of handling the largest LPG carrier currently afloat.

The onshore facilities, which process previously flared Kuwaiti associated gas, consist of three production trains, each train consisting of five units handling extraction, fractionation, product treatment, product cooling, and refrigeration. Each train has a daily design capacity of 560 mmscf of gas making annual plant capacity 1.68 billion scfd or, in liquid terms, 101,310 b/d of propane, 54,970 b/d of butane and 41,250 b/d of natural gasoline.

Three storage tanks are available for each product. The six propane and butane storage tanks are of fixed dome roof-design and are maintained at a slight pressure. The contents are constantly refrigerated to -44°C for propane and -4°C for butane. Each propane tank holds 433,000 barrels and each butane tank 267,000 barrels.

Low temperature, large diameter butane and propane lines connect the storage area to berth Numbers 1 and 10 at the KOC south pier. These berths are equipped with 16-inch LPG loading lines and a 10-inch vapour return line and a six-inch circulating line. LPG can be loaded at 1,000 tonnes/hour. Heavy, light and diesel fuel are available.

### 2.12.2 Facilities at Reception Terminals

Reception terminal facilities are largely, in effect, mirror images of export terminal facilities, enabling a reversed version of the practices necessary to facilitate LPG loading to be accomplished.

Upon docking, liquid and vapour reception lines are connected and discharge commences. Vapour connections are essential : as the cargo is removed, the tank pressure is reduced and, if the discharge rate is high enough, insufficient boil-off may be generated to maintain positive pressure in the tank. In order to prevent a vacuum forming and tank damage, vapour must be introduced either from shore facilties or by diverting some cargo liquid to an on-board vapouriser. Discharge rates can vary considerably : the Tokoka Oil LPG Pier at Shiogama is capable of receiving 4,000 tonnes per hour whilst other Japanese facilities can only accommodate discharges of a fraction of this rate, the Mitsui Tocitsu facility handling 1,000 tonnes hourly and the Idemistu Chita Pier at Nagoya handling 2,000 tonnes an hour. A booster pump may be required to deliver the LPG to the shore-based storage tanks if they are a considerable distance from the ship or above sea level.

The recently expanded Warren Petroleum Company Houston area natural gas liquids (NGL) terminal and processing facilities provide an example of the facilities required by LPG carriers. Initially, the terminal consisted of two barge docks and two docks capable of handling ships of up to 53,400 cubic metres (with a 300,000 barrels capacity) at a rate of 20,000 b/d. The new facilities increase terminal NGL handling ability to 200,000 b/d and enable the simultaneous docking and unloading of three 80,000 cubic metre LPG vessels at a one-product rate of 15,000 barrels hourly. To accommodate increased terminal throughput, a 24-mile 20-inch pipeline will be laid between the terminal on the Houston Ship Channel and storage facilities at Mont Belvieu, Texas and storage facilities at Mont Belvieu, capable of handling a variety of LPGs and liquid chemical gases, increased by eight million barrels to 42 million barrels following the drilling of five additional salt-dome storage wells. In addition, fractionation capability at Mont Belvieu was increased by 16,000 b/d to 156,000 b/d.

## 2.13 SPECIFIC HAZARDS/SPECIALISED SHIPPING REQUIREMENTS OF LPG TRADING

As with LNG trading, the carriage of liquid cargoes that are gaseous at ambient temperature and at normal levels of pressure requires the use of specialised tonnage, namely the LPG carrier. The potentially volatile nature of the cargo vapour (or toxic in the case of ammonia) in the event of liquid spillage has resulted in LPG carriers being built to meet strict standards and incorporating sophisticated equipment which, whilst ensuring an exemplory safety record, has resulted in heavy LPG carrier construction costs. Moreover, the speculative ordering of large LPG carriers prior to trade growth has resulted in LPG carrier unemployment and suboptimal operation. Unlike LNG carriers, LPG carriers do possess a certain amount of operational flexibility, normally being able to carry ammonia, chemical gas, naphtha, gas oil and other clean petroleum cargoes in addition to liquefied propane and butane. Indeed, LPG carriers have, of late frequently appeared on the clean products spot market, drawn by high rates and better prospects of employment. Such operational practice is, however, a poor substitute for LPG trading and is a form of sub-optimisation, an indicator of considerable excess capacity. This would suggest that the chances of obtaining some back-haul business is improved (compared to that of the LNG carrier). However, given that the carrying capability of such vessels is limited to hydrocarbon based products, little demand in the area of the exporting terminal is likely to be generated for back-hauls. Moreover, chemical gas cargoes are unlikely to be of sufficiently large sizes to interest deepsea vessels in possible back-hauls. Occassional part cargoes of ammonia may be available on a spot basis for transportation from the US Gulf to Turkey in vessels returning from discharging at New Orleans and transitting the Suez Canal but this would simply increase vessel requirement on the tied trade.

## 2.14 CURRENT SHIPPING PRACTICE AND POSSIBLE FUTURE REVISIONS

At present, the standard deep-sea, long-haul LPG carrier is of about 75,000 M3 but economies of scale are available if larger LPG tankers were to be built. Indeed, recent orders, such as the mid-1980 contracts for an 83,000 $M^3$ carrier to be built at Hitachi and an 85,000 $M^3$ carrier for construction by Chantiers Navals de La Ciotat, suggest that a trend may be developing towards the construction of larger carriers. Designs for significantly larger vessels are already available, for example the 160,000 $M^3$ LPG carrier design available at the Gdynia Shipyard, Poland. Moreover, facilities are already available that can cater for significantly larger vessels : according to the Gulf Agency Company bulletin "Port News" dated June 1980, the new Saudi Arabian LPG terminal of Ju'Aymah is designed to load refrigerated liquid petroleum gas aboard LPG carriers ranging in size from 25,000 $M^3$ to 200,000 $M^3$ whilst Westernport (maximum capacity 100,000 DWT LPG carriers), Dubai (100,000 DWT), Nagoya (100,000 DWT), Sakai (160,000 DWT) and Chiba (70,000 DWT) regularly handle the two 100,000 $M^3$ LPG carriers, the "Esso Fuji" and "Esso Westernport" and could conceivably handle larger carriers.

Thus, facilities are available to cater for larger LPG carriers than those currently considered of standard size for deep-sea operations. Whilst a few larger vessels may, in the future, be ordered to help fulfil Japanese LPG demand, a general change in cargo lots is unlikely due to the lack of operational flexibility afforded to larger vessels as a result of port restrictions.

## 2.15 THE AVAILABILITY OF LPG CARRIERS IN 1985

The market conditions associated with LPG (and thus LPG carriers) are likely to undergo radical alterations during the 1980s due to the massive increases in LPG export availability following developments in the Middle East and Africa. The extent to which this additional capacity is utilised is however debatable and will depend on a plethora of factors including oil demand (a fall in crude oil production will lead to a reduction in the output of associated gas and thus LPG), the price of LPG (if producers are dissatisfied with propane/butane prices, associated gas may be flared, as in Sauid Arabia late in 1980, or diverted for internal use), the price of alternative sources of energy, economic growth and the proliferation of energy conservation measures.

### 2.15.1 Inter-area Demand

For the purposes of this consultancy, future long-haul LPG movements will be calculated with reference to :

(a) estimates of export availability, as defined by plant capacity and known future output levels, which will be made on the basis of in-house data;

(b) recent estimates of likely demand levels in the major LPG consuming markets.

The above data will give estimates of long-haul LPG movements by sea. This will be translated into shipping demand and termed inter-area demand. It will be assumed that inter-area demand will be fulfilled by LPG carriers of over 50,000 $M^3$.

(i) Export Availability

A brief investigation of export project data has revealed the following likely export capacities in the key years 1980 and 1985. as shown below.

EXPORT AVAILABILITY
(million tonnes)

| | 1980 | 1985 |
|---|---|---|
| Middle East | 14.53 | 32.69 |
| Africa | 2.85 | 8.04 |
| North Sea | 1.65 | 3.15 |
| Western Hemisphere | 3.09 | 3.27 |
| Other | 2.97 | 6.12 |
| TOTAL | 25.09 | 53.27 |

Export availability, however, does not necessairly equal the amount consumed by importing nations. If all the amounts shown above were in fact exported to the main consuming areas of Japan, the USA and Europe, then deep-sea carrier demand would probably be in the order of 9-10 million cubic metres in 1985 or about 80% in excess of currently projected long-haul carrier supply at that time. Thus, it is necessary to take a stance on the actual level of exports moved by sea in 1985 to enable the calculation of contemporary LPG carrier demand levels. This can be achieved by assessing likely import demand in the target year.

(ii) Import Demand

Recent estimates suggest widely conflicting views regarding future demand for imported LPG in the major consuming areas, namely Japan, the US and Western Europe.

(a) Mr. E. Faridany, managing director of Ocean Pheonix Gas Transport of Rotterdam estimated, in July 1980, that US LPG import requirements would rise from 6.5 million tonnes in 1979 to 9.8 million tonnes in 1985 and 22.0 million tonnes in 1990; that Japanese requirements would hit 15.0 million tonnes in 1985 and 21.7 million tonnes in 1990, rising from the 1979 level of 9.7 million tonnes; and that Western European import demand would rise from 4.1 million tonnes in 1979 to 8.9 million tonnes in 1985 and 13.2 million tonnes in 1990.

(b) Japan Line believes Japanese imports will rise from an estimated 11.4 million tonnes in 1980 to 20 million tonnes in 1985, a September 1980 report reveals.

(c) Transcontinental Gas Pipeline Corporation commissioned Jensen Associates to review the future propane market and these consultants discovered that the European LPG market would be approximately in balance in 1985, although net exports of propane during the 1980s are to be anticipated.

(d) Estimates of US import requirements in 1990 vary from 12 million tons, as suggested by consultants Chem systems, to up to 30 million tonnes.

Thus, the likely future demand for LPG imports over the period 1980-85 is a matter open to debate on which no two experts in the field are likely to agree. Without entering into a lengthy analytical exercise, which would be beyond the scope of this report and may be of limited validity anyway, definitive answers cannot be arrived at. However, by briefly assessing the above data and pointing out a few salient features, the Consultants have been able to construct estimates of LPG import demand for 1985. (Import demand in intermediate years has been calculated by interpolation).

(a) Japan

The Consultants suggest that Japanese LPG import demand could rise to about 18 million tonnes in 1985 from the current government imposed ceiling of 10.4 million tonnes. This estimate falls roughly midway between those of Japan Line and Mr. Faridany. A steady growth in LPG demand is to be anticipated due to the wish of the Japanese to diversify their energy base.

(b) US

LPG demand in the United States in 1985 has been estimated at 12.5 million tonnes, above the estimate of Mr. Faridany.

(c) Europe

With the commencing of North Sea LPG output, Europe is likely to meet much of its own LPG requirement, despite increasing demand for chemical feedstock and fuel uses. Thus, the inter-area demand for LPG generated by Europe is taken as being only 5.5 million tonnes in 1985.

TABLE 30 shows the anticipated growth path of LPG import demand over the period 1980-85.

TABLE 30

ESTIMATED LPG IMPORT DEMAND 1980-85
(Million Tonnes)

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| Japan | 10.4[1] | 11.9 | 13.4 | 14.9 | 16.3 | 18.0 |
| US | 6.5[2] | 7.7 | 8.9 | 10.1 | 11.3 | 12.5 |
| Europe | 4.1[2] | 4.3 | 4.6 | 4.9 | 5.2 | 5.5 |
| Others | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| TOTAL | 21.5 | 24.5 | 27.6 | 30.7 | 33.7 | 37.0 |

1 As per 1980 Japanese government ceiling level.
2 As per Mr. Faridany estimate for 1979.

By assuming an average speed of 15.5 knots, an operating year of 340 days, port time of 2 days per visit and an allowance of 1 day per Canal transit, TABLE 31 can be constructed showing the approximate levels of demand for deep-sea LPG carriers operating on these trades.

TABLE 31

INTER-AREA DEMAND FOR DEEP-SEA LPG CARRIERS 1980-85
(000 $M^3$)

| 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| 3,998 | 4,586 | 5,174 | 5,762 | 6,350 | 6,940 |

2.15.2 Intra-area Demand

Intra-area (or short-haul) LPG carrier demand presents a more complex problem but a sophisticated approach to the question appears outside the scope of this report. Thus, a simple analysis has been used here :

(a) all intra-area demand for LPG will be carried in LPG tanker of 1,000 $M^3$ to 50,000 $M^3$ (for the purposes of this analysis, liquid chemical gas/ammonia will be assumed to be carried in vessels of 1,000 $M^3$ to 50,000 $M^3$).

(b) intra-area demand will be looked upon as a residual element, equating, in the base year, to total fleet as at end year less average laid-up capacity less inter-area demand.

(c) intra-area demand in future years will be based upon the result of (ii) above plus the weighted average of GDP growth in North America and Western Europe plus two percentage points. The growth rates for 1980 and 1981 have been based upon those published by the National Institute of Economic and Social Research in their November 1980 edition of National Institute Economic Review : average GDP growth in 1982 is estimated at 2% and is assumed to rise to 3% in subsequent years.

Thus, intra-area demand for LPG carriers will grow as in TABLE 32.

TABLE 32

INTRA-AREA DEMAND GROWTH FOR LPG CARRIERS 1980-1985

| 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| 2.5% | 3.3% | 4.4% | 5.0% | 5.0% | 5.0% |

Intra-Area Demand for LPG Carriers

Based on the methodology outline above, and taking 1979 as a base year, intra-area trade in 1979 totalled :

| | |
|---|---|
| Total Fleet as at 31.12.79 | 6,356,000 |
| Capacity laid-up/inactive/operating in oil | 350,000 |
| Active Fleet | 6,006,000 |
| Inter-Area Demand | 3,998,000 |
| | 2,008,000 |

Using the growth rates shown in TABLE 32, intra-area demand for LPG carriers can be derived. The results are displayed in TABLE 33.

TABLE 33

FORECAST INTRA-AREA DEMAND FOR LPG CARRIERS 1980-1985
(000 M3)

| 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| 2,008 | 2,058 | 2,126 | 2,232 | 2,316 | 2,432 |

2.15.3 LPG Carrier Supply

This has been calculated by :

(i) taking the end-1980 existing fleet and orderbook as a base;

(ii) assuming delayed 1980 deliveries will be completed in 1981 and all other orders will be completed as per schedule;

(iii) assuming a scrapping rate of 10% per annum of all vessels in excess of 20 years of age.

The results are shown overleaf in TABLE 34.

TABLE 34

LPG CARRIER SUPPLY/DEMAND BALANCE
(000 $M^3$)

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| INTRA-AREA (1,000-49,999 $M^3$) | | | | | | |
| Supply | 1,898 | 2,111 | 2,230 | 2,219 | 2,206 | 2,185 |
| Demand | 2,008 | 2,058 | 2,126 | 2,232 | 2,316 | 2,432 |
| Excess Supply (New. Build. Demand) | (110) | 53 | 104 | (13) | (110) | (247) |
| INTER-AREA (50,000 $M^3$+) | | | | | | |
| Supply | 4,458 | 4,799 | 5,163 | 5,248 | 5,248 | 5,248 |
| Demand | 3,998 | 4,586 | 5,174 | 5,762 | 6,350 | 6,940 |
| Excess Supply (New. Build. Demand) | 460 | 213 | (11) | (514) | (1,102) | (1,692) |
| TOTAL FLEET | | | | | | |
| Supply | 6,356 | 6,910 | 7,393 | 7,467 | 7,454 | 7,433 |
| Demand | 6,006 | 6,644 | 7,300 | 7,994 | 8,666 | 9,372 |
| Excess Supply (New. Build. Demand) | 350 | 266 | 93 | (527) | (1,212) | (1,939) |

2.15.4 LPG Carrier Supply/Demand Balance

Based on the above import demand assumptions and known vessel supply, the likely supply/demand position for LPG carriers has been calculated and is displayed in TABLE 34. This suggests that by 1985 additional vessel capacity will be required and thus the Consultants believe that the Clients will have to consider building new vessels to fulfil their transportation needs. The factors governing both sides of the equation are very finely balanced, however, and many predictions regarding the particular market have gone awry in the past. (The current disagreement amongst forecasters in this field only goes to underline this statement). The estimates do at present seem reasonable, however.

STUDY OF TRANSPORT COSTS FOR SHIPPING PETROCHEMICALS

# SECTION 3

# METHANOL

## 3.1 CARGO CHARACTERISTICS

The cargo characteristics of methanol are outlined in TABLE 35. From this information it would appear that methanol can be transported in standard crude carriers with mild steel tanks.

TABLE 35

THE CHARACTERISTICS OF METHANOL

Properties (100% conc.)

1. Clear, colourless liquid
2. Characteristic odour
3. Specific Gravity 0.796 @ 15.5°/15.5°C
4. Boiling Point 64.6°C
5. Freezing Point -97.6°C
6. Vapour Pressure @ 20°C = 96mm Hg
7. Coefficient of Cubic Expansion 0.0012/°C @ 20°C
8. Vapour Density 1.1
9. Solubility in Water - complete
10. Viscosity 0.60cP @ 20°C
11. Electrostatic Generation - unknown

Normal carriage temperature - ambient

Normal carriage pressure - atmospheric

Handling and Storage Materials

| Unsuitable | Suitable |
|---|---|
| Zinc (galvanised metals) Synthetic Resins, Leather, Polystyrene, "Perspex", Plasticised PVC, Certain rubbers | Stainless Steel<br>Mild Steel |

N.B. Corrosivity greatly accelerated by moisture.

Reactivity With:

| | | |
|---|---|---|
| Oxidising Agents | : | Vigorous reaction possible |
| Acids | : | Conc. Nitric - vigorous reaction<br>Conc. Sulphuric - great deal of heat may be evolved.<br>Other acids - no dangerous reaction |
| Alkalis | : | No dangerous reaction |
| Salt or Fresh Water | : | No reaction |
| Air | : | No reaction |
| Other Chemicals | : | No dangerous reaction in general |

## 3.2 INSTITUTIONAL METHANOL CARRIAGE REQUIREMENTS

Reference to current IMCO regulations and discussions with industry contacts suggest that there are no barriers to slightly modified crude carriers undertaking a dedicated methanol trade. The current practice is to carry methanol in product/chemical carriers but such tankers are apparently used only because the size of cargo is at present relatively small (normally only a few thousand tonnes is carried at a time, a parcel size suitable for carriage in the smaller tanks available on chemical carriers), the tanks are easier to clean than is the case with crude carriers (chloride/hydrocarbon residues can lead to a significant deterioration in chemical quality methanol) and the pumps of crude carriers are often unsuitable for methanol carriage. However, by ensuring that the vessels operate exclusively in methanol, the problem of tank cleanliness can be overcome, whilst the installation of suitable pumps should have little effect on the overall cost of such a vessel. Thus crude carrier prices would appear to be indicative of methanol carrier capital costs and will thus be used throughout this section.

