UNIVERSITY OF NEWCASTLE UPON TYNE

SCHOOL OF MARINE TECHNOLOGY

DEPARTMENT OF NAVAL ARCHITECTURE & SHIPBUILDING

A TECHNO-ECONOMIC MODEL OF SHIP OPERATION WITH SPECIAL REFERENCE TO HULL AND PROPELLER MAINTENANCE IN THE FACE OF UNCERTAINTY

by

TOR E. SVENSEN

VOLUME II

MARCH 1983

A Thesis submitted to the University of Newcastle upon Tyne for the Degree of Doctor of Philosophy

REFERENCES

1. BENFORD, H., "Fundamentals of Ship Design Economics", Department of Naval Architecture and Marine Engineering, University of Michigan, 1976.

2. BENFORD, H., "Principles of Engineering Economy in Ship Design", Trans. SNAME, Vol. 71, 1963.

3. BENFORD, H., "A Second Look at Measures of Merit for Ship Design", Report No. 223, Department of Naval Architecture and Marine Engineering, University of Michigan, 1980.

4. BUXTON, I.L., "Engineering Economics Applied to Ship Design", Trans. RINA, Vol. 114, 1972.

5. BUXTON, I.L., "Engineering Economics and Ship Design", Published by The British Ship Research Association, Second Edition, 1976.

6. GOSS, R.O., "Economic Criteria for Optimal Ship Design", Trans. RINA, Vol. 107, 1965.

7. GOSS, R.O., "Advances in Maritime Economics", Cambridge University Press, 1977, Edited by R.O. GOSS.

8. MILNE, A., "On the Corrosion and Fouling of Iron Ships: 110 Years on", N.E.C.I.E.S. Junior Section, March, 1982.

9. TELFER, I.E., "Some Aspects of the External Maintenance of Tankers", Trans. RINA, Vol. 114, 1972.

10. TOWNSIN, R.L., BYRNE, D., MILNE, A. & SVENSEN, T.E., "Speed, Power and Roughness: the Economics of Outer Bottom Maintenance", Trans. RINA, Vol. 122, 1981.

11. TOWNSIN, R.L., BYRNE, D., SVENSEN, T.E. & MILNE, A., "Estimating the Technical and Economic Penalties of Hull and Propeller Roughness", Trans. SNAME, Vol. 90, 1981.

12. MILNE, A., "Self-Polishing Coatings in Marine Antifouling Paints", The Royal Institute of Chemistry, Annual Chemical Congress, Durham, April, 1980.

13. BYRNE, D., "Hull Roughness of Ships in Service", M.Sc. Thesis, University of Newcastle upon Tyne, U.K., 1981.

14. TOWNSIN, R.L., WYNNE, J.B., MILNE, A & HAILS, G., "Hull Condition, Penalties and Pallatives for Poor Performance", 4th Int. Congress on Marine Fouling and Corrosion, Antibes, 1976.

15. BOWDEN, B.S. & DAVIDSON, N.J., "Ship Resistance and Hull Roughness", National Maritime Institute, Ship TM356, July, 1973.

16. BOWDEN, B.S. & DAVIDSON, N.J., "Resistance Increments due to Hull Roughness Associated with Form Factor Extrapolation Methods", National Maritime Institute, Ship TM380, January, 1974.

17. "Report of the Performance Committee", Proceedings 15th ITTC, The Hague, 3rd-10th September, 1978.

18. "Report of the Performance Committee", Proceedings 16th ITTC, Volume 1, Leningrad, 31st August-9th September, 1981.

19. REYNOLDS, W.C., "A Morphology of Prediction Methods", AFOSR-IFP Stanford Conference, 1968, Calculation of Turbulent Boundary Layers.

20. HEAD, M.R., "Entrainment in the Turbulent Boundary Layer", ARC R&M 3152, 1960.

21. TOWNSIN, R.L., MILNE, A. & MEDHURST, J.S., "The Differential Maintenance of Outer Bottom Hull Surfaces", I.M.A.E.H. 2nd Int. Congress, Trieste, September, 1981.

22. MEDHURST, J.S., "Making do and Mending", Third Round Table Meeting on Hull Roughness and Drag, Teesside Polytechnic, September, 1982.

23. LEWKOWICZ, A.K., HOADLEY, D., HORLOCK, J.H. & PERKINS, H.J., "A Family of Integral Methods for Predicting Turbulent Boundary Layers", A.I.A.A. Journal, Vol. 8, No. 1 (1970).

24. HAMA, F.R., "Boundary Layer Characteristics for Smooth and Rough Surfaces", Trans. SNAME, Vol. 162, 1954.

25. GRIGSON, C.W.B., "The Drag Coefficients of a Range of Ship Surfaces", Trans. RINA, Vol. 123, 1981.

26. COLEBROOK, C.F., "Turbulent Flow in Pipes with Particular Reference to

Transition Region Between the Smooth and Rough Pipe Laws", Journal Inst. Civ. Engrs., 11, 1938-39.

27. MUSKER, A.J., LEWKOWICZ, A.K. & PRESTON, J.H., "Investigation of the Effect of Surface Roughness of a Ship on the Wall Friction using a Pipe Flow Technique", Liverpool University, Dept. of Mech. Eng., Report No. FM/24/76, 1976.

28. HAMLIN, N.A. & SEDAT, R.D., "The In-Service Roughness Allowance; Effect of Drydocking, Recoating and the Passing of Time", Shipboard Energy Conservation '80 Symposium, SNAME, New York, September, 1980.

29. YOUNG, A.D. & OWEN, P.R., "A Simplified Theory for Streamline Bodies of Revolution, and its Application to the Development of High Speed Low Drag Shapes", R.A.E. Aero Report No. 2071, 1943.

30. ATKINSON, J., "International DATAPLAN", Proceedings, Third International Ships Painting and Corrosion Congress, Monte Carlo, April, 1978.

31. KAN, S., SHIBA, H., TSUCHIDA, K. & YOKOO, K., "Effect of Fouling of a Ship's Hull and Propeller upon Propulsive Performance", I.S.P., Vol. 5, No. 41, January, 1958.

32. TOKUNAGA, K., "Local Roughness Effect on Self Propulsion Factors", Trans. West Japan Society of Naval Architects, No. 63, March, 1982.

33. SASAJIMA, H. & TANAKA, I., "On the Estimation of Wake of Ships", Appendix X, Performance Session, 11th ITTC, Tokyo, 1966.

34. VAN BERLEKOM, W.B., "Wind Forces on Modern Ship Forms - Effects on Performance", Trans. N.E.C.I.E.S., Vol. 97, 1981.

35. FISHMAN, G.S., "Principles of Discrete Event Simulation", John Wiley & Sons, 1978.

36. NAYLOR, T.H., "Computer Simulation Experiments with Models of Economic Systems", John Wiley & Sons, 1971.

37. ZACHARIADES, A., "Optimal Speed of Existing Bulk Vessels", M.Sc. Thesis University of Newcastle upon Tyne, 1980.

38. DREUFUS, S.E. & LAW, A.M., "The Art and Theory of Dynamic Programming", Volume 130, Mathematics in Science and Engineering, Academic Press, 1977.

39. BELLMAN, R.E. & DREUFUS, S.E., "Applied Dynamic Programming", Princeton University Press, New Jersey, 1962.

40. SVENSEN, T.E., "Techno-Economic Reasons for Selecting Fuel-Saving Priorities", Trans. Institute of Marine Engineers (C), Vol. 94, 1982.

41. DnV Rules for Classification of Steel Ships, Part 1, Chapter 2, 1982.

42. Lloyds Rules and Regulations for the Construction and Classification of Steel Ships, Part 1, Chapter 3, 1981.

43. WHYTE, I.M., "A Study of a Service Performance Analysis System for a Tanker Fleet", M.Sc. Thesis, University of Newcastle upon Tyne, 1973.

44. "S.S. 'MUREX', Hull Scrubbing Investigation 1972-74", Shell International Marine Limited, Internal Report No. MR/33/75, 1975.

45. TOWNSIN, R.L., MOSS, B., WYNNE, J.B. & WHYTE, I.M., "Monitoring the Speed Performance of Ships", Trans. N.E.C.I.E.S., Vol. 91, 1975.

46. "Cupro-Nickel Material Study, an Economic Feasibility Study", Private Report Prepared for INCO Europe Limited, London, by Marine Service GMBH, Hamburg. Initial Report 1978, Revised Report 1979.

47. MALONE, J.A. LITTLE D.E. & ALLMAN, M., "Effects of Hull Foulants and Cleaning/Coating Practices on Ship Performance and Economics", Trans. SNAME, Vol. 88, 1980.

48. SCHLICHTING, H., "Boundary-Layer Theory", McGraw Hill Book Company, Seventh Edition, 1979.

49. GRIGSON, C.W.B., "Propeller Roughness, its Nature and Effect Upon the Drag Coefficients of Blades and Ship Power", Trans. RINA, Vol. 124, 1982.

50. MUSKER, A.J. & LEWKOWICZ, A.K., "The Effect of Ship Hull Roughness on the Development of Turbulent Boundary Layers", Int. Symposium on Ship Resistance, Gothenborg, 1978.

51. MUSKER, A.J. "Turbulent Shear-Flows Near Irregularly Rough Surfaces with Particular Reference to Ships' Hulls", Ph.D. Thesis, University of Liverpool, 1977.

52. BURRILL, L.C., "Calculation of Marine Propeller Performance Characteristics", Trans N.E.C.I.E.S., VOL. 60, 1943-44.

53. BURRILL, L.C., "Aerodynamics and Marine Propeller Design", Trans. N.E.C.I.E.S., Vol. 80, 1964.

54. ABBOTT, I.A., VAN DOENHOFF, A.E. & STIWERS, L.S., "Summary of Airfoil Data", N.A.C.A. Report No. 824.

55. SQUIRE, H.B. & YOUNG A.D., "The Calculation of the Profile Drag of Aerofoils", A.R.C., R & M No. 1838 (U.K.), November, 1937.

56. BYRNE, D., FITZSIMMONS, P.A. & BROOK, A.K., "Maintaining Propeller Smoothness: a Cost Effective Means of Energy Saving", Ship Cost and Energy '82 Symposium, SNAME, New York, 30th September - 1st October, 1982.

57. WELLMAN, F., "A Survey of Hull and Propeller Roughness Data", British Ship Research Association, Report No. 354, 1961.

58. BROWN, D.K., "Fouling and Economic Ship Performance", Fifth Inter-Naval Conference, April, 1976.

59. VON NEUMAN, J. & MORGENSTERN, O., "Theory of Games and Economic Behaviour", 3rd Edition, John Wiley & Sons, 1953.

60. MARSCHAK, J. "Rational Behaviour, Uncertain Prospects and Measurable Utility", Econometrica, 1950. pp 111-141.

61. SAVAGE, L.J., "The Foundations of Statistics", John Wiley & Sons, 1954.

62. BERNOULLI, D., "Exposition of a New Theory on the Measurement of Risk", Originally Published in Papers of the Imperial Academy of Sciences in Petersburg, Vol. V, 1738, English Translation Published in Econometrica, Vol. 22, 1954.

63. HILLIER, F.S., "The Derivation of Probabilistic Information for the Evaluation of Risky Investments", Management Science, Vol. 9, 1963.

64. HILLIER, F.S., "The Evaluation of Risky Interrelated Investments", Studies in Mathematical and Management Economics, Vol. 9, North-Holland Publishing Co., 1969.

65. HESS, S.W. & QUIGLEY, H.A., "Analysis of Risk in Investments using Monte Carlo Techniques", Chemical Engineering Progress, Symposium 42: Statistics and Numerical Methods, 1963.

66. HERZ, D.B., "Risk Analysis in Capital Investment", Originally Published

in Harward Business Review, 1964, Revised Paper Published in Harward Business Review, 1979.

67. KLAUSNER, R.F., "The Evaluation of Risk in Marine Capital Investments", SNAME Marine Technology, Vol. 7, No. 4, 1970.

68. LORANGE, P. & NORMAN, V.D., "Shipping Management", Proceedings from Seminar at the Institute for Shipping Research, Bergen, 23rd-26th August, 1972. Edited by Lorange & Norman.

69. FARRAR, D.E., "The Investment Decision Under Uncertainty", Ford Foundation Prize Dissertation, Markham Publishing Company, 1962.

70. WOLFRAM, J., "Uncertainty in Engineering Economics and Ship Design", Trans N.E.C.I.E.S., Vol. 96, 1979.

71. KEYNES, J.M., "A Treatise on Probability", Chapter 5, MacMillan Publishing Co., 1921.

72. SPETZELER, C.S., "The Developmnt of a Corporate Risk Policy for Capital Investment Decisions", I.E.E.E. Transactions on Systems Science and Cybernetics, Vol. SSC-4, No. 3, September, 1968.

73. LUCE, R.D. & RAIFFA, H., "Games and Decisions", John Wiley & Sons, 7th Edition, 1967.

74. RUBINSTEIN, R.Y., "The Strong Case for the Generalised Logarithmic Utility Model as the Premier Model of Financial Markets"; "Financial Decision Making under Uncertainty", edited by Levy,H. & Sarnat,H., Academic Press, 1977.

75. ROSE, I.M., "Engineering Investment Decision, Planning Under Uncertainty", Elsevier Scientific Publishing Company, 1976.

76. POLIQUEN, L.Y., "Project Analysis in Project Appraisal", World Bank Occasional Paper No. 11, John Hopkins Press, Baltimore, 1970.

77. NAG Fortran Library, Mark 9, Numerical Alogrithms Group, Oxford, England.

78. BRENT, R.P., "A Gaussian Pseudo-Random Number Generator", Communications of the A.C.M., DECEMBER, 1974, Vol. 117, No. 12.

79. HASTINGS, C., "Approximations for Digital Computers", Princeton

University Press, 1955.

80. LINDEBERG, J.W., "Eine neue Herleitung des Exponentialgesetzes in der Wahrscheinlichkeitsrechnung", Mathematische Zeitung, Vol. 15, 1922.

81. FELLER, W., "An Introduction to Probability Theory and its Applications", Vol. II, John Wiley & Sons, 1966.

82. TOWNSIN, R.L. & SVENSEN, T.E., "Monitoring Speed and Power for Fuel Economy", Shipboard Energy Conservation '80 Symposium, SNAME, New York, September, 1980.

83. TOWNSIN, R.L. & ROBINSON, C.A., "The Minitoring of Ship Performance", General Council of British Shipping, Report J-10-04-042, 1975.

84. KWON, Y.J., "The Effect of Weather, Particularly Short Sea Waves, on Ship Speed Performance", Ph.D. Thesis, University of Newcastle upon Tyne, 1982.

85. TOWNSIN, R.L. & KWON, Y.J., "Approximate Formulae for the Speed Loss Due to Added Resistance in Waves", Trans. RINA, Vol. 124, 1982.

86. TELFER, E.V., "On Taking the Rough with the Smooth", Trans. Institution of Engineers and Shipbuilders in Scotland, Vol. 112, 1968-69.

87. "Service Trial on a Power Meter Manufactured by Jungner Instrument AB", British Ship Research Association, Report No. NS324.

BIBLIOGRAPHY

BABA, E. & TOKUNAGA, K., "Approximate Calculation of Ship Frictional Resistance Increase due to Surface Roughness", Weighart Retirement Meeting, Germany, 1982.

BABA, E. & TOKUNAGA, K., "Study of Local Roughness Effect on Ship Resistance for Effective Cleaning and Protection of Hull Surface", Shipboard Energy Conservation '80 Symposium, SNAME, New York, September, 1980.

BORCH, K.H., "The Economics of Uncertainty", Princeton Studies in Mathematical Economics, No. 2, 1968.

BYRNE, D. & WARD, G., "The Cost of Hull Rougness Versus the Cost of Hull Smoothness", Trans. Institute of Marine Engineers (C), Vol. 94, 1982.

CANHAM, H.J.S. & LYNN, W.M., "The Propulsive Performance of a Group of Intermediate Tankers", Trans. RINA, Vol. 104, 1962.

DE GARMO, E.P. & CANADA, J.R., "Engineering Economy", The Macmillan Company, New York, 1973.

ENGINEERING ECONOMIST, THE, "Decision and Risk Analysis, Powerful New Tools for Management", Summer Symposium Series VI, 19th-20th June, 1971.

FEARNLEYS REVIEW, Published by Fearnleys, Oslo, Norway.

GRONWALL, P.E. & ZINK, P.F., "A Containership Operator's Program of Bottom Maintenance for Reducing Fuel Consumption", SNAME, Spring Meeting/STAR Symposium, 1982.

HAMMERSLEY, J.M. & HANDESCOMB, D.C., "Monte Carlo Methods", Methuen's Statistical Monographs, 1964.

INTRILLIGATOR, M.D., "Econometric Models, Techniques and Applications", Advanced Textbook in Economics, North-Holland Publishing Co., 1978.

JOHNSON, N.L. & LEONE, F.C., "Statistics and Experimental Design in Engineering and the Physical Sciences", Vol. 2, 2nd Edition, John Wiley & Sons, 1977.

KARLSSON, R.J., "The Effect of Irregular Surface Roughness on the Frictional Resistance of Ships", Int. Symposium on Ship Viscous Resistance, Gothenburg, 1978.

LACKENBY, H., "Resistance of Ships with Special Reference to Skin Friction and Hull Surface Condition", 34th Thomas Lowe Gray Lecture, Proceedings Institute of Mechanical Engineers, 1962.

LERBS, H.W., "On the Effects of Scale and Roughness on Free Running Propellers", Journal of the American Society of Naval Engineers, Vol. 63, 1951.

LINDLEY, D., "Making Decisions", Wiley Interscience, 1971.

von MAYDELL, O., "Assessing and Planning for Drydocking", HANSA, Zentralorgan Fur Schiffart-Schiffbau-Hafen, No. 10, 1978.

MEGILL, R.E., "An Introduction to Risk Analysis", Petroleum Publishing Company, 1977.

MERRETT, A.J. & SYKES, A., "The Finance and Analysis of Capital Projects", Second Edition, Longman, 1973.

NASH, D.P., "Best Ship Speed", Canadian Shipping and Marine Engineering, July, 1978.

OECD Economic Outlook, 6 Monthly Publication, by The Organisation for Economic Co-operation and Development.

PETROLEUM ECONOMIST, Published Monthly by Petroleum Press Bureau Ltd., London.

PLATOU REPORT, THE, Published by R.S. Platou, Oslo, Norway.

PROCHASKA, F., "Timing of Drydocking Intervals to Most Economical Effect", Propellers '81 Symposium, SNAME, Virginia Beach, 26th-27th May, 1981.

REUTLINGER, S., "Techniques for Project Appraisal Under Uncertainty", World Bank Staff Occasional Papers, No. 10, 1970, John Hopkins Press, Baltimore.

RUBERT, M.I., Confusion in Measuring Surface Roughness", Engineering, May, 1960.

RUBINSTEIN, R.Y., "Simulation and the Monte Carlo Method", Wiley Series in

Probability and Statistics, 1981.

SCHLAIFER, R., "Probability and Statistics for Business Decisions - An Introduction to Managerial Economics Under Uncertainty", McGraw-Hill Book Company, 1959.

SCHORSCH, E., BICICCHI, R.T. & FU, J.W., "Hull Experiments on 24-Knot Ro/Ro Vessel Directed towards Fuel Saving Application of Copper-Nickel", Trans. SNAME, Vol. 86, 1978.

SILLERUD, B.O., "The Economic Consequence of Ship Service Speed Reduction", Norwegian Maritime Research, No. 1, 1974.

SOBOL, I.M., "The Monte Carlo Method", Translated from Russian by Messer, R., Stone, J. & Fortini, P., The University of Chicago Press, 1974.

SYMPOSIUM ON MONTE CARLO METHODS, Edited by Meyer, H.A., University of Florida, March 16th-17th, 1954, John Wiley & Sons, 1956.

TELFER, E.V., "Further Ship Resistance Similarity", Trans. RINA, Vol. 93, 1951.

TELFER, E.V., "Some Ship Generalised Power Diagram Developments and Related Considerations. Ingenieurs Navales Societe, Belge, April, 1964.

TOWNSEND, E.C., "Investment and Uncertainty, a Practical Guide", Oliver & Boyd Ltd., Edinburgh, 1969.

WAGLE, B., "A Statistical Analysis of Risk in Capital Investment Projects", Operational Research Quarterly, Vol. 18, 1967.

WATSON, D.G.M., "Designing Ships for Fuel Economy", The Forty-Sixth Parsons Memorial Lecture, RINA, 1981.

WOODS, D.H., "Improving Estimates that Involve Uncertainty", Harward Business Review, July-August, 1976.

Appendix A

A-1 INTRODUCTION

The various methods available for investigating the relationship between hull roughness and drag have been described in Chapter 1. None of these methods have on their own provided an entirely satisfactory answer to the problem. Since Telfer proposed his one third power law relationship between roughness and drag, the only major improvement until very recently has been the ITTC correlation formula for hull roughness, although it is now accepted that this formula includes other model to ship correlation factors as well. Faced with this uncertain basis for the economic modelling of hull maintenance strategies, a search of ways of obtaining more information was initiated. This search finally resulted in an opportunity being created for the undertaking of a full scale performance monitoring experiment on two sisterships with a known difference in hull surface condition. Following the successful outcome of the first experiment, as reported in Reference (82), it was decided to repeat the monitoring exercise after the two vessels had spent another 12 months in service. The two objectives of this experiment were, firstly to obtain a confirmation of the results obtained for the two ships in the previous year and secondly to relate any change in speed performance to changes in the condition of each ship's underwater hull. Neither of the vessels were drydocked during the 12 month period between the two experiments, and the change in hull condition therefore would reflect a change in service only. An additional benefit from a second experiment was the further evaluation of the monitoring system itself to see whether some of the procedures could be improved.

In both experiments an independent observer was placed on each ship for the purpose of continuous data collection and analysis during the deep sea passages of a complete roundtrip. Both vessels were on each occasion makfng identical voyages between Europe and the Far East at approximately the same time of the year.

The general principles behind a system for monitoring speed and power performance have been discussed thoroughly in References (43) and (83). The basic parameters to be monitored are speed and power. In addition, corresponding readings of shaft revolutions and fuel consumption are taken as a measure for checking the consistency of the speed and power data, and recordings are made of draught, trim and weather for the purpose of correcting speed and power to a common basis for comparison. Two main options are availale in the final interpretation of the recorded data. If the vessel is operating at nearly constant power, the data can be corrected to a constant power basis, and each voyage will then normally yield one single average point on the speed-power curve. On the other hand, if the vessel is operating over a range of powers during its round voyage, then with an adequate number of data readings, a complete speed-power curve can be constructed for each voyage and used for comparison. A third and useful way of presenting the results is to calculate the energy requirement per nautical mile by integrating the power multiplied by the time over the total round voyage and divide by the distance. Every voyage will then yield a specific energy requirement per mile, and one voyage can be compared with the next, provided each voyage is corrected to the same average speed.

A-2 VESSEL DESCRIPTIONS

SHIP PARTICULARS:

Cellular type container ships, maximum capacity 2865 TEU, carrying 3 high on deck.

Overall Length	=	288.75 m
Length B.P.	=	274.32 m
Breadth	=	32.26 m
Depth	=	24.60 m
Maximum Summer Draught	=	13.03 m
Average Operating Draught	=	11.00 m
Deadweight at max. Summer Draught	=	49600 t
Displacement at 13.03 m draught	=	73600 t
Displacement at 11.00 m draught	=	58900 t
Block coefficient	=	0.623
Wetted surface area at 11.0 m draught	=	11100 m^2
Transverse projected area above waterline at 11.0 m draught A_T	=	900 m^2
Design Speed	=	26.5 knots
Average operating speed	=	21.0 knots

MACHINERY:

2 Steam Turbines

Design Output 29825 kW/40550 HP (metric) each at 136 RPM

Max. Output 32810 kW/44610 HP (metric) each at 140.4 RPM

PROPELLERS:

Diameter	=	6200 mm
Pitch	=	7500 mm
No. of blades	=	5
Approximate Quasi Propulsive Coefficient in operating range 20 - 25 kn	=	0.67

A-2.1 UNDERWATER HULL MAINTENANCE HISTORIES

SHIP A:

Coated with a Vinyl Organo-Tin antifouling prior to delivery in December 1972 and subsequently recoated with the same at guarantee drydocking in 1973. At normal maintenance drydocking in June 1975 the complete underwater hull was coated with Intersmooth SPC 1 and was also recoated with the same at maintenance drydocking in 1977. Due to some detachment both sides were grit blasted during maintenance drydocking in June 1979 and the complete underwater hull recoated with Intersmooth SPC4. Outdocking roughness was measured in June 1979 yielding a result of 136 μm AHR with 149 μm for the flats and 129 μm for the sides.

SHIP E:

Coated with a Vinyl Organo-Tin antifouling prior to delivery in November 1973, and recoated with the same at guarantee drydocking in 1974. During maintenance drydocking in 1976 the underwater hull was coated with a High Performance Chlorinated Rubber antifouling and the same specification was used at normal maintenance drydocking in 1978.

From the above specifications it can be seen that at the time of the first experiment in July/August 1979, Ship E had been through one drydocking less than Ship A.

A-3 INSTRUMENTATION FOR MONITORING

Only the ships' own instrumentation was used. The vessels were both fitted with Jungner AEM-1 torsion meters on each propeller shaft. Prior to the start of the first experiment, a malfunction in one of the torsion meters on ship A was repaired, and the instruments on both shafts re-calibrated by the manufacturer. In the case of ship E, no malfunction had ever occured, and a simple zero check was made at the end of the voyage. Any relative change in calibration between the instruments on each shaft could easily be detected during the voyage, and this eliminated the need for a zero check before as well as after the completion of the voyage. In the second experiment a zero calibration check was carried out on both vessels immediately before the start of each voyage by a representative of the manufacturer. No significant drift in the zero-point had occured during the 12 month period and this confirmed the high reliability of this particular make of instrumentation. Shaft revolutions were measured using double sets of counters mounted on each gearbox and with an electronic repeater for each shaft positioned in the engine control room. Fuel consumption was measured by the use of flowmeters positioned at the point of fuel entry to each boiler. A double check on fuel consumption was made by taking readings from the daily settling tanks. Observed speed over the ground was calculated by the use of Magnavox MX 1102 satellite navigator, and log speed was measured using a Jungner pitot type log. An anemometer was fitted, but its positioning caused inaccurate readings for certain wind directions, and wind speeds were therefore recorded on the basis of observation of sea state as customary. For the purpose of continuous data checking, a power diagram was used throughout the voyage for plotting difference curves between observed speed, log speed and speed derived from the power diagram. This enabled errors in power, speed or RPM readings to be spotted quickly and inaccurate data to be eliminated from the final analysis. Prior to the monitoring exercise, a series of power diagrams were constructed for a range of values of apparent wake on the basis of the open water characteristics of the propellers. The correct diagram to be used and the corresponding value of apparent wake was hence found, using a trial and error process with the recorded values of observed speed, power and RPM at the start of the monitoring exercise.

A-4 EXPERIMENTAL PROCEDURE

The system set up on board was based on a satellite fix to satellite fix recording procedure. The reason behind this, rather than using a fixed interval procedure, (eg: watch-by-watch), was to eliminate the accumulated error introduced in using a dead reckoning position between satellite fixes. This error can, after two hours, be as much as one mile. At the time of satellite fix, readings of log speed, RPM, power and fuel consumption with corresponding temperature were recorded. Time between satellite fixes could vary between two and twelve hours, but on average was 4 to 6 hours. In order to compute a good average value of power between fixes, a continuous log of power readings was kept in the engine control room. Recordings were taken every hour in the first experiment and reduced to every half our in the second experiment. Weather and ship motion recordings were made on a watch-by-watch basis by deck officers, so that each inter-fix period could be associated with a particular set of weather conditions, and corrections could later be made to a standard basis for comparison. Only data corresponding to wind strengths less than and including Beaufort 5 have been used, and no shallow water data or data including substantial course changes have been included in the final analysis. The limiting value of Beaufort 5 has been applied in accordance with the results of Kwon's work, as reported in References (84) and (85). Kwon concluded that the added resistance due to waves becomes significant for full form tankers at a fully developed sea state above level 4 on the Beaufort scale, and for fine form container ships at a level above Beaufort 5, provided there are no significant ship motions. Draught readings were made on departure and arrival in ports. Recordings were also made of daily fuel consumption and changes to ballasting condition for the purpose of calculating draughts on a daily basis throughout the complete voyage.

A-5 DATA ANALYSIS

A-5.1 PROCEDURE FOR RELATING SPEED AND POWER

In both experiments the two vessels were operating over a wide range of engine power during the voyage, and rather than correcting to a standard power for comparison, the data have been used to construct a speed-power curve for each vessel.

Corrections to power have been made for the effect of direct wind resistance and changes in draught. The wind resistance corrections have been made on the basis of recent wind tunnel tests for container ships, [Reference (34)]. From the general wind tunnel test data, a particular correction curve for the vessel type employed in this experiment was derived, based on the projected transverse area above the waterline as calculated from drawings. The curve of resistance coefficient C_x against angle of relative wind resistance is given in Figure (A-1). When correcting power to a basis of still air wind resistance, account was also taken of the change in propulsive efficiency with added resistance. This correction curve was derived using the open water characteristics of the propellers and is shown in Figure (A-2). The corrections to power due to changes in draught were made to a standard draught value of 11.0m. The required correction curves were derived using the original tank test results for these ships and were expressed as percentage change in power per 0.1 m change in draught over a range of speeds. A mean curve was produced for every 0.5 m step in draught. The correction curves for variation in draught are shown in Figure (A-3), and the final tabulated corrections to power are given in Column 24 of Tables (A-18) to (A-21).

Speed over the ground, as calculated from individual position fixes obtained from the satellite navigator, has been used as the principal measure of speed. A basic assumption for fitting a mean speed-power curve to the corrected set of power date is that with a sufficient number of inter-fix recordings in both directions on a complete round voyage, the net effect of ocean currents will be zero. From routing charts the ocean currents on the roundtrip voyage covered in this experiment were found to be predominantly "following" on the outward bound part of the voyage and "against" on the homeward bound part. Hence as long as an equal number of inter-fix periods are obtained "out" and "home", and both data sets are equally distributed over the speed and power range included in the analysis, then this assumption will be valid.

In the first experiment, the above conditions for averaging out the effects of ocean currents were satisfied. However, a different situation arose with the second experiment in which there was not an equal distribution of outward and homeward bound data over the complete speed and power range. In the case of Ship A, all the outward bound data were at relatively high speeds and the homeward bound data at low speeds, while for Ship E, the low speeds occured outward bound and the higher range homeward bound.

As a result of this different situation a more detailed examination had to be made of ocean currents, since an error in the applied current correction would have significant effect on the slope of the deduced speed-power curve.

The method adopted was to make use of the pitot log distance reading and calculate the difference between observed distance and log distance for each leg of the voyage, and hence obtain the difference between mean observed speed and mean log speed. This mean difference can, however, not be used as a measure of average current since the recorded log speed will nearly always contain a calibration error. This calibration constant is determined by assuming equal magnitude of average strength of currents on the outward and homeward bound leg of the voyage. The average net current bias, with which all the recorded observed speeds are to be corrected, is subsequently calculated for the total voyage of each vessel.

As a result of this analysis, two sets of measurements of speed through the water were obtained. In this particular exercise, the observed speed was considered to be the most accurate and most reliable measurement of speed and was therefore used as the primary measurement. The log speed was used to obtain the current corrections as described above and as a secondary measurement of speed to be used as a consistency check.

This method of correcting for the effects of ocean currents has subsequently been applied to the complete data set of each vessel from both experiments.

A-5.2 ANALYSIS OF SPEED AND POWER DATA FROM THE FIRST EXPERIMENT

A-5.2.1 SPEED AND POWER RELATED

For ship A, a total of 90 good weather interfix periods were obtained, and for ship E the corresponding number was 78. In both cases, the periods covered a total of approximately 10,000 miles of deep sea passage.

Corrections to power were made for the effect of direct wind resistance and changes in draught as described in the previous section. Malfunction of the speed log resulted in only 71 and 70 interfix periods for Ship A and Ship E respectively being suitable for the calculation of the current correction. The calculations for the current correction and speed log calibration are presented in Tables (A-1) and (A-2).

TABLE (A-1) CURRENT CORRECTION SHIP A, FIRST EXPERIMENT

	TOTAL TIME	OBS DISTANCE	LOG DISTANCE	AVERAGE (OBS SPEED-LOGSPEED)
OUT	182.8 hrs.	3749.1 miles	3670.5 Miles	0.43 knots
HOME	211.6 hrs.	4313.4 miles	4289.1 miles	0.11 knots

Average net current bias = $\frac{0.43-0.11}{2}$ = 0.16 knots (following out and against home)

Log calibration constant = 0.43-0.16 = +0.27 knots (i.e. speed log is 0.27 knots slow)

TABLE (A-2) CURRENT CORRECTION SHIP E, FIRST EXPERIMENT

	TOTAL TIME	OBS DISTANCE	LOG DISTANCE	AVERAGE (OBS SPEED-LOGSPEED)
OUT	106.0 hrs.	2289.2 miles	2239.4 miles	0.47 knots
HOME	266.9 hrs.	5984.9 miles	5868.7 miles	0.44 knots

Average net current bias = $\frac{0.47-0.44}{2}$ = 0.015 knots (ie: negligible)

Log calibration constant = +0.45 knots (ie: speed log is 0.45 knots slow)

After correcting observed speeds for the average net current bias a mean speed power curve was fitted based on logarithmic regression.

The following equations between speed power were obtained:

SHIP A: $P_{A1} = 1.808V^{3.074}$ with a correlation coefficient r=0.925

SHIP E: $P_{E1} = 1.882V^{3.095}$ with correlation coefficient r=0.926

P = power delivered to the propeller measured in kW (allowing for 2% loss in shafting).

V = observed speed corrected for average current bias, measured in knots.

For the same speeds the difference in power between those two mean lines over the speed range is substantially constant and

$$\frac{P_{E1} - P_{A1}}{P_{A1}} = 10.7\%$$

[see Figure (A-8)]

Compared with a similar value of 11.4% obtained when current corrections were not applied this demonstrates that current corrections are not critical when recorded data in both current directions show an equal distribution over the speed/power range.

A-5.2.2 CALCULATION OF DIFFERENCE IN ENERGY CONSUMPTION USING TORSION METERS

This method of calculation has been adopted, as explained in the introduction to this chapter, in order to yield a single representative number as a measure of performance for comparison purposes between the two ships.

$$\sum \frac{(\text{average power}) \times (\text{time})}{(\text{corrected observed distance})}$$

represents the energy per nautical mile to drive the ship.

Table (A-3) CALCULATION OF ENERGY REQUIREMENT PER MILE, FIRST EXPERIMENT

	SHIP A	SHIP E
Power x Time	9.881×10^6 kW hr	12.232×10^6 kW hr
Total Distance	10107.9 miles	9759.4 miles
Total Time	488.40 hrs	440.86 hrs
Average Speed	20.70 knots	22.14 knots
Average Power	20230 kW	27740 kW
$\frac{\text{Power x Time}}{\text{Distance}}$	0.9776×10^3 $\frac{\text{kW hr}}{\text{mile}}$	1.25341×10^3 $\frac{\text{kW hr}}{\text{mile}}$

A higher average speed and power will result in a higher energy requirement per mile for the same ship, and this is corrected by using the regressed mean speed power curve.

TABLE (A-4) CORRECTION FOR DIFFERENT MEAN SPEED

(Correcting Ship E to the mean speed of Ship A)

Mean Speed Power	20.70 knots 22260 kW	22.14 knots 27410 kW
$\frac{\text{Power x Time}}{\text{Distance}}$	$1.0754 \times 10^3 \ \frac{\text{kW hr}}{\text{mile}}$	$1.2381 \times 10^3 \ \frac{\text{kW hr}}{\text{mile}}$

Hence correction = $1.2381 \times 10^3 - 1.0754 \times 10^3 = \underline{0.1627 \times 10^3} \ \frac{\text{kW hr}}{\text{mile}}$

which is the extra energy consumption per mile due to the higher speed only. The corrected energy consumption per mile is given in Table(A-5).

TABLE (A-5) ENERGY REQUIREMENT PER MILE FOR SHIP A AND SHIP E

FIRST EXPERIMENT

	SHIP A	SHIP E
Corrected $\frac{\text{Power x Time}}{\text{Distance}}$ (at 20.70 knots)	$0.9776 \times 10^3 \ \frac{\text{kW hr}}{\text{mile}}$	$1.0907 \times 10^3 \ \frac{\text{kW hr}}{\text{mile}}$

In percentage terms this difference is 11.6%, which is in satisfactory agreement with the mean difference of 10.7% in power between the two speed/power curves.

A-5.2.3 AVERAGE SPEED AFTER CORRECTING TO A CONSTANT POWER BASIS

In statistical terms a more satisfactory single number representation of the vessel is obtained by calculating the average speed, after first having corrected each individual speed-power point to a selected standard power value using the speed-power curve from regression analysis. Effectively, this is the same as taking the centroid of the data set used in the regression analysis as a representative number of the complete sample, or in other words, transforming the speed and power values into a logarithmic scale and taking the mean of each. Transformed back into the normal speed and power scales this will yield a single representative point for each vessel on each occasion. Using one vessel as basis, the average speed and power value for the second vessel can subsequently be corrected to the same basis and the difference in performance between the two vessels can be calculated.

The results for Ship A and Ship E in the first experiment are shown in Table (A-6).

TABLE (A-6) RESULTS FOR SHIP A AND SHIP E AFTER CORRECTING TO A CONSTANT POWER BASIS, FIRST EXPERIMENT

	SPEED (knots)	POWER (kW)	POWER CORRECTED TO THE SPEED OF SHIP A
SHIP A	20.723	20150	20150
SHIP E	22.100	27270	22350

In percentage terms the difference is 10.9%. This is in good agreement with the results obtained from the previous two methods.

A-5.3 ANALYSIS OF SPEED AND POWER DATA FROM THE SECOND EXPERIMENT

A-5.3.1 SPEED AND POWER RELATED

For Ship A a total number of 109 good weather interfix periods were obtained, covering a total of about 10,000 miles of deep sea passage, and for Ship E the corresponding numbers were 88 good weather interfix periods and approximately 8,000 miles of deep sea passage. Again, both vessels were operating over a wide range of engine power, but the distribution of data over the speed-power range on each leg of the voyage was unequal as discussed in Section A-5.1. It was therefore essential that the average net current bias was calculated and corrected for prior to obtaining a mean speed-power curve based on logarithmic regression techniques.

Malfunction of the speed log resulted in only 105 and 85 of the interfix periods for Ship A and Ship E respectively being suitable for the calculation of current correction. The calculation for current correction and speed log calibration are presented in Tables (A-7) and (A-8).

TABLE (A-7) CURRENT CORRECTION SHIP A, SECOND EXPERIMENT

	TOTAL TIME	OBS DISTANCE	LOG DISTANCE	AVERAGE (OBS SPEED-LOG SPEED)
OUT	212.8 hrs	4770.8 miles	4670.1 miles	+0.48 knots
HOME	234.4 hrs	4766.0 miles	4894.0 miles	-0.08 knots

Average net current bias = $\dfrac{0.488-(0.08)}{2}$ = <u>0.28 knots</u> (following out and against home)

Log calibration constant = 0.48-0.28 = <u>0.20 knots</u> (slow)

TABLE (A-8) <u>CURRENT CORRECTION SHIP E, SECOND EXPERIMENT</u>

	TOTAL TIME	OBS DISTANCE	LOG DISTANCE	AVERAGE (OBS SPEED-LOG SPEED)
OUT	224.0 hrs.	4327.3 miles	4303.0 miles	0.11 knots
HOME	153.4 hrs.	3547.9 miles	3558.1 miles	-0.07 knots

Average net current bias = $\dfrac{0.11-(0.07)}{2}$ = <u>0.09 knots</u> (following out and against home)

Log Calibration constant = 0.11-0.09 = <u>+0.02 knots</u> (i.e. negligible)

After correcting observed speeds for the average net current bias a mean speed-power curve was fitted, and the following two equations between speed and power were obtained:

<u>SHIP A:</u> $P_{A2} = 2.404V^{2.990}$ with a correlation coefficient r = 0.920

<u>SHIP E:</u> $P_{E2} = 3.129V^{2.934}$ with a correlation coefficient r = 0.979

For the same speeds the difference in power between these two mean lines over the common speed range is substantially constant and

$$\frac{P_{E2} - P_{A2}}{P_{A2}} = 10.2\%$$ [see Figure(A-8)]

A-5.3.2 CALCULATION OF DIFFERENCE IN ENERGY CONSUMPTION USING TORSION METERS

In Section A-5.2.2 a calculation was made for the energy required per nautical mile to drive each ship in order to yield a single representative number for comparison purposes with the data collected in the first experiment. In order to enable a similar comparison between the two ships in the second part of the experiment and also to enable a comparison of the results for the same ship after a period of 12 months, this calculation was repeated for the new set of data from the second experiment.

$$\sum \frac{\text{(average power) x (time)}}{\text{(corrected observed distance)}}$$ represents the energy per nautical mile to drive the ship

TABLE (A-9) CALCULATION OF ENERGY REQUIREMENT PER MILE, SECOND EXPERIMENT

	SHIP A	SHIP E
Power x Time	10.895×10^6 kW hr	9.244×10^6 kW hr
Total Distance	10197.4 miles	8059.5 miles
Total Time	479.2 hrs	387.5 hrs
Average Speed	21.28 knots	20.80 knots
Average Power	22740 kW	23850 kW
$\frac{\text{Power x Time}}{\text{Distance}}$	1.0684×10^3 $\frac{\text{kW hr}}{\text{mile}}$	1.1469×10^3 $\frac{\text{kW hr}}{\text{mile}}$

In order make the comparison on the same basis, all values are corrected to the mean speed of Ship A in the first experiment of 20.70 knots.

TABLE (A-10) CORRECTION FOR DIFFERENT MEAN SPEED

	SHIP A		SHIP E	
Mean Speed Power	20.70 knots 20690 kW	21.28 knots 22470 kW	20.70 knots 22720 kW	20.80 knots 23050 kW
$\frac{\text{Power x Time}}{\text{distance}}$	$0.9993 \times 10^3 \frac{kW\ hr}{mile}$	$1.0558 \times 10^3 \frac{kW\ hr}{mile}$	$1.0997 \times 10^3 \frac{kW\ hr}{mile}$	$1.1080 \times 10^3 \frac{kW\ hr}{mile}$

Correction Ship A: $1.0558 \times 10^3 - 0.9993 \times 10^3 = 0.0565 \times 10^3 \frac{kW\ hr}{mile}$

Correction Ship E: $1.1080 \times 10^3 - 1.0977 \times 10^3 = 0.0103 \times 10^3 \frac{kW\ hr}{mile}$

The corrected energy consumption per mile is given in Table (A-11).

TABLE (A-11) ENERGY REQUIREMENT PER MILE FOR SHIP A AND SHIP E, SECOND EXPERIMENT

	SHIP A	SHIP E
Corrected $\frac{\text{Power x Time}}{\text{Distance}}$	$1.0119 \times 10^3 \frac{kW\ hr}{mile}$	$1.1366 \times 10^3 \frac{kW\ hr}{mile}$

In percentage terms this difference is 12.3% between the two ships.

A-5.3.3 AVERAGE SPEED AFTER CORRECTING TO A CONSTANT POWER BASIS

As explained in Section A-5.2.3, a more satisfactory single number representation of the vessel performance in statistical terms is obtained from the centroid of the speed/power data when transformed to a logarithmic scale for use in the linear regression analysis. The results for Ship A and Ship E in the second experiment are shown in Table (A-12). For the purpose of comparison with the results of the previous experiment, the speed and power values have been corrected to the speed of Ship A in the first experiment using the regressed speed/power curves.

TABLE (A-12). RESULTS FOR SHIP A AND SHIP E AFTER CORRECTING TO A CONSTANT POWER BASIS, SECOND EXPERIMENT

	SPEED (knots)	POWER (kW)	POWER CORRECTED TO THE SPEED OF SHIP A IN THE FIRST EXPERIMENT
SHIP A	21.267	22420	20750
SHIP E	20.626	22490	22800

In percentage terms the difference between the two vessels is 9.9% which is in good agreement with the first method of comparing the individual speed/power curves and in reasonable agreement with the results obtained from the calculation of energy requirement per mile.

A-5.4 COMPARISON OF SPEED AND POWER PERFORMANCE RESULTS FOR THE TWO EXPERIMENTS

A comparison between the two mean speed/power curves from the first experiment, as analysed in Section A-5.2 and shown in Figures (A-4) and (A-5), shows an average difference between the two ships of 10.7%. The same analysis performed on the data collected 12 months later, as shown in Section A-5.3 and Figures (A-6) and (A-7), indicates an average difference between the two ships of 10.2%. An individual comparision of each vessel after this 12 month period shows that the performance of Ship A has deteriorated approximately 2% while Ship E shows an average deterioration of about 1.5% in power terms, although these figures are too small for any conclusions to be drawn about the change in performance of each ship over the 12 month period.

In the case of Ship A the mean speed/power curves for the two experiments are parallel, while for Ship E this is not strictly true. Furthermore, the speed/power curves cover slightly different ranges of speed and power. A mean speed/power curve based on logarithmic regression is already a compromise to obtain a best fit line, since a true speed/power curve of the form $P = k \cdot V^n$ will have a continuously changing exponent N with varying speed V, and an attempt to extend the curve beyond its regression boundaries will introduce errors. It therefore follows that a single number representation of change in performance evaluated on the basis of speed/power curves only will not be an entirely accurate and reliable measure.