## 3.3 METHANOL CARRIER NEWBUILDING PRICES

The nature of the vessel chosen for methanol transport inevitably limits the choice of shipbuilding nation. The choice of vessels with specifications similar to crude carriers requires the construction of relatively unsophisticated tonnage and it is in such an area that Japan's competitive advantage is the greatest. Thus, Japanese product/crude carrier prices have been investigated here and vessel sizes selected to facilitate the size of trade under scrutiny after taking voyage distance into account.

(a) Short-haul tankers

Methanol carrier demand on the Skikda-Genoa, Skikda-Rotterdam and Veracruz-New Orleans routes only justifies the construction of relatively small vessels and thus tankers of 12,500 DWT and 17,200 DWT have been utilised in this cost generation exercise. A few crude/products carriers of this size were ordered in 1979: an order for two 17,200 DWT products carriers were placed with Hitachi for $10.0 million each ($581/DWT) in January 1979; Kurushima secured an order for a 17,900 DWT carrier the following month priced at $10.0 million ($558.7/DWT); Naikai obtained an order for a 17,200 DWT products tanker at $10 million ($581/DWT) in May 1979 whilst Namura secured a contract for a single 12,500-tonner in June 1979 for $6.88 million ($551/DWT). All these vessels were due for end 1979/first half 1980 delivery. Based on this data, the Consultants have assumed a newbuilding price of $575/DWT for both 12,500 and 17,200 DWT tankers, implying newbuilding prices of $7.19 million and $9.89 million respectively and annual capital costs of $1.222 million and $1.681 million.

(b) Long-haul tankers

Carriers of 35,000 DWT and 55,000 DWT are assumed to operate on the deep-sea hauls. Business for tankers of c.55,000 DWT has been brisk recently. (Data concerning 35,000 DWT tanker prices is rather scarce and thus estimates have been calculated by interpolation). Sasebo secured two orders in July 1978 for 51,000 DWT carriers at $19.3 million ($379/DWT) per unit for third/fourth quarter 1979 delivery. Two additional orders, for 50,000 DWT tankers, were obtained by the same yard in October 1978 for $18.0 million each ($360/DWT) for delivery in the second half of 1979/first half 1980. This price mirrors that obtained by I.H.I. for the construction of two 50,000 DWT units for first half 1979 delivery, these orders also being placed in October 1978. In May 1979, two 55,000 DWT tankers were ordered from Koyo Dock for end-1980/start-1981 delivery. A price of $20.0 million ($364/DWT) was attached. Finally, in July 1979, a single 55,000 DWT order was placed with the Mitsui yard for end-1980 delivery at a cost of $21.2 million ($385.5/DWT). The Consultants feel that this data points to a cost per DWT for a 55,000 DWT methanol carrier of $365/DWT for a 1980 delivery, equating to a unit cost of $20.08 million or an annual capital cost of $3.414 million. By interpolation this would suggest a cost of $470/DWT for a 35,000 DWT carrier or a cost per vessel of $16.45 million. This would be consistent with an annual capital cost of $2.797 million.

## 3.4 METHANOL CARRIER OPERATING COSTS

The annual costs associated with the regular operation of a ship, which come under the heading of operating costs, include:

- manning
- repairs and maintenance
- insurance
- stores and supplies
- administration and management overheads
- other miscellaneous costs

Annual methanol carrier operating costs have been based upon the results of the Consultants' confidential operating costs survey for 1979 and are shown in TABLE 36 below. (Tanker operating costs have been taken as indicative of methanol carrier operating costs).

TABLE 36

1980 ESTIMATED ANNUAL METHANOL CARRIER OPERATING COSTS

($)

| COST TYPE | LEVEL OF COST | | |
|---|---|---|---|
| | 12,500-17,200 DWT | ±35,000 DWT | ±55,000 DWT |
| Manning | 668,000 | 792,000 | 825,000 |
| Repairs and Maintenance | 231,000 | 445,000 | 670,000 |
| Insurance | 160,000 | 178,000 | 227,000 |
| Stores and Supplies | 114,000 | 173,000 | 239,000 |
| Administration and Others | 200,000 | 200,000 | 200,000 |
| Total Per Vessel | 1,373,000 | 1,788,000 | 2,161,000 |

## 3.5 METHANOL CARRIER VOYAGE COSTS

As with other types of vessel reviewed, methanol carrier voyage costs consist of three basic elements:

(i) fuel costs
(ii) port costs
(iii) canal dues (where applicable)

### 3.5.1 Fuel Costs

Fuel costs are dependent on a number of factors:

(i) Length of Voyage

The voyage distances used are displayed in SECTION 1.5 TABLE 3.

(ii) Length of Loading/Discharging Procedure

Turnaround time per port visit is estimated at 2 days. This includes an allowance for time consumed manoeuvering the vessel, for hose connection/disconnection activities and for port delays.

(iii) Canal Transit Time

Canal transit time is assumed to be one day per transit. This exceeds advertised transit times but makes allowances for mustering activities and cancellation due to bad weather.

(iv) Bunker Consumption

Bunker consumption levels at sea are as shown in TABLE 37 below. Fuel utilisation in port will be 25% of sea-going consumption whilst useage in the canal will be 60% of consumption at sea. These consumption levels reflect the use of the latest type of fuel conserving diesel engine and are thus considerably below the consumption levels applicable to older vessels or the fleet average for each size in question.

TABLE 37

BUNKER CONSUMPTION AT SEA

(tons per day)

| | 12,500 DWT | 17,200 DWT | 35,000 DWT | 55,000 DWT |
|---|---|---|---|---|
| Fuel Oil | 25 | 27 | 35 | 40 |
| Marine Diesel | 1.0 | 1.0 | 1.5 | 1.5 |

(v) Bunker Costs

Fuel costs per tonne are displayed in SECTION 1.5 TABLE 4 and these figures have been used in the calculation of total bunker costs. These assumptions have enabled the Consultants to construct TABLE 38 which shows total bunker costs associated with methanol carriers trading on the routes in question on an annual basis.

TABLE 38

ANNUAL BUNKER COSTS
(US Dollars)

| DISCHARGING PORT \ LOADING PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| Genoa | 976,287[1] | 2,068,428[3] | 2,149,450[3] | 2,095,331[3] |
| Rotterdam | 1,403,584[2] | 2,037,071[3] | 2,373,066[4] | 1,984,273[3] |
| New Orleans | 1,867,994[3] | 2,136,649[4] | 2,343,747[4] | 947,493[1] |
| Yokohama | 2,502,330[4] | 2,166,562[3] | 2,085,371[3] | 2,407,102[4] |

1 12,500 DWT carrier base
2 17,200 DWT carrier base
3 35,000 DWT carrier base
4 55,000 DWT carrier base

TABLE 39

PORT CHARGES PER VISIT AS AT MID-1980
(US Dollars)

| VESSEL SIZES \ PORT | SKIKDA | DOHA | ACEH | VERACRUZ | GENOA | ROTTERDAM | NEW ORLEANS | YOKOHAMA |
|---|---|---|---|---|---|---|---|---|
| 12,500 DWT | 5,400 | 5,292 | 3,840 | 2,160 | 2,280 | 8,300 | 10,000 | 8,400 |
| 17,200 DWT | 7,650 | 5,723 | 5,410 | 3,060 | 3,230 | 11,650 | 11,000 | 11,900 |
| 35,000 DWT | 15,750 | 7,275 | 7,670 | 6,300 | 5,950 | 24,000 | 15,250 | 16,000 |
| 55,000 DWT | 24,750 | 9,230 | 10,190 | 9,900 | 9,350 | 38,000 | 19,750 | 21,500 |

### 3.5.2 Port Disbursements

Port disbursements normally account for a relatively small proportion of total voyage costs. (On short-haul routes, however, their importance increases substantially) . Port charges include the cost of terminalling operations, pilotage, tug hire etc. Such charges will vary substantially between ports and over time, and are likely to alter with length of stay. For the purposes of this consultancy, port charges have been derived using the port disbursement accounts of tankers as reported by the Consultants confidential sources. The Consultants' estimates of port charges are displayed in TABLE 39.

### 3.5.3 Canal Charges

#### (i) Suez Canal Tolls

Using the route structure and SDR/$ exchange rate shown in SECTION 1.5.3 in conjunction with

(a) an SCNRT equivalent of 20,000 for a 35,000 DWT methanol carrier;
(b) an SCNRT equivalent of 26,500 for a 55,000 DWT methanol carrier ;

Suez Canal tolls of $80,950 per round trip for a 35,000 DWT methanol carrier and $105,455 per round trip for a 55,000 DWT methanol carrier have been calculated.

#### (ii) Panama Canal Tolls

Panama Canal tolls as at mid-1980 were $1.29 per Panama Canal Net Registered Ton (PCNRT) laden and $1.03 PCNRT ballast. In addition, an allowance of $2,000 has been made to account for possible tug usage costs. If it is assumed that a methanol carrier of 55,000 DWT has a PCNRT of 23,000, then canal charges per round trip will equate to $55,360.

### 3.5.4 Total Methanol Carrier Voyage Costs Per Annum

By annualising port charges and canal tolls and adding to annual bunker costs, total voyage costs per annum per vessel can be estimated as shown in TABLE 40. For the purposes of this exercise, it has been assumed that a single vessel of the required size will operate exclusively on the chosen trade.

TABLE 40

TOTAL VOYAGE COSTS PER ANNUM PER VESSEL AS AT MID-1980
(US Dollars)

| | ROUND TRIPS PER VESSEL | BUNKER COSTS | PORT CHARGES | CANAL TOLLS | TOTAL |
|---|---|---|---|---|---|
| SKIKDA-GENOA | 51.65 | 976,287 | 396,672 | - | 1,372,959 |
| SKIKDA-ROTTERDAM | 22.64 | 1,403,584 | 436,952 | - | 1,840,536 |
| SKIKDA-NEW ORLEANS | 10.24 | 1,867,994 | 317,440 | - | 2,185,434 |
| SKIKDA-YOKOHAMA | 5.82 | 2,502,330 | 125,130 | 613,748 | 3,241,208 |
| DOHA-GENOA | 10.81 | 2,068,428 | 142,962 | 875,070 | 3,086,460 |
| DOHA-ROTTERDAM | 8.10 | 2,037,071 | 253,328 | 655,695 | 2,946,094 |
| DOHA-NEW ORLEANS | 5.65 | 2,136,649 | 163,737 | 595,821 | 2,896,207 |
| DOHA-YOKOHAMA | 8.32 | 2,166,562 | 193,648 | - | 2,360,210 |
| ACEH-GENOA | 8.71 | 2,149,450 | 118,630 | 705,075 | 2,973,155 |
| ACEH-ROTTERDAM | 6.86 | 2,373,066 | 330,583 | 723,421 | 3,427,070 |
| ACEH-NEW ORLEANS | 5.02 | 2,343,747 | 167,768 | 529,384 | 3,040,899 |
| ACEH-YOKOHAMA | 14.25 | 2,085,371 | 337,298 | - | 2,422,669 |
| VERACRUZ-GENOA | 9.44 | 2,095,331 | 115,640 | - | 2,210,971 |
| VERACRUZ-ROTTERDAM | 10.29 | 1,984,273 | 311,787 | - | 2,296,060 |
| VERACRUZ-NEW ORLEANS | 39.84 | 947,493 | 484,454 | - | 1,431,947 |
| VERACRUZ-YOKOHAMA | 5.89 | 2,407,102 | 184,946 | 326,070 | 2,918,118 |

## 3.6 TRANSPORT COSTS PER TONNE DELIVERED-VARYING VESSEL SIZES

The Consultants have been asked to assume an annual trade of 300,000 tons on the routes in question. This figure has been used in conjunction with an assumed speed of 14.5 knots, port time of 2 days per visit, canal time per round trip of two days and a 345-day operating year to calculate methanol carrier requirement on each route. Although the opportunities for carrying spot cargoes of methanol are somewhat limited, it may be possible to gain employment on the oil market for the excess capacity unutilised on the tied trades and thus it seems reasonable to treat all three cost elements as continuous variables. (This assumes that the resulting tank contamination does not make subsequent methanol cargoes of a quality unacceptable to the consumer).

Using this methodology, TABLE 41 has been constructed and transport costs per metric tonne delivered calculated.

TABLE 41

CALCULATION OF TRANSPORT COSTS PER TONNE DELIVERED AS AT MID-1980 - VARYING VESSEL SIZES

(US Dollars)

| ROUTE | UNIT SIZE (DWT) | ANNUAL CAPITAL COSTS PER VESSEL | ANNUAL OPERATING COSTS PER VESSEL | ANNUAL VOYAGE COSTS PER VESSEL | ANNUAL FULLY BUILT-UP COSTS PER VESSEL | UTILISATION FACTOR | ANNUAL FULLY BUILT-UP COSTS PER ROUTE | ANNUAL FULLY BUILT-UP COSTS ($/METRIC TONNE) |
|---|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 12,500 | 1,222,000 | 1,373,000 | 1,372,959 | 3,967,959 | 0.5050 | 2,003,819 | 6.68 |
| SKIKDA-ROTTERDAM | 17,200 | 1,681,000 | 1,373,000 | 1,840,536 | 4,894,536 | 0.8334 | 4,079,106 | 13.60 |
| SKIKDA-NEW ORLEANS | 35,000 | 2,797,000 | 1,788,000 | 2,185,434 | 6,770,434 | 0.9084 | 5,150,262 | 20.50 |
| SKIKDA-YOKOHAMA | 55,000 | 3,414,000 | 2,161,000 | 3,241,208 | 8,316,208 | 0.9970 | 8,789,759 | 29.30 |
| DOHA-GENOA | 55,000 | 2,797,000 | 1,788,000 | 3,086,460 | 7,671,460 | 0.8605 | 6,601,291 | 22.00 |
| DOHA-ROTTERDAM | 39,825 | 3,182,000 | 1,788,000 | 2,946,094 | 7,916,094 | 1 | 7,916,094 | 26.39 |
| DOHA-NEW ORLEANS | 56,500 | 3,505,000 | 2,161,000 | 2,896,207 | 8,562,207 | 1 | 8,562,207 | 28.54 |
| DOHA-YOKOHAMA | 38,775 | 3,097,000 | 1,788,000 | 2,360,210 | 7,245,210 | 1 | 7,245,210 | 24.15 |
| ACEH-GENOA | 37,035 | 2,960,000 | 1,788,000 | 2,973,155 | 7,721,155 | 1 | 7,721,155 | 25.74 |
| ACEH-ROTTERDAM | 55,000 | 3,414,000 | 2,161,000 | 3,427,070 | 9,002,070 | 0.8459 | 7,614,851 | 25.38 |
| ACEH-NEW ORLEANS | 63,575 | 3,944,000 | 2,161,000 | 3,040,899 | 9,145,899 | 1 | 9,145,899 | 30.49 |
| ACEH-YOKOHAMA | 35,000 | 2,797,000 | 1,788,000 | 2,422,669 | 7,007,669 | 0.6528 | 4,574,606 | 15.25 |
| VERACRUZ-GENOA | 35,000 | 2,797,000 | 1,788,000 | 2,210,971 | 6,795,971 | 0.9854 | 6,696,750 | 22.32 |
| VERACRUZ-ROTTERDAM | 35,000 | 2,797,000 | 1,788,000 | 2,496,060 | 6,881,060 | 0.9040 | 6,220,478 | 20.73 |
| VERACRUZ-NEW ORLEANS | 12,500 | 1,222,000 | 1,373,000 | 1,431,947 | 4,026,947 | 0.6548 | 2,636,845 | 8.79 |
| VERACRUZ-YOKOHAMA | 55,000 | 3,414,000 | 2,161,000 | 2,918,118 | 8,493,118 | 0.9852 | 8,367,420 | 27.89 |

Source : H.P.Drewry Shipping Consultants Ltd.

## 3.7 TRANSPORT COSTS PER TONNE DELIVERED - ALTERNATIVE METHODOLOGY

The costs in TABLE 41 are based on the assumption that orders for the required tonnage are placed in 1978/9 for 1980 delivery and thus prices quoted as at time of ordering have been utilised in estimating costs per metric tonne delivered. This example briefly assesses the costs involved in transporting methanol based on newbuilding price levels as at mid-1980.

The general trend in newbuilding prices between 1978/9 and 1980 was upward. It would appear that crude/products tanker prices perhaps rose by 15% over the period (individual order prices for vessels of the sizes in question fluctuated and probably depended largely on differences in vessel sophistication). Thus, the Consultants have, for the purposes of this exercise, estimated the following prices:

| | | | |
|---|---|---|---|
| (i) | 12,500 DWT | \$661 per DWT | \$ 8.26 million per vessel |
| (ii) | 17,200 DWT | \$661 per DWT | \$11.37 million per vessel |
| (iii) | 35,000 DWT | \$541 per DWT | \$18.94 million per vessel |
| (iv) | 55,000 DWT | \$420 per DWT | \$23.10 million per vessel |

which are consistent with capital costs per annum per vessel of \$1.404 million for a 12,500 DWT carrier, \$1.933 million for a 17,200 DWT unit, \$3.220 million for a 35,000 DWT carrier and \$3.927 million for a 55,000 DWT carrier. This alternative methodology gives the costs per metric tonne delivered as shown in TABLE 42.