A simple and more practical method of obtaining a single number for comparison purposes is the calculation of energy requirement per mile as presented in Sections A-5.2.2 and A-5.3.2. In these calculations each interfix period carried equal weight in the analysis, and the mean speed/power curve only is utilised in the process of correcting the values to the same basis of mean speed. If a speed/power curve is not available, the approximate relationship $P = k \cdot V^n$ can be used.

In Section A-5.2.2 it was shown that based on the calculations of energy consumption per mile there was, in the first experiment, a difference in performance between the two vessels of 11.6%. After a period of 12 months in service this difference had increased to 12.3% as shown in Section A-5.3.2. An individual comparison of the results of each vessel by this method has shown that the performance of Ship A deteriorated by 3.5% over this 12 month period, while Ship E deteriorated by 4.2% over the same period. This method has the advantage of making no initial assumption about the relationship between speed and power, and the calculation procedure is simple. An error will, however, be introduced due to the fact that no account is taken of the gradually increasing rate of change in the energy requirement per mile with an increasing speed.

The final method, believed in statistical terms to be the most correct, has yielded a single representative number for each vessel on each occasion after first transforming the speed and power values to a logarithmic scale and taking the mean of each. In percentage terms the difference in performance between Ship A and Ship E in the first experiment was found to be 10.9%, and in the second experiment the difference had been reduced to 9.9%. An individual comparison of each vessel between the two experiments indicated a deterioration of 3.0% for Ship A and 2.0% for Ship E.

Clearly, this method is only correct if the linear relationship between the transformed value of speed and power is true.

A-5.5 STATISTICAL INTERPRETATION OF THE MEASURED PERFORMANCE RESULTS

The performance monitoring experiment has yielded a set of measurements of the two variables speed and power on the sisterships on two occasions a year apart. Each set of measurements can be regarded as an independent group giving a total of 4 groups obtained from the complete experiment. The data analysis has hitherto been centered around the analysis within each group, and the comparisons made between groups have simply been based upon the "within group" results in terms of mean values. The regression lines fitted to each group have been based upon the general linear model

$$Y_{ti} = \alpha_t + \beta_t X_{ti} + Z_{ti} \qquad (t = 1, \ldots.. k \ , \ i = 1, \ldots.. n \ )$$

where Speed is the independent variable and takes the transformation X = ln(Speed) and Power is the dependent variable with the transformation Y = ln(Power) and Z_{ti} represents the random residual for each observation. This residual variable complies with the following 4 assumptions.

1) Expected value of Z_{ti} is zero for all t and i
2) All values of Z_{ti} are mutually independent
3) Variance of Z_{ti} is constant for all t and i
4) The variable Z_{ti} is normally distributed

In the general case with t groups of bivariate observations and regression lines fitted to each individual group according to the above model, an obvious natural extension to this analysis is to consider whether it is possible for a single linear regression line $Y = \alpha + \beta X$ to represent all the t groups of observations. In other words, we have the linear hypothesis:

$H_o \; : (\alpha_1 = \alpha_2 = \ldots\ldots = \alpha_k \text{ and } \beta_1 = \beta_2 = \ldots\ldots = \beta_k)$

The test of this hypothesis will yield an answer to the question of whether all the groups can in fact be represented by a single regression line, or alternatively, the level of significance at which the null hypothesis is rejected and the alternative hypothesis of separate individual regression lines for each group can be accepted. The above linear hypothesis is most conveniently split into 3 parts where each part can be tested separately.

(1)	Null Hypothesis $H_o(1)$:	The regression lines are parallel, $\beta_1 = \beta_2 = \ldots\ldots\ldots \beta_k$
	Alternative Hypothesis $H_1(1)$:	The regression lines are not parallel
(2)	Null Hypothesis $H_o(2)$:	The group means lie on a straight line, i.e. the residual sum of squares for the regression line on the points $[\bar{X}_t, (\alpha_t + \beta_t\bar{X})]$ is zero.
	Alternative Hypothesis $H_1(2)$:	The group means does not lie on a straight line
(3)	Null Hypothesis $H_o(3)$:	The slope of the regression line on the group means equals the common value of $\beta_1 \ldots\ldots \beta_k$
	Alternative Hypothesis $H_1(3)$:	The slope of the regression line on the group means is not equal to the common value of $\beta_1 \ldots\ldots \beta_k$

The test of each Null Hypothesis is conducted in accordance with the principles for the analysis of variance where ratios of sums of squares are compared with the appropriate points on the F- distribution. The basic parameters required for the test are set out in the following table:

ANALYSIS OF COVARIANCE TABLE

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Common regression line	1	$S_G = w_o B_o^2$	S_G
Slope of group means vs. Average within group slope	1	$S_{WG} = \frac{w_c w_m}{w_o}(B_c - B_m)^2$	S_{WG}
Residual about linear regression - of group means	k-2	$S_G = \sum_{t=1}^{k} n_t [\bar{Y}_t - \bar{Y} - B_m(\bar{X}_t - \bar{X})]^2$	$S_G/(k-2)$
Between within group slopes	k-1	$S_w = \sum_{t=1}^{k} w_t (B_t - B_c)^2$	$S_w/(k-1)$
Residual about within group - linear regression (sep.reg.lines)	N-2k	$S_R = \sum_{t=1}^{k}\sum_{i=1}^{n_t}[Y_{ti} - \bar{Y}_t - B_t(X_{ti} - \bar{X}_t)]^2$	$S_R/(N-2k)$
TOTAL	N-1	$\sum_{t=1}^{k}\sum_{i=1}^{n_t}(Y_{ti} - \bar{Y})^2$	

The symbols used can briefly be explained as:

$$w_t = \sum_{i=1}^{n_t}(X_{ti} - \bar{X}_t)^2 \quad \text{and} \quad B_t = \sum_{i=1}^{n_t}(Y_{ti} - \bar{Y}_t)\cdot(X_{ti} - \bar{X}_t)/w_t$$

$$w_c = \sum_{t=1}^{k} w_t \qquad B_c = [\sum_{t=1}^{k} w_t B_t]/w_c$$

$$w_m = \sum_{t=1}^{k} n_t (\bar{X}_t - \bar{X})^2 \qquad B_m = \sum_{t=1}^{k} n_t (\bar{X}_t - \bar{X})\cdot(\bar{Y}_t - \bar{Y})$$

$$N = \sum_{t=1}^{k} n_t \qquad \bar{X}_t = \sum_{i=1}^{n_t} X_{ti}/n_t \qquad \bar{X} = \sum_{t=1}^{k}\sum_{i=1}^{n_t} X_{ti}/N$$

$$\bar{Y}_t = \sum_{i=1}^{n_t} Y_{ti}/n_t \qquad \bar{Y} = \sum_{t=1}^{k}\sum_{i=1}^{n_t} Y_{ti}/N$$

- $H_o(1)$ is tested by comparing the mean square ratio $\frac{S_W/(k-1)}{S_R/(N-2k)}$ with the F distribution with (k-1), (N-2k) degrees of freedom

- $H_o(2)$ is tested by comparing the mean square ratio $\frac{S_G/(k-2)}{S_R/(N-2k)}$ with the F distribution with (k-2), (N-2k) degrees of freedom

- $H_o(3)$ is tested by comparing the mean square ratio $\frac{S_{wa}}{S_R/(N-2k)}$ with the F distribution with 1, (N-2k) degrees of freedom

In all 3 cases a two tailed test must be used because of the way the alternative hypothesis is formulated.

The problem under consideration consists in total of 4 groups of bivariate observations. However, the primary objective is to examine the difference in performance between the two vessels on each occasion, and the comparative study of changes in performance on each vessel from one occasion to the next is only a secondary interest. Each analysis performed will therefore consist of 2 groups of observations only, and the test of the second null hypothesis, $H_o(2)$, becomes redundant because the residual about linear regression of group means is always zero with zero degrees of freedom. Only tests of $H_o(1)$ and H_o (3) will therefore be required.

A-5.5.1 TEST OF RESULTS FOR SHIP A AND SHIP E, FIRST EXPERIMENT

Number of observations for Ship A: 90
Number of observations for Ship E: 78

TABLE (A-13) ANALYSIS OF COVARIANCE, SHIPS A AND E, FIRST EXPERIMENT

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Common regression line	1	9.06708	
Slope of group means vs. average within group slope	1	0.3493	0.3493
Between within group slopes	1	0.00006	0.00006
Residual about within group - linear reg.	164	0.9393	0.000573
TOTAL	167	10.3557	

Null Hypothesis $H_o(1)$: F ratio $= \frac{0.00006}{0.00573} = \underline{0.0105}$

Null Hypothesis $H_o(3)$: F ratio $= \frac{0.3493}{0.00573} = \underline{60.96}$

From statistical tables: $F_{0.02,1,164} = \underline{10.8}$ and $F_{0.20,1,164} = \underline{2.7}$

The null hypothesis $H_o(1)$ is therefore clearly accepted, while the null hypothesis $H_o(3)$ is rejected at the 0.2% level. In other words, there is clear statistical evidence that the regression lines on Ship A and Ship E are parallel, while there is less than 0.2% chance that the measured difference between Ships A and E could have occured by chance only. We are therefore more than 99.8% confident that there is a true difference in performance between Ship A and Ship E in the first experiment.

A-5.5.2 TEST OF RESULTS FOR SHIP A AND SHIP E, SECOND EXPERIMENT

Number of observations for Ship A: 109
Number of observations for Ship E: 88

TABLE (A-14) ANALYSIS OF COVARIANCE, SHIPS A AND E, SECOND EXPERIMENT

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Common regression line	1	10.21036	
Slope of group means vs. Average within group slope	1	0.40945	0.40945
Between within group slopes	1	0.00007	0.00007
Residual about within group linear reg.	193	0.813	0.00421
TOTAL	196	11.4334	

Null Hypothesis $H_0(1)$: F ratio $= \frac{0.00007}{0.00421} = \underline{0.0166}$

Null Hypothesis $H_0(3)$: F ratio $= \frac{0.40945}{0.00421} = \underline{97.26}$

From statistical tables: $F_{0.002, 1, 193} = \underline{10.8}$ and $F_{0.20, 1, 193} = \underline{2.7}$

The null hypothesis $H_0(1)$ is therefore clearly accepted while the null hypothesis $H_0(3)$ is rejected at the 0.2% level. Again therefore, clear statistical evidence exists that the regression lines on Ship A and Ship E are parallel while there is less than 0.2% chance that the measured difference in performance between Ships A and E could have occured by chance only. We are therefore more than 99.8% confident that there is a true difference in performance between Ship A and Ship E in the second experiment.

A-5.5.3 A COMPARATIVE TEST OF RESULTS BETWEEN THE TWO EXPERIMENTS FOR SHIP A

Number of observations for Ship A, first experiment: 90
Number of observations for Ship A, second experiment: 109

TABLE (A-15) ANALYSIS OF COVARIANCE, SHIP A, FIRST AND SECOND EXPERIMENT

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Common regression line	1	5.90353	
Slope of group means vs. Average within group slope	1	0.03652	0.03652
Between within group slopes	1	0.00100	0.00100
Residual about within group linear reg.	195	0.94354	0.004839
TOTAL	198	6.88459	

Null Hypothesis $H_o(1)$: F ratio $= \frac{0.00100}{0.004839} = \underline{0.2067}$

Null Hypothesis $H_o(3)$: F ratio $= \frac{0.03652}{0.004839} = \underline{7.547}$

From statistical tables: $F_{0.02,1,195} = \underline{6.6}$

Again, the null hypothesis $H_o(1)$ is clearly accepted while the null hypothesis $H_o(3)$ is rejected at the 2% level. Clear statistical evidence therefore exisits that the measured difference in performance between the first and the second experiment could not have occured by chance only.

A-5.5.4 COMPARATIVE TEST RESULTS BETWEEN THE TWO EXPERIMENTS FOR SHIP E

Number of observations for Ship E, first experiment: 78
Number of observations for Ship E, second experiment: 88

Table (A-16) ANALYSIS OF COVARIANCE, SHIP E, FIRST AND SECOND EXPERIMENT

SOURCE	DEGREE OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Common regression line	1	12.3590	
Slope of group means vs. Average within group slope	1	0.00545	0.00545
Between within group slopes	1	0.00504	0.00504
Residual about within group - liner reg.	162	0.80929	0.00500
TOTAL	165	13.1788	

Null Hypothesis $H_0(1)$: F ratio $= \frac{0.00504}{0.00500} = \underline{1.008}$

Null Hypothesis $H_0(3)$: F ratio $= \frac{0.00545}{0.00500} = \underline{1.09}$

From statistical tables: $F_{0.002, 1, 162} = \underline{10.8}$ and $F_{0.20, 1, 162} = \underline{2.7}$

The level of significance for an F ratio of unity with 1 and 162 degrees of freedom is in fact 64%. Both null hypothesis $H_0(1)$ and $H_0(3)$ are therefore accepted and we conclude that the regression lines for Ship E in the two experiments are parallel, and that there is no significant difference in the results from the first to the second experiment.

A-6 HULL ROUGHNESS SURVEYS

Prior to the first experiment a hull roughness survey was carried out on Ship A in drydock, and a weighted value of 136 μm AHR was found.

The roughness history of Ship E is incomplete, and as a consequence of this an underwater roughness survey was performed at the end of the first voyage. This was the first time that the BSRA hull roughness analyser had been used under water, and the survey only covered the sides of the vessel. The AHR of the sides was found to be 384 μm but unfortunately no measurements could be taken on the flat bottom, and the survey therefore remains incomplete.

Further development of the underwater measurement technique proved successful, and it was therefore decided to perform underwater roughness surveys on both vessels at the end of the second experiment, and subsequently to compare the measured difference in AHR in more detail.

For Ship A a complete survey covering 96 locations on the hull was obtained and weighted AHR of 147 μm calculated. An identical survey of Ship E covering 84 locations yielded a weighted AHR of 452 μm. The results of the hull roughness survey for both vessels in the two experiments are given in Table (A-17). As shown, the weighted AHR of Ship A has over the 12 month period increased from 136 μm to 147 μm. This difference of only 11 μm is less than the stated error bounds of the measuring instrument, and the conclusion will therefore have to be that the AHR of Ship A have remained unchanged over the 12 month period.

TABLE (A-17) HULL ROUGHNESS SURVEYS, SHIPS A AND E, BOTH EXPERIMENTS

	EXPERIMENT 1		EXPERIMENT 2	
	SHIP A	SHIP E	SHIP A	SHIP E
Slides	129 μm (2)	384 μm (1)	134 μm (1)	430 μm (1)
Flats	149 μm	-	172 μm (1)	493 μm (1)
Mean AHR	139 μm	-	153 μm (1)	462 μm (1)
Weighted AHR (3)	136 μm	-	147 μm (1)	452 μm (1)

(1) Underwater survey

(2) One side only

(3) For the weighting, the ratio of sides to flat of bottom is taken as: 0.65 : 0.35

The sides of Ship E show a significant increase in roughness from 384 to 439 μm. Unfortunately measurements could not be taken on the flats of Ship E at the time of the first experiment, and a total AHR can only be obtained by estimating roughness of the flats on the basis of the measurements taken 12 months later. It is unlikely that the roughness on the flats of Ship E will have decreased over the 12 months. If it has remained unchanged over the period at 493 μm the weighted AHR at the time of the first experiment would have been 422 μm. On the other hand, if the roughness has increased at the average rate since new over this 12 month period the roughness of the flats at the time of the first experiment would have been 450 μm giving a weighted AHR of 400 μm. The estimated AHR for Ship E during the first experiment is therefore in the region 400 to 420 μm, but since this is only an estimate it should also be treated as such in the following evaluations.

The average hull roughness of a vessel is obtained by calculating the weighted average of the mean roughness at each measurement location. Although it is this AHR value that is required for relating hull roughness to speed and power performance, it does not give a very good description of what is happening to the hull surface itself over a period of time. In particular this is true in the case of self polishing coatings, where a major part of the surface may experience a reduction in roughness with time, but because of some areas of high roughness readings due to damage, the overall result may be that the AHR has increased. A better method for demonstrating both trends in polishing and roughening is to plot a frequency distribution of the total number of ungrouped data from all measurement locations. The plots of frequency distributions comparing the roughness surveys on Ship A and Ship E in the two experiments are shown in Figures (A-9), (A-10) and (A-11). In Figure (A-11) it can be seen that the sides of Ship E have deteriorated further over the past 12 months, and the mean has increased, mainly due to the large increase in values above 500 μm. In Figure (A-10) a similar frequency distribution for the sides of Ship A show that the modal value of the distribution has decreased, indicating that a major part of the surface has experienced a reduction in roughness. At the same time there has been an increase in high roughness values from damage to the surface, and the overall effect is that the mean roughness value remains approximately the same as 12 months earlier.

The same development can be seen in Figure (A-9) only more dramatically. The flats on Ship A have suffered some detachment from the earlier system, and as a result of this the proportion of high roughness readings (above 500 μm) has increased from 0.9% to 6.0%. Although a major part of the surface has experienced a reduction in the local roughness as indicated by the reduction in modal value, this is not sufficient to offset the increased proportion of high readings, and as a result the mean roughness value shows an increase.

As a further continuation in monitoring of the hull surface condition on these two sisterships, another underwater hull roughness survey was carried out 4 months after the completion of the second monitoring experiment. Due to repeated failure of the BSRA hull roughness analyser to work underwater, readings were obtained for only about 70% of the underwater hull surface. For the sides a total number of 55 measurement locations were obtained and this constitutes a sufficiently large sample to enable comparison with the earlier surveys. For the flats, however, only 16 measurement locations were obtained and greater care should be taken when comparing this result with the previous surveys. The 55 measurement loations on the sides yielded an average roughness value of 123 µm, while for the flats the corresponding value for the 16 measurement locations was 176 µm. This gave a weighted AHR for the complete ship of 140 µm and served as confirmation of the results obtained 4 months earlier.

A-7 POWER AND ROUGHNESS RELATED

The fundamental relationship: $\Delta C_F \propto \left(\frac{h}{L}\right)^{1/3}$

where ΔC_F is the increment to the total resistance coefficient due to hull roughness.

h is the average hull roughness.

L is the ship length between perpendiculars.

was first suggested by Telfer, [Reference (86)], and later supported by Bowden in his ship-model correlation work, as well as by more recent prediction methods based upon boundary layer integration techniques [Reference (22)]. If this basic relationship is accepted the general linear equation for ΔC_F can be written:

$$10^3 \times \Delta C_F = a \left(\frac{h}{L}\right)^{1/3} + b$$ where a and b are constants.

For the purpose of evaluating the difference in ΔC_F between two roughness levels, only the constant "a" will have to be defined. Estimates of the magnitude of "a" can therefore be made if two roughness levels and the corresponding difference in resistance or power performance is known. The difference in power requirement between two roughness levels, h_1 and h_2 can be expressed:

$$\Delta P = a \times \left[\left(\frac{h_2}{L}\right)^{1/3} - \left(\frac{h_1}{L}\right)^{1/3} \right] \times \frac{\rho S V^3}{2 \times QPC}$$

and therefore $$a = \frac{\Delta P \times 2 \times QPC}{\rho \times S \times V^3 \left[\left(\frac{h_2}{L}\right)^{1/3} - \left(\frac{h_1}{L}\right)^{1/3} \right]}$$ (assuming QPC remains unchanged)

Using this relationship estimates of "a" have been made from the results of the of the two performance monitoring experiments. Since the hull roughness survey on Ship E in the first experiment is incomplete only a probable range of AHR have been given and the calculated values for "a" are subsequently also presented in the form of an estimated range. Results from all 3 methods of calculating the difference in performance between the two vessels are included, although in statistical terms the method of calculating the mean on the basis of transforming the speed and power values to a logarithmic scale is believed to be the most correct.

From the first experiment the estimated values of the constant "a" are as follows:

(i) between 58.2 and 61.4 by direct comparison of the regressed speed/power curves

(ii) between 63.4 and 66.8 on the basis of calculating the energy consumption per mile for each vessel

(iii) between 59.3 and 62.5 by comparing values obtained following a logarithmic transformation of speed and power scales.

The second experiment with complete roughness surveys for both vessels has provided the following set of values for "a":

(i) a = 56.0 by direct comparison of the regressed speed/power curves

(ii) a = 67.3 on the basis of calculating the energy consumption per mile for each vessel

(iii) a = 54.3 by comparing mean values obtained following a logarithmic transformation of speed and power scales

This range of values for the constant "a" clearly does not correspond with the value of a=105, as suggested by Bowden, but are on the other hand in good agreement with the recent results obtained from prediction methods based upon boundary layer integration techniques. It has been suggested that the values of $\triangle C_F$ calculated from Bowden's formula also includes other correlation factors. The present study conforms this statement and tentatively suggests that approximately 60% of the values predicted by Bowden's formula are due to hull roughness and the remaining 40% due to other unexplained factors.

A-8 DISCUSSION OF RESULTS

A true difference in speed/power performance of between 10% and 12% on account of under water hull condition only has been shown to exist between the two vessels included in the present study. This difference has remained practically unchanged over a 12 month period with a slight, although not statistically conclusive deterioration in the performance of each individual vessel over the same time period. The assumption that the difference in speed/power performance is due to a difference in underwater hull condition only has been substantiated by the repeated underwater inspections and hull roughness measurements carried out on the two vessels. At the time of the first experiment when Ship E had been out of dock for a period of 14 months, the underwater hull was reported to be free from macroscopic fouling, and the propellers were also reported to be free from any marine growth. After completion of the second experiment both vessels were again examined for the presence of fouling. Ship A was reported to be clean, while Ship E had a small band of weed fouling just below the waterline extending around the complete ship. In terms of area, this fouling covered less than 4% of the total wetted surface area, and the effects upon performance were assumed negligible. The propellers on both vessels were reported to be clean, apparently undamaged and of similar surface condition according to visual inspections by divers. All propellers had some long standing cavitation damage at the tips, but of small extent. The nearly complete absence of hull fouling on the conventionally coated Ship E after a period of 26 months in service is quite remarkable. The lifetime of the antifouling system, as claimed by the manufacturer, is only of the order of 18 months, and the system must therefore be said to have performed extraordinarily well.

Unfortunately, the underwater hull roughness of Ship E after the first experiment was incomplete, and from the point of view of relating differences in hull condition between the two vessels to actual measured differences in speed and power performance, this first experiment was not entirely successful. Although the findings of the first experiment based upon an estimated value of AHR for Ship E are in good agreement with the results of the more successful second experiment, they should be treated with some caution as a result of their unsatisfactory scientific basis.

The comparision of measured differences in hull roughness with measured differences in power requirement at constant speed have been made using a constant propulsive coefficient. This is in accordance with the recommendations in Chapter 1, which concluded that for single screw ships the added resistance due to roughness would result in a decrease in the open water efficiency component, while at the same time, the increased roughness would have the opposite effect of increasing the wake fraction and therefore also the hull efficiency component. The net effect of the two efficiency changes is therefore that they practically cancel each other out and the total efficiency remains more or less unchanged. No data are available for twin screw ships, but it is belived that the changes in wake fraction, and therefore hull efficiency will be less than for single screw ships. However, as shown in Figure (A-2), the higher pitch ratio propellers on the twin screw container vessel experience only half the change in open water efficiency due to the added resistance compared with the lower pitch ratio propellers of the single screw vessels shown in Figure (1.6), and the net effect may be that the total efficiency remains substantially constant for the twin screw ships as well. In the absence of further arguments therefore, it appears to be justified to make use of the results from single screw ships and maintain a constant propulsive coefficient.

The statistical analysis has shown that a true difference in performance exists between the two vessels, but no attempt has been made to quantify the possible experimental error. Principal sources of experimental error are in power readings and speed measurements, but due to the method of data analysis, it is impossible to provide an exact quantification of the total expected error. The large data-samples obtained in each experiment, ranging from a minimum of 78 to a maximum of 109 effectively reduces the random error in the final results to a negligible amount. Instrumental error from the satellite navigator can be assumed zero when only exact satellite fix positions are used. The random errors in the pitot tube log used for estimating current corrections are significant, but due to the large data-samples, the final error in the current corrections are expected to be small. Only the power-meter readings therefore remain as a principal source of error. Tests carried out by the British Ship Research Association, [Reference (87)], have shown the instruments used to be of an accuracy at least as good as the reference instruments employed in the test and therefore within ±2%. Fortunately, the vessels used in this experiment are twin screw with twin sets of instruments, and a continuous check on the relative accuracy between the two instruments could be made on the basis of accurate rpm readings and the propeller characteristics. The relative accuracy was found to be within 1% for both vessels on both occasions. In fact, the only discrepancy observed was a difference of 0.9% in the power readings for each shaft at the same rpm for Ship E, but this was later identified as being mainly due to a difference of 17mm in pitch between the two propellers. The instrumental accuracy of the torsion meters is therefore believed to be nearer to 1% than the value of 2% quoted by BSRA.

A subjective estimate of the total error limits of the experiment would therefore be ±2-2.5%.

In conclusion, a further comment is required about the attempt to relate the measured difference in performance to a measured difference in roughness. The roughness measurements are based upon a single height parameter only and as discussed in Chapter 1, this is not an adequate parameter for describing the relationship between frictional drag and a 3-dimensional surface texture. Present instrumentation, however, are only capable of providing a single peak to trough measure of height, and this is therefore the only parameter on which a comparison between the two vessels could be made.

Recent prediction methods based upon boundary layer integration techniques also indicate a certain speed dependence between roughness and drag, and therefore that the basic relationship

$$10^3 \times \Delta C_F = a\left(\frac{h}{L}\right)^{1/3} + b$$ is not quite correct.

Despite the areas of uncertainty outlined above, the experiment has resulted in a proposed modification to the original correlation formula for hull roughness developed by Bowden as a part of an attempt to separate the contribution due to hull roughness from other correlation factors.

In addition, the range of roughness values covered in the present experiment is approximately twice the range covered in Bowden's work, and this provides some support to the validity of extrapolating the formula to higher values of roughness.

Finally, it is of interest to notice that recent work using prediction methods based upon boundary layer integration techniques have predicted the difference in power performance between Ship A and Ship E in the second experiment to be approximately 8.2% based upon the measured hull roughness values of 147 and 452 μm, respectively, [Reference (22)].