TABLE 42

TRANSPORT COSTS PER TONNE DELIVERED-MID-1980 ORDERED AND DELIVERED TONNAGE
(US Dollars)

| LOADING PORT / DISCHARGING PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| GENOA | 6.99 | 23.22 | 26.83 | 23.71 |
| ROTTERDAM | 14.30 | 27.99 | 30.49 | 22.01 |
| NEW ORLEANS | 21.78 | 30.30 | 32.35 | 9.19 |
| YOKOHAMA | 31.00 | 25.71 | 16.17 | 29.58 |

## 3.8 TRANSPORT COSTS PER TONNE DELIVERED - STANDARD 55,000 DWT UNIT

Finally, to show the cost relationships on different routes, the Consultants have calculated costs per metric tonne delivered on the assumption that all methanol will be transported in 55,000 DWT units, irrespective of distance. The results are shown in TABLE 43. (Both capital costs assumptions, viz mid-1980 delivery and mid-1980 order have been used in this exercise).

TABLE 43

TRANSPORT COSTS PER TONNE DELIVERED - STANDARD 55,000 DWT UNIT

| LOADING PORT / DISCHARGING PORT | SKIKDA | | DOHA | | ACEH | | VERACRUZ | |
|---|---|---|---|---|---|---|---|---|
| | 1980 DEL. | 1980 ORD. | 1980 DEL. | 1980 ORD. | 1980 DEL. | 1980 ORD. | 1980 DEL. | 1980 ORD. |
| GENOA | 3.26 | 3.52 | 16.56 | 17.48 | 20.20 | 21.34 | 16.65 | 17.71 |
| ROTTERDAM | 7.75 | 8.19 | 21.76 | 22.99 | 25.19 | 26.63 | 15.63 | 16.59 |
| NEW ORLEANS | 15.38 | 16.35 | 29.00 | 30.76 | 32.54 | 34.52 | 4.01 | 4.25 |
| YOKOHAMA | 29.78 | 31.48 | 19.25 | 20.44 | 11.38 | 12.08 | 27.89 | 29.58 |

## 3.9 MID-1985 METHANOL TRANSPORTATION COSTS

The assumptions in SECTION 1.8 have been utilised to calculate mid-1985 methanol transportation costs in conjunction with the following assumptions concerning the newbuilding prices of methanol carriers. As the market for small tankers, and thus by inference methanol carriers, will be supply deficient throughout the period under examination (see SECTION 3.15), the newbuilding price of a 55,000 DWT methanol carrier is likely to be in excess of construction costs to 1985 at least and thus Japanese builders will be able to reap a certain amount of excess profits on each vessel constructed. Thus, the newbuilding price for a 55,000 DWT methanol carrier in 1983 could reach $30 million (see FIGURE 5) and perhaps $33.5 million in 1985. (As indicated previously, construction cost data is very limited and its reliability questionable, and even newbuilding price information may contain anomalies such as preferential finance terms, discounts for early repayment etc.). Such price levels indicate annual capital costs of $ 5.1 million and $5.695 million respectively. This would suggest newbuilding prices for 35,000 DWT methanol carriers of $24.6 million in 1983 and $27.5 million in 1985, of $15.9 million and $18.6 million respectively for 17,200 DWT carriers in those years and finally of $13.5 million and $15.79 million for 12,500 DWT vessels. This would be consistent with capital costs of $4.102 million and $4.675 million for 35,000 DWT carriers, $2.703 million and $3.162 million for 17,200 DWT methanol tankers and $2.295 million and $2.655 million for the smallest sized vessel under investigation. The resulting costs per metric tonne delivered are displayed in TABLE 44.

TABLE 44

TRANSPORT COST PER TONNE OF METHANOL DELIVERED AS AT MID-1985
(US Dollars)

(i) Varying Vessel Sizes

| ROUTE \ COST BASIS | Mid 1983 Order/ Crude Oil Cost $40 Per Barrel | Mid 1983 Order/ Crude Oil Cost $80 Per Barrel | Mid 1985 Order/ Crude Oil Cost $40 Per Barrel | Mid 1985 Order/ Crude Oil Cost $80 Per Barrel |
|---|---|---|---|---|
| SKIKDA-GENOA | 10.86 | 13.16 | 11.52 | 13.81 |
| SKIKDA-ROTTERDAM | 21.13 | 26.82 | 22.66 | 28.35 |
| SKIKDA-NEW ORLEANS [1] | 31.92 | 41.05 | 33.42 | 42.55 |
| SKIKDA-YOKOHAMA | 43.19 | 54.79 | 46.17 | 57.77 |
| DOHA-GONOA [1] | 32.57 | 40.96 | 33.85 | 42.24 |
| DOHA-ROTTERDAM | 40.87 | 50.92 | 40.86 | 52.91 |
| DOHA-NEW ORLEANS | 43.91 | 55.58 | 45.95 | 57.62 |
| DOHA-YOKOHAMA [1] | 36.22 | 46.45 | 38,04 | 48.27 |
| ACEH-GENOA [1] | 38.03 | 48.02 | 39.76 | 49.76 |
| ACEH-ROTTERDAM | 37.77 | 47.52 | 39,45 | 49.20 |
| ACEH-NEW ORLEANS | 46.76 | 59.34 | 49.05 | 61.32 |
| ACEH-YOKOHAMA [1] | 22.78 | 29.12 | 23.85 | 30.19 |
| VERACRUZ-GENOA [1] | 33.74 | 43.72 | 35.36 | 45.34 |
| VERACRUZ-ROTTERDAM [1] | 31.75 | 40.83 | 33.24 | 42.42 |
| VERACRUZ-NEW ORLEANS | 14.85 | 18.31 | 15.70 | 19.16 |
| VERACRUZ-YOKOHAMA | 40.85 | 52.32 | 42.80 | 54.27 |

1 Amended Figures

TABLE 44 (Cont'd)

(ii) Standard 55,000 DWT Carriers

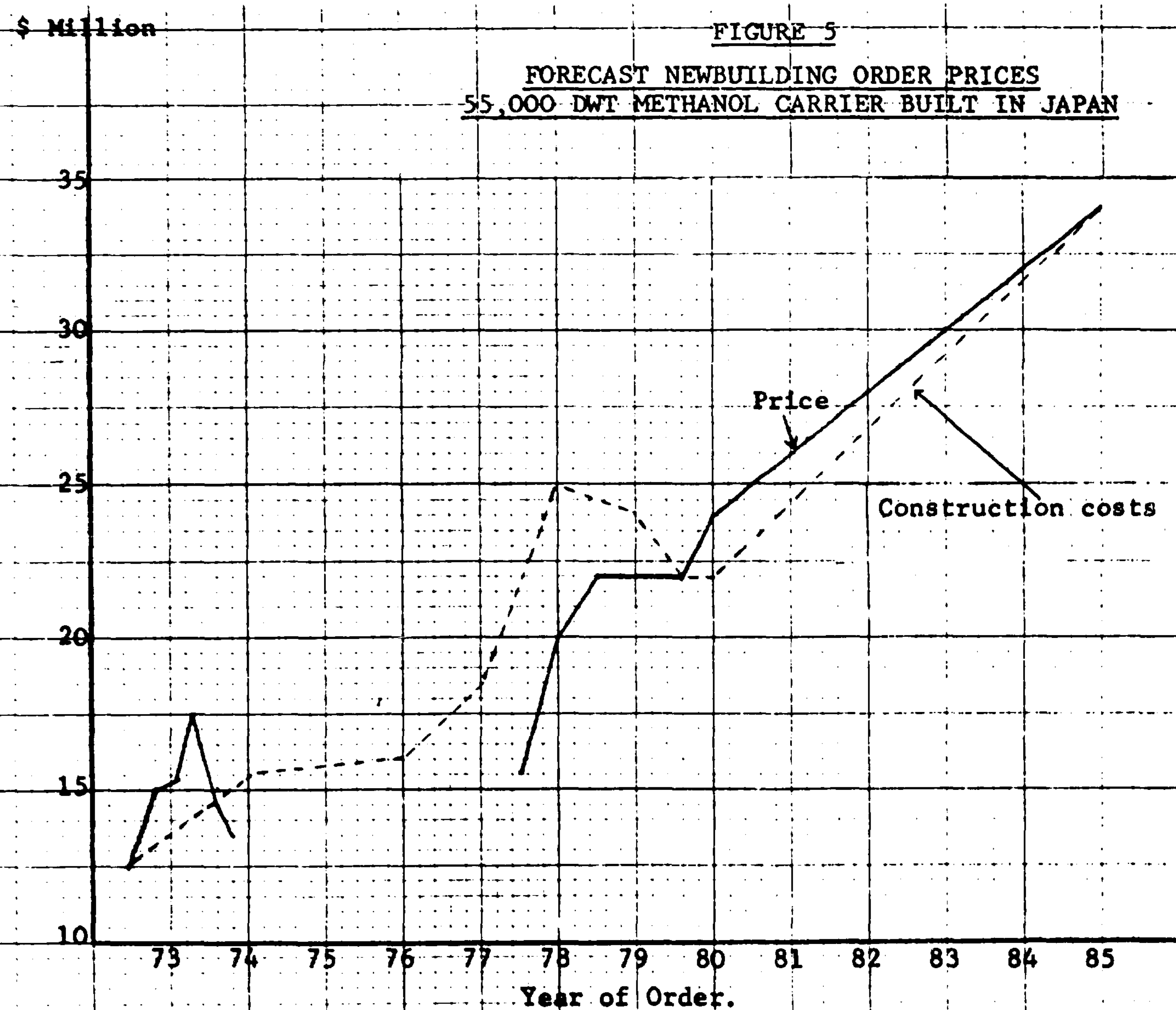
(US Dollars)

| ROUTE \ COST BASIS | Mid 1983 Order/ Crude Oil Cost $40 Per Barrel | Mid 1983 Order/ Crude Oil Cost $80 Per Barrel | Mid 1985 Order/ Crude Oil Cost $40 Per Barrel | Mid 1985 Order/ Crude Oil Cost $80 Per Barrel |
|---|---|---|---|---|
| SKIKDA-GENOA | 5.01 | 5.82 | 5.23 | 6.04 |
| SKIKDA-ROTTERDAM | 11.75 | 14.35 | 12.26 | 14.86 |
| SKIKDA-NEW ORLEANS | 23.94 | 30.38 | 25.06 | 31.50 |
| SKIKDA-YOKOHAMA | 45.05 | 55.53 | 47.03 | 57.51 |
| DOHA-GENOA | 24.26 | 30.18 | 25.32 | 31.24 |
| DOHA-ROTTERDAM | 32.45 | 40.59 | 33.87 | 42.01 |
| DOHA-NEW ORLEANS | 44.66 | 56.64 | 46.70 | 58.68 |
| DOHA-YOKOHAMA | 28.91 | 36.97 | 30.29 | 38.35 |
| ACEH-GENOA | 29.60 | 37.13 | 30.92 | 38.45 |
| ACEH-ROTTERDAM | 37.50 | 47.25 | 39.18 | 48.93 |
| ACEH-NEW ORLEANS | 50.09 | 63.69 | 52.38 | 65.98 |
| ACEH-YOKOHAMA | 17.03 | 21.50 | 17.84 | 22.31 |
| VERACRUZ-GENOA | 25.18 | 32.22 | 26.40 | 33.44 |
| VERACRUZ-ROTTERDAM | 23.93 | 29.46 | 25.05 | 30.58 |
| VERACRUZ-NEW ORLEANS | 6.25 | 7.48 | 6.54 | 7.77 |
| VERACRUZ-YOKOHAMA | 41.93 | 53.39 | 43.88 | 55.34 |

Source : H.P.Drewry Shipping Consultants Ltd.

FIGURE 5

FORECAST NEWBUILDING ORDER PRICES
55,000 DWT METHANOL CARRIER BUILT IN JAPAN



## 3.10 METHANOL TRANSPORTATION COSTS - CHANGES OVER THE PERIOD 1975 TO 1980 AND 1980 TO 1985

The seaborne carriage of methanol is a relatively low volume trade and parcel sizes historically are rather small, i.e. a few thousand tonnes. This position is likely to change in the future, however, as large capacity export plants are due to come on stream in the 1980's in a number of areas, notably the Middle East. The ordering of tonnage to fulfil this additional demand has already commenced and the contracted vessel prices suggest a low level of sophistication has been requested. Thus, modified crude carriers will certainly be used for methanol carriage in the future and, as a result, comparisons of cost alterations over time will be based upon this type of vessel. (Comparative chemical tanker costs are displayed in Appendix 1).

The US exported considerable quantities of methanol to the Far East, Oceania, Europe and the Mediterranean in the late 1960's/early 1970's when production outside North America was unable to satisfy domestic demand levels. However, the opening of new production facilities in the UK and West Germany helped to plug the local supply gap whilst US domestic demands have grown, thus curtailing US exports. Short-sea movements on the inter-UK/Cont/Med route have recently increased considerably.

### 3.10.1 Recent Trade Patterns

(i) Europe

The Italian market has recently received considerable quantities of chemical grade methanol from the Libyan Marsa el Brega plant and the Sonatrach plant in Algeria. Marsa el Brega has also exported methanol to North West Europe but production difficulties may limit export capability below capacity levels. Mexican spot movements to Spain have recently been recorded but the US and Latin American markets may curtail this trade in future.

European methanol exports are largely confined to those of I.C.I. from its UK plant at Billingham but its major markets, New Zealand and Latin America, will be hit by increases in home production and short-haul competition in the near future. However, exports to the US could be sti. ılated if a significant price differential between North Western European and US prices were to develop.

(ii) US

The US imported some 215.000 tonnes of chemical grade methanol in 1978, 70% of which came from Canada and the remainder from Mexico and South Korea. The Mexican trade is likely to expand considerably in the near future.

Exports in 1978 stood at 110,000 tonnes, almost all going to the Latin American market. Spot cargoes are, however, attracted to the North West European market from US Gulf production facilities when the price differential makes such transactions profitable.

(iii) Japan
Korea is the main supplier of Japanese imports: total contracted amounts currently stand at 150,000 tonnes annually, although average contract uptake is limited to about 120,000 tonnes. In addition, Canada exports significant volumes to Japan (65,000 tonnes in 1978), some of which is generally re-exported to other south-east Asian markets.

From the very brief survey of methanol trade routes above, it seems that no single route can be taken as typical over the period 1975 to 1985. However, price sensitive movements between the US Gulf and North West Europe, although sporadic, have occurred over the period 1975 to 1980 and are likely to continue to occur between 1980 and 1985 and thus the costs associated with such movements (in 55,000 DWT carriers) will be reviewed here.

### 3.10.2 Capital Costs

As methanol carriers can be assumed to carry a variety of petroleum based products (assuming the problems of contamination can be overcome) and as , until recently, tied trading was unusual, it is assumed for the purposes of this exercise that delivery will be in recently delivered tonnage and thus capital costs will reflect this assumption. From FIGURE 5 , tonnage newly delivered in 1975 would have a price of about $13.50 million attached, whilst 1980 delivered capacity would cost in the region of $20.08 million and 1983 orders for 1985 delivery $30.00 million per unit. Annual capital costs of $2.295 million $3.414 million and $5.1 million would be associated with such newbuilding costs.

### 3.10.3 Operating Costs

As was the case with the LNG and LPG carrier operating costs, methanol carrier costs are anticipated to increase at 10% per annum over the period 1980 to 1985 following an annual rise of 13.8% over the period 1975 to 1980. Given an operating cost level of $2,161,000 in 1980, this would suggest total operating costs per 55,000 DWT unit of $1,288,504 in 1975 and $3,480,312 in 1985.

### 3.10.4 Voyage Costs

Bunker price levels have altered considerably between 1975 and 1980 as shown in TABLE 45 below. Under the assumptions given to the Consultants by the Clients, fuel oil prices could rise to $251 a tonne or $502 a tonne in 1985 and marine diesel prices to $494 or $988 a tonne by that date. Port charges are assumed to have risen at 8.5% per annum throughout the period. Thus,

TABLE 45

APPROXIMATE BUNKER PRICE LEVELS AT MID-YEAR
(US Dollars)

| | | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| US Gulf | Fo | 55.00 | 56.00 | 65.00 | 69.00 | 121.50 | 131.00 |
| | Do | 72.00 | 94.00 | 105.00 | 106.00 | 365.00 | 241.00 |
| North Europe | Fo | 65.00 | 67.00 | 76.00 | 77.75 | 159.00 | 164.00 |
| | Do | 87.00 | 103.00 | 116.00 | 118.00 | 340.00 | 303.00 |

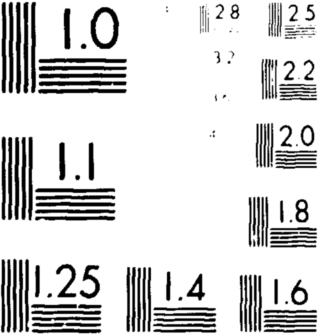
port costs will have risen from $38,406 per round trip in 1975 to $57,750 in 1980 and $86,836 in 1985.

These bunker costs and port charges have been used to calculate annual voyage costs in conjunction with the following assumptions:-

(i) a round voyage distance of 9,708 nautical miles;
(ii) consumption of 40 tonnes of HVF and 1.5 tonnes of marine diesel per day at sea at a speed of 14.5 knots;
(iii) consumption of HVF in port of 10 tonnes per day;
(iv) two days per port visit;
(v) an operating year of 345 days

3.10.5 Changes in Overall Cost Levels

Using the above data, cost comparisons can be made for the period between 1975 and 1985. These comparisons are shown in TABLE 46.




MICROCOPY RESOLUTION TEST CHART

## TABLE 46

### COMPARISON OF TRANSPORT COST OF METHANOL MOVEMENTS 1975 TO 1980 AND 1980 TO 1985 US GULF TO EUROPE

(US Dollars)

| | ANNUAL CAPITAL COSTS | ANNUAL OPERATING COSTS | ANNUAL BUNKER COSTS | ANNUAL PORT CHARGES | TOTAL ANNUAL COSTS | COSTS PER ROUND TRIP | COSTS PER TONNE DELIVERED | CHANGE IN COSTS OVER PERIOD |
|---|---|---|---|---|---|---|---|---|
| 1975 | 2,295,000 | 1,288,504 | 791,453 | 415,553 | 4,790,510 | 442,746 | 8.56 | |
| 1980 | 3,414,000 | 2,161,000 | 1,985,217 | 624,815 | 8,185,072 | 756,476 | 14.63 | 70.9% |
| 1985 (a) | 5,100,000 | 3,480,312 | 3,394,480 | 939,566 | 12,914,358 | 1,193,564 | 23.09 | 57.8% |
| (b) | 5,100,000 | 3,480,312 | 6,788,900 | 939,566 | 16,308,778 | 1,507,281 | 29.15 | 99.2% |

(a) Crude Oil costing $40 per barrel.