FIGURE (A-1)
LEVEL OF WIND COEFFICIENT C_x AT
DIFFERENT ANGLES OF APPARENT WIND γ_R

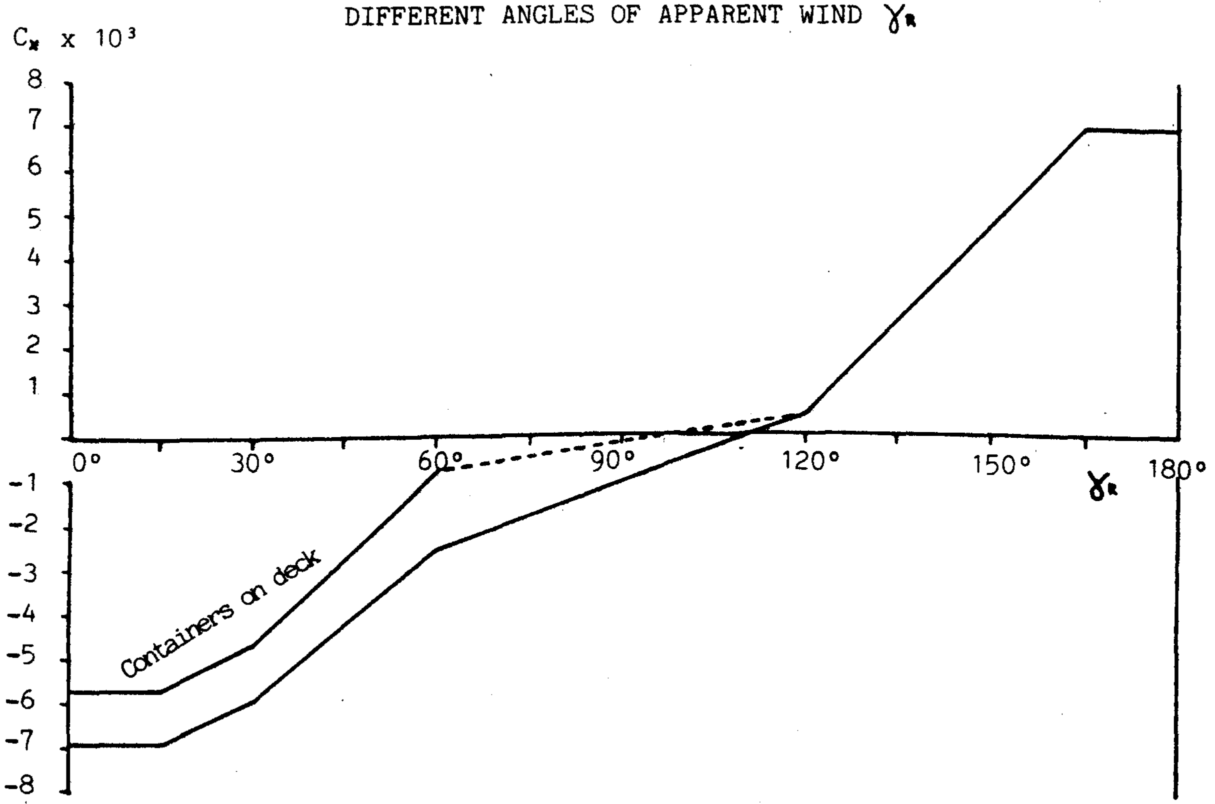


FIGURE (A-2)
EFFECT OF ADDED RESISTANCE ΔR
ON PROPELLER EFFICIENCY η_o

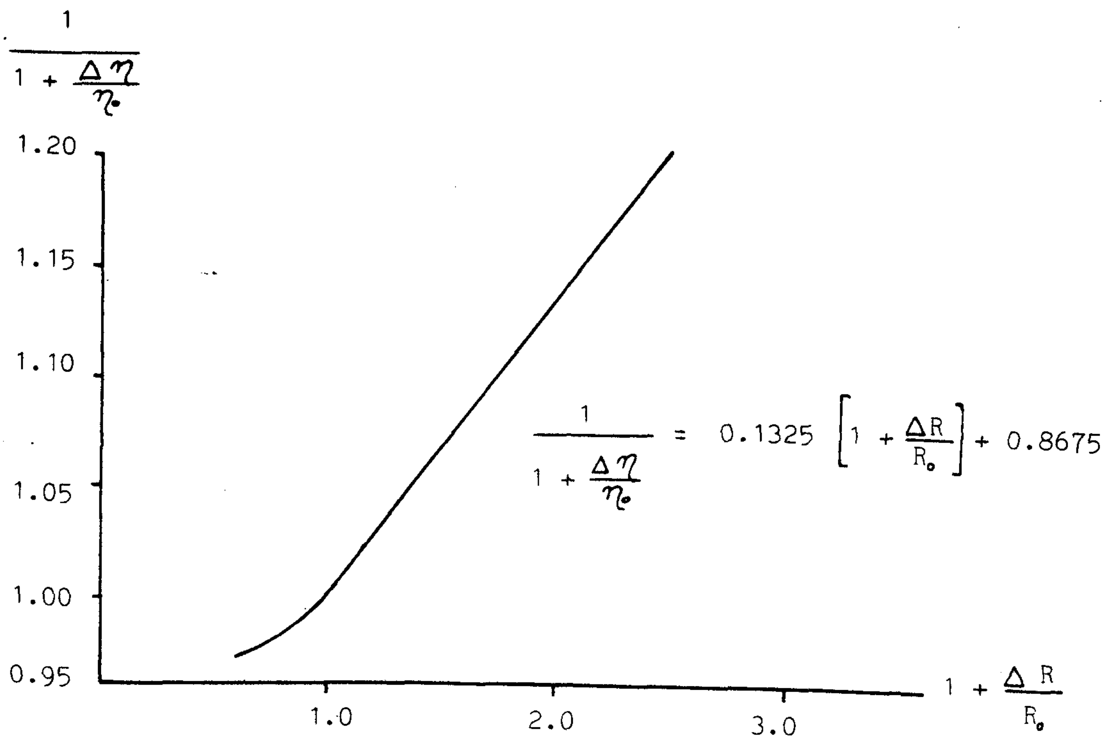


FIGURE (A-3)
PERCENTAGE CHANGE IN POWER REQUIREMENT
PER 0.1m CHANGE IN DRAUGHT

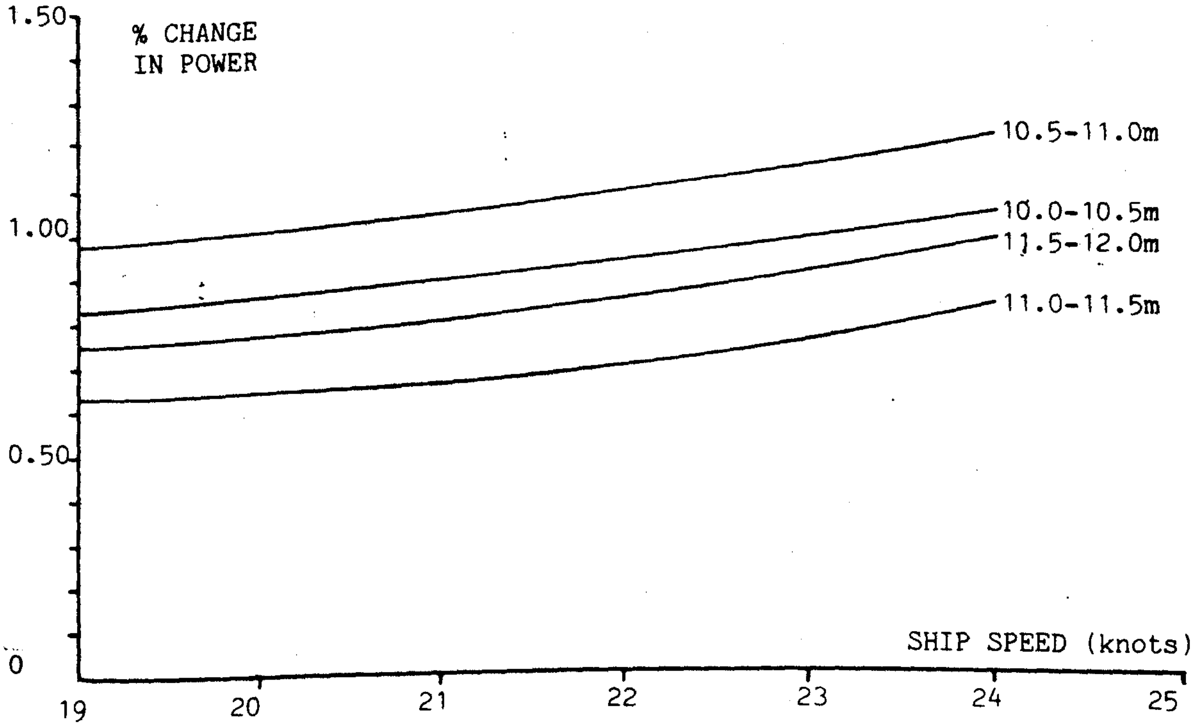


FIGURE (A-4)
SPEED vs POWER FOR SHIP A
FIRST EXPERIMENT

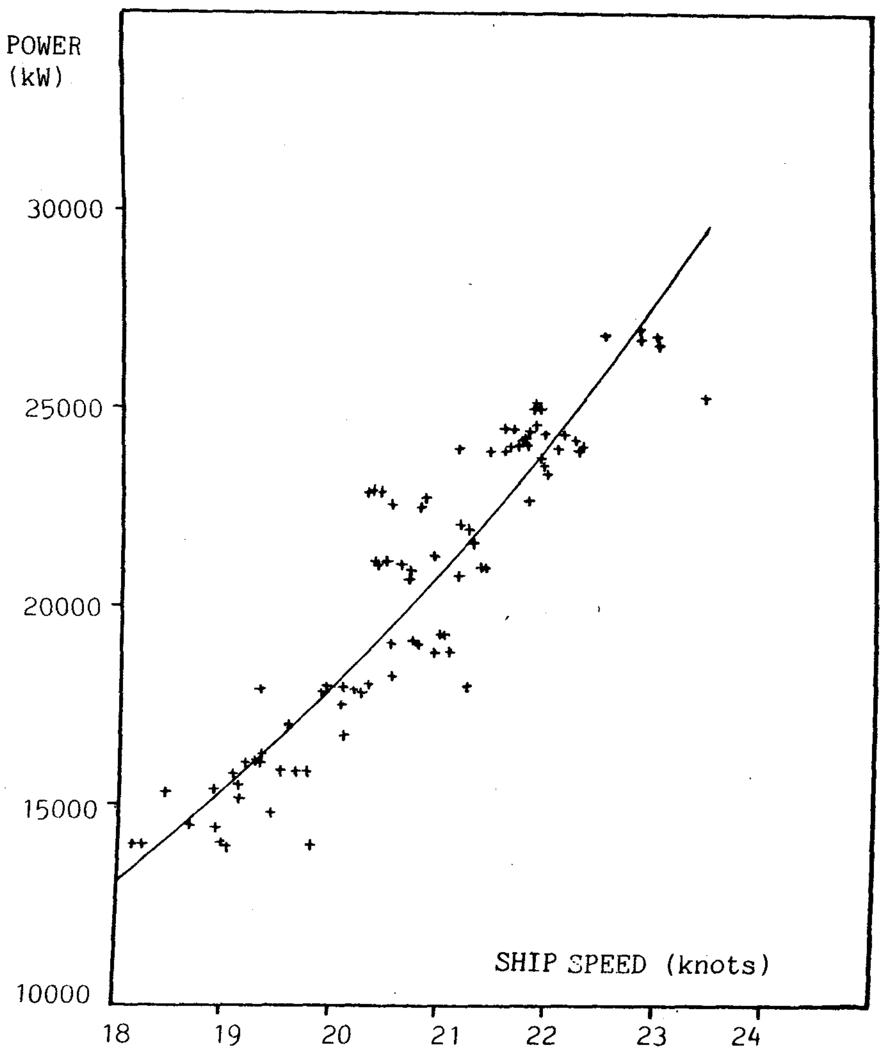


FIGURE (A-5)
SPEED vs POWER FOR SHIP E
FIRST EXPERIMENT

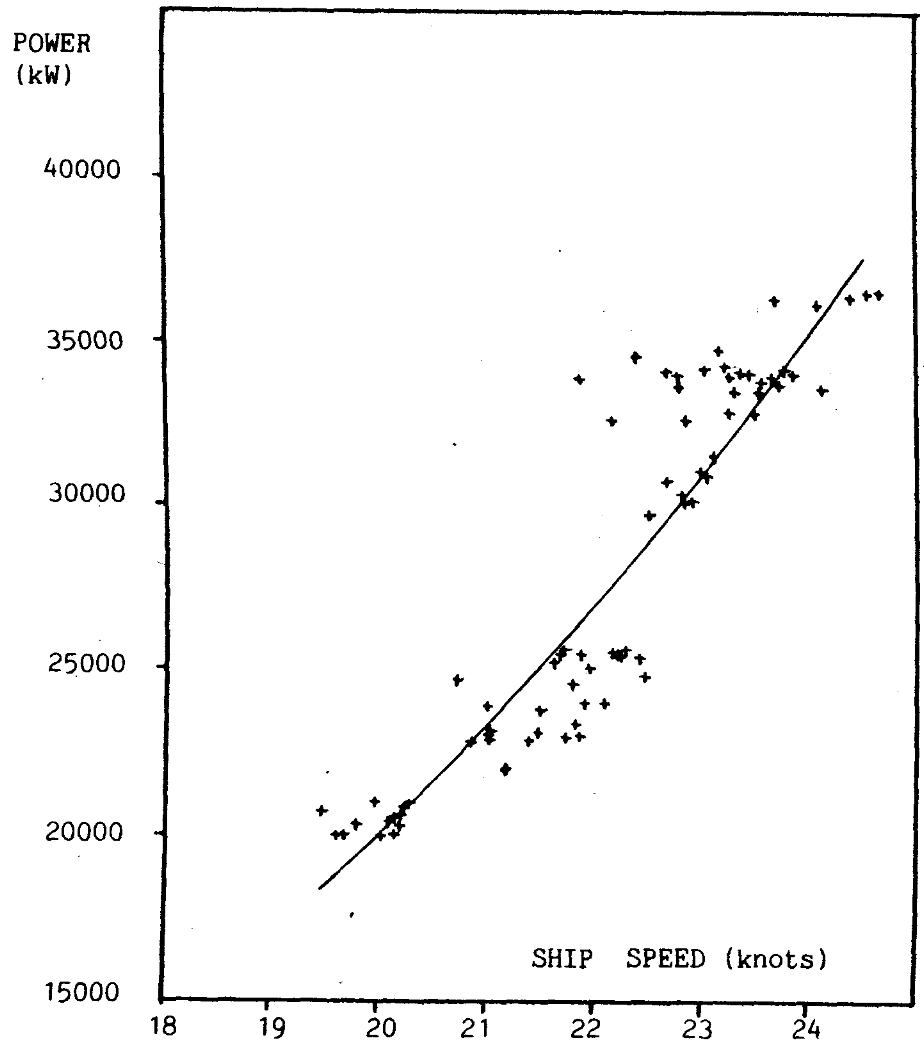


FIGURE (A-6)
SPEED vs POWER FOR SHIP A
SECOND EXPERIMENT

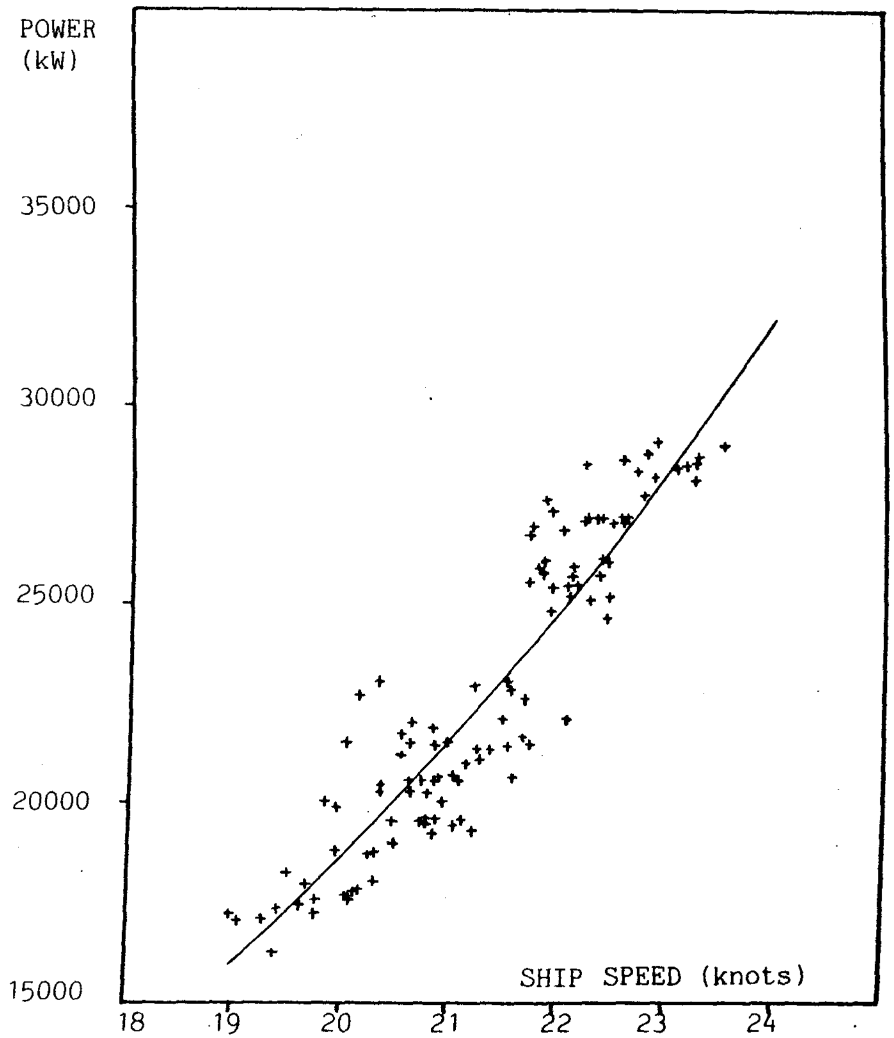


FIGURE (A-7)
SPEED vs POWER FOR SHIP E
SECOND EXPERIMENT

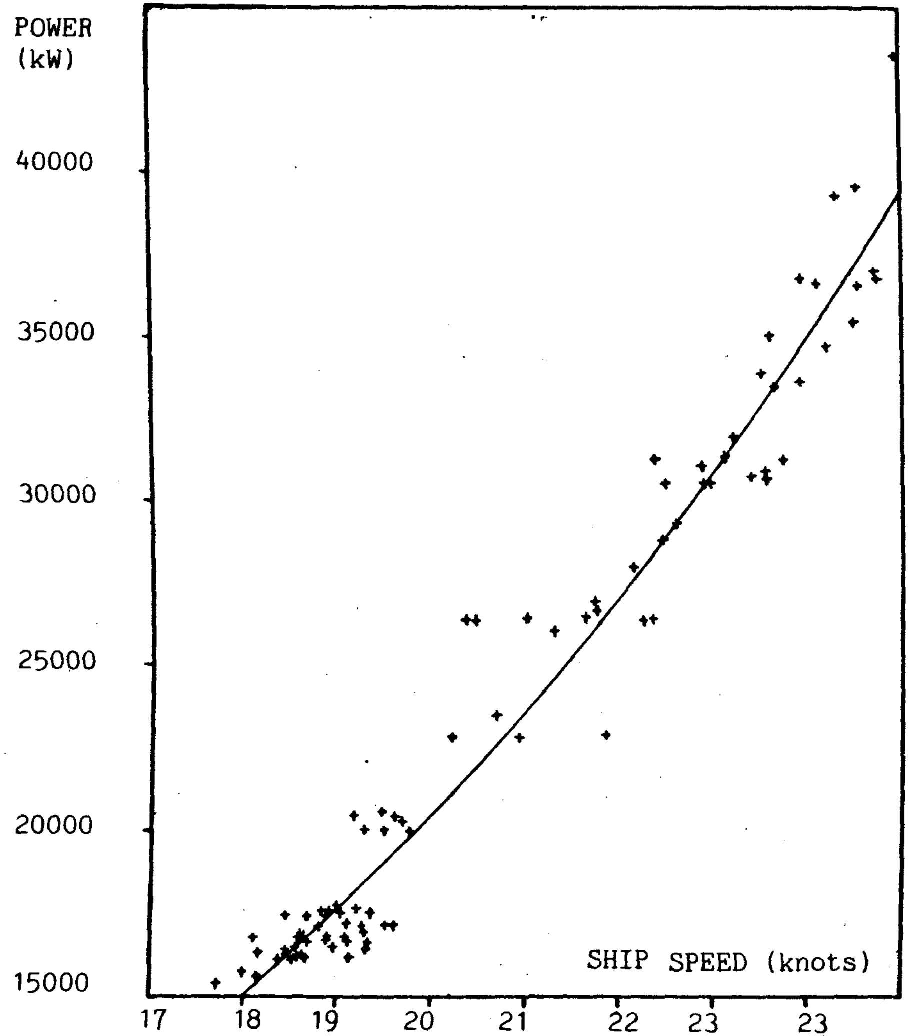
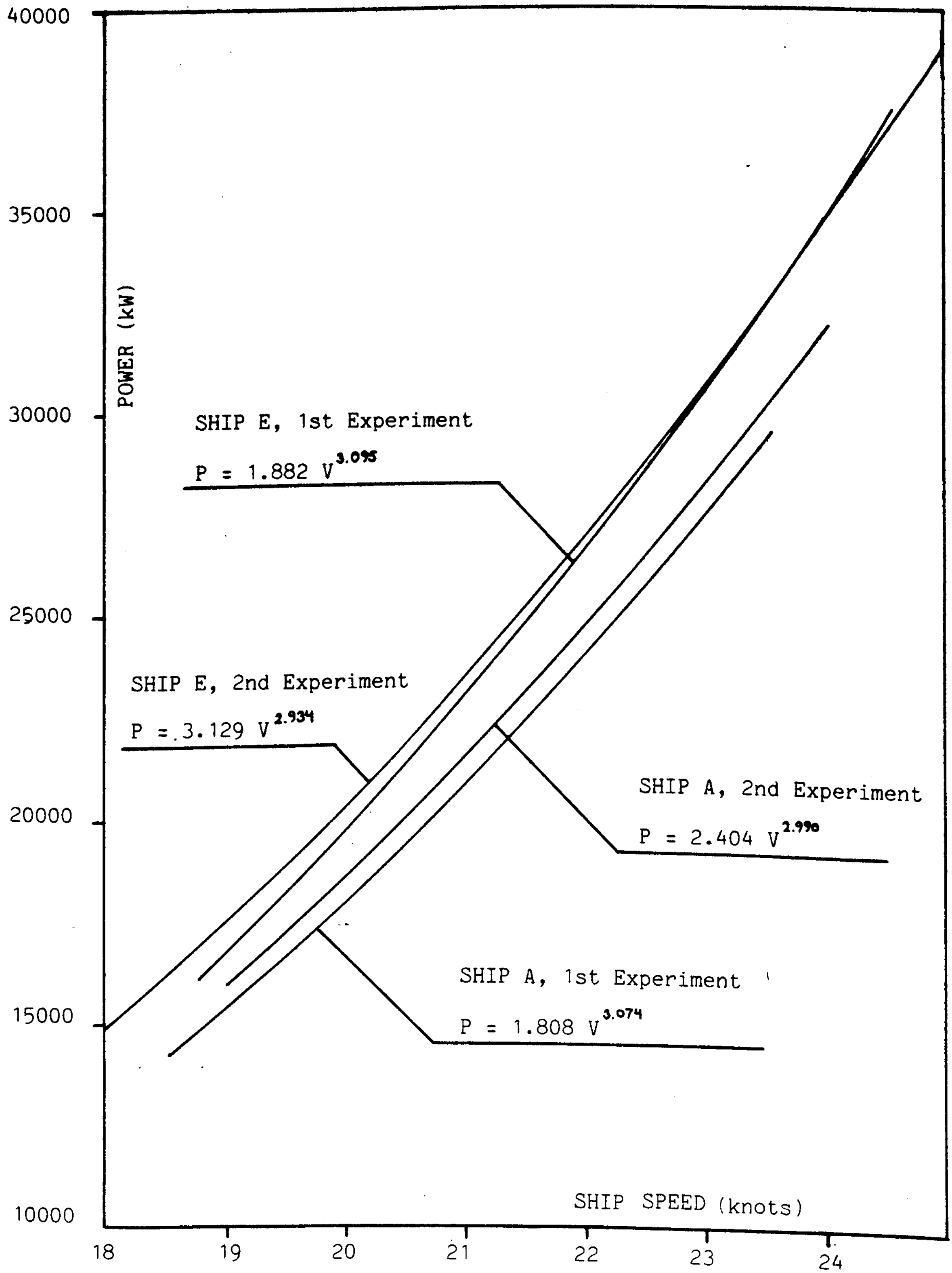


FIGURE (A-8)
REGRESSION CURVES FOR SPEED AGAINST POWER, SHIP A AND SHIP E, FIRST AND SECOND EXPERIMENT



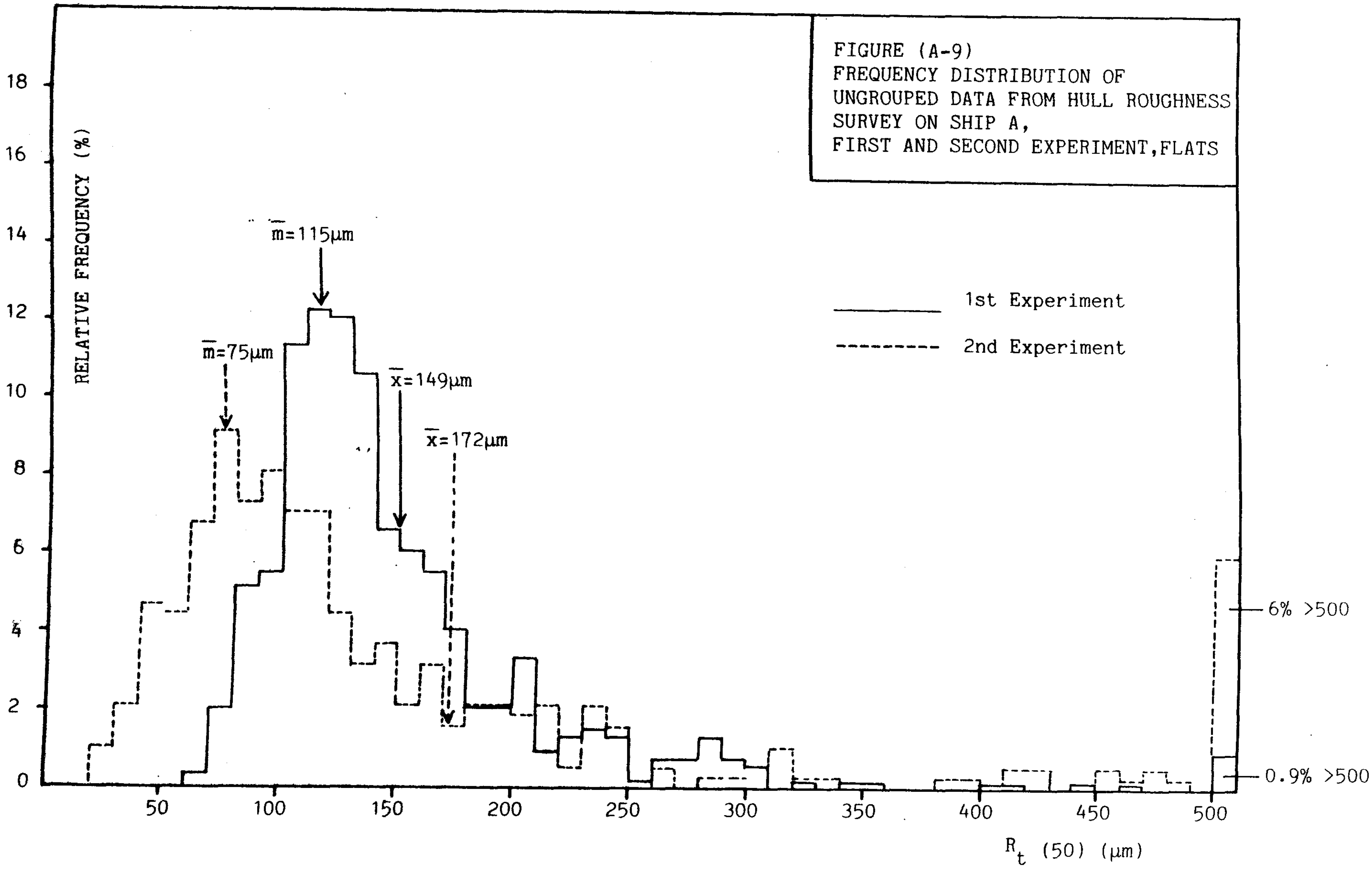


FIGURE (A-9)
FREQUENCY DISTRIBUTION OF UNGROUPED DATA FROM HULL ROUGHNESS SURVEY ON SHIP A, FIRST AND SECOND EXPERIMENT, FLATS

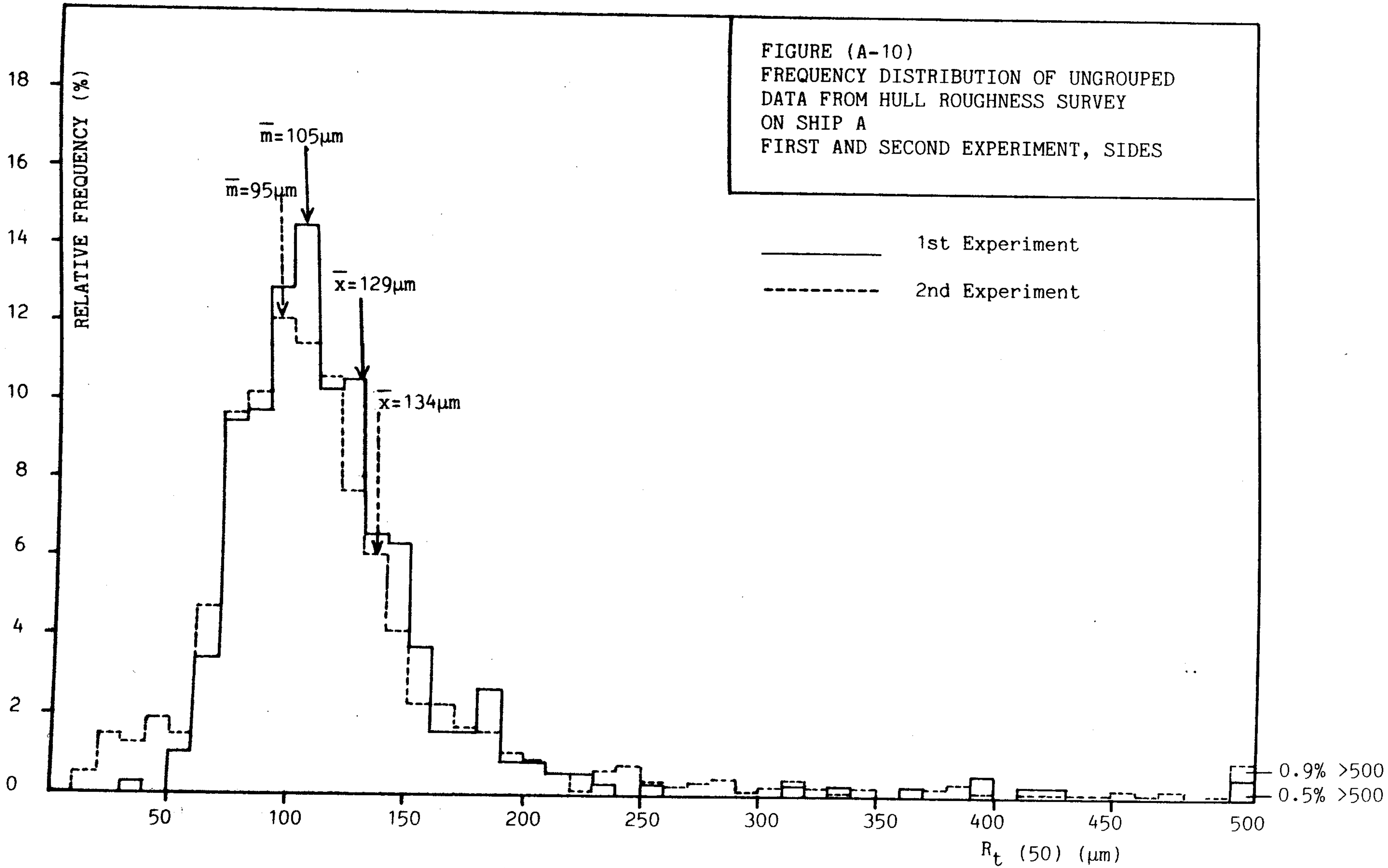


FIGURE (A-10)
FREQUENCY DISTRIBUTION OF UNGROUPED
DATA FROM HULL ROUGHNESS SURVEY
ON SHIP A
FIRST AND SECOND EXPERIMENT, SIDES

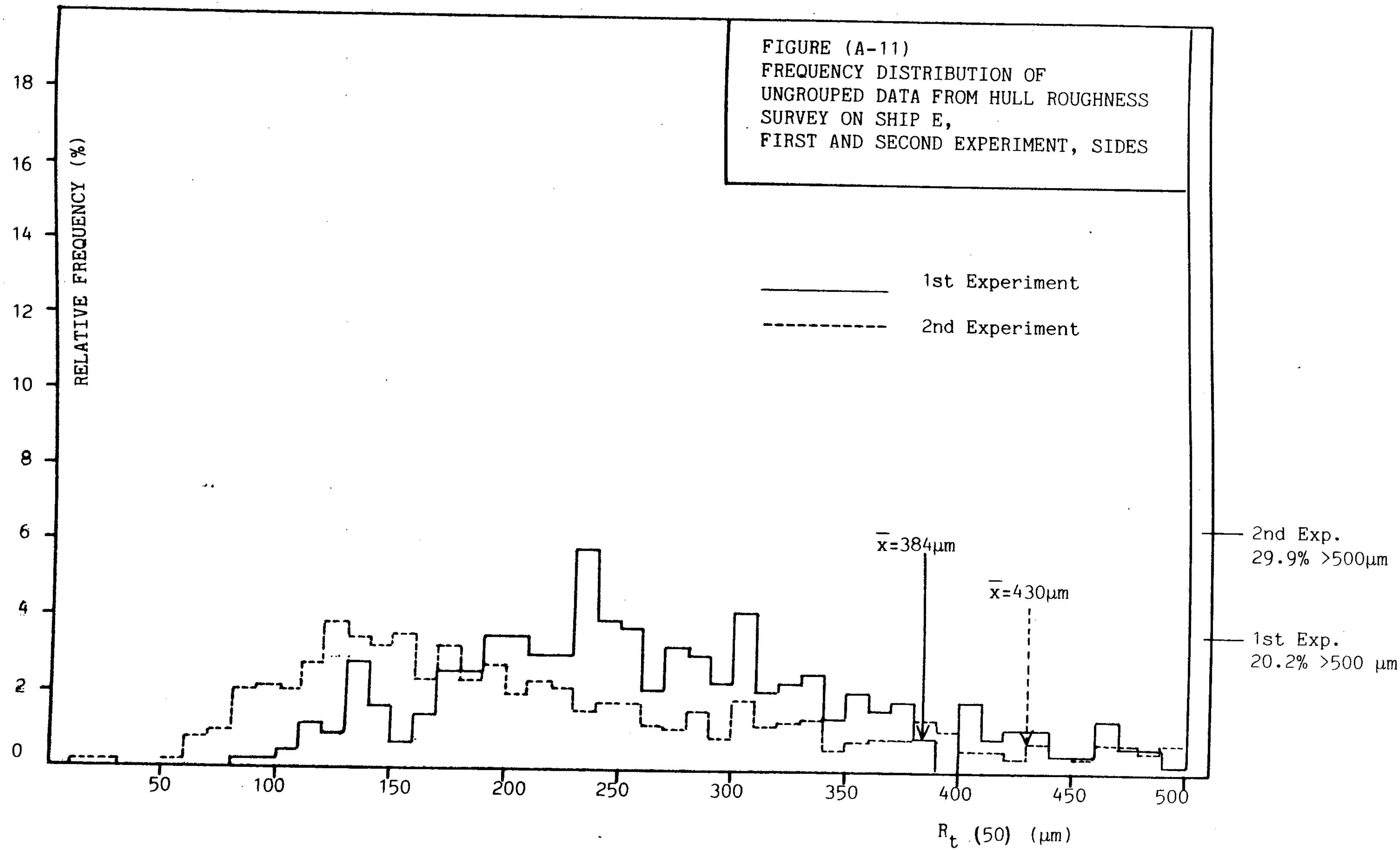


FIGURE (A-11)
FREQUENCY DISTRIBUTION OF UNGROUPED DATA FROM HULL ROUGHNESS SURVEY ON SHIP E,
FIRST AND SECOND EXPERIMENT, SIDES

TABLE (A-18)

SUMMARY OF MONITORING DATA FOR SHIP A, FIRST EXPERIMENT

Summary of recorded voyage data:

Column 1. Inter-fix period identification number.

2. Observed distance between satellite fixes, calculated on the basis of navigational position.

3. Time between satellite fixes.

4. Observed average speed between fixes.

5. Average speed as recorded from pitot tube log.

6. Average shaft revolutions over inter-fix period.

7. Average recorded shaft power over inter-fix period (metric horse power).

8. Average power delivered to the propellers after allowing for 2½% shafting losses.

9. Speed from the Power Diagram, based on RPM from column 6 and DHP from column 8.

10. Difference between Observed Speed (column 4) and Log Speed (column 5).

11. Difference between Observed Speed (column 4) and Speed from Power Diagram (column 9).

12. Difference between Speed from Power Diagram (column 9) and Log Speed (column 5).

13. Total fuel consumption in tonnes per hour and grammes per shaft horsepower per hour.

14. Draughts, calculated daily.

15. Observed Wind, given by Beaufort number and direction from code indicated below.

16. Observed Swell, period, height and direction given by code below.

17. Ship motion, pitch and roll, given by codes below.

18. Ocean Current, speed and direction as taken from seasonal current charts.

19. Observed Sea State, given by code below.

Summary of Corrections made to Data:

Column 20. As column 1.

21. As column 4.

22. Observed Speed (column 4) corrected for average seasonal current (column 18).

23. As column 8.

24. Correction to Power for wind resistance different from still air condition.

25. Correction to Power for mean draught difference from basis condition of 11.0m.

26. Power delivered to propellers after corrections to standard basis.

27. Fuel consumption in tonnes per hour (as column 13).

28. Fuel consumption corrected to standard basis as for power in column 26.

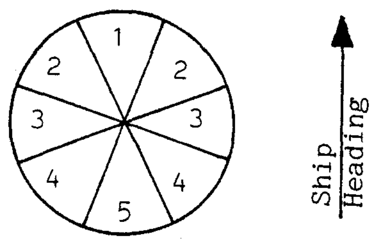
Swell Period Code	
1	2 sec period
2	4 sec period
3	6 sec period
4	8 sec period
5	10 sec period

Swell Height Code	
0	Less than ½m
1	½ metre
2	1 metre
3	1½ metre
4	2 metre

Pitch & Roll Code	
0	Total angle 0°
1	Total angle 2°
2	Total angle 4°
3	Total angle 6°
4	Total angle 8°

Sea Code	
0	Calm
1	Rippled
2	Slight
3	Slight/Mod
4	Moderate

Wind, Swell, Current Direction Code



1 RUN NO.	2 OBS. DIST.	3 Δ TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 S.P.D. SPEED	10 OBS. -LOG	11 OBS. -S.P.D.	12 P.D. -LOG	13 FUEL CONS. t/hr g/shphr	14 DRAUGHTS For'd	Aft	Mean	15 WIND Beauf No.	Dirn	16 SWELL Perd	Hgt	Dirn	17 MOTION Pitch	Roll	18 CURRENT Speed	Dirn	19 SEA STATE
3	81.56	3.733	21.85	20.7	105.0	34200	33500	21.80	1.11	0.05	1.06	9.474/277	11.00	11.13	11.06	2/3	2	3	2	2/3	0	0	0.5	5	2
4	43.16	1.983	21.77	21.25	105.0	34200	33500	21.80	0.52	-0.03	0.55	9.522/278				2/3	2	3	2	2/3	0	0	0.5	5	2
5	71.10	3.248	21.89	21.62	105.1	34200	33500	21.84	0.27	0.05	0.22					2	2	3	2	2	0	0	0.5	5	2
6	33.12	1.457	22.73	21.63	105.4	34300	33600	21.96	1.10	0.77	0.33	9.491/277				1	1	2	2	2	0	0	0.5	5	0
7	87.42	3.984	21.94	20.36	104.9	34300	33600	21.72	1.58	0.22	1.36	9.432/275	10.95	11.11	11.03	3	1	4	2	1	0	0	0.5	5	3
8	88.20	4.024	21.92	20.37	105.2	34400	33700	21.82	1.55	0.10	1.45	9.451/275				3	2	3	2	1	0	0	0.5	5	2
9	70.54	3.23	21.82	20.41	105.3	34700	34000	21.78	1.41	0.04	1.37	9.493/274				3	2	3	2	1	0	0	0.5	5	2
10	88.92	4.049	21.96	20.28	105.2	34800	34100	21.71	1.68	0.25	1.43	9.438/272				3	1	3	2	1	0	0	0.5	5	3
11	135.95	6.181	22.00	20.76	105.6	34700	34000	21.95	1.24	0.05	1.19	9.276/267				2/3	3/4	0/1	0/1	0/1	0	0	0.5	5	2
12	72.08	3.769	22.05	21.28	105.8	34100	33400	22.21	0.77	-0.16	0.93	9.456/277				3	5	0	0	0	0	0	0.5	5	2
13	181.19	8.233	22.01	20.74	105.3	33600	32900	22.10	1.27	-0.09	1.36	9.369/278	10.90	11.10	11.00	4	4	3	2	5	0	0	0.5	5	4
14	97.32	4.500	21.74	20.33	105.5	33600	32900	22.21	1.41	-0.47	1.88	9.373/279				4	4	3	3	5	0	1	0.5	5	3/4
15	110.72	5.128	21.59	20.0	104.0	33500	32800	21.50	1.58	0.09	1.49	9.292/277				2	2	3	3	3	1	1	0.5	5	2
16	131.85	5.978	22.06	19.75	104.3	33100	32400	21.75	2.31	0.31	2.00	9.322/282				3	3	3	4	3	1	0/1	0.5	5	3
17	129.64	5.835	22.21	19.63	104.5	33300	32600	21.82	2.58	0.39	2.19	9.316/280	10.85	11.09	10.97	4	3	3	4	3	1	1	0.5	5	4
18	81.98	3.774	21.72	19.50	104.7	33200	32500	21.94	2.22	-0.22	2.44	9.329/281				3	3	3	3	4	0	1	0.5	5	3
19	90.93	4.112	22.11	18.84		33300	32600	22.06	2.27	0.05	2.22	9.335/280				3	4	3	4	4	1	2	0.5	5	3
20	153.03	6.988	21.90	19.82	104.7	33200	32500	21.94	2.08	-0.04	2.12	9.307/280				2/1	4	2	2/1	4/5	0	1/0	0.5	5	2/1
21	95.30	4.258	22.38	19.68	104.8	33200	32500	22.00	2.70	0.38	2.32	9.318/281				2	5	2	1	5	0	0	0.5	5	2
22	112.48	5.048	22.28	19.37	104.9	33200	32500	22.04	2.91	0.24	2.67	9.132/275	10.80	11.08	10.94	3	5	2	1	5	0	0	0.5	5	2
23	151.95	7.192	21.13	-	97.3	26200	25700	20.54	-	0.59	-	8.040/307	11.29	11.01	11.15	4/5	5	3	2	4	0	0	0.5	5	3/4
24	83.19	3.933	21.15	-	97.3	26200	25700	20.54	-	0.61	-	8.008/306				4	5	3	2	4	0	0	0.5	5	4
25	75.70	3.628	20.87	20.25	97.0	25900	25400	20.49	0.62	0.38	0.24	7.975/307				4	5	3	2	4	0	0	0.5	5	3
26	73.77	3.739	21.07	20.21	96.7	25900	25400	20.35	0.86	0.72	0.14	7.957/307				2	5	3	1	4	0	0	0.5	5	2
27	94.13	4.440	21.20	20.15	96.6	25700	25200	20.37	1.05	0.83	0.22	7.964/310				3	5	3	2	4	0	0	0.5	5	3
28	152.66	7.305	20.90	20.39	97.0	26000	25500	20.46	0.51	0.44	0.07	3.020/308				3	5	3	2	4/5	0	0	0.5	5	3/2
29	97.64	4.726	20.66	20.52	97.1	26000	25500	20.50	0.14	0.16	-0.02	3.063/310	11.22	11.00	11.11	3	5	3	2	5	0	0	0.5	5	3

1	2	3	4	5	6	7	8	9	10	11	12	13	14			15		16			17		18		19
RUN NO.	OBS. DIST.	Δ TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	P.D. SPEED	OBS. -LOG	OBS. -P.D.	P.D. -LOG	FUEL CONS. t/hr g/shphr	DRAUGHTS For'd	Aft	Mean	WIND Beauf No.	Dirn	SWELL Perd	Aft	Dirn	MOTION Pitch	Roll	CURRENT Speed	Dirn	SEA STATE
32	51.30	2.526	20.31	20.3	95.5	25400	24900	19.94	0.0	0.37	-0.36	8.029/318	11.18	10.99	11.09	2/3	2	3	3	2	1	1	0.5	5	3
33	158.19	7.398	21.38	20.3	95.3	25100	24600	19.95	1.04	1.43	-0.39					2	4/3	3/2	3	2	1	1/0	0.5	5	2/1
34	88.31	4.333	20.38	19.9	95.1	24800	24300	19.95	0.46	0.43	0.03	7.962/321				2/3	3	3	3	2	1	1	0.5	5	3
35	73.31	3.804	19.27	19.40	90.4	21400	21000	18.91	-0.13	0.36	-0.49	7.368/344	11.07	10.97	11.02	4/5	3	3	4	4	1	5	0.5	5	4
36	163.16	8.565	19.05	19.32	90.3	21300	20900	18.90	-0.27	0.15	-0.42	7.354/345				3	3	3/4	4	4	1	4	0.5	5	3/2
37	56.52	2.941	19.22	19.20	90.5	21300	20900	19.00	-0.02	0.22	-0.20	7.354/345				3	5	5	4	4	1	4	0.5	5	2
38	168.72	8.584	19.66	19.09	90.7	21400	21000	19.05	0.57	0.61	-0.04					3	5	5/4	4	4	1	4	0.5	5	2
39	93.90	4.721	19.89	18.96	90.6	21400	21000	19.00	-0.07	-0.11	0.14	7.416/346				3	5	4	4	4	1	4	0.5	5	3
40	195.83	9.892	19.80	19.03	90.5	21400	21000	18.95	0.77	0.85	-0.08	7.337/343				3	5	3	3	4	1	3	0.5	5	2
41	65.66	3.353	19.58	18.60	87.9	20100	19700	18.22	0.98	1.36	-0.38	6.936/345	11.00	10.95	10.98	3	5	3	3	4	1	2	0.5	5	2
42	151.68	8.290	18.30	18.47	87.0	19000	18600	18.25	-0.17	0.05	-0.22	6.723/354				3	5/4	3	3	4	1	2	0	-	2/3
43	179.86	9.384	19.17	18.66	86.9	18900	18500	18.24	0.51	0.93	-0.42	6.939/367				4	4	3	3	4	0/1	2	1.0	5	3
44	209.88	10.522	10.95	19.11	86.9	19000	18600	18.20	0.84	1.75	-0.91	6.883/362	11.02	11.09	11.05	4	4	3	3	4	1	3	1.0	5	3/4
45	62.70	3.279	19.12	19.18	86.8	19100	18700	18.10	-0.06	1.02	-1.08	6.970/365				4	4	3	3	4	1	3	1.0	5	4
46	171.60	9.331	18.39	18.92	87.0	19000	18600	18.25	-0.53	0.14	-0.67	6.874/362				4	4	3	3	4/5	1	3	0	-	3
47	52.86	2.807	18.83	19.17	88.7	19700	19300	18.78	-0.34	0.05	-0.39	7.203/351				4	4	3	3	5	2	3	0	-	4
48	142.44	7.657	18.60	19.14	89.7	20800	20400	18.80	-0.54	-0.20	-0.34		10.95	11.10	11.03	4	4	3	3	5	2	2	0	-	4
49	96.23	4.151	23.18	22.66	107.3	35200	34500	22.63	0.52	0.55	-0.03	10.003/284	10.76	10.59	10.67	2	4	3	1	5	0	0	0.5	5	2
50	181.55	7.892	23.00	22.60	108.0	35700	25000	22.82	0.40	0.18	0.22	9.895/277				2	4/5	2	1	5	0	0	0.5	5	2
51	97.26	4.200	23.16	22.24	107.2	35300	34600	22.55	0.92	0.61	0.31	9.657				4	4	2	1	4	0	0	0.5	5	3
52	163.59	6.932	23.60	21.96	105.2	33300	32600	22.14	1.64	1.46	0.18	9.322/280	10.72	10.58	10.65	4/1	4/5	1	1	4	0	0	1.0	5	2/1
53	94.26	4.198	22.45	21.80	103.9	32000	21400	21.87	0.65	0.58	0.07	9.101/284				1	5	1	1	4	0	0	1.0	5	1
54	159.43	7.220	22.08	21.56	103.0	31400	30800	21.64	0.52	0.44	0.08	8.986/286				1/0	VAR	1	1		0	0	1.0	5	1/0
55	67.75	3.024	22.41	21.77	104.2	31900	31300	22.05	0.64	0.36	0.28	9.267/290				0/1	/	1	1	2	0	0	1.0	5	0
56	94.11	4.257	22.11	21.51	103.0	31100	30500	21.73	0.60	0.38	0.22	9.016/290				0/1	VAR	1	1	2/3	0	0	0.5	5	0
57	95.62	4.486	21.31	21.12	100.8	29400	28800	21.20	0.19	0.11	0.08	8.714/296	10.67	10.56	10.62	0/1	VAR	1	1	3	0	0	0.5	5	0
58	71.35	3.40	20.98	21.37	103.3	31700	31100	21.68	-0.39	-0.70	0.31	9.236/291	9.95	11.10	10.53	2	3	2	3	5	0	2	1.0	1	2
59	116.47	5.357	21.70	21.82	104.9	33900	33200	21.83	-0.12	-0.13	0.01	9.579/286				3/4	3/2	2/3	3		0	1	1.0	1	3
60	79.59	3.508	22.69	22.37	107.3	36700	36000	22.19	0.32	0.50	-0.18	10.176/277				4	2	3	3	3/2	1	1	1.0	1	3/4
61	93.52	4.184	22.35	22.27	107.8	37100	36400	22.32	0.08	0.03	-0.05	10.086/272				4/5	2	3	3	2	1	1	1.0	1	4

1 RUN NO.	2 OBS. DIST.	3 Δ TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 P.D. SPEED	10 OBS. -LOG	11 OBS. -P.D.	12 P.D. -LOG	13 FUEL CONS. t/hr g/shphr	14 DRAUGHTS For'd	14 DRAUGHTS Aft	14 DRAUGHTS Mean	15 WIND Beauf No.	15 WIND Dirn	16 SWELL Perd	16 SWELL Aft	16 SWELL Dirn	17 MOTION Pitch	17 MOTION Roll	18 CURRENT Speed	18 CURRENT Dirn	19 SEA STATE
64	113.44	5.492	20.66	20.18	102.2	32600	32000	20.88	0.48	-0.22	0.70	9.299/285	11.12	11.12	11.12	5	2/3	3	4	3	2	2	0	-	4/5
65	142.40	6.588	21.62	20.38	102.8	33000	32300	21.08	1.24	0.54	0.54	9.407/285				4/5	2	3	4	3	2	2	0	-	4
66	76.83	3.726	20.62	20.44	103.2	33100	32400	20.24	0.18	-0.62	0.80	9.410/284				5	2	3	3	3	1	2	1.0	1	4/5
67	160.80	7.902	20.35	20.46	103.2	38200	32500	21.20	-0.11	-0.85	0.74	9.457/285	11.00	11.16	11.09	5	2	3	3	3	1	2	1.0	1	4/5
68	100.67	5.000	20.13	20.53	103.1	33000	32300	21.22	-0.40	-1.09	0.69	9.598/289				4	2	3	3	3	1	2/3	1.0	1	4
69	64.00	3.174	20.16	20.55	102.9	33000	32300	21.12	-0.39	-0.96	0.57	9.378/284				4	2	3	3	3	1	3	1.0	1	4
71	92.47	4.567	20.25	20.75	103.1	32900	32200	21.25	-0.50	-1.00	0.50	9.368/284				3	1	3	4	4	1	3	1.0	1	3
72	213.07	10.095	21.11	20.76	101.3	31500	30900	20.76	0.35	0.35	0.00	9.019/286	11.12	11.18	11.15	3/4	1	4	4	4	1	4/3	0.5	1	3
73	86.94	4.108	21.16	20.69	100.2	30300	29700	20.61	0.47	0.55	-0.08	8.803/291				3	2	3	4	4	1	3	0.5	1	2
74	135.81	6.549	20.74	20.71	100.2	30300	29700	20.61	0.03	0.13	-0.10	8.783/291				2	2	3	4	4	1	1	0.5	1	2
75	79.99	3.898	20.52	20.46	100.1	30200	29600	20.59	0.06	-0.07	0.13	8.817/292				3	1	3	4	1	2	2	0.5	1	2
76	212.93	10.418	20.44	20.15	99.7	30200	29600	20.38	0.29	0.06	0.23	8.806/292	10.98	11.23	11.11	3	2	3	4	1	2	2	0.5	1	2
77	111.34	5.510	20.21	20.05	100.2	30500	29900	20.54	0.16	-0.33	0.49	8.969/294				4	2	3	4	2	2	2	0.5	1	3
78	120.80	5.982	20.19	19.86	99.9	30500	29900	20.39	0.33	-0.20	0.53	8.926/293	10.85	11.29	11.07	4	2	3	4	2	2	2	0.5	1	3
84	108.14	5.431	19.91	19.50	94.2	24500	24000	19.61	0.41	0.30	0.11	7.722/316	10.82	11.20	11.02	4	1	2	1	1	0	0	0.5	1	2
85	88.74	4.574	19.40	18.78	94.0	24900	24400	19.37	0.62	0.03	0.59	8.005/322				4/5	2	2	1	1	0	1	0.5	1	4
86	82.07	4.128	19.88	19.79	95.4	25200	24700	20.00	0.09	-0.12	0.21	8.222/329	10.80	11.17	10.99	3	1	2	1	1	0	0	0.5	1	2
87	169.95	8.873	19.15	19.01	92.4	23400	22900	19.14	0.14	0.01	0.13	7.553/323				3	1	2	1	1	0	0	0.5	1	2
88	174.56	9.118	19.15	18.73	92.2	23300	22800	19.17	0.42	-0.02	0.44	7.521/323				3/4	1	2	1	1	1	0	0.5	1	2/3
89	77.33	4.049	19.10	19.25	92.1	23100	22600	19.12	-0.15	-0.02	-0.13	7.449/324				3	3	2	1	1	0	0	0.5	1	2
90	83.35	4.384	19.01	19.06	92.2	23000	22500	19.18	-0.05	-0.17	0.12	7.494/326				3	1	2	1	1	0	0	0.5	1	2
91	62.96	3.359	18.74	18.60	89.5	21000	20600	18.62	0.14	0.12	0.02	7.491/355	10.77	11.13	10.95	4	1	2	1	1	0	0	0.5	1	2
92	70.7	3.73	18.95	18.60	89.8	21600	21200	18.54	0.35	0.41	-0.06	7.531/349				3	1	2	1	1	0	0	0.5	1	2
93	217.03	10.355	20.96	20.92	100.0	29300	28700	20.84	0.04	0.12	-0.08	8.647/295	10.71	11.04	10.88	3	1	3/2	2	1	0	0	0.5	1	2
94	312.69	14.765	21.19	21.13	100.4	29200	28600	21.06	0.06	0.13	-0.07	8.626/295				2/3	2	2	2/1	1	0	0	0.5	1	2
98	130.36	6.357	20.51	20.69	99.7	29600	29000	20.58	-0.18	-0.07	-0.11	8.649/296	10.50	11.12	10.81	4	1	3	3	1	1	0	0.5	1	2
99	108.05	5.323	20.30	20.79	100.1	29500	28900	20.82	-0.49	-0.52	0.03	8.600/292				2/3	1	2	3	3	1	0	0.5	1	2
100	65.09	3.090	21.06	21.09	100.7	29500	28900	21.10	-0.03	-0.04	0.01	8.621/292	10.42	11.15	10.79	2	5	2	3	3	1	0	0.5	1	1

1 RUN NO.	2 OBS. DIST.	3 Δ TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 P.D. SPEED	10 OBS. -LOG	11 OBS. -P.D.	12 P.D. -LOG	13 FUEL CONS. t/hr g/shphr	14 DRAUGHTS For'd	14 DRAUGHTS Aft	14 DRAUGHTS Mean	15 WIND Beauf No.	15 WIND Dirn	16 SWELL Perd	16 SWELL Aft	16 SWELL Dirn	17 MOTION Pitch	17 MOTION Roll	18 CURRENT Speed	18 CURRENT Dirn	19 SEA STATE
102	111.69	5.486	20.36	20.05	95.1	24600	24100	20.02	0.31	0.34	-0.03	7.654/311	11.06	11.20	11.13	4	5	2	2	4/5	0	0	0.5	1	3/4
103	70.69	3.555	19.88	19.96	94.7	24400	23900	19.90	-0.08	-0.02	-0.06	7.409/304				5/4	5	3	3	5	0	1	0.5	1	4
104	76.03	3.776	20.13	19.97	94.9	24500	24000	19.95	0.16	0.18	-0.02	7.683/314				4	5	3	3	5	0	1	0.5	1	4/3
105	112.30	5.689	19.74	19.99	94.7	24500	24000	19.86	-0.25	-0.12	0.13	7.817/319				3	5	2	2	5	0	1	0.5	1	3/2
106	60.13	3.052	19.70	19.77	94.2	24600	24100	19.58	0.12	-0.07	-0.19	7.730/314				2	5	3	3	5	0	0	0.5	1	2
107	58.82	3.074	19.13	19.58	95.0	24700	24200	19.93	-0.45	-0.80	0.35	7.650/310	10.94	11.24	11.09	2/2	5	2	3	5	0	1	1.0	1	2/1

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONS.	28 CORRECTED FUEL CONS.
3	21,85	21,69	33500	- 700	- 100	32700	9,474	9,252
4	21,77	21,61	33500	- 700	- 100	32700	9,522	9,300
5	21,89	21,73	33500	- 500	- 100	32900		9,355
7	21,94	21,78	33600	- 900	0	32700	9,432	9,185
8	21,92	21,76	33700	- 700	0	33000	9,451	9,259
9	21,82	21,66	34000	- 700	0	33300	9,493	9,301
10	21,96	21,80	34100	- 900	0	33200	9,438	9,193
11	22,00	21,84	34000	0	0	34000	9,276	9,276
12	22,05	21,89	33400	+ 600	0	34000	9,456	9,622
13	22,01	21,85	32900	+ 500	0	33400	9,369	9,508
14	21,74	21,58	32900	+ 400	0	33300	9,373	9,485
15	21,59	21,43	32800	- 300	0	32500	9,292	9,209
16	22,06	21,90	32400	- 100	0	32300	9,322	9,294
17	22,21	22,05	32600	- 100	+ 100	32600	9,316	9,316
18	21,72	21,56	32500	- 100	+ 100	32500	9,329	9,329
19	22,11	21,95	32600	+ 400	+ 100	33100	9,335	9,475
20	21,90	21,74	32500	+ 200	+ 100	32800	9,307	9,402
21	22,38	22,22	32500	+ 300	+ 100	32900	9,318	9,430
22	22,28	22,12	32500	+ 500	+ 100	33100	9,182	9,297
23	21,13	20,97	25700	+ 800	- 300	26200	8,040	8,194
24	21,15	20,99	25700	+ 800	- 300	26200	8,008	8,161
25	20,87	20,71	25400	+ 800	- 200	26000	7,975	8,159
26	21,07	20,91	25400	+ 400	- 200	25600	7,975	8,036
27	21,20	21,04	25200	+ 600	- 200	25600	7,964	8,088
28	20,90	20,74	25500	+ 600	- 200	25900	8,020	8,143
29	20,66	20,50	25500	+ 600	- 200	25900	8,063	8,187
32	20,31	20,15	24900	- 400	- 200	24300	8,020	7,829
33	21,38	21,22	24600	0	- 200	24400		7,956
34	20,38	20,22	24300	0	- 100	24200	7,962	7,930
35	19,27	19,11	21000	0	0	21000	7,368	7,368
36	19,05	18,98	20900	0	0	20900	7,354	7,354
37	19,22	19,06	20900	+ 500	0	21400	7,354	7,527
38	19,66	19,50	21000	+ 500	0	21500		7,527
39	19,89	19,73	21000	+ 500	0	21500	7,416	7,589
40	19,80	19,64	21000	+ 500	0	21500	7,337	7,509
41	19,58	19,42	19700	+ 400	0	20100	6,936	7,074
42	18,30	18,14	18600	+ 400	0	19000	6,723	6,865
43	19,17	19,01	18500	+ 400	0	18900	6,939	7,086
44	19,95	19,79	18600	+ 400	0	19000	6,883	7,028
45	19,12	18,96	18700	+ 400	0	19100	6,970	7,116

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONS.	28 CORRECTED FUEL CONS.
46	18.39	18.23	18600	+ 400	0	19000	6.874	7.019
47	18.83	18.67	19300	+ 400	0	19700	7.203	7.343
48	18.60	18.44	20400	+ 400	0	20800		7.343
49	23.18	23.02	34500	+ 400	+ 1300	36000	10.003	10.486
50	23.00	22.84	35000	+ 400	+ 1300	36700	9.895	10.366
51	23.16	23.00	34600	+ 600	+ 1300	36500	9.657	10.178
52	23.60	23.44	32600	+ 500	+ 1300	34400	9.322	9.826
53	22.45	22.29	31400	+ 100	+ 1200	32700	9.101	9.470
54	22.08	21.92	30800	-	+ 1200	32000	8.986	9.329
55	22.41	22.25	31300	-	+ 1200	32500	9.267	9.617
56	22.11	21.95	30500	-	+ 1200	31700	9.016	9.364
57	21.31	21.15	28800	-	+ 1200	30000	8.714	9.069
58	20.93	21.14	31100	-	+ 1500	32600	9.236	9.673
59	21.70	21.86	33200	- 600	+ 1600	34200	9.679	9.965
60	22.69	22.85	36000	- 1300	+ 1700	36400	10.176	10.287
61	22.35	22,51	36400	- 1600	+ 1700	36500	10.086	10.113
64	20.66	20.82	32000	- 900	- 200	30900	9.299	8.986
65	21.62	21.78	32300	- 1300	- 200	30300	9.407	8.980
66	20.62	20.78	32400	- 1600	- 200	30600	9.410	8.899
67	20.35	20.51	32500	- 1600	- 200	30700	9.457	8.944
68	20.13	20.29	32300	- 1000	- 200	31100	9.528	9.181
69	20.16	20.32	32300	- 1000	- 100	31200	9.378	9.066
70	20.25	20.41	32200	- 1000	- 100	31100	9.368	9.056
72	21.11	21.27	30900	- 1100	- 500	29300	9.019	8.561
73	21.16	21.32	29700	- 700	- 500	28500	8.803	8.454
74	20.74	20.90	29700	- 400	- 400	28900	8.783	8.550
75	20.52	20.68	29600	- 800	- 400	28400	8.817	8.467
76	20.44	20.60	29600	- 700	- 300	28600	8.806	8.514
77	20.21	20.37	29900	- 1000	- 300	28600	8.969	8.587
78	20.19	20.35	29900	- 1000	- 200	28700	8.926	8.574
84	19.91	20.07	24000	- 1300	-	22700	7.722	7.311
85	19.40	19.56	24400	- 1300	-	23100	8.005	7.586
86	19.88	20.04	24700	- 900	-	23800	8.222	7.926
87	19.15	19.31	22900	- 800	-	22100	7.553	7.295
88	19.15	19.31	22800	- 1000	-	21800	7.521	7.198
89	19.10	19.26	22600	- 800	- 100	21900	7.449	7.222
90	19.01	19.17	22500	- 800	- 100	21800	7.424	7.266
91	18.74	18.90	20600	- 1100	- 100	19600	7.491	7.136
92	18.95	19.11	21200	- 700	+ 100	20600	7.531	7.142