(b) Crude Oil Costing $80 per barrel.

Source : H.P.Drewry Shipping Consultants Ltd.

## 3.11 OTHER ALLIED PRODUCTS

### Ethylene Glycol

(a) Properties

1. Formula $HO.CH_2.CH_2OH$
2. Colourless, slightly viscous and virtually odourless
3. Boiling point 197.6°C.
4. Specific gravity 1.116 @ 20°/20°C.
5. Coefficient of cubic expansion, 0.00062 per °C.
6. Vapour density 2.14
7. Explosion hazard, very slight.

(b) Conditions of Carriage

1. Normal carriage temperature - ambient
2. Normal carriage pressure - atmospheric

(c) Materials of Construction

1. Unless they contain corrosion inhibitors, aqueous solutions of ethylene glycol will corrode most metals.
2. Mild steel, stainless steel and aluminium are suitable.

Source : Tanker Safety Guide (chemicals) - International Chamber of Shipping.

Ethylene glycol is formed in a variety of ways and has been the subject of recent innovative techniques. It is an ingredient in a variety of products including antifreeze, cosmetics, printing ink, paints and lacquers. The textile processing, leather dyeing and tobacco industries also utilise this chemical.

As is the case with methanol, ethylene glycol is not classed as a hazardous cargo in the 1977 IMCO publication "Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk" and as such can, in theory, be carried in Crude/products tankers. Thus, transportation costs should be comparable to those of the methanol carriers shown above. Specific gravity differences would suggest that ethylene glycol would cost significantly less to transport than methanol (on a cost per metric tonne delivered basis). A crude comparison of specific gravities would seem to suggest that ethylene glycol could be carried at a cost of about 70% of methanol delivered costs. However, the specific gravity of ethylene glycol would require the fitting of more expensive tanks, and thus increase initial construction costs, than would be required for methanol carriers, thus reducing the transportation cost differential considerably.

## 3.12 SPECIFIC HAZARDS/SPECIALISED SHIPPING REQUIREMENTS OF METHANOL/ ETHYLENE GLYCOL TRADING

### 3.12.1 Methanol

The main hazard faced by methanol traders is that of fire. This can be combated by the use of alcohol foam, dry powder or carbon dioxide. Exposure of personnel to methanol in a liquid form can result in irritating disorders, for example the burning and watering of the eyes and the drying and defatting of skin, but vapour inhalation can result in death if the exposure is severe. Mild exposure to methanol vapour can lead to blurred vision, nausea and intoxication and permanent blindness may result sometime after the patient has apparently recovered.

Despite the fire and health risk, methanol carriage in crude type carriers is allowed under the IMCO regulations.

### 3.12.2 Ethylene Glycol

Compared to methanol, the risk of explosion or fire is less, but combatitive methods i.e. alcohol foam, water spray, dry powder or carbon dioxide are similar to those associated with methanol. The effect of ethylene glycol under normal circumstances on personnel is negligible although ingestion may have fatal results. Similarly, insufficient vapour is given off at ambient temperatures to affect personnel in the vicinity; when sufficient vapour is present headache, nausea and dizziness may result.

As the IMCO regulations do not specify the use of chemical carriers for the seaborne transportation of ethylene glycol, and the commodity can be carried in mild steel tanks, crude carriers can be utilised in the carriage of this commodity assuming parcel sizes are large enough and the tanks/pumps are designed to handle a liquid with a specific gravity of 1.116. (The specific gravity of crude will vary between 0.80 and 0.97 depending on grade and source).

## 3.13 POSSIBLE REVISIONS IN SHIPPING POLICY

IMCO has, in the past, added commodities to its hazardous cargoes listing. As a result, traders in these commodities wishing to comply with the IMCO regulations have been obliged to alter their trading specifications and use more sophisticated chemical carriers. (Three categories of chemical carrier - types I, II and III - are outlined in the 1977 IMCO publication "Code for the Construction and

Equipment of Ship carrying Dangerous Chemicals in Bulk". Type I vessels are designed to carry type I cargoes as outlined in the IMCO Dangerous Chemicals Code: such vessels are the most sophisticated type of chemical carrier, transporting commodities considered to be in the most hazardous class by IMCO. Type III cargoes, the least hazardous type quoted in the IMCO Dangerous Chemicals Code, form the bulk of seaborne chemical movements, and can be transported in the least sophiscated chemical carriers as defined by IMCO). Future revisions may occur which could bring methanol and ethylene glycol within the auspices of the IMCO Dangerous Chemicals Code as type III cargoes. The Consultants believe that such a possibility is at present remote, however, particularly in the light of recent orders for methanol carriers, placed in Japan, at prices that suggest a closer affinity to the crude carrier than to the chemical carrier. If the volume of such constructions increased, the lobby against the re-evaluation of the hazards involved in methanol carriage would be sufficient to ensure that the status quo was maintained.

## 3.14 TERMINAL AND STORAGE FACILITIES FOR METHANOL AND ETHYLENE GYLCOL

Information relating to facilities designed specifically to handle methanol and ethylene glycol is very limited. Thus, the Consultants will review terminal/storage facilities/requirements for chemicals and make comments upon likely alterations required to facilitate the throughput of the liquids in question.

Upon docking at the berth/jetty, cargo and vapour lines are attached and the loading/discharge procedure commences. Tankers are loaded either by pumps located on shore, taking suction by tankage, or by gravity flow where the tank farm is at a materially higher level than that of the jetty. Discharge rates achieved by a vessel should be much the same as loading rates for that vessel, but the actual rates achieved will depend largely on the characteristics of the discharge terminal. Discharge rates can be reduced, for example, if the tankage is a long distance from the berth or if the tankage is at a high elevation, causing considerable back pressure. As increasing the size of discharge lines can only improve discharge rates to a limited extent, booster pumps may be fitted to assist tanker discharge although the high horsepowers required for intermitent use often make the provision of such a facility uneconomic.

Thus, loading and discharge rates, and indeed the size of cargo and vapour lines, will vary greatly between facilities. At the Asahi Kasei KK Mizushima Works C-8 Pier in Japan, a terminal handling tankers of up to 10,000 DWT, discharge rates of between 100 and 200 tons hourly can be achieved via a single 6-inch chemical cargo line and using a single 4-inch vapour line. Shell Oil's main jetty at Yokohama handles chemicals at 150 tons/hour via a single 8-inch connection. Chemical transfer rates at the El Segundo Terminal, California can reach 2,100 barrels/hour although this rate will vary with product type. The Texaco terminal at Port Arthur, USA normally discharges vessels via two 4-inch hoses at an hourly rate of about 1,200 barrels. This facility can handle tankers of up to 30,000 DWT. Chemical products are handled at Antwerp via 6-inch or 4 inch hoses, loading rates varying between 100 and 200 tons/hour/shoreline and discharge rates between 100 and 300 tons/hour/shoreline.

Total storage capacity at any terminal will vary with a number of factors. These are, principally, the size and frequency of vessel arrival, the specific gravity of the products emanating from, or arriving at, the terminal and the number of grades of chemical to be handled at one time. Governmental requirements as to minimum strategic storage often have a substantial effect. Taking these factors into account, a storage capacity of perhaps between five and ten days of terminal throughput is to be anticipated.

The methanol/ethylene glycol will flow from the tanker via the cargo lines into a pipeline and from thence along the jetty to the storage farm. Both pipework and tankage are likely to be constructed of mild or stainless steel and storage will be at ambient termperature and atmospheric pressure.

## 3.15 THE AVAILABILITY OF METHANOL CARRIERS IN 1985.

Few specialist methanol carriers have, to date, been constructed, yet the technology required would not seem dissimilar to that involved in oil carrier construction. (The reporting in October 1980 of Mitsui OSK Lines awarding a provisional contract to Imaban Shipbuilding Co. for the construction of a 35,000 DWT methanol carrier to be constructed under the 37th shipbuilding programme and of NYK Line contracting a vessel of similar size with the Kasado yard for December 1982 delivery suggest that the move towards methanol carrier construction per se is gathering pace). Indeed, the likely similarities between a crude/unsophisticated products carrier and a methanol carrier are such that with a little modification, such as pump refits, oil carriers could fulfil the requirements of methanol trading. Thus, by reviewing the market for small oil carriers of the size 10-59,999 DWT over the period 1980-1985 the availability of tonnage for methanol trading can be assessed.

In June 1980, the Consultants published a survey, number 21 in an occasional series, titled "Tankers for the 1980's - Demand, Supply and Investment Potential". The aim of the report was to review the tanker market historically and to assess the requirement for new tanker tonnage in the light of contemporary market conditions and factors likely to affect those conditions in the future i.e. Suez Canal development, the implementation of IMCO regulations, likely regulatory action of individual governments, the scrapping and loss of tankers and the delivery of additional tonnage. To aid analysis, the tanker fleet was divided into four broad size categories, 10-59,999 DWT

60-99,999 DWT, 100-174,939 DWT and 175,000 DWT or more. For the purposes of this Consultancy the market for tankers of the smallest size range, that of 10-59,999 DWT, will be reveiwed.

At mid-1979, the base used for the survey, the world tanker fleet in the size range 10-59,999 DWT stood at 44.67 million DWT whilst the orderbook was fractionally over 4 million DWT. At that time, this market, the survey revealed, showed a tonnage deficit of 1.4 million DWT and the gap between supply and demand would grow considerably in the 1980's even if no growth in tanker demand on the small ship trades was apparent, simply due to the scrapping of obsolete tonnage. Replacement demand over the decade was likely to be considerable in the light of owners concentrating on the ordering of carriers of other sizes during the 1970's.

Over the period mid-1979 to end-1980, the supply position changed somewhat due to:

(a) the scrapping of 104 vessels of 2.86 million DWT within the 10-59,999 DWT size category; about 7.5% p.a. of fleet over 15 years old.
(b) the delivery of 104 vessels of 3.44 million DWT.

Thus at end 1980 the world tanker fleet of between 10 and 59,999 DWT totalled 45.23 million DWT. In addition, the orderbook had grown considerably to stand at 7.38 million DWT with delivery dates as follows:

(i) 2.15 million DWT in the first half of 1981;

(ii) 1.89 million DWT in the second half of 1981;

(iii) 1.03 million DWT in the first half of 1982;

(iv) 1.66 million DWT in the second half of 1982;

(v) 0.52 million DWT on the first half of 1983.

(vi) 0.13 million DWT in the second half of 1983.

At the time of publication, the Consultants used two scrapping assumptions to enable the development of high and low supply forecasts for the years to 1990. The survey assumed:

(i) a high level of scrapping - 8% of the 10-59,999 DWT fleet of between 10 and 14 years were scrapped on an annual basis, whilst 25% of the fleet of 15 years or more were scrapped annually. This assumption, when applied to the mid-1979 fleet in conjunction with the known orderbook at that date resulted in a 1985 small tanker fleet of about 24.6 million DWT.

(ii) a low scrapping assumption - 10% of tanker of 15 years of age or greater were assumed to be scrapped during each forecast year. The mid-1979 fleet was adjusted accordingly, and new deliveries added, the result being a small tanker fleet in 1985 of 36.1 million DWT.

The experience of the last 18 months, however, would suggest that a scrapping rate of 7.5% per annum would be appropriate for small tankers of 15 years of age or over. The market for such tonnage over this period has been buoyant resulting in high revenue levels for owners. Thus, it has been profitable to maintain oil tonnage, offsetting high repair costs with high income. Small tankers have only been scrapped as a last resort or in the event of replacement tonnage delivery. If it is assumed that this level of scrapping is maintained, the existing fleet at end-1985 will equate to 44.65 million DWT.

Such a level, although considerably above that forecast under the most optimistic supply forecast in the survey, would still be below the projected demand levels for carriers of this size as shown in the survey. Even if demand levels for such tonnage remained static at the end-1978 level, demand would still exceed supply by 2.35 million DWT. Thus it seems inevitable that the Clients will be faced with the ordering of considerable additional capacity to facilitate the methanol trades in question.

# SECTION 4

# DRY CARGO PRODUCTS

## 4.1 DESCRIPTION AND PHYSICAL PROPERTIES

### 4.1.1 Urea

Urea (CO $(NH_2)_2$) is a nitrogenous fertilizer intermediary for which ammonia is the principal raw material. The physical and chemical properties of urea are:-

- White crystals or powder, almost odourless, saline taste.

- Stowage factor about 1.4 cubic metres per metric ton.

- Hygroscopic. Will cake over if left exposed to damp atmosphere.

- Low toxicity, non-combustible.

Urea is extensively trade[illegible]dwide, either in bulk or bagged form. It is not particul[illegible]azardous to transport, and there are no special requirement[illegible]garding types of vessel employed, except the normal requirement that the holds must be properly cleaned and free from all contaminating agents before being loaded with urea.

### 4.1.2 PVC (Polyvinyl Chloride) Powder

PVC ($-H_2CCHCl-$) is a synthetic thermoplastic polymer used in the manufacture of a wide variety of plastic products. In its raw form PVC is produced as a fine powder or granules, with the product being further processed for the manufacture of the final product. There are three main types of PVC, depending on the manufacturing process used:-

1. Paste process. Usually used for manufacture of PVC coatings. A sticky powder that compounds easily and is difficult to handle.

2. Suspension, or Dispersion process. The most common type of PVC produced, with a stowage factor varying around 1.9 cubic metres per metric ton.

3. Mass process. A high density powder with the same properties as PVC from the Suspension/Dispension process.

The physical and chemical properties of PVC powder are:-

- White powder or colourless granules.
- Resistant to most acids, fats, petroleum hydrocarbons and fungus.
- Good insulating properties
- Self-extinguishing, but decomposes at 300°F evolving toxic fumes of hydrogen chloride.
- Highly sensitive to dirt contamination.

PVC powder is produced worldwide and a good portion is traded internationally. However, due to the nature of demand for/and supply of the product, shipment sizes are generally small, consignments usually being made on part cargoes of up to 1,200-1,500 tons. Due to its sensitivity PVC is not transported in bulk, as even small amounts of contamination could render the product useless for further processing. PVC powder is usually shipped in bagged form, or in ISO containers with polythene liners.

## 4.2 CURRENT SHIPPING PRACTICE

### 4.2.1 Urea

There is a fairly well developed shipping market for the ocean transportation of urea and other fertilizer products. India, China and Indonesia presently are the largest importers of urea, with shipments originating mainly from East and West Europe and North America. Shipments are usually made in full cargo lots, although there are variations in vessel size and type.

Urea is normally shipped in bagged form in lots of between 10,000 and 14.000 metric tons, although some bulk shipments up to about 20,000 metric tons are also frequently reported. In its bagged form, urea is generally carried in conventional'tweendecker general cargo vessels of between 12,000 DWT and 18,000 DWT.

Multi-purpose cargo ships in this size range are very common, and traditionally have been employed in both tramp and liner services. Their popularity rests in their adaptability, as 'tweendeckers are designed to accomodate a variety of different cargoes, both bulk and break-bulk, either as full or part cargoes. There are few differences in basic configuration of the general cargo vessel, although there are significant variations in propulsive unit, speed, consumption and cargo handling gear among the different standard design vessels available.

Most recent designs concentrate on the ±15,000 DWT range, and there are a wide variety of standard design vessels available from European and Far Eastern shipyards. One of the more economical general cargo vessels in this range is the "Freedom" type, built by Ishikawajima-Harima Heavy Industries Ltd (IHI) of Japan. With well over 170 ships sold, the "Freedom" is easily the most successful Japanese-built general cargo ship, its large cargo capacity and low fuel consumption being particularly favoured by shipowners.

More recently, IHI has successfully marketed the "Freedom Mk2", which has a carrying capacity of 15,600 DWT, and a grain cubic capacity (i.e. hold space) of 22,500 cubic metres. The Mk2 is powered by a 6,850 BHP IHI-Pielstick medium-speed main engine, which consumes 18-19 tons heavy fuel plus 1.5 tons diesel per day at 13.5-14.0 knots. The design offers large unobstructed 'tweendeck space, fitted with flush hatches reinforced for fork-lift trucks, four holds, and twin derricks of up to 10 tons capacity.

For the packag f bagged urea, various bag sizes are available up to one ton capacity terriwoven bags, although larger bags are seldom used as they are more difficult to handle. It is normal practice for 50kg woven polypropylene bags to be used for the packing of urea. In its bulk form, urea has a stowage factor of about 1.4 cubic metres per metric ton. Bagging of the cargo will increase the stowage factor due to:-

- broken stowage (i.e. loss of usable space between bags), inherent in bagged cargo;

- additional broken stowage resulting from stowing bag-on-bag to give better ventilation of the cargo;

- the use of dunnage in the stowing of bagged cargo; and

- loss of bale capacity due to inaccessibility of certain hold spaces.

Considering these factors it is likely that the average stowage factor of bagged urea would be about 1.52 cubic metres per metric ton. Furthermore, it is estimated that a general cargo vessel with a grain capacity of 22,500 cubic metres would have a bale capacity of about 20,880 cubic metres. This means that a 15,600 DWT "Freedom Mk2" would carry an average of about 13,700 metric tons of bagged urea.

With regard to the transportation of bulk urea, shipments are normally made in lots of 16,000 metric tons to 20,000 metric tons. Vessels employed for these cargoes would be handy-sized bulk carriers up to about 26,000 DWT. Vessels of this size and type have a fairly strong position in the world shipping market, and are employed principally in the bulk grain trades.

In the past few decades the trend towards the carriage of major raw materials by bulk has led to the rapid growth in the dry bulk fleet. Due to the economies of scale in bulk shipping, the handy-sized bulk carrier has effectively superseded the multi-purpose cargo liner in the main commodity trades. The general configuration of a 20,000 DWT to 25,000 DWT bulk carrier would include the following features:-

- large hatches to facilitate easy discharge by grabs;

- high cubic capacity for the carriage of relatively low density cargoes such as grain, sugar or urea; and

- self-trimming holds to facilitate bulk loading.

In order to accomodate a 20,000 ton cargo of urea, a bulk carrier of about 23,000 DWT to 25,000 DWT with a grain cubic capacity of 28,320 cubic metres would be required. A Japanese-built bulk carrier of such dimensions would consume about 29 tons fuel oil plus 2 tons diesel per day steaming at 14.5 knots.