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONS.	28 CORRECTED FUEL CONS.
93	20.96	21.12	28700	- 900	+ 400	28200	8.647	8.500
94	21.19	21.35	28600	- 500	+ 400	28500	8.626	8.597
98	20.51	20.67	29000	- 1400	+ 500	28100	8.649	8.383
99	20.30	20.46	28900	- 700	+ 300	28700	8.600	8.542
100	21.06	21.22	28900	+ 400	+ 500	29800	8.021	8.884
102	20.36	20.52	24100	+ 700	- 200	24800	7.654	7.810
103	19.88	20.04	23900	+ 700	- 200	24400	7.409	7.561
104	20.13	20.29	24000	+ 700	- 200	24500	7.683	7.840
105	19.74	19.90	24000	+ 600	- 200	24400	7.817	7.945
106	19.70	19.86	24100	+ 300	- 200	24200	7.730	7.761
107	19.13	19.29	24200	+ 300	- 200	24300	7.650	7.681

TABLE (A- 19)

SUMMARY OF MONITORING DATA FOR SHIP E, FIRST EXPERIMENT

Column Configuration as for Table (A-18), Except for Swell Period Which is not Included

1 RUN NO.	2 OBS. DIST.	3 Δ TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 P.D. SPEED	10 OBS. -LOG	11 OBS. -P.D.	12 P.D. -LOG	13 FUEL CONS. t/hr g/shphr	14 DRAUGHTS For'd	14 DRAUGHTS Aft	14 DRAUGHTS Mean	15 WIND Beauf No.	15 WIND Dirn	16 SWELL Hgt	16 SWELL Dirn	17 MOTION Pitch	17 MOTION Roll	18 CURRENT Speed	18 CURRENT Dirn	19 SEA STATE
1	39.17	1.767	22.17	21.38	106.3	34800	34100	22.24	10.79	-0.07	0.86	9.878/284	11.01	11.32	11.17	4	5	0	0	0	0	0.5	5	3
2	86.68	3.900	22.23	20.96	106.3	34900	34200	22.19	1.27	0.04	1.23	9.839/282				4	5	0	0	0	0	0.5	5	5
3	83.47	3.817	21.87	21.15	106.9	35500	34800	22.36	0.72	-0.49	1.21	9.785/276				3/4	5	0	0	0	0	0.5	5	3
5-6	108.6	4.833	22.47	21.50	105.8	34500	33800	22.09	0.97	0.38	0.59	9.654/280	10.88	11.37	11.13	1	2	0	0	0	0	0.5	5	2
8	73.18	3.333	21.95	21.19	104.6	33500	32800	21.77	0.76	0.18	0.58	9.480/282				3	5	0	0	0	0	0.5	5	3
9	119.91	5.500	21.80	21.39	105.5	34800	34100	21.83	0.41	-0.03	0.44	9.761/281	10.63	11.45	11.04	3/2	2	0	0	0	0	0.5	5	3/2
13	153.06	6.925	22.10	21.06	104.0	32500	31900	21.77	1.04	0.33	0.71	9.565/294	10.65	11.04	10.85	1	4	0	0	0	0	0.5	5	0
14	33.78	1.542	21.91	20.6	103.9	32500	31900	21.72	1.30	0.19	1.12	9.486/292				1	4	0	0	0	0	0.5	5	0
17	70.82	3.158	22.42	21.32	104.5	33300	32600	21.78	1.10	0.64	0.46	9.530/286	10.52	10.92	10.72	5/4	4	4/3	4	2/1	4/3	0.5	5	4/3
18	182.47	8.217	22.21	-	104.3	33000	32600	21.67	-	0.54	-	9.506/286				4	4	3/2	4/5	1	2	0.5	5	3
19	287.65	13.242	21.72	-	104.6	33600	32900	21.75	-	-0.03	-	9.527/284				4	4/5	2	5	1	1	0.5	5	3
20	213.86	9.642	22.18	-	104.8	33400	32700	21.90	-	0.28	-	9.568/286	10.48	10.89	10.69	4/5	5/4	-	-	-	-	1.0	5	3/4
21	232.14	10.475	22.16	-	104.1	33400	32700	21.58	-	0.58	-	9.492/284				5	4	2/3	5/4	1	1/2	1.0	5	4
22	158.12	7.092	22.30	-	104.1	33300	32600	21.56	-	0.74	-	9.509/286	10.40	10.90	10.65	5-4	4	3/2	4	1	2	1.0	5	4/3
23	151.86	7.000	21.69	-	103.8	33100	32400	21.49	-	0.20	-	9.458/286				4	4	2/1	4	1/0	1	0	-	3
24	124.30	5.750	21.62	-	103.9	33200	32500	21.55	-	0.07	-	9.703/292				4/3	4/3	1	4	0	1	0	-	3
25	134.61	6.500	20.71	-	104.1	32900	32200	21.72	-	-1.01	-	9.524/289	10.30	10.92	10.61	2	3	0	0	0	0	0.5	1	2
30	129.35	5.917	21.86	21.02	101.9	30600	30000	21.31	0.84	0.55	0.29	9.123/298	10.62	10.90	10.76	4/3	4	2/1	4	0	1	1.0	5	3
31	117.40	5.433	21.74	20.96	101.4	30500	29900	21.13	0.78	0.61	0.17	9.000/295				3	4/5	1	4/5	0	1	1.0	5	3/2
32	171.99	7.883	21.82	21.00	101.8	30900	30300	21.22	0.82	0.60	0.22	9.165/297				3/4	5/4	0	0	0	1	1.0	5	2/3
33	108.54	5.125	21.18	20.24	100.5	31100	30400	20.52	0.94	0.66	0.28	9.220/296	10.53	10.92	10.73	4/5	1	1/2	0/1	0/1	1/0	1.0	5	3/4
34	98.70	4.350	20.85	21.42	101.9	32400	31700	20.80	-0.57	0.05	-0.62	9.458/292				5/4	1/2	3	1/2	1	0/1	0.5	5	4
35	155.57	7.408	21.00	21.80	102.3	32500	31800	20.97	-0.80	0.03	-0.83	9.407/289				4/3	3	2/1	2	0	1	0.5	5	3
36	129.28	6.017	21.49	21.52	102.1	32000	31300	21.00	-0.03	0.49	-0.52	9.322/291				3/2	4	0	2	0	1	0.5	5	2
37	112.71	5.267	21.40	21.06	101.1	30400	29800	21.03	0.34	0.37	-0.03	9.063/298	10.45	10.93	10.69	2	4	0/1	0	0	1	0.5	5	2
38	124.57	5.925	21.02	20.87	100.7	30300	29700	20.88	0.15	0.14	0.01	9.165/302				2/3	4/5	1/0	2/1	0	1	0.5	5	2/1
39	123.76	5.892	21.01	21.02	101.1	30300	29700	21.02	-0.01	-0.01	0.00	9.046/299				3	5	0	0	0	0	0.5	5	1
40	125.04	5.825	21.47	20.92	101.0	30300	29700	21.02	0.55	0.45	0.10	9.084/300				3	5	0	0	0	0	0.5	5	1
41	129.85	6.175	21.03	20.91	101.2	30400	29800	21.06	0.12	-0.03	0.15	9.106/300	10.34	10.97	10.66	3	5	0	0	0	0	0.5	5	1

1	2	3	4	5	6	7	8	9	10	11	12	13	14			15		16		17		18		19
RUN NO.	OBS. DIST.	Δ TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	P.D. SPEED	OBS. -LOG	OBS. -P.D.	P.D. -LOG	FUEL CONS. t/hr g/shphr	DRAUGHTS			WIND		SWELL		MOTION		CURRENT		SEA STATE
													For'd	Aft	Mean	Beauf No.	Dirn	Hgt	Dirn	Pitch	Roll	Speed	Dirn	
42	128.32	5.225	24.56	23.95	118.1	48000	47100	24.61	0.61	-0.05	0.66	12.320/257	10.56	10.69	10.63	2	4	0	0	0	0	0.5	5	0
43	141.04	5.717	24.67	24.02	118.0	47900	46900	24.64	0.65	0.03	0.62	12.133/253				2/3	4/5	0	0	0	0	0.5	5	0/1
44	102.29	4.192	24.40	23.93	117.9	47600	46700	24.63	0.47	-0.23	0.70	12.199/256				3/2	5/4	0	0	0	0	0.5	5	1/2
45	181.49	7.658	23.70	23.66	117.5	47900	46900	24.37	0.04	-0.67	0.71	12.256/256	10.46	10.67	10.57	2/3	3	0	0	0	0	0.5	5	2/3
46	87.33	3.625	24.09	23.61	117.8	49200	48200	24.21	0.48	-0.12	0.60	12.421/252				3/5	1	0	0	0	0	1.0	5	3/4
47	89.18	3.758	23.73	23.39	115.3	45500	44600	23.93	0.34	-0.20	0.54	11.841/260				3	1	1	1	0	0	1.0	5	3
48	185.74	8.000	23.22	23.21	115.6	46100	45100	23.88	0.01	-0.66	0.67	11.940/259	10.32	10.64	10.48	3/4	1	1	1	0	0	0.5	5	3
49	99.09	4.250	23.32	23.00	114.7	45400	44500	23.57	0.32	-0.25	0.57	11.917/262				4	1	1	1	0	0	0.5	5	3
50	168.91	7.167	23.57	23.03	115.1	45800	44800	23.72	0.54	-0.15	0.69	11.982/262				4	1	1	1	0	0	0.5	5	3/4
51	89.03	3.808	23.38	23.16	115.6	46100	45200	23.72	0.22	-0.34	0.56	11.980/260				4	1	1	1	0	0	0.5	5	4/3
52	74.09	3.267	22.68	23.01	115.0	45700	44700	23.57	-0.33	-0.89	0.56	11.924/261				4/3	1	1	1	0	0	0.5	5	3
53	153.78	6.750	22.78	23.12	114.8	45400	44400	23.70	-0.34	-0.92	0.58	11.940/263	10.19	10.62	10.40	3	1	1	1	0	0	0.5	5	3
54	148.91	6.350	23.45	23.21	115.1	45300	44400	23.85	0.24	-0.40	0.64	11.978/264				3	1	1	1	0	0	0.5	5	3
55	113.24	4.783	23.67	23.32	115.0	45200	44300	23.78	0.35	-0.11	0.46	11.900/263				3	1	1	1	0	0	0.5	5	3
56	103.00	4.317	23.86	23.06	114.8	45300	44400	23.71	0.80	0.15	0.65	11.957/264				3	1	1	1	0	0	0.5	5	3
63	128.39	5.450	23.55	22.81	115.1	46200	45300	23.63	0.74	-0.08	0.82	11.951/259	10.40	10.84	10.63	4	1/2	3	1/2	1	1	0.5	5	4/5
64	135.06	5.925	22.80	22.56	114.8	46100	45200	23.53	0.24	-0.73	0.97	12.020/261				4/5	2	4	2	1	1	1.0	1	4/5
65	122.16	5.583	21.88	22.50	114.9	46500	45600	23.42	-0.62	-1.54	0.92	11.903/256				5/4	2	4/3	2	1	1	1.0	1	4
66	89.59	4.000	22.40	22.59	115.3	47000	46000	23.54	-0.19	-1.14	0.95	12.020/256				4	2	3	2	1	1	1.0	1	4/3
67	79.36	3.425	23.17	21.31	116.0	47100	46200	23.83	1.86	-0.66	2.52	12.002/255				4/3	2/1	3/2	2	1	1	0.5	1	3
68	141.11	6.125	23.04	22.28	115.1	46100	45100	23.68	0.76	-0.64	1.40	11.828/257	10.27	10.81	10.54	3	1	2	2/1	0/1	0/1	0.5	1	3
69	127.77	5.492	23.27	22.86	115.0	45700	44800	23.74	0.41	-0.47	0.88	11.846/259				3	1	2/1	1	0/1	0/1	0.5	1	3
70	181.42	7.633	23.77	22.97	115.2	45900	45000	23.74	0.80	0.03	0.77	11.829/258				3	1/2	1/2	1	0	0	0.5	1	3
71	238.42	9.883	24.12	23.02	114.5	44800	43900	23.66	1.10	0.46	0.64	11.683/261				3	2	2	1	0	0	0.5	1	3
72	162.49	7.108	22.86	22.62	113.3	43500	42600	23.38	0.24	-0.52	0.76	11.449/263	10.13	10.78	10.45	3	2	2	1	0	0	0.5	1	3
73	144.36	6.142	23.50	22.59	113.5	43200	42300	23.56	0.91	-0.06	0.97	11.295/261				2/1	2	2/1	1	0	0	0.5	1	2
74	95.36	4.100	23.26	22.56	113.1	42900	42000	23.40	0.70	-0.14	0.84	11.268/263				1	2	1	1	0	0	0.5	1	1/2
75	68.01	3.067	22.18	22.54	113.1	43000	42100	23.50	-0.36	-1.32	0.96	11.266/262				2/3	2	1	1	0	0	0.5	1	2/3
76	141.58	6.242	22.68	22.07	110.8	40700	39900	22.85	0.61	-0.17	0.78	10.795/265	10.00	10.75	10.38	3	2	1/2	1	0	0	0.5	1	3

1	2	3	4	5	6	7	8	9	10	11	12	13	14			15		16		17		18		19
RUN NO.	OBS. DIST.	Δ TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	P.D. SPEED	OBS. -LOG	OBS. -P.D.	P.D. -LOG	FUEL CONS. t/hr g/shphr	DRAUGHTS			WIND		SWELL		MOTION		CURRENT		SEA STATE
													For'd	Aft	Mean	Beauf No.	Dirn	Hgt	Dirn	Pitch	Roll	Speed	Dirn	
77	116.97	5.075	23.05	21.77	110.6	40900	40100	22.69	1.28	0.36	0.92	10.764/263				3	2	2	1	0	0	0.5	1	3
80	150.29	6.500	23.12	22.53	111.8	40600	39800	23.47	0.59	-0.35	0.94	10.912/269	9.85	10.72	10.29	3/2	3	0	0	0	0	0.5	1	2/1
81	116.19	5.054	22.99	22.43	110.9	40000	39200	23.12	0.56	-0.13	0.69	10.596/265	10.00	10.65	10.32	2	3	0	0	0	0	0.5	1	1/2
82	145.84	6.388	22.83	22.20	110.2	38700	37900	23.09	0.63	-0.26	0.89	10.725/277				2	3	0	0	0	0	0.5	1	1
83	119.08	5.221	22.81	22.32	110.3	39000	38200	23.07	0.49	-0.26	0.75	10.591/272				2	3	0	0	0	0	0.5	1	1
84	107.09	4.675	22.91	22.33	110.1	38700	37900	23.02	0.58	-0.11	0.69	10.571/273				2	3	0	0	0	0	0.5	1	1
85	119.89	5.325	22.51	22.07	109.6	38200	37400	22.88	0.44	-0.37	0.81	10.471/274	9.95	10.64	10.27	2	3	0	0	0	0	0.5	1	1
86	85.85	4.408	19.47	20.13	97.3	28200	27600	19.86	-0.66	-0.39	-0.27	8.503/302	10.11	10.49	10.30	4	1/2	2	1	0	0	0.5	1	4/3
87	150.50	7.492	20.09	19.85	97.1	27500	26900	19.99	0.24	0.10	0.14	8.360/304				4/3	2/1	2	1	0	0	0.5	1	3/2
88	62.47	3.083	20.26	19.81	97.5	27800	27300	20.09	0.45	0.17	0.28	8.390/302				3/2	1	2	1	0	0	0.5	1	2
89	107.39	5.383	19.95	20.15	96.7	27600	27100	19.76	-0.20	0.19	-0.39	8.335/302				2	1	2/1	2	0	0	0.5	1	2
90	118.29	5.850	20.22	19.77	97.1	27500	27000	19.99	0.45	0.23	0.22	8.328/303				2/3	1	1/0	1	0	0	0.5	1	2/1
91	84.82	4.200	20.20	19.75	97.2	27400	26900	20.08	0.45	0.12	0.33	8.364/305				3/2	1	0	0	0	0	0.5	1	1
92	128.97	6.400	20.15	19.65	96.4	27100	26500	19.78	0.50	0.37	01.3	8.322/307	10.08	10.46	10.27	2	1/2	0	0	0	0	0.5	1	1
93	127.17	6.425	19.79	19.54	96.6	26800	26200	19.97	0.25	-0.18	0.43	8.065/301				2	2	0	0	0	0	0.5	1	1
94	99.24	4.917	20.18	19.15	95.7	25900	25400	19.82	1.03	0.36	0.67	7.908/305	10.06	10.43	10.25	2/3	4	0/1	5	0	0	0.5	1	1
95	89.88	4.492	20.01	19.25	94.5	25000	24500	19.64	0.76	0.37	0.39	7.725/309				4	5	1	5	0	0	0.5	1	1
96	166.16	8.467	19.62	19.26	94.7	25100	24600	19.67	0.36	-0.05	0.41	7.750/309				4/3	5	1/0	5	0	0	0.5	1	1
97	55.75	2.767	20.15	19.19	95.1	25300	24800	19.75	0.96	0.40	0.56	7.712/305				3/2	5	0	0	0	0	0.5	1	1
98	112.73	5.733	19.66	19.20	95.3	25400	24900	19.82	0.46	-0.16	0.62	7.788/307			10.22	2	5	0	0	0	0	0.5	1	1/0

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONS.	28 CORRECTED FUEL CONS.
1	22.17	21,67	34100	+ 900	- 400	34600	9,878	10,020
2	22,23	21,73	34200	- 900	- 400	34600	9,839	9,980
3	21,87	21,37	34600	+ 800	- 400	34600	9,785	9,895
5+6	22,47	21,97	33800	+ 200	- 300	33700	9,654	9,626
8	21,95	21,45	32800	+ 700	- 200	34000	9,480	9,622
9	21,80	21,30	34100	- 600	- 100	33400	9,761	9,564
13	22,10	21,60	31900	+ 200	+ 500	32600	9,565	9,771
14	21,91	21,41	31900	+ 200	+ 500	32600	9,486	9,690
17	22,42	21,92	32600	+ 900	+ 1000	34500	9,530	10,073
18	22,21	21,71	32600	+ 900	+ 1000	34500	9,506	10,049
19	21,72	21,22	32900	+ 900	+ 1000	34800	9,527	10,067
20	22,18	21,18	32700	+ 900	+ 1100	34700	9,568	10,140
21	22,16	21,16	32700	+ 900	+ 1100	34700	9,492	10,060
22	22,30	21,30	32600	+ 900	+ 1300	34800	9,509	10,138
23	21,69	21,69	32400	+ 900	+ 1300	34600	9,458	10,087
24	21,62	21,62	32500	+ 400	+ 1300	34200	9,703	10,199
25	20,71	21,21	32200	-	+ 1300	33500	9,524	9,900
30	21,86	20,86	30000	+ 500	+ 800	31300	9,123	9,510
31	21,74	20,74	29900	+ 500	+ 800	31200	9,000	9,384
32	21,82	20,82	30300	+ 600	+ 800	31700	9,165	9,964
33	21,18	20,18	30400	- 1400	+ 800	29800	9,220	9,028
34	20,85	20,35	31700	- 1500	+ 800	31000	9,458	9,254
35	21,00	20,50	31800	- 200	+ 800	32400	9,407	9,580
36	21,49	20,99	31300	+ 200	+ 800	32300	9,322	9,613
37	21,40	20,90	29800	+ 200	+ 1000	31000	9,063	9,421
38	21,02	20,52	29700	+ 400	+ 1000	31100	9,165	9,588
39	21,01	20,51	29700	+ 600	+ 1000	31300	9,046	9,524
40	21,47	20,97	29700	+ 600	+ 1100	31400	9,084	9,594
41	21,03	20,53	29800	+ 600	+ 1100	31500	9,106	9,616
42	24,56	24,06	47100	+ 300	+ 2200	49600	12,320	12,963
43	24,67	24,17	46900	+ 500	+ 2200	49600	12,133	12,816
44	24,40	23,90	46700	+ 500	+ 2200	49400	12,199	12,890
45	23,70	23,20	46900	-	+ 2400	49300	12,256	12,870
46	24,09	23,09	48200	- 1500	+ 2400	49100	12,421	12,642
47	23,73	22,73	44600	- 1200	+ 2400	45800	11,841	12,153
48	23,22	22,72	45100	- 1300	+ 2700	46500	11,940	12,303
49	23,32	22,82	44500	- 1700	+ 2700	45500	11,917	12,179
50	23,57	23,07	44200	- 1700	+ 2800	45900	11,982	12,270

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONS.	28 CORRECTED FUEL CONS.
51	23.38	22.82	45200	- 1200	+ 2800	46300	11.980	12.396
52	22.68	22.18	44700	- 1300	+ 2900	46300	11.924	12.342
53	22.78	22.28	44400	- 1200	+ 2900	46100	11.940	12.387
54	23.45	22.95	44400	- 1200	+ 3000	46200	11.978	12.453
55	23.67	23.17	44300	- 1200	+ 3000	46100	11.900	12.373
56	23.86	23.26	44400	- 1200	+ 3000	46200	11.957	12.432
63	23.55	23.05	45300	- 1700	+ 1900	45500	11.951	12.003
64	22.80	23.80	45200	- 1500	+ 2000	45700	12.020	12.151
65	21.88	22.88	45600	- 1700	+ 2100	46000	11.903	12.005
66	22.40	23.40	46000	- 1300	+ 2200	46900	12.020	12.250
67	23.17	23.67	46200	- 1300	+ 2300	47200	12.002	12.257
68	23.04	23.54	45100	- 1100	+ 2400	46400	11.828	12.162
69	23.27	23.77	44800	- 1100	+ 2400	46100	11.846	12.183
70	23.77	24.37	45000	- 1100	+ 2500	46400	11.829	12.190
71	24.12	24.62	48900	- 800	+ 2500	45600	11.683	12.127
72	22.86	23.36	42600	- 900	+ 2600	44300	11.449	11.896
73	23.50	24.00	42300	- 300	+ 2600	44600	11.295	11.895
74	23.26	23.76	42000	- 100	+ 2700	44600	11.268	11.952
75	22.18	22.68	42100	- 600	+ 2800	44300	11.266	11.842
76	22.68	23.18	39900	- 800	+ 2700	41800	10.795	11.299
77	23.05	23.55	40100	- 800	+ 2700	42000	10.764	11.264
80	23.12	23.62	39800	-	+ 3000	42800	10.912	11.719
81	22.99	23.49	39200	-	+ 3000	42200	10.596	11.391
82	22.83	23.33	37900	-	+ 3000	40900	10.725	11.556
83	22.81	23.31	38200	-	+ 3000	41200	10.591	11.407
84	22.91	23.41	37900	-	+ 3000	40900	10.571	11.390
85	22.51	23.01	37400	-	+ 3000	40400	10.471	11.293
86	19.47	19.97	27600	- 1300	+ 1800	28100	8.503	9.047
87	20 09	20.59	26900	- 1000	+ 1800	27700	8.360	8.907
88	20.26	20.76	27300	- 700	+ 1800	28400	8.390	8.937
89	19.95	20.45	27100	- 400	+ 1800	28500	8.335	8.882
90	20.22	20.72	27000	- 600	+ 1800	28200	8.328	8.875
91	20.20	20.70	26900	- 700	+ 1800	28000	8.364	8.911
92	20.15	20.65	26500	- 400	+ 1800	27900	8.322	8.875
93	19.79	20.29	26200	- 400	+ 1800	27600	8.065	8.607
94	20.18	20.68	25400	+ 300	+ 1800	27500	7.908	8.457
95	20.01	20.51	24500	+ 700	+ 1900	27100	7.725	8.312
96	19.62	20.12	24600	+ 600	+ 1900	27100	7.750	8.337
97	20.15	20.65	24800	+ 500	+ 1900	27200	7.712	8.292
98	19.66	20.16	24900	+ 300	+ 1900	27100	7.788	8.371