### 4.2.2 PVC Powder

It has been mentioned that PVC powder is extremely sensitive to contamination from moisture and dirt, such contamination being likely to render the product useless for the purpose of manufacturing the final products of this chemical intermediary. For this reason, PVC powder has traditionally been transported in polythene-lined sacks, either break-bulk or containerised. Loading and discharging PVC powder in bulk form could be a troublesome process, and would require sophisticated, specialised and therefore expensive handling equipment to be worthwhile. For this reason the shipping of this commodity in bulk form is not generally undertaken, and therefore cost calculations have been omitted from this study.

With regard to the transportation of bagged PVC powder, it would be feasible to ship this commodity via full cargoes, rather than as part cargoes as is generally done at present. The stowage factor of bulk PVC powder averages at about 1.98 cubic metres per metric ton. When bagged, it is estimated that the stowage factor wouldincrease to about 2.2 cubic metres per metric ton. For the purposes of this study it may be assumed that bagged PVC powder can be carried in the same type of vessel used in the transportation of bagged urea, i.e. the "Freedom Mk2". With bale capacity of 20,380 cubic metres, this vessel would have a carrying capacity of about 9,500 metric tons of bagged PVC powder.

### 4.3 LIKELY FUTURE CHANGES IN SHIPPING PRACTICES

In the shipment of bulk commodities, there is a trend towards increasing shipment sizes in order to obtain greater economies of scale. However, in order for increases in shipment size to be properly cost-effective, they must be matched by improvements in handling, storage and reception facilities for the particular commodity. It is likely that over the next few years this trend will influence the average size of urea cargoes, although it is not possible at this stage to estimate the extent to which bulk urea cargoes will increase in size.

In the transportation of bagged cargoes, recent trends have been towards unitisation. This involves either pre-slinging, palletisation, or containerisation. With regard to bagged urea, it is not generally the practice to unitise the cargo in any form, although pre-slinging is carried out in some cases. It is likely that in the future there will be a trend towards palletisation of bagged urea, although higher costs and tradition militate against this form at present.

Another recent trend worth mentioning is the development of bag loading and unloading machines which can result in higher load and discharge rates than traditional methods. These systems, pioneered by Interplan and Fördertechnik Hamburg of West Germany, utilise roller-conveyors and boom-mounted spiral loading and unloading chutes. The design of each installation has to be tailor-made according to the corresponding parameters of ship size/type, jetty, length and width, etc. Although involving high capital costs, the installation of such machinery can produce loading rates of about 1,500 tons per day and unloading rates of about 1,200 tons per day, resulting in considerable savings in ships' time as well as labour costs.

In the transportation of PVC powder, there already exists a certain amount of unitisation. The commodity is often shipped in ISO containers of 20-foot or 40-foot capacity, with the powder packed inside either polythene container liners or large bags. However, international trading in PVC exists only on a fairly small scale, and average shipment sizes are generally small. It is feasible that this commodity could be moved in full container lots, utilising one of the various "Unibulk" systems already in use. Most of these systems are based on the use of a "linerbag" within either standard or semi-specialised containers. There would need to be a detailed investigation to establish the technical and economic feasibility of using such a system for the transportation of PVC powder.

## 4.4 COST CALCULATIONS

### 4.4.1 Capital Costs

#### 4.4.1.1 Newbuilding Prices

Up until early 1978 the newbuilding market for handy-sized bulk carriers was relatively healthy, with a significant level of ordering from mainly Japanese shipyards. By mid-1978 prices had slumped to figures which were considered to be some 20% below construction costs. During 1979 the rate of ordering picked up slightly, with newbuilding prices rising to equal or slightly exceed construction costs. It is estimated that a 25,000 DWT bulk carrier ordered from a Japanese yard in mid to late 1979 for delivery in mid-1980 would cost about $12.5 million ($500 per DWT).

Newbuilding prices for general cargo vessels vary according to design, movements in construction costs, exchange rates, and contracting activity. Estimates for newbuilding prices for mid-1980 delivery are based on reported orderings of "Freedom" or similar type vessels at Japanese shipyards. Between 1975 and 1977 there was a lull in ordering this size and type of vessel. However, activity increased during 1978, and by mid to late 1979, average newbuilding prices stood at about $11.0 million.

4.4.1.2 Annual Capital Costs

Annual capital costs, comprising loan interest, loan repayment, return on equity, and depreciation are directly related to the capital cost (i.e. the newbuilding price) of the vessel. The methodology for deriving annual capital costs, based on OECD financing terms, is explained in Section 1.5, and the linear relationship between newbuilding prices and annual costs is shown graphically in FIGURE 1, with an example worked out in TABLE 1. A handy-sized bulk carrier with an acquisition cost of $12.5 million would have annual capital costs of $2.125 million per annum, while an $11.0 million general cargo vessel would attract annual capital costs of $2.0 million.

4.4.2 Vessel Operating Costs

Effectively, operating costs can be categorised into five main components namely manning costs, the costs associated with stores and supplies, repairs and maintenance costs, insurance costs and administrative costs.

Manning Costs or crew expenses are a combination of direct payments (i.e. wages) and indirect payments (such as social insurance and persions, leave pay, overtime, travelling, etc.). Wage levels are, in the main, agreed between vessel operators and seamen's unions, or are controlled by the authorities in the country in which the vessel is registered. In the main, differences in manning costs are attributable to:

(a) the size and composition of the crew

(b) the nationality of the officers and seamen employed.

For efficient manning, dry bulk carriers generally require 8-10 officers, and a crew of at least 15, although the number employed is often much larger than this, ranging up to 50 in some cases. In general, multi-purpose cargoships/modern multideckers of 15-16,000 DWT carry a complement of around 30.

Whatever the size of their complements, the manning costs of these vessels have risen sharply in recent years due to generous wage settlements, ITF intervention, and other factors, and have more or less doubled since 1973. The cost of victualling (or provisioning) a vessel is also a factor in determining manning costs and this is also a function of the size of the vessel and, to an even greater extent, the nationality of the crew. Manning costs are invariably the main item in bulk carrier operating expenses and can represent 50% or even more of a vessel's total operating costs.

Stores and Supplies for deck and engine room departments - of which lubricating oils are the main item - have become more significant in recent years, mainly due to inflation and the increased cost of oil. Other influences in the costs of stores and supplies are mainly related to the use or non-use of stock control techniques and systems. Such items generally represent 10-15% of total operating costs.

Whereas crew (manning) costs, as a proportion of total annual operating costs, decrease in importance with increasing vessel size, the opposite is often true for repairs and maintenance. Expenditure on repairs and maintenance can vary considerably, the actual outlay depending upon the owner's operating policy and experience. Even routine maintenance - which includes Annual and Special Surveys (or 'Classification') is extremely costly, but with unexpected repairs due to damage or collision, R & M costs can rise to over 40% of annual operating expenses. Depending on the age (and presumably, general condition) of the ship, repairs and maintenance costs will generally represent between 15-20% of the total.

Insurance costs consist of premia for a basic form of insurance cover (including cover for total loss) - i.e. hull and machinery insurance - and some form of third party cover - or protection and indemnity insurance - for collisions, pollution etc. Insurance premia are usually governed by the owner's previous record, the prevailing level of repair charges and the level of competition in the insurance market. Other factors to be taken into account include hull value (although this is less significant in the setting of insurance rates than might be imagined) and the age, general condition and perhaps the flag of the individual vessel. Of the total insurance costs of a bulk vessel, the premium on hull and machinery typically represents over 80%, with the remaining expense being attributable to what are called 'Club Calls' (i.e. payments to Protection and Indemnity Societies or 'P & I Clubs').

A proportion of a vessel's annual operating costs is represented by management overheads or administration costs. However, this is a very variable item due to different shipowner's methods of accounting, the size and composition of the owner's fleet and the domicile of the owner or the management company. Essentially, administrative costs are a function of the size and managerial efficiency of the ship operating company.

Using information supplied to HPD's annual confidential operating cost survey as a base, 1980 operating costs for handy-sized bulk carriers of ±25,000 DWT and multipurpose general cargo vessels of ±15,000 DWT were estimated, and are presented in TABLE 47. It is assumed the vessels will be registered under "Flags of

Convenience". Bulk carriers have average total operating costs of $1,590,000 per annum, or about $4,609 per day, assuming 345 working days per year. General cargo vessels have lower average operating costs, at $1,205,000 per annum, equivalent to a daily cost of $3,493.

TABLE 47

ESTIMATED REPRESENTATIVE OPERATING COSTS FOR SELECTED CONVENIENCE FLAG VESSELS UNDER 1980 TRADING CONDITIONS (US$ 000's)

| | Multi-Purpose Cargo Ship ±15,000 DWT | Handy-Sized Bulk Carriers ±25,000 DWT |
|---|---|---|
| Manning[1] | 620 | 827 |
| Stores & Lubes[2] | 127 | 159 |
| Repairs & Maintenance[3] | 139 | 239 |
| Insurance[4] | 211 | 230 |
| Administration & Other | 108 | 135 |
| TOTAL | 1,205 | 1,590 |

(1) Includes Wages, Social Insurance/Pension, Victualling and Travelling.
(2) Includes Lubes, Spare Parts and Tools/Equipment
(3) Includes Drydocking, Repairs and Classification Expenses.
(4) Includes Hull & Machinery and Protection ar Indemnity Expenses

### 4.4.3 Voyage Costs

#### 4.4.3.1 Bunkers

The purchase of fuel (bunkers) has in recent years become by far the largest element of overall voyage expenses. Fuel prices have risen dramatically since 1973, when bunker costs accounted for a relatively small proportion of the total costs of owning and operating a vessel. Moreover, bunker prices have become more variable, with significant price differentials due to location, type of purchase (i.e. spot or contract), and fuel quality. Fuel prices at mid-1980 used in the cost calculations are presented in TABLE 4, Section 1.5.

For the purposes of this study, it is assumed that half of the vessel's fuel requirements per voyage will be purchased at the loading port, and half at discharge port. Marine distances from and to the various load and discharge ports are contained in TABLE 3, Section 1.5. An average 25,000 DWT bulk carrier will consume 29 tons fuel oil and 2 tons diesel oil per day steaming at 14.5 knots, and 6 tons fuel oil and 2 tons diesel oil per day in port. A Freedom Mk2 consumes 19 tons fuel oil and 1.5 tons diesel oil per day steaming at 13.5 knots, and 4 tons fuel oil and 1.5 tons diesel oil per day in port. Determination of average port stays, which depend on cargo load and discharge rates, is contained in the following Section. Fuel costs per voyage for Bulk Urea, Bagged Urea, and Bagged PVC Powder are summarized in TABLES 48, 49, and 50 respectively.

#### 4.4.3.2 Port Charges

Total port expenses include harbour dues, terminal expenses, pilotage, tug hire, light dues, agency fees, etc. Estimates are based on actual disbursement accounts published by INTERTANKO and BIMCO, as well as data contained in the "Ports of the World" 1980 handbook. Where data on the port in question were not available, costs of neighbouring ports were used for estimating purposes.

Some elements of overall port expenses are lump-sum costs which do not vary with length of stay in port, such as tug hire, pilotage, light dues, etc. Other costs, however, are related to the number of days the vessel occupies the berth, such as harbour dues and agency fees. In order to determine average port stays, the following load and discharge rates are assumed, based on reported world market spot fixtures and available cargo handling gear in the ports in question.

| | Load Ports | Discharge Rate |
|---|---|---|
| Bulk Urea | 3,000 tons/day | 8,000 tons/day |
| Bagged Urea/PVC (Pre-slung) | 1,000 tons/day | 750 tons/day |

Estimated port charges per visit are summarized in TABLE 51.

#### 4.4.3.3 Canal Tolls

Transit charges for the Suez Canal are outlined in Section 1.5.3. For a 25,000 DWT bulk carrier with a Suez Canal Net Tonnage of 12,610, canal tolls per round voyage would be $47,530, and for a 15,600 DWT general cargo vessel with a Suez Canal Net Tonnage of 7,800, canal tolls would be $29,400 per round voyage.

Panama Canal transit charges during 1980 were $1.21 per Panama Canal Net Tonne for all laden vessels, and $1.03 per Panama

Canal Net Tonne for vessels in ballast. It is assumed that towage and other sundry expenses will amount to $2,000 each transit. A 25,000 DWT bulk carrier would on average have a Panama Canal Net Tonnage of 11,690, giving a total cost of $31,120 per round voyage, and a 15,600 DWT general cargo vessel would have a Panama Canal Net Tonnage of 7,400, giving a total cost of $20,570 per voyage.

TABLE 48

FUEL COSTS PER VOYAGE ON BULK UREA CARGOES AS AT MID-1980
(US Dollars)

| LOAD PORTS / DISCHARGE PORTS | SKIKDA, ALGERIA | DOHA, QATAR | ACEH, INDONESIA | VERACRUZ, MEXICO |
|---|---|---|---|---|
| GENOA | 35,910 | 175,020 | 222,850 | 205,190 |
| ROTTERDAM | 83,300 | 227,530 | 274,080 | 178,500 |
| NEW ORLEANS | 171,820 | 286,200 | 341,750 | 42,450 |
| YOKOHAMA | 343,150 | 240,150 | 140,110 | 322,920 |

TABLE 49

FUEL COSTS PER VOYAGE ON BAGGED UREA CARGOES AS AT MID-1980
(US Dollars)

| LOAD PORTS / DISCHARGE PORTS | SKIKDA, ALGERIA | DOHA, QATAR | ACEH, INDONESIA | VERACRUZ, MEXICO |
|---|---|---|---|---|
| GENOA | 53,230 | 151,790 | 186,610 | 190,360 |
| ROTTERDAM | 84,420 | 187,370 | 220,870 | 150,490 |
| NEW ORLEANS | 144,490 | 223,320 | 264,920 | 49,010 |
| YOKOHAMA | 272,600 | 198,820 | 127,420 | 255,900 |

TABLE 50

FUEL COSTS PER VOYAGE ON BAGGED PVC POWDER CARGOES AS AT MID-1980
(US Dollars)

| DISCHARGE PORTS \ LOAD PORTS | SKIKDA, ALGERIA | DOHA, QATAR | ACEH, INDONESIA | VERACRUZ, MEXICO |
|---|---|---|---|---|
| GENOA | 40,670 | 139,450 | 174,200 | 178,580 |
| ROTTERDAM | 72,580 | 175,690 | 209,120 | 139,420 |
| NEW ORLEANS | 133,780 | 212,980 | 254,340 | 39,070 |
| YOKOHAMA | 260,080 | 186,520 | 115,040 | 232,780 |

TABLE 51

AVERAGE PORT CHARGES PER VISIT AS AT MID-1980
(US Dollars)

| PORT | BULK UREA | BAGGED UREA | BAGGED PVC POWDER |
|---|---|---|---|
| SKIKDA | 9,000 | 13,500 | 10,800 |
| DOHA | 9,000 | 13,500 | 10,800 |
| ACEH | 9,000 | 13,500 | 10,800 |
| VERACRUZ | 10,000 | 15,000 | 12,000 |
| GENOA | 11,900 | 22,000 | 19,000 |
| ROTTERDAM | 14,500 | 27,000 | 24,000 |
| NEW ORLEANS | 9,600 | 17,900 | 15,900 |
| YOKOHAMA | 13,000 | 24,300 | 22,000 |

TABLE 52

TOTAL VOYAGE COSTS PER ROUND TRIP AS AT MID-1980
BULK UREA
(US Dollars)

| ROUTE | FUEL COSTS | PORT COSTS | CANAL TOLLS | TOTAL VOYAGE COSTS |
|---|---|---|---|---|
| SKIKDA-GENOA | 35,910 | 20,900 | - | 56,810 |
| SKIKDA-ROTTERDAM | 83,300 | 23,500 | - | 106,800 |
| SKIKDA-NEW ORLEANS | 171,820 | 18,600 | - | 190,420 |
| SKIKDA-YOKOHAMA | 343,150 | 22,000 | 47,530 | 412,680 |
| DOHA-GENOA | 175,020 | 20,900 | 47,530 | 243,450 |
| DOHA-ROTTERDAM | 227,530 | 23,500 | 47,530 | 298,560 |
| DOHA-NEW ORLEANS | 286,200 | 18,600 | 47,530 | 352,330 |
| DOHA-YOKOHAMA | 240,150 | 22,000 | - | 262,150 |
| ACEH-GENOA | 222,850 | 20,900 | 47,530 | 291,280 |
| ACEH-ROTTERDAM | 274,080 | 23,500 | 47,530 | 345,110 |
| ACEH-NEW ORLEANS | 341,750 | 18,600 | 47,530 | 407,880 |
| ACEH-YOKOHAMA | 140,110 | 22,000 | - | 162,110 |
| VERACRUZ-GENOA | 205,190 | 21,900 | - | 227,090 |
| VERACRUZ-ROTTERDAM | 178,500 | 24,500 | - | 203,000 |
| VERACRUZ-NEW ORLEANS | 42,450 | 19,600 | - | 62,050 |
| VERACRUZ-YOKOHAMA | 322,920 | 23,000 | 31,120 | 377,040 |

Source : H.P.Drewry Shipping Consultants Ltd.

TABLE 53

TOTAL VOYAGE COSTS PER ROUND TRIP AS AT MID-1980

BAGGED UREA

(US Dollars)

| ROUTE | FUEL COSTS | PORT COSTS | CANAL TOLLS | TOTAL VOYAGE COSTS |
|---|---|---|---|---|
| SKIKDA-GENOA | 53,230 | 35,500 | - | 88,730 |
| SKIKDA-ROTTERDAM | 84,420 | 40,500 | - | 124,920 |
| SKIKDA-NEW ORLEANS | 144,490 | 31,400 | - | 175,890 |
| SKIKDA-YOKOHAMA | 272,600 | 37,800 | 29,400 | 339,800 |
| DOHA-GENOA | 151,790 | 35,500 | 29,400 | 216,690 |
| DOHA-ROTTERDAM | 187,370 | 40,500 | 29,400 | 257,270 |
| DOHA-NEW ORLEANS | 223,320 | 31,400 | 29,400 | 284,120 |
| DOHA-YOKOHAMA | 198,820 | 37,800 | - | 236,620 |
| ACEH-GENOA | 186,610 | 35,500 | 29,400 | 251,510 |
| ACEH-ROTTERDAM | 220,870 | 40,500 | 29,400 | 290,770 |
| ACEH-NEW ORLEANS | 264,920 | 31,400 | 29,400 | 325,720 |
| ACEH-YOKOHAMA | 127,420 | 37,800 | - | 165,220 |
| VERACRUZ-GENOA | 190,360 | 37,000 | - | 227,360 |
| VERACRUZ-ROTTERDAM | 150,490 | 42,000 | - | 192,490 |
| VERACRUZ-NEW ORLEANS | 49,010 | 32,900 | - | 81,910 |
| VERACRUZ-YOKOHAMA | 255,900 | 39,300 | 20,570 | 315,770 |

Source : H.P.Drewry Shipping Consultants Ltd.

## TABLE 54

### TOTAL VOYAGE COSTS PER ROUND TRIP AS AT MID-1980
### BAGGED PVC POWDER
### (US Dollars)

| ROUTE | FUEL COSTS | PORT COSTS | CANAL TOLLS | TOTAL VOYAGE COSTS |
|---|---|---|---|---|
| SKIKDA-GENOA | 40,670 | 29,800 | - | 70,420 |
| SKIKDA-ROTTERDAM | 72,580 | 34,800 | - | 107,380 |
| SKIKDA-NEW ORLEANS | 133,780 | 26,700 | - | 160,480 |
| SKIKDA-YOKOHAMA | 260,080 | 32,800 | 29,400 | 322,280 |
| DOHA-GENOA | 139,450 | 29,800 | 29,400 | 198,650 |
| DOHA-ROTTERDAM | 175,690 | 34,800 | 29,400 | 239,890 |
| DOHA-NEW ORLEANS | 212,980 | 26,700 | 29,400 | 269,080 |
| DOHA-YOKOHAMA | 186,520 | 32,800 | - | 219,320 |
| ACEH-GENOA | 174,200 | 29,800 | 29,400 | 233,400 |
| ACEH-ROTTERDAM | 209,120 | 34,800 | 29,400 | 273,320 |
| ACEH-NEW ORLEANS | 254,340 | 26,700 | 29,400 | 310,440 |
| ACEH-YOKOHAMA | 115,040 | 32,800 | - | 147,840 |
| VERACRUZ-GENOA | 178,580 | 31,000 | - | 209,580 |
| VERACRUZ-ROTTERDAM | 139,420 | 36,000 | - | 175,420 |
| VERACRUZ-NEW ORLEANS | 39,070 | 27,900 | - | 66,970 |
| VERACRUZ-YOKOHAMA | 232,780 | 34,000 | 20,570 | 287,350 |

Source : H.P.Drewry Shipping Consultants Ltd.

#### 4.4.3.4 Total Voyage Costs per Round Trip

TABLES 52 , 53 and 54 show estimated Total Voyage Costs per round trip for the transportation of Bulk Urea, Bagged Urea, and Bagged PVC Powder under mid-1980 cost levels.

#### 4.4.3.5 Fully Built-Up Shipping Costs

By combining voyage costs, vessel operating costs, and capital costs we can derive fully built-up shipping costs for the transportation of bulk and bagged urea and bagged PVC powder. These costs are summarized in TABLES 55 , 56 and 57 . Operating and capital costs per voyage are computed on the basis of 345 working days per annum.

It is evident that the lowest transportation costs are achieved on bulk urea shipments, which is to be expected considering the economies of scale to be derived from bulk shipments. Freight rates on bagged urea shipments are on average 80-90% higher than rates on bulk shipments, with the highest increases occurring on the shorter routes. The reasons for this relatively large cost increase are:-

- The smaller carrying capacity of vessels carrying bagged cargoes;
- A less than proportionate reduction in daily operating and capital costs on the smaller general cargo vessels; and
- Significantly longer voyage times due to the slower load and discharge rates of bagged cargoes, resulting in high fixed operating and capital costs while the vessel is in port.

Freight rates on bagged PVC powder are on average about 20-25% higher than rates on bagged urea. Due to the higher stowage factor of bagged PVC powder, only 9,500 metric tons can be carried on a 15,600 DWT general cargo vessel, compared to 13,700 metric tons of bagged urea. The lower tonnages,however,result in shorter load and discharge times, hence shorter voyage times, which partly offsets the rate-increasing effects of the reduced cargo capacities.

4.4.3.6 Required Shipping Capacity

Required shipping capacity, i.e. the amount of vessels required to ship the annual export tonnages, are shown in the last column of TABLES 55 , 56 and 57 . Capacities are based on 500,000 tons urea and 150,000 tons PVC powder per annum. Where the number of vessels required is stated as a fraction, e.g. 3.5, the actual number would be the next highest whole number, in this case 4, with the remaining vessel capacity being chartered out on a voyage or timecharter basis. In any case, the annual vessel requirements are based on continuous uninterrupted voyage performances, and the inevitable but unforeseeable stoppages, delays, etc., will increase the annual effective shipping capacity required.

4.4.3.7 Shipping Costs on Low and High Density Polyethylene Granulate

Polyethylene (Low Density - LDPE, and High Density - HDPE) is a thermoplastic white solid normally shipped in the form of free-flowing ⅛-inch granules. The substance is non-soluble in water, combustible and is non-toxic. It is normally shipped in terriwoven bags (either loose or on pallets) or containers with liners. The physical properties of LDPE and HDPE are similar to those of PVC powder, and the same restrictions regarding contamination against shipping in bulk would also apply.

LDPE has a bulk stowage factor of 83 cubic feet per metric ton (2.35 cubic metres per tonne), and HDPE has a bulk stowage factor of 80 cubic feet per metric ton (2.265 cubic metres per tonne). It would be possible to ship this commodity by full shiploads, in which case the shipping practices would be very similar to those in the transportation of bagged PVC powder.

Freight rates for LDPE and HDPE would be higher than rates for bagged PVC powder due to their higher stowage factors. It is estimated that LDPE, with a bulk stowage factor of $2.35m^3$/tonne, would have a bagged stowage factor of about $2.63m^3$/tonne. This, it is estimated, would result in freight rate increases of between 8% and 9% on all routes. The estimated rates for Low Density Polyethylene are contained in TABLE 58 . High Density Polyethylene, with a slightly lower stowage factor, would have marginally lower freight rates.

TABLE 55

FULLY BUILT-UP SHIPPING COSTS AS AT MID-1980
BULK UREA-500,000 TONNES PER ANNUM
(US Dollars)

| ROUTE | VOYAGE TIME (DAYS) | VOYAGE COSTS | OPERATING COSTS PER VOYAGE | CAPITAL COSTS PER VOYAGE | TOTAL COSTS PER VOYAGE | FREIGHT RATE | VOYAGES PER VESSEL PER ANNUM | VESSELS RE[illegible]ED PER ANNUM |
|---|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 14.7 | 56,810 | 67,750 | 90,530 | 215,090 | 10.75 | 23.5 | 1.1 |
| SKIKDA-ROTTERDAM | 22.2 | 106,800 | 102,310 | 136,730 | 345,840 | 17.29 | 15.5 | 1.6 |
| SKIKDA-NEW ORLEANS | 40.7 | 190,420 | 187,570 | 250,670 | 628,660 | 31.43 | 8.5 | 2.9 |
| SKIKDA-YOKOHAMA | 66.3 | 412,680 | 305,560 | 408,340 | 1,126,580 | 56.33 | 5.2 | 4.8 |
| DOHA-GENOA | 38.9 | 243,450 | 179,280 | 239,580 | 662,310 | 33.12 | 8.9 | 2.8 |
| DOHA-ROTTERDAM | 49.6 | 298,560 | 228,590 | 305,490 | 832,640 | 41.63 | 6.9 | 3.6 |
| DOHA-NEW ORLEANS | 68.0 | 352,330 | 313,390 | 418,810 | 1,084,530 | 54.23 | 5.1 | 4.9 |
| DOHA-YOKOHAMA | 48.5 | 262,150 | 223,520 | 298,710 | 784,380 | 39.22 | 7.1 | 3.5 |
| ACEH-GENOA | 46.6 | 291,280 | 214,760 | 287,010 | 793,050 | 39.65 | 7.4 | 3.4 |
| ACEH-ROTTERDAM | 57.3 | 345,110 | 264,080 | 352,910 | 962,100 | 48.11 | 6.0 | 4.2 |
| ACEH-NEW ORLEANS | 75.7 | 407,880 | 348,880 | 466,240 | 1,223,000 | 61.15 | 4.6 | 5.5 |
| ACEH-YOKOHAMA | 31.2 | 162,110 | 143,790 | 192,160 | 498,060 | 24.90 | 11.1 | 2.3 |
| VERACRUZ-GENOA | 43.6 | 227,090 | 200,940 | 268,530 | 696,560 | 34.83 | 7.9 | 3.2 |
| VERACRUZ-ROTTERDAM | 40.5 | 203,000 | 186,650 | 249,440 | 639,090 | 31.95 | 8.5 | 3.0 |
| VERACRUZ-NEW ORLEANS | 15.7 | 62,050 | 72,360 | 96,700 | 231,110 | 11.56 | 22.0 | 1.2 |
| VERACRUZ-YOKOHAMA | 65.5 | 377,040 | 301,870 | 403,410 | 1,082,320 | 54.12 | 5.3 | 4.7 |

Source: H.P. Drewry (Shipping Consultants) Ltd.

TABLE 56

FULLY BUILT-UP SHIPPING COSTS AS AT MID-1980
BAGGED UREA-500,000 TONNES PER ANNUM
(US Dollars)

| ROUTE | VOYAGE TIME (DAYS) | VOYAGE COSTS | OPERATING COSTS PER VOYAGE | CAPITAL COSTS PER VOYAGE | TOTAL COSTS PER VOYAGE | FREIGHT RATE | VOYAGES PER VESSEL PER ANNUM | VESSELS REQUIRED PER ANNUM |
|---|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 36.0 | 88,730 | 125,750 | 208,690 | 423,170 | 30.89 | 9.6 | 3.8 |
| SKIKDA-ROTTERDAM | 45.0 | 124,920 | 157,180 | 260,670 | 542,770 | 39.62 | 7.7 | 4.8 |
| SKIKDA-NEW ORLEANS | 65.0 | 175,890 | 227,040 | 376,810 | 779,740 | 56.92 | 5.3 | 6.8 |
| SKIKDA-YOKOHAMA | 92.2 | 339,800 | 322,050 | 534,480 | 1,196,330 | 87.22 | 3.7 | 9.7 |
| DOHA-GENOA | 62.8 | 216,690 | 219,360 | 364,050 | 800,100 | 58.40 | 5.5 | 6.6 |
| DOHA-ROTTERDAM | 74.4 | 257,270 | 259,880 | 431,300 | 948,450 | 69.23 | 4.6 | 7.9 |
| DOHA-NEW ORLEANS | 94.2 | 284,120 | 329,040 | 546,080 | 1,159,240 | 84.62 | 3.7 | 10.0 |
| DOHA-YOKOHAMA | 73.4 | 236,620 | 256,390 | 425,500 | 918,510 | 67.04 | 4.7 | 7.8 |
| ACEH-GENOA | 71.2 | 251,510 | 248,700 | 412,750 | 912,960 | 66.64 | 4.8 | 7.5 |
| ACEH-ROTTERDAM | 82.6 | 290,770 | 288,520 | 478,830 | 1,258,120 | 77.24 | 4.2 | 8.7 |
| ACEH-NEW ORLEANS | 102.4 | 325,720 | 357,680 | 593,610 | 1,227,010 | 93.21 | 3.4 | 10.8 |
| ACEH-YOKOHAMA | 54.8 | 165,220 | 191,420 | 317,680 | 674,320 | 49.22 | 6.3 | 5.8 |
| VERACRUZ-GENOA | 73.0 | 227,360 | 254,990 | 423,180 | 905,530 | 66.10 | 4.7 | 7.7 |
| VERACRUZ-ROTTERDAM | 64.8 | 192,490 | 226,350 | 375,650 | 794,490 | 57.99 | 5.3 | 6.8 |
| VERACRUZ-NEW ORLEANS | 38.0 | 81,910 | 132,730 | 220,290 | 434,930 | 31.75 | 9.1 | 4.0 |
| VERACRUZ-YOKOHAMA | 91.5 | 315,770 | 319,610 | 530,430 | 1,165,810 | 85.10 | 3.8 | 9.7 |

Source: H.P. Drewry (Shipping Consultants) Ltd.

TABLE 57

FULLY BUILT-UP SHIPPING COSTS AS AT MID-1980
BAGGED PVC POWDER-150,000 TONNES PER ANNUM
(US Dollars)

| ROUTE | VOYAGE TIME (DAYS) | VOYAGE COSTS | OPERATING COSTS PER VOYAGE | CAPITAL COSTS PER VOYAGE | TOTAL COSTS PER VOYAGE | FREIGHT RATE | VOYAGES PER VESSEL PER ANNUM | VESSELS REQUIRED PER ANNUM |
|---|---|---|---|---|---|---|---|---|
| SKIKDA-GENOA | 26.0 | 70,470 | 90,820 | 150,720 | 312,010 | 32.84 | 13.3 | 1.2 |
| SKIKDA-ROTTERDAM | 35.0 | 107,380 | 122,250 | 202,890 | 432,520 | 45.53 | 9.8 | 1.6 |
| SKIKDA-NEW ORLEANS | 55.0 | 160,480 | 192,110 | 318,840 | 671,430 | 70.68 | 6.3 | 2.6 |
| SKIKDA-YOKOHAMA | 82.2 | 322,280 | 287,130 | 476,510 | 1,085,920 | 114.31 | 4.2 | 3.8 |
| DOHA-GENOA | 52.8 | 198,650 | 184,430 | 306,080 | 689,160 | 72.54 | 6.5 | 2.4 |
| DOHA-ROTTERDAM | 64.4 | 239,890 | 224,950 | 373,330 | 383,170 | 88.23 | 5.4 | 2.9 |
| DOHA-NEW ORLEANS | 84.2 | 269,070 | 294,110 | 488,110 | 1,051,290 | 110.66 | 4.1 | 3.8 |
| DOHA-YOKOHAMA | 63.4 | 219,320 | 221,460 | 367,530 | 808,310 | 85.08 | 5.4 | 2.9 |
| ACEH-GENOA | 61.2 | 233,400 | 213,770 | 354,780 | 801,950 | 84.41 | 5.6 | 2.8 |
| ACEH-ROTTERDAM | 72.6 | 273,320 | 253,590 | 420,860 | 947,770 | 99.77 | 4.7 | 3.3 |
| ACEH-NEW ORLEANS | 92.4 | 310,440 | 322,750 | 535,640 | 1,168,830 | 123.04 | 3.7 | 4.2 |
| ACEH-YOKOHAMA | 44.8 | 147,840 | 156,490 | 259,710 | 564,040 | 59.37 | 7.7 | 2.0 |
| VERACRUZ-GENOA | 63.0 | 209,580 | 220,060 | 365,210 | 794,850 | 83.67 | 5.5 | 2.9 |
| VERACRUZ-ROTTERDAM | 54.8 | 175,420 | 191,420 | 317,680 | 684,520 | 72.05 | 6.3 | 2.5 |
| VERACRUZ-NEW ORLEANS | 28.0 | 66,970 | 97,800 | 162,320 | 327,090 | 34.43 | 12.3 | 1.3 |
| VERACRUZ-YOKOHAMA | 81.5 | 287,350 | 284,680 | 472,460 | 1,044,090 | 109.95 | 4.2 | 3.7 |

Source: H.P. Drewry (Shipping Consultants) Ltd.

TABLE 58

ESTIMATED FREIGHT COSTS ON LOW-DENSITY POLYETHYLENE GRANULATE AS AT MID-1980
(US Dollars per Metric Ton)

| DISCHARGE PORTS \ LOAD PORTS | SKIKDA, ALGERIA | DOHA, QATAR | ACEH, INDONESIA | VERACRUZ, MEXICO |
|---|---|---|---|---|
| GENOA | 35.65 | 78.70 | 91.60 | 90.80 |
| ROTTERDAM | 49.50 | 95.75 | 108.25 | 78.15 |
| NEW ORLEANS | 76.70 | 120.05 | 133.50 | 37.35 |
| YOKOHAMA | 124.00 | 92.30 | 64.40 | 119.30 |

## 4.5 POSSIBILITY OF OBTAINING BACKHAUL CARGOES

The above freight costs have been calculated assuming consecutive round voyages with the return journey being made in ballast. In order to minimize shipping costs, return, or backhaul cargoes should be sought whenever possible. A backhaul cargo need not necessarily be from the last discharge port to the next load port, although that would be the optimum situation, but the general aim would be to keep ballast journeys to a minimum. One important consideration is the supply/delivery schedule of the main cargo, in this case urea or PVC powder. If there are rigid delivery schedules due to contractual or operational reasons, then the flexibility for arranging suitable backhaul cargoes will be seriously impaired.

In the shipping market, trading flexibility diminishes as the size and draft of a vessel increases. The vessels identified in this study, a ±25,000 DWT bulk carrier and a "Freedom" type general cargo vessel, can be considered to be very versatile for general trading. The problem then is to find suitable cargoes moving on the backhaul legs of the given trade matrix. The following is an indication of the types of cargoes which may be available as backhaul:

GENOA - vessels would be able to pick up cargoes from other points of Southern Europe and Black Sea ports, involving only a short ballast journey from Genoa. From Southern Europe, a good deal of Iron and Steel products (coils, bars, pipes, etc.) and scrap move to the Arabian Gulf and the Far East. This type of cargo would be suitable for both 'tweendeckers and bulk carriers, although not necessarily as full vessel loads. From Black Sea ports, vessels could load bagged or bulk fertilizers for India and to a lesser extent the Far East. Black Sea ports also export significant quantities of bagged cement to India, China, and the Arabian Gulf.

ROTTERDAM - including North European range. Outbound cargoes include bagged fertilizers from the Antwerp-Hamburg range to India and China; Iron/Steel scrap from North Europe to the Arabian Gulf and the Far East; and Grains from North Europe to North Africa and the Arabian Gulf.

NEW ORLEANS - including US Gulf ports. The main cargo moving out of New Orleans in smaller vessels is bulk grains. There is an active spot market in grains from this and other Gulf ports to Mexico, North Africa, the Arabian Gulf, and the Far East. Significant quantities of bulk and bagged fertilizer products (mainly urea) moving from the Gulf to India.

YOKOHAMA - including other Far Eastern ports. Japan exports considerable amounts of bagged cement and Iron and Steel products to the Arabian Gulf, and these would be suitable backhaul cargoes for shortening ballast distances to Doha, Skikda, and possibly Veracruz. However, Japanese export sales are closely linked to Japanese shipping, and it may be difficult for third flag shipping interests to pick up Japanese cargo on a regular basis. An alternative could be to load bagged cement in North Korea for India, or possibly a ballast voyage to Australia to load grain for Arabian Gulf ports.

This,however, is only a general guide to the possible availability of backhaul cargoes from and to the regions concerned in this Study. The actual availability of cargo at any given time would depend on the tonnage balance in the region at that particular time. Furthermore, the economies of individual backhaul ventures would have to be worked out with regard to the freight rate on the backhaul cargo vis-a-vis the freight rate on the "primary" cargo, and the diversion time involved.

## 4.6 TERMINAL AND STORAGE FACILITIES

### 4.6.1 Bulk Cargoes

For trading and discharging operations, bulk urea is similar to many other bulk commodities, and does not require any specialized equipment. Urea is not as free-flowing as many bulk products, such as grain, therefore mechanical handling systems are generally chosen over pneumatic systems. There are a wide variety of designs and manufacturers of mechanical bulk handling systems which would be suitable for urea. The final choice of system would depend largely upon factors outside the scope of this study, such as whether the equipment would be for the exclusive use of the urea interests or whether they would be shared facilities, the cost-effectiveness of alternative designs, or the delivery and supply characteristics of the producer and user interests.

The variety in choice lies more with bulk unloading than with loading systems. Most bulk loading facilities are fairly straightforward, utilizing rail-or wheel-mounted conveyors. This includes large capacity silos at or near the quayside, with receiving facilities via rail, road or conveyor from the urea plant. It is advisable to have high capacity storage silos so that production need not be hampered in the event that shipments of urea are unduly delayed for whatever reason. For a system based on shipment sizes of 20,000 tons, there should be a storage capacity of at least 40,000 to 50,000 tons. When dealing with urea, it is important that the storage facilities both at load and discharge ports be dry and well ventilated, as urea is very hygroscopic, and will cake over if exposed to damp conditions.

The urea is transferred from the storage silo to the quayside via either fixed or mobile horizontal conveyors, and fed into the ship's holds by travelling conveyor loaders which traverse the entire length of the vessel thereby avoiding the necessity of shifting the vessel during the loading operations. The conveyor arm can be easily positioned in the ship's hold to facilitate trimming operations, with the final trimming being carried out by stevedores with spreaders.

There are four main types of mechanical systems suitable for discharging urea:-

1. Grabs. This is the most straightforward discharging system, utilizing 5- or 10- ton capacity grabs discharging directly into hopper/conveyor facilities leading to quayside storage silos. Although having relatively low capital, operating and maintenance costs, this method has low discharge rates compared to other more sophisticated discharging systems.

2. Marine Leg (Bucket Elevator). This involves a gantry-mounted boom which is inserted into the hold and discharges via a continuous rotating bucket elevator onto a conveyor system. For "non-flow" commodities such as urea, a remote-controlled or manually-guided powered shovel is often used for guiding the product into the intake of the marine leg. The marine leg is swivel-mounted and therefore is free to swing in all directions within the hold.

3. Chain Elevator. Similar in concept to the bucket elevator, this system utilizes rotating "clamshells" instead of [illegible]ts. The final choice between bucket or chain elevators is [illegible] a matter of preference of the engineer in charge of equipment

purchase, although observations show that bucket elevators have a slight advantage over clamshell systems in terms of power consumption, while the clamshell gives a more stable discharge rate.

4. Screw Unloaders. This is a fairly new bulk discharge concept, pioneered by Siwertell, and, more recently, Nordströms, of Sweden. The system utilizes an enclosed screw which is rotated and inserted into the ship's hold, thereby drawing quantities of the bulk material up the length of the screw and onto gantry-mounted conveyors. This discharging system is finding increasing acceptance at bulk discharging terminals, with its ability to break down cargo overhangs and to "hunt" for cargo within the hold being features particularly favoured by terminal operators.

Regardless of which discharging system is utilized, wheel or track mounted front-end loaders are necessary for "clean-up" operations in the more inaccessible corners of the ship's hold so that discharge rates can be maintained when the hold is nearing completion of discharge. The loader is lowered into the hold by either ship or shore gear, and although they usually handle only the last 10% or 20% of the cargo, they can significantly shorten the vessel's turnaround time.

In addition to the actual discharging and storage facilities, a bagging/stitching plant may also be required. This would depend on the mode of transportation for oncarriage to the purchaser. It is normal practice for bulk urea shipments to be bagged at the dock, although it is feasible to deliver the product in bulk form via road or rail.

### 4.6.2 Bagged Cargoes

The loading and discharging of pre-slung bagged cargoes is a relatively straightforward procedure, and can be undertaken using either the ship's gear or shore cranes. The pre-slinging of bagged cargoes would normally take place at the producing plant, and the web sling provides easy top lifting facilities at every handling point along the transport chain.

The handling of pre-slung bagged cargoes requires a minimum of investment in terminal facilities at load and discharge ports. Conventional shore cranes of maximum five tons capacity would be required, plus conveyor and storage facilites.

## 4.7 TRENDS IN SHIPPING COSTS, 1975-1980 AND 1980-1985

### 4.7.1 Newbuilding Prices and Future Tonnage Balance

Historically, there has been a very strong correlation between movements in freight rates and newbuilding prices. This was amply demonstrated in the early - and mid-seventies, when newbuilding prices rose sharply with high and rising freight markets, and then fell to levels well below construction costs after the collapse of freight rates in 1974 and 1975. Effectively, prices of most categories of dry bulk vessel were reduced by up to 30% in 1976 and 1977, providing shipowners with the opportunity to acquire new tonnage at well below actual cost - and on very advantageous financing terms.

Briefly, during 1976, a rise in the freight market, allied to the prevailing low newbuilding prices, encouraged large-scale ordering of handy-sized bulk carriers in the ±25,000 DWT range from Japanese yards. However, interest soon waned, and there were several cancellations and renegotiations of orders in 1977. After 1978, interest in small bulk carriers improved, and since then prices have been steadily increasing with improvements in the freight market.

Price movements for general cargo vessels are less volatile than newbuilding prices of bulk carriers. Prices decreased slightly between 1976 and 1978, but have been increasing steadily since then as orders at Japanese yards have maintained a steady pace.

In attempting to forecast the future supply/demand balance in the world shipping market, it must be borne in mind that there are many unforeseeable natural, industrial, and political events which can completely throw off the most carefully constructed forecast. Furthermore, forecasting depends to a large extent on the interpretation on vessel productivity levels. Changes in the level of operating efficiency can significantly alter the effective capacity of shipping tonnage. In recent years certain operating inefficiencies (slow steaming, part cargo trading, multiporting, etc.) have become commonplace, and it is difficult to estimate the extent to which these practices will alter in the future.

Turning firstly to bulk carriers, future deliveries to the bulk carrier fleet are based upon the existing orderbook at the time of writing, adjusted to show the effect of "slippage", i.e. orders which for one reason or another are not delivered as scheduled.

The growth of the bulk carrier fleet cannot be arrived at by simply adding future deliveries to the present fleet. Some allowance has to be made for deletions (due to scrappage, losses and conversions). These deletions have been assumed to equate to the scrappage of all tonnage over twenty years of age.

The effects of additions and deletions to the handy-sized bulk carrier fleet are summarised in TABLE 59 . This shows a steady reduction in fleet size from 1,779 vessels (47.08 million DWT) in mid-1980 to 1,681 vessels (44.60 million DWT) in mid-1985.

When seeking to assess future potential demand for bulk vessels, estimates must first be made of the prospective ton-mile transport requirements generated by the major and minor dry bulk trades. Matching this to existing data on the size distribution of the entire fleet engaged in the various trades, we can derive estimates of future demand for bulk carriers by size. From previous studies undertaken by HPD, the estimated future demand for handy-sized bulk carriers has been translated into annual DWT requirements.

FIGURE 6 plots projected demand and supply of dry bulk tonnage in the 20-24,999 DWT range up to 1985. This shows that, based on the existing world orderbook and assumed scrappage rates, the present surplus of handy-sized tonnage (of about 3.0 million DWT) will diminish until about 1983, when the market should be in balance. Thereafter a deficit in this size range will develop, reaching about 6.0 million DWT by mid-1985. However, it must be stressed that this projection is based upon the existing orderbook for handy-sized bulk carriers, and that the future pattern of ordering by shipowners could seriously affect the future shipping balance.

It is more difficult to project the future tonnage balance in conventional 'tweendeckers due to the wide variety of trades and cargoes involved. Therefore instead of attempting to give numerical projections of future general cargo supply and demand, we shall comment briefly on the fleet structure and prospects over the next five years.

Market opportunities for traditional 'tweendeckers have been eroded by the advance of fully-cellular shipping and the development of ro-ro types. To an extent, the general cargo sector has countered these developments through the growing importance of the "multi-purpose" cargoship-cum-semi-containership. The standardised,

## TABLE 59

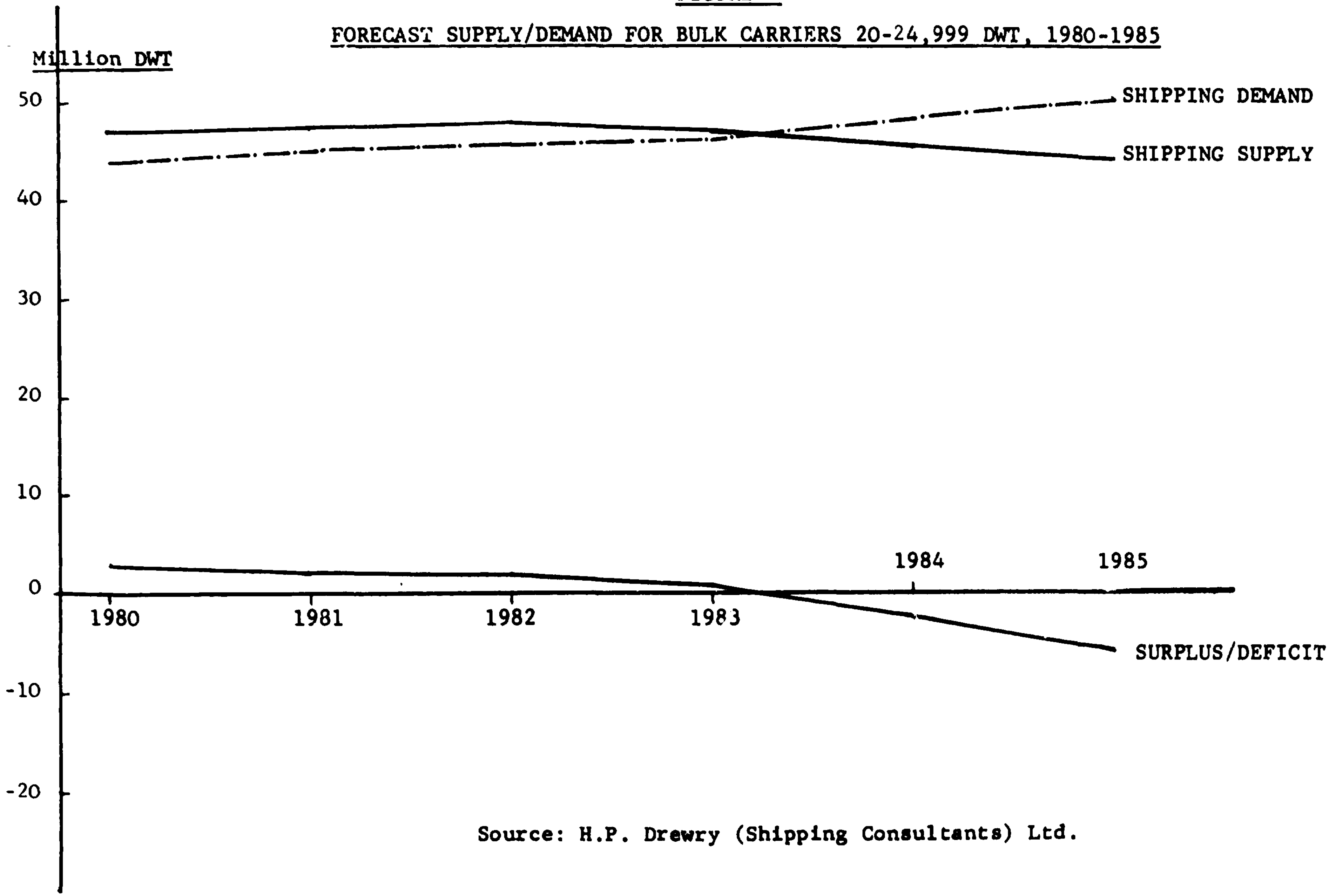
## FORECAST DEVELOPMENT OF WORLD BULK CARRIER FLEET 20-34,999 DWT, 1980-1985

| | NUMBER OF VESSELS | 000 DWT |
|---|---|---|
| MID-1980 FLEET | 1,779 | 47,084 |
| DELIVERIES (+) | 107 | 2,864 |
| DELETIONS (-) | 107 | 2,574 |
| MID-1981 FLEET | 1,779 | 47,374 |
| DELIVERIES (+) | 50 | 1,369 |
| DELTIONS (-) | 31 | 766 |
| MID-1982 FLEET | 1,798 | 47,977 |
| DELIVERIES (+) | 11 | 298 |
| DELETIONS (-) | 36 | 945 |
| MID-1983 FLEET | 1,773 | 47,330 |
| DELIVERIES (+) | 2 | 57 |
| DELETIONS (-) | 58 | 1,781 |
| MID-1984 FLEET | 1,717 | 45,606 |
| DELIVERIES (+) | - | - |
| DELFTIONS (-) | 36 | 1,007 |
| MID-1985 FLEET | 1,681 | 44,599 |

Source: H.P. Drewry (Shipping Consultants) Ltd.

FIGURE 6

FORECAST SUPPLY/DEMAND FOR BULK CARRIERS 20-24,999 DWT, 1980-1985




Source: H.P. Drewry (Shipping Consultants) Ltd.

series-built multi-purpose cargoship is now recognised as an important ship type in its own right, fulfilling a special role in both dry bulk and general cargo trade. The multi-purpose cargoship has emerged as the successor to the wartime "Liberty" ships reflecting the continuing need for vessels of a similar size and type (i.e. flexible, two deck ships of ±15,000 DWT). Despite the greater publicity surrounding container and ro-ro operations, conventional liner shipping still carries a relatively high proportion of trade on all liner routes, with the exception of those linking the major industrialised nations. In terms of quay-to-quay costs per cargo tonne, conventional shipping (on account of its lower capital costs) maintains an edge over unitised container or ro-ro operations on many routes. There is more to competitiveness though - particularly in liner shipping - than minimising quay-to-quay costs. Conventional vessels are slower, with longer voyage times than unitised vessels, and break-bulk cargo is likely to spend more time waiting around in ports. Shippers, particularly of higher-value manufactured goods, may have strong preferences for the benefits of faster transit times and reduced risk of damage and pilferage offered by containers.

Modern conventional liners are, of course, designed to carry containers as well as a range of other cargoes, and it is this flexibility which has undoubtedly attracted many owners to this type of ship. Whilst the volume of container traffic on a route is small, such vessels may be able to compete effectively for it. Once this intermediate phase has passed, however, and the increasing volume of container traffic begins to justify the development of specialised terminals and inland transport facilities, the advantage of the fully-cellular vessel (as an integral part of a through-transport system) are likely to become dominant. Whilst modern multi-purpose vessels may be designed to carry a full cargo of containers, they are not competitive in this configuration with cellular vessels.

In the bulk sector, the multi-decker is in many respects fighting a losing battle against the single deck bulk carrier (especially on long-haul routes). However combinations of draft restrictions, problems with storage or cargo handling and other limitations on shipload size should ensure that 'tweendeckers retain a significant share of certain bulk trades over the next ten years.

Taking into account these observations regarding the projected supply and demand for handy-sized and general cargo vessels, it is reasonable to assume that newbuilding prices will increase by about 10 per cent per annum over the period 1980 to 1985. Price data is summarised in graphical form in FIGURE 7, which shows that projected newbuilding prices in 1985 are about $20.1 million for bulk carriers, and $17.7 million for general cargo vessels. Historically, timecharter rates have shown a high correlation with the supply/demand situation in the shipping market. It is likely that charter rates will harden considerably over the next five year period as the shipping market returns to some sort of equilibrium, therefore it would be advisable for long-term operators to purchase tonnage rather than to rely on the charter market.

4.7.2 Vessel Operating Costs

From data submitted by shipowners to HPD's annual confidential Operating Cost Survey, it is evident that between 1975-1980 overall vessel operating costs were increasing at an average annual rate of between eight to twelve per cent. For the purposes of forecasting freight costs to 1985, an annual increase in vessel operating costs of ten per cent has been assumed.

4.7.3 Voyage Costs

4.7.3.1 Bunkers

An analysis of movements in bunker prices between 1975-1980 is contained in SECTION 1.9. Two sets of freight rate estimates for 1985 were made, according to the crude oil price assumptions specified by UNIDO. Assumption "A", with a crude oil price of $40 per barrel, gives bunker prices of $251 per ton of fuel oil, and $494 per ton of diesel; and Assumption "B", of $80 per barrel of crude, gives bunker prices of $502 per ton of fuel oil and $988 per ton of diesel.

4.7.3.2 Port Charges

Based on shipowners' port disbursement accounts and the published tariff structures of various port authorities, it is evident that overall port charges have been rising by about eight to ten per cent per annum between 1975 and 1980. An annual cost increase of eight percent has been assumed for the period 1980-1985.

4.7.3.3 Canal Tolls

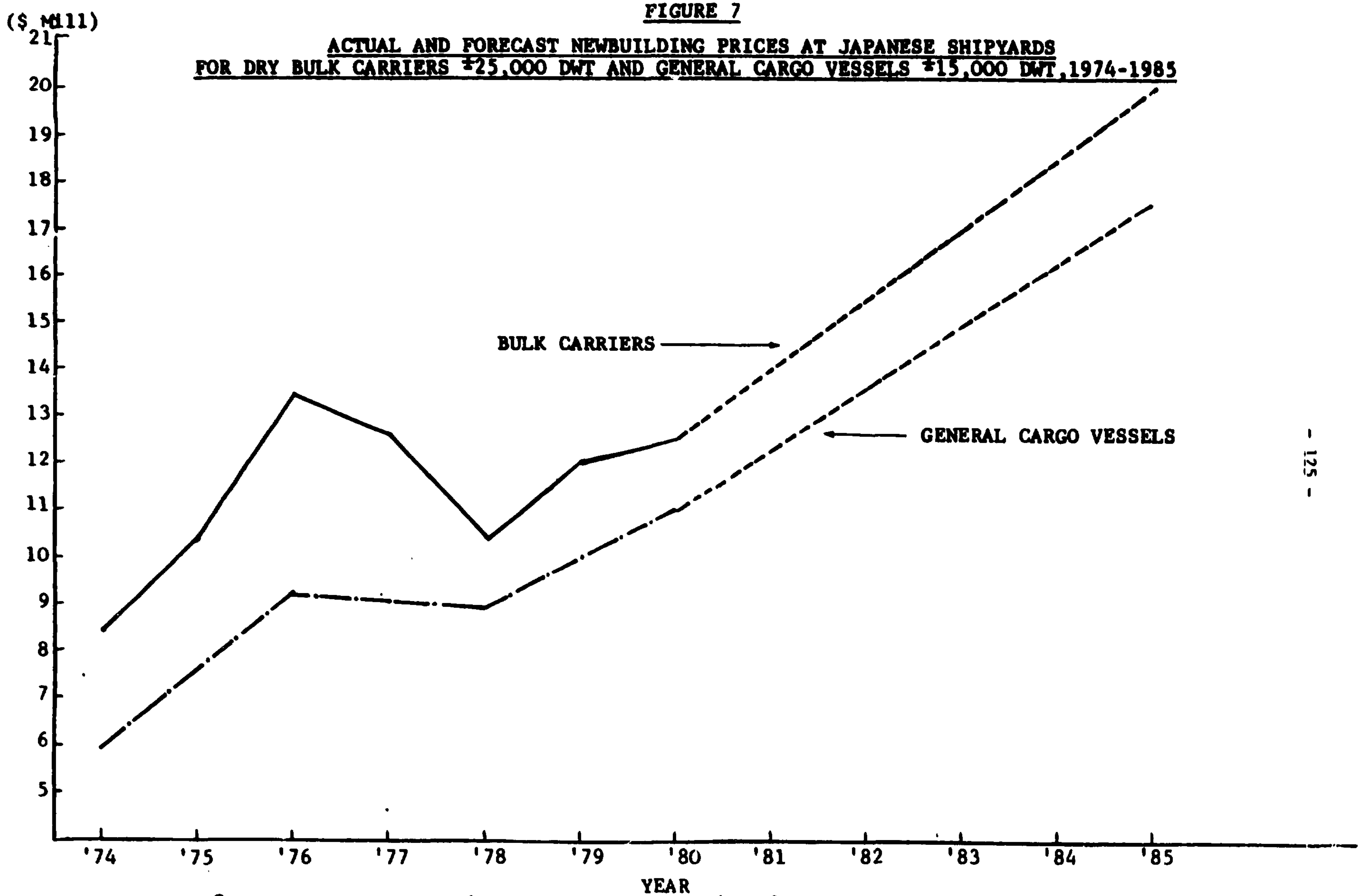
Suez canal tolls were increased in December 1980, prior to which the tolls for dry cargo vessels had remained unchanged since the Canal's re-opening in 1975. Transit tolls for the Panama Canal were increased by 20 per cent in 1974, the first time in the Canal's history, and again in 1976, also by 20%. For the purpose of estimating 1985 shipping costs, Suez Canal tolls are assumed to be identical to existing (1981) tolls, and Panama Canal tolls are assumed to increase by five per cent per annum based on the 1980 level.

4.7.3.4 <u>Freight Costs - 1985</u>

Based on the cost increase assumptions outlined above, freight costs were projected to 1985 for bulk and bagged urea, bagged PVC powder, and bagged low-density polyethylene. The estimated costs are contained in TABLE 60 .

*FIGURE 7*

**ACTUAL AND FORECAST NEWBUILDING PRICES AT JAPANESE SHIPYARDS FOR DRY BULK CARRIERS ±25,000 DWT AND GENERAL CARGO VESSELS ±15,000 DWT,1974-1985**




Source: H.P. Drewry (Shipping Consultants) Ltd.

TABLE 60

FORECAST 1985 FREIGHT COSTS ON UREA, PVC POWDER, AND LOW-DENSITY POLYETHYLENE (LDPE)
(Dollars per Metric Ton)

| ROUTE | BULK UREA | | BAGGED UREA | | BAGGED PVC | | BAGGED LDPE | |
|---|---|---|---|---|---|---|---|---|
| | ASSUMPTION "A" | ASSUMPTION "B" | ASSUMPTION "A" | ASSUMPTION "B" | ASSUMPTION "A" | ASSUMPTION "B" | ASSUMPTION "A" | ASSUMPTION "B" |
| SKIKDA-GENOA | 16.89 | 19.38 | 48.82 | 54.21 | 51.94 | 57.88 | 56.35 | 63.00 |
| SKIKDA-ROTTERDAM | 27.12 | 33.12 | 62.86 | 71.89 | 72.20 | 83.39 | 78.35 | 90.50 |
| SKIKDA-NEW ORLEANS | 50.40 | 64.04 | 91.69 | 108.77 | 113.93 | 136.71 | 123.60 | 148.35 |
| SKIKDA-YOKOHAMA | 86.80 | 110.46 | 136.94 | 164.42 | 179.15 | 216.93 | 194.40 | 235.40 |
| DOHA-GENOA | 51.63 | 63.96 | 92.74 | 108.39 | 115.28 | 136.01 | 125.10 | 147.60 |
| DOHA-ROTTERDAM | 65.53 | 82.29 | 110.65 | 130.96 | 139.65 | 165.64 | 151.50 | 179.70 |
| DOHA-NEW ORLEANS | 88.71 | 113.07 | 139.19 | 167.47 | 182.42 | 221.37 | 197.90 | 240.20 |
| DOHA-YOKOHAMA | 60.67 | 77.53 | 104.99 | 125.44 | 131.07 | 160.73 | 144.40 | 174.40 |
| ACEH-GENOA | 61.48 | 76.98 | 105.28 | 124.29 | 133.36 | 158.94 | 144.70 | 172.45 |
| ACEH-ROTTERDAM | 75.40 | 95.34 | 122.93 | 146.42 | 158.83 | 191.08 | 172.35 | 207.30 |
| ACEH-NEW ORLEANS | 98.56 | 126.08 | 151.42 | 182.97 | 200.06 | 243.72 | 217.05 | 264.45 |
| ACEH-YOKOHAMA | 38.47 | 48.20 | 77.20 | 90.18 | 92.99 | 109.87 | 100.90 | 119.20 |
| VERACRUZ-GENOA | 53.93 | 68.78 | 104.30 | 124.59 | 131.89 | 159.32 | 143.10 | 172.85 |
| VERACRUZ-ROTTERDAM | 50.63 | 64.19 | 92.63 | 109.63 | 115.08 | 137.76 | 124.85 | 149.45 |
| VERACRUZ-NEW ORLEANS | 18.48 | 21.80 | 51.54 | 57.77 | 55.97 | 63.12 | 60.75 | 68.50 |
| VERACRUZ-YOKOHAMA | 83.93 | 107.24 | 133.59 | 160.79 | 174.26 | 211.65 | 189.05 | 229.65 |

Source: H.P. Drewry (Shipping Consultants) Ltd.

## APPENDIX 1

### THE TRANSPORTATION OF CHEMICALS

By transporting methanol and ethylene glycol in crude/products tankers, the costs of carriage can be minimised. However, the parcel size involved is often too small to justify the use of such tonnage and thus chemical carriers may be used in practice. The following data outlines the costs of methanol/ethylene glycol carriage utilising chemical carrying capacity.

### CAPITAL COSTS PER VESSEL

Chemical carrier newbuilding prices have varied markedly in recent years. This is due not only to differences in building costs between yards and countries but also due to dissimilarities in vessel specification. Thus, estimating typical chemical tanker newbuilding prices is problematical. However, a trend towards constructing larger chemical carriers has developed and thus the ordering of chemical carriers in excess of 30,000 DWT is becoming more commonplace. Such a size can however, be taken as relatively typical and thus will be used in this exercise.

A newbuilding price for a relatively unsophisticated 30,000 DWT chemical carrier of about $25 million would seem appropriate and thus this has been used for the purposes of this exercise. This would seem reasonable given:

(i) the ordering in August 1979 for 1980 delivery of a 30,500 DWT solvents carrier for $24 million at the Ankerlokken yard;

(ii) the ordering in March 1980 of four 40,000 DWT chemical carriers from Yugoslavia for second half 1982 delivery at $32.75 million each;

(iii) the placing of a 30,000 DWT chemical carrier order in Japan in the first half of 1980 for $25 million.

Such a price is consistent with an annual capital charge of $4.25 million.

### OPERATING COSTS PER VESSEL

Operating costs, as indicated by the Consultants' in-house data, would approximate to the level shown in TABLE A.1.

TABLE A.1

1980 ESTIMATED ANNUAL CHEMICAL CARRIER OPERATING COSTS
(US Dollars)

| COST TYPE | LEVEL OF COST |
|---|---|
| Manning | 1,222,000 |
| Repairs & Maintenance | 572,000 |
| Stores and Supplies | 364,000 |
| Insurance | 260,000 |
| Administration and Other | 182,000 |
| TOTAL | 2,600,000 |

VOYAGE COSTS PER VESSEL

(i) fuel costs

The assumptions used are outlined in Section 3.5.1. However, recent chemical carrier deliveries have been equipped with powerful engines capable of 17 knots and as a result fuel consumption has been high at about 64 tonnes of HVF daily. The nature of the chemical trade, the loading/discharge of many parcels at a wide variety of ports, has made such units vital and ensures that capital costs per cargo tonne delivered is minimised. Thus, this speed/consumption combination will be utilised here.

(ii) port charges

Port charges per visit are unlikely to be significantly different from those for 35,000 DWT methanol carriers and thus the figures shown in TABLE 39, Section 3.5.1, have been adopted for this exercise.

(iii) canal charges

(a) Suez Canal

A 30,000 DWT chemical carrier has a SCNRT of about 26,500 which, using the rate structure outlined in Section 1.5.3, gives a Suez Canal toll per round trip of $67,738.

(b) Panama Canal

Given that a 30,000 DWT chemical carrier has a PCNRT equivalent of 14,000, the Panama Canal charge per round trip would equate to $32,480.

TOTAL CHEMICAL CARRIER VOYAGE COSTS PER VESSEL PER ANNUM

By combining annual bunker costs, port charges and canal dues, annual bunker costs per vessel can be calculated. The results are shown below in TABLE A.2.

TABLE A.2

1980 ANNUAL VOYAGE COSTS PER VESSEL - CHEMICAL CARRIERS
(US Dollars)

| LOADING PORT / DISCHARGE PORT | SKIKDA | DOHA | ACEH | VERACRUZ |
|---|---|---|---|---|
| GENOA | 3,509,643 | 4,621,666 | 4,595,488 | 3,833,484 |
| ROTTERDAM | 4,203,196 | 4,560,275 | 4,492,851 | 3,860,787 |
| NEW ORLEANS | 3,660,529 | 3.937,391 | 3,962,180 | 3,182,205 |
| YOKOHAMA | 4,586,435 | 4,051,769 | 4,040,545 | 4,383,744 |

TRANSPORT COSTS PER TONNE DELIVERED - 30,000 DWT CHEMICAL CARRIERS

Transport costs per tonne delivered have been calculated assuming:

(i) an annual trade of either methanol or ethylene glycol of 300,000 tonnes per annum on each route in question;

(ii) the carrier under examination can carry full cargoes of either commodity;

(iii) fully loaded capacity is 36,750 $M^3$ or 29,250 tons of methanol or 41,000 tons of ethylene glycol.

On the basis of these assumptions in TABLE A.3 transport costs per tonne delivered relating to methanol and ethylene glycol have been calculated.

CHEMICAL CARRIER COSTS IN 1985

CAPITAL COSTS PER VESSEL

On the assumption that chemical carrier newbuilding prices will increase at a similar rate to that forecast for 55,000 DWT methanol carriers, 30,000 DWT chemical carrier prices will increase from $25 million in 1980 to an order price of $32.5 million in 1983 and $36.3 million in 1985, suggesting annual capital costs of $5.525 million and $6.171 million respectively.

TABLE A.3

1980 TRANSPORT COSTS PER TONNE DELIVERED - METHANOL/ETHYLENE GLYCOL IN 30,000 DWT CHEMICAL CARRIERS

($/TONNE)

| LOADING PORT / DISCHARGE PORT | SKIKDA | | DOHA | | ACEH | | VERACRUZ | |
|---|---|---|---|---|---|---|---|---|
| | METH. | ETH. GLYCOL | METH. | ETH. GLYCOL | METH. | ETH. GLYCOL | METH. | ETH. GLYCOL |
| GENOA | 6.46 | 4.61 | 31.96 | 22.80 | 39.33 | 28.06 | 33.63 | 23.99 |
| ROTTERDAM | 14.87 | 10.61 | 42.08 | 30.02 | 49.21 | 35.11 | 30.98 | 22.10 |
| NEW ORLEANS | 30.53 | 21.78 | 56.56 | 40.36 | 63.73 | 45.47 | 7.92 | 5.65 |
| YOKOHAMA | 58.27 | 41.57 | 38.86 | 27.73 | 22.93 | 16.36 | 56.56 | 40.35 |

## OPERATING COSTS PER VESSEL

Given a 10% annual increase in operating costs, annual operating costs in 1985 per 30,000 DWT chemical carrier will have reached $4,187,326 from the 1980 level of $2,600,000.

## VOYAGE COSTS PER VESSEL

Bunker prices are assumed to reach $251 per tonne for fuel oil and $494 per tonne for marine diesel given a crude oil cost of $40 per barrel, and $502 and $988 respectively assuming the cost of crude rises to $80 per barrel. Port charges between 1980 and 1985 are assumed to rise at an annual rate of 8.5%. Suez Canal charges per round trip are estimated at $97,415 in 1985 whilst Panama Canal tolls will reach $86,453 per round trip for 30,000 DWT chemical carriers in 1985.

## TRANSPORT COSTS PER TONNE DELIVERED

Based on the assumptions above and those outlined in earlier parts of this Appendix, transport costs per tonne delivered in 1985 can be estimated. The results are shown in TABLE A.4.

## TABLE A.4

## 1985 TRANSPORT COSTS PER TONNE DELIVERED - METHANOL/ETHYLENE GLYCOL IN 30,000 DWT CHEMICAL CARRIERS

($/TONNE)

| ROUTE \ COST BASIS | 1983 ORDER/ $40 PER BARREL | | 1983 ORDER/ $80 PER BARREL | | 1985 ORDER/ $40 PER BARREL | | 1985 ORDER/ $80 PER BARREL | |
|---|---|---|---|---|---|---|---|---|
| | METHANOL | ETHYLENE GLYCOL | METHANOL | ETHYLENE GLYCOL | METHANOL | ETHYLENE GLYCOL | METHANOL | ETHYLENE GLYCOL |
| SKIKDA-GENOA | 9.19 | 6.55 | 11.21 | 8.00 | 9.59 | 6.84 | 11.61 | 8.29 |
| SKIKDA-ROTTERDAM | 21.38 | 15.25 | 34.44 | 24.58 | 22.25 | 15.87 | 35.31 | 25.20 |
| SKIKDA-NEW ORLEANS | 45.24 | 32.28 | 73.45 | 52.41 | 47.12 | 33.62 | 75.33 | 53.75 |
| SKIKDA-YOKOHAMA | 82.33 | 58.74 | 131.87 | 94.05 | 85.62 | 61.09 | 135.11 | 96.40 |
| DOHA-GENOA | 45.37 | 32.37 | 72.43 | 51.67 | 47.17 | 33.65 | 74.23 | 52.95 |
| DOHA-ROTTERDAM | 60.36 | 43.06 | 96.18 | 68.61 | 62.74 | 44.76 | 98.56 | 70.31 |
| DOHA-NEW ORLEANS | 84.18 | 60.06 | 135.11 | 96.37 | 87.57 | 62.48 | 138.50 | 98.79 |
| DOHA-YOKOHAMA | 55.14 | 39.34 | 89.76 | 64.04 | 57.44 | 40.98 | 92.06 | 65.68 |
| ACEH-GENOA | 55.54 | 39.62 | 88.91 | 63.43 | 57.76 | 41.20 | 92.13 | 65.01 |
| ACEH-ROTTERDAM | 70.53 | 50.31 | 112.66 | 80.37 | 73.33 | 52.31 | 115.46 | 82.37 |
| ACEH-NEW ORLEANS | 94.36 | 67.32 | 151.61 | 108.16 | 98.17 | 70.04 | 155.42 | 110.88 |
| ACEH-YOKOHAMA | 32.38 | 23.11 | 52.83 | 37.69 | 33.74 | 24.08 | 54.19 | 38.66 |
| VERACRUZ-GENOA | 48.08 | 34.30 | 78.65 | 56.11 | 50.11 | 35.75 | 80.68 | 57.56 |
| VERACRUZ-ROTTERDAM | 45.01 | 32.11 | 73.10 | 52.15 | 46.88 | 33.44 | 74.97 | 53.48 |
| VERACRUZ-NEW ORLEANS | 11.78 | 8.40 | 19.45 | 13.87 | 12.29 | 8.76 | 19.96 | 14.23 |
| VERACRUZ-YOKOHAMA | 80.54 | 57.46 | 129.44 | 92.34 | 83.79 | 59.78 | 132.69 | 94.66 |

## APPENDIX 2

### CAPITAL COSTS

The capital cost recovery mocel formated in SECTION 1.3 ignores tax concessions/depreciation allowances offered by many Governments as part of their shipbuilding support programmes. Such deductions act effectively as newbuilding price discounts and will thus reduce annual capital charges to below the levels stated in this consultancy.