TABLE (A-20)

SUMMARY OF MONITORING DATA FOR SHIP A, SECOND EXPERIMENT

Column Configuration as for Table (A-18)

1	2	3	4	5	6	7	8	9	10	11	12	13		14			15		16			17		18		19
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D. -LOG	FUEL t/hr	CONS. g/shp hr	DRAUGHTS			WIND		SWELL			MOTION		CURRENT From charts		SEA STATE
														For'd	Aft	Mean	Beauf No.	Dirn	Perd	Hgt	Dirn	Pitch	Roll	Speed	Dirn	
1	101.21	4.426	22.87	22.55	108.4	38600	37800	22.23	0.32	0.64	-0.32	10.699	277	10.52	10.99	10.75	5	2	3	3/4	2	0	0	0.5	5	3
2	98.16	4.425	22.18	22.44	108.7	39000	38200	22.28	-0.26	-0.10	-0.16	10.702	274				5/4	2/1	3	4	2	1	1	0.5	5	3
3	73.95	3.344	22.12	22.15	108.4	39000	38200	22.12	-0.03	0.00	-0.03	10.717	275				4	1	3	4	2	1	1	0.5	5	3/4
4	132.21	5.733	23.06	22.53	109.1	39000	38200	22.47	0.53	0.59	-0.06	10.522	270				3	3	3/2	3	3	1/0	1	0.5	5	3/2
5	83.56	3.659	22.84	22.80	109.6	38700	37300	22.78	0.04	0.06	-0.02	10.609	274				2	3	4	1	4	0	1	0.5	5	1/2
6	73.91	3.350	22.49	22.57	108.8	38000	37200	22.59	-0.08	-0.10	0.02	10.287	271	10.54	10.92	10.73	2	4	3	2	4	0	1	0.5	5	2
7	80.85	3.439	23.51	22.50	108.9	37200	36500	22.72	1.01	0.79	0.22	10.139	273				2/3	4/5	1/2	1/2	5	0	1	0.5	5	2
8	85.45	3.694	23.13	22.42	108.7	36900	36200	22.80	0.71	0.33	0.38	10.121	274				4	5	2	2	5	0	1	0.5	5	2
9	85.60	3.820	22.41	22.13	105.0	33500	32800	22.00	0.28	0.41	-0.13	9.493	283				4	4/5	2/3	2/1	4	0	1	0.5	5	3
10	79.26	3.518	22.53	21.86	104.9	33200	32500	22.07	0.67	0.67	0.21	9.360	282	10.59	10.81	10.70	4/3	4	2	1	4	0	1	0.5	5	3
11	72.17	3.181	22.69	21.75	104.6	33000	32300	21.95	0.94	0.74	0.20	9.338	283				1	4	1	0	4	0	0	0.5	5	1
12	71.30	3.218	22.17	21.53	104.2	33200	32500	21.70	0.64	0.47	0.17	9.372	282				1	5	1	0	4	0	0	0.5	5	1
13	140.49	6.190	22.70	21.75	105.3	33800	33100	22.05	0.95	0.65	0.30	9.521	282				0	0	0	0	0	0	0	0.5	5	0
14	71.93	3.241	22.19	21.80	105.2	33800	33100	22.00	0.49	0.19	0.20	9.574	283				2	4	2	1	2	0	0	0.5	5	1/2
15	91.83	4.061	22.76	21.76	105.5	33800	33100	22.14	0.85	0.47	0.38	9.511	281				3	5	2/3	1	1/2	0	0	0.5	5	2
16	103.75	4.639	22.36	21.77	105.5	33900	33200	22.11	0.59	0.25	0.34	9.522	281	10.64	10.71	10.68	3	4	2	1	2/3	0	0	0.5	5	2
17	84.62	3.786	22.35	21.38	104.9	33800	33100	21.86	0.47	0.49	-0.02	9.542	282				3/4	3	2/3	1/2	3	0	0	0.5	5	2/3
18	79.52	3.561	22.33	22.07	104.8	34200	33500	21.70	0.26	0.63	-0.37	9.575	280				4	3	3	2	3	0	1	0.5	5	3
19	157.74	7.137	22.10	22.01	105.3	34600	22900	21.82	0.08	0.28	-0.20	9.617	278				3	3	2	2	3	0	1	0.5	5	2
20	91.20	4.076	22.37	21.94	105.7	34200	33500	22.12	0.43	0.25	0.18	9.616	281			10.60	1	5	0	0	0	0	0	0.5	5	1
21	103.18	4.557	22.64	21.77	105.6	34200	33500	22.08	0.87	0.56	0.31	9.518	278	10.18	10.94	10.56	4	3/4	2	1/2	4/3	0	1	0.5	5	3
22	115.41	5.084	22.70	21.93	105.5	34200	33500	22.04	0.77	0.66	0.11	9.523	278				3	3/4	2	2/1	3/4	0	1	0.5	5	3/2
23	90.04	4.098	21.97	21.89	105.2	33800	33100	22.00	0.08	0.03	0.11	9.642	285				0	0	0	0	0	0	0	0.5	5	0
24	129.87	5.888	22.06	21.82	105.2	33900	33200	21.97	0.24	0.90	0.15	9.667	285				2	4	2	2	4	0/1	0/1	0.5	5	1/2
25	90.73	4.106	22.10	21.86	105.2	34000	33300	21.96	0.24	0.14	0.10	9.705	285	10.15	10.90	10.53	2/3	4	3	2	4	0	1	0.5	5	2
26	97.30	4.091	23.78	23.01	107.9	36000	35300	22.67	0.77	1.11	-0.34	10.239	284				5	5/4	3	3	4	0	2	0.5	4	4
27	76.45	3.275	23.35	22.29	107.7	35900	35200	22.60	1.06	0.75	0.31	10.167	283	10.17	10.21	10.19	5/1	5/3	3/0	3/0	3/0	0	2/0	0.5	4/0	4/0
28	141.88	6.157	23.04	22.28	107.7	35800	35100	22.64	0.76	0.40	0.36	10.100	283				2	4	2	2	4	0	1	0.5	2	2

1 RUN No.	2 OBS. DIST.	3 TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 G.P.D. SPEED	10 OBS. -LOG	11 OBS. G.P.D.	12 G.P.D. -LOG	13 FUEL CONS. t/hr	13 g/shp hr	14 DRAUGHTS For'd	14 Aft	14 Mean	15. WIND Beau. No.	15. Dirn	16 SWELL Perd	16 Hgt	16 Dirn	17 MOTION Pitch	17 Roll	18 CURRENT From Charts Speed	18 Dirn	19 SEA STATE
29	121.90	5.308	22.97	22.69	107.7	35700	35000	22.66	0.28	0.31	0.03	10.100	284				3	4	2	2	4	0	1	0.5	5	2
30	76.30	3.241	23.54	22.89	107.9	36000	35300	22.67	0.65	0.87	-0.22	10.086	289	10.09	10.22	10.16	3	4/5	3	3	4	0	3	0.5	4	3
31	102.17	4.443	23.52	22.60	108.0	36000	35300	22.72	0.92	0.80	0.12	10.102	281				3	4	2	2	3	0	2	0.5	4	2
32	96.51	4.118	23.44	22.57	107.3	36300	35600	22.30	0.87	1.14	-0.27	10.168	280	10.04	10.22	10.13	5	3	3	4	3	0	2	0.5	4	4
33	115.90	5.008	23.16	22.82	107.1	36100	35400	22.30	0.34	0.86	-0.52	9.838	273	9.89	10.25	10.07	4	4	3	3	4	1	1	0.5	3	3
34	96.69	4.233	22.84	22.34	105.3	33700	33000	22.00	0.50	0.84	-0.34	9.477	281				4	4	4	4	4	1	2	0.5	3/4	3/4
35	93.77	4.210	22.28	22.15	105.2	33500	32800	22.08	0.13	0.20	-0.07	9.414	281				4/3	4	4	4	4	1	2	0.5	5	3
36	120.79	5.490	22.00	22.09	105.3	33600	32900	22.12	0.09	0.12	0.03	9.411	280				3	4	4	4	4	1	1	0.5	5	2
37	96.37	4.251	22.74	21.98	105.3	33400	32700	22.16	0.76	0.58	0.18	9.514	285	9.81	10.27	10.04	3/4	4/5	3/4	3	4	0	1	0.5	4	3
38	109.32	4.831	22.63	21.93	105.3	33500	32800	22.14	0.07	0.49	0.21	9.427	281				3/4	5	3/4	2/3	4/5	0/1	1/2	0.5	5	3
39	97.95	4.333	22.60	21.84	105.3	33500	32800	22.14	0.70	0.49	0.21	9.437	281	9.86	10.15	10.00	4	5	3/4	3	5	1	2	0.5	5	3
40	95.75	4.259	22.48	21.90	104.9	33300	32600	22.00	0.58	0.48	0.10	9.423	283				4	5	3	3	5	1	2	0.5	5/4	3/2
41	123.12	5.469	22.50	22.05	105.1	33400	32700	22.06	0.45	0.44	0.01	9.383	281				4	5	3	4	5	1	2	0.5	3	3
42	139.37	6.106	22.83	22.10	105.4	33500	32800	22.18	0.73	0.65	0.08	9.427	281	9.63	10.18	9.90	3	4	3	1	4	0	1/0	0.5	2	2
43	121.90	5.545	21.98	21.84	104.9	33300	32600	22.00	0.14	0.02	0.16	9.481	285				1/2	4/3	1	0	5	0	0	0.5	2/1	2
44	110.09	5.718	19.25	19.17	90.0	21600	21200	18.63	0.08	0.62	-0.54	7.405	343	9.26	10.45	9.85	2	3	1	0	3/4	0	0	0.5	3	2
45	71.93	3.677	19.18	19.18	90.3	21600	18200	18.79	0.38	0.77	-0.39	7.360	341				2	3/2	1	0	3/2	0	0	0.5	3/2	2/1
46	117.24	5.065	99.33	19.19	90.4	21600	21200	18.84	0.14	0.49	-0.35	7.334	340				2	2/3	1	0	2/3	0	0	0.5	2/4	1
47	81.76	4.102	19.69	19.19	90.4	21600	21200	18.84	0.50	0.85	-0.35	7.404	343				2	4	3	0	4	0	0	0.5	5	2
48	67.12	3.298	20.35	19.16	90.7	21700	21300	18.93	1.19	1.42	-0.23	7.384	340	9.32	10.35	9.83	3	4	3	2	4	0	0	0.5	5	2
49	91.25	4.192	21.77	—	102.3	31900	31300	21.14	—	0.63	—	9.042	283	10.16	11.15	10.66	5	1	1	1	2	0	0	0.5	2	4
50	87.97	4.151	21.19	—	101.7	31900	31300	20.84	—	0.35	—	9.064	284				5	1	1	2	1	0	0	0.5	2	4
51	105.33	4.924	21.39	—	101.6	31700	31100	20.86	—	0.53	—	8.967	283	10.18	11.11	10.65	4	1	3	2	1	0	0	0.5	2	3
52	94.63	4.451	21.26	—	101.8	31800	31200	20.92	—	0.34	—	8.933	281				3/4	1	3	2	1	0	0	0.5	2	3
53	70.29	3.541	19.85	—	102.1	31800	31200	21.07	—	-1.22	—	8.913	280				4	1	3	2	1	0	0	0.5	2	3
54	104.65	5.226	20.03	—	101.6	31800	31200	20.83	—	0.08	—	8.909	280				3/4	2	3	2	1	0	0	0.5	2	2
55	93.68	4.476	20.93	—	101.9	31700	31100	21.00	—	0.07	—	9.045	285				4	2	2	2	1	0	0	1.0	2	3
56	84.19	3.965	21.23	21.49	102.1	31800	31200	21.07	-0.26	0.16	-0.42	9.052	285	10.23	11.02	10.63	4	2	2	2	1	0	0	0.5	2	3

1	2	3	4	5	6	7	8	9	10	11	12	13 FUEL CONS.		14 DRAUGHTS			15 WIND		16 SWELL			17 MOTION		18 CURRENT From Charts		19
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D -LOG	t/hr	g/shp hr	For'd	Aft	Mean	Beauf No.	Dirn	Perd	Hgt	Dirn	Pitch	Roll	Speed	Dirn	SEA STATE
57	95.70	4.540	21.08	20.76	100.7	31000	30400	20.64	0.32	0.44	−0.12	9.115	295	11.05	11.29	11.17	4	2	2	3	2	0	0	0.5	5	3
58	107.46	5.025	21.38	20.36	101.0	31700	31100	20.56	1.02	0.82	0.20	9.070	287				4/5	2	2/3	3	2	0	1	0.5	5	3/4
59	88.56	4.133	21.43	20.36	101.2	31900	31300	20.61	1.07	0.82	0.25	9.095	285				4/5	2/1	3	3	2	1	1	0.5	1	4
60	88.31	4.159	21.24	20.34	101.2	31800	31200	20.64	0.90	0.70	0.30	9.198	289			11.20	5	2	3	4	2	1	1	0.5	1	4
61	70.54	3.365	20.96	20.23	101.0	31800	31200	20.53	0.73	0.43	0.30	9.099	286	11.20	11.30	11.25	5	2	3/4	3	2	1	1	0.5	1	4
62	76.45	3.761	19.74	20.05	100.7	32000	31400	20.31	0.31	0.02	0.26	9.076	284				5	2	4	4	2	1	1	0.5	1	4
63	71.87	3.641	19.74	20.05	100.7	32000	31400	20.31	−0.31	−0.57	0.26	9.106	285	11.11	11.34	11.23	5	2	4	4	2	1	1	0.5	1	4
64	83.97	4.126	20.35	20.62	101.5	32000	31400	20.71	−0.27	−0.36	0.09	9.106	285	11.02	11.38	11.20	4	2	3	3	1	1	1	0.5	1/2	3
65	85.31	4.153	20.54	20.78	101.8	32000	31400	20.86	−0.24	−0.32	0.08	9.110	285				4/5	2	3	3	1/2	1	1/2	0.5	1/2	3/4
66	88.73	4.383	20.25	20.67	101.3	31800	31200	20.68	−0.42	−0.43	0.01	9.100	286				4/5	2	3	3	2	1	1	0.5	1/2	3/4
67	111.11	5.373	20.68	20.68	101.2	31700	31100	20.67	0.00	0.01	−0.01	9.165	289				4	1	3	4	2	1	1	0.5	1	3
68	106.38	5.174	20.56	20.77	101.1	31700	31100	20.61	−0.21	−0.05	−0.16	9.233	291			11.25	4	1	3	4	1	1	1	0.5	2	3
69	82.40	4.106	10.06	20.09	98.8	29900	29300	20.06	−0.03	0.00	−0.03	8.723	292	11.15	11.51	11.33	3	1	4	4	2	1	1	0.5	2	3
70	97.48	4.859	20.06	20.00	98.7	29800	29200	20.04	0.06	0.02	0.04	8.706	292				3	1	4	4	2	1	1	0.5	1	3
71	74.49	3.608	20.65	19.94	98.7	29900	29300	20.01	0.71	0.64	0.07	8.721	292				4	1	4	4	1	1	1	0.5	1	3
72	111.30	5.431	20.49	19.78	98.4	30000	29400	19.84	0.71	0.65	0.06	8.730	291				5/4	1	4	4	2	1	1	0.5	1	4
73	71.60	3.643	19.65	20.32	99.2	29500	28900	20.39	−0.67	−0.74	0.07	8.841	300	10.98	11.51	11.24	4	1	2	2	2	0	1	0.5	2	3
74	84 05	4.298	19.55	20.32	98.7	29500	29000	20.14	−0.77	−0.39	−0.18	8.736	296				3/4	1	3	3	2	0	1	0.5	1	2
75	100.13	4.927	20.32	20.41	99.5	30000	29400	20.36	−0.09	−0.04	−0.05	8.763	292				3	1	2	2	3	0	0	0.5	2	2
76	67.66	3.310	20.44	20.41	97.5	27400	26800	20.20	0.03	0.24	−0.21	8.485	310	10.92	11.49	11.21	1	3	1	1	2	0	0	0.5	1	1
77	129.90	6.667	19.81	19.48	94.3	25300	24800	19.37	−0.33	0.11	−0.44	8.303	238				3/4	1	2	2	1	0	0	0.5	1	2
78	130.99	6.724	19.48	20.02	95.1	25600	25100	19.66	−0.54	−0.18	−0.36	8.335	326				3	1	2	1	1	0	0	0.5	1	2
79	80.45	4.051	19.86	19.79	94.9	25800	25300	19.49	0.07	0.37	−0.30	8.345	323				3	1/2	2	1	1/2	0	0	0.5	1	2
80	82.34	4.169	19.75	20.07	95.3	25700	25200	19.72	−0.32	0.03	−0.35	8.459	329	10.87	11.48	11.18	3	1	1	1/0	2	0	0	0.5	1	2
81	71.12	3.588	19.82	19.94	95.5	26000	25500	19.74	−0.12	0.08	−0.20	8.466	326				3/4	1	1/2	1/2	1/2	0	0	0.5	1	2
82	81.17	4.059	20.00	20.28	96.9	27200	26700	19.98	−0.28	0.02	−0.30	8.696	320				3	1	2/1	1	1	0	0	0.5	1	2/1
83	85.25	4.176	20.56	20.26	97.1	27400	26900	20.00	0.30	0.56	−0.26	8.640	315				2	1	1	0	1	0	0	0.5	1	1

1 RUN No.	2 OBS. DIST.	3 TIME	4 OBS. SPEED	5 LOG SPEED	6 RPM	7 SHP	8 DHP	9 G.P.D. SPEED	10 OBS. -LOG	11 OBS. G.P.D.	12 G.P.D. -LOG	13 FUEL t/hr	13 CONS. g/shp hr	14 DRAUGHTS For'd	14 DRAUGHTS Aft	14 DRAUGHTS Mean	15 WIND Beau No.	15 WIND Dirn	16 SWELL Perd	16 SWELL Hgt	16 SWELL Dirn	17 MOTION Pitch	17 MOTION Roll	18 CURRENT From Charts Speed	18 CURRENT From Charts Dirn	19 SEA STATE
84	78.50	2.884	20.21	20.24	97.2	27400	26900	20.67	0.	0.1	0.	8.623	315	10.83	11.47	11.15	3	1/2	1/2	0/1	1	0	0	0.5	1/2	1/2
85	83.74	4.014	20.86	21.06	101.2	31700	31100	20.67	-0.20	0.19	-0.39	9.278	293	10.73	11.48	11.11	5	1	2	2	1	0	0	0.5	1	3
86	82.35	3.961	20.79	20.81	99.9	30700	30100	20.32	-0.02	0.47	-0.49	9.103	297			11.15	4/5	1	2	2	1	0	0	0.5	1	3
87	80.35	3.931	20.44	20.72	99.1	29900	29300	20.21	-0.28	0.23	0.51	8.961	300	11.02	11.38	11.20	3	1	2/3	2/3	1	0	0	0.5	1	3
88	112.14	5.451	20.57	21.23	99.4	30000	29400	20.32	-0.66	0.25	-0.91	8.973	299				3/4	1/2	3	2	1/2	0	0	0.5	1	3/2
89	85.41	4.167	20.50	21.07	98.8	29200	28600	20.29	-0.57	0.21	-0.78	8.876	304				3	2	3	2	2	0	0	0.5	1	2
90	84.97	4.049	20.98	21.7	99.7	30300	29600	20.35	-0.41	0.63	-1.04	8.928	295				3	2	3	2	2	0	0	0.5	1	2
91	75.85	3.684	20.59	20.95	99.5	29700	29100	20.45	-0.36	0.14	-0.50	8.876	299				3	2	3	2	2	0	0	0.5	1	2
92	75.16	3.625	20.86	20.62	98.8	29900	29300	20.06	0.24	0.80	-0.56	8.655	298	10.87	11.44	11.16	3/2	2	3	2/1	2	0	0	0.5	1	2/1
93	96.23	4.641	20.73	20.75	99.0	29300	28700	20.35	-0.02	0.38	-0.40	8.649	295				1/2	1/2	3/2	0/2	3	0	0	0.5	1	1/2
94	133.81	6.574	20.35	20.87	98.7	29100	28500	20.27	-0.52	0.08	-0.60	8.633	297				3	2	2	1	2	0	0	0.5	1	2
95	80.83	3.992	20.25	20.93	99.7	29800	29200	20.52	-0.68	-0.27	-0.41	8.729	293				1	2	0	0	0	0	0	0.5	1	1
96	85.51	4.020	21.29	21.05	99.9	29400	28800	20.75	0.24	0.54	-0.30	8.770	298				2	1	0	0	0	0	0	0.5	1	1
97	83.03	3.967	20.93	20.79	98.2	27900	27300	20.42	0.14	0.51	-0.37	8.266	296	10.72	11.12		3	1	0	0	0	0	0	0.5	1	2
98	95.11	4.621	20.58	20.58	97.3	27100	26600	20.22	0.00	0.36	-0.36	8.048	297				2	4	0	0	0	0	0	0.5	1	2
99	120.44	5.971	20.17	20.49	96.9	2700	26500	20.05	-0.32	0.12	-0.44	7.984	296				2	4	0	0	0	0	0	0.5	1	1
100	108.89	5.233	20.81	20.37	96.6	27100	26600	19.88	0.44	0.93	-0.49	8.002	295				2	4	0	0	0	0	0	0.5	1	2
101	74.01	3.567	20.75	20.25	96.9	27300	26800	19.95	0.50	0.80	-0.30	8.168	299				2	2	0	0	0	0	0	0.5	1	2
102	69.76	3.404	20.49	20.15	97.5	28200	27600	19.97	0.34	0.52	-0.18	8.324	295	10.56	11.55	11.06	3/4	2	2	2	2	0	0	0.5	1	2
103	70.00	3.506	19.97	19.62	95.1	26700	26200	19.26	0.35	0.71	-0.36	7.835	293				3	2	3	1	1	0	0	0.5	1	2
104	63.50	3.274	19.39	19.64	93.9	25700	25200	19.03	-0.24	0.36	-0.60	7.697	299				3	2	3	2	2	0	0/1	0.5	1	2
105	81.17	4.224	19.22	10.47	93.9	25400	24900	19.13	-0.25	0.09	-0.34	7.611	300				3/2	3	3	3	2	0	0/1	0.5	1	2
106	101.31	5.157	19.65	20.14	94.0	25400	24900	19.18	-0.49	0.47	-0.96	7.577	298	10.52	11.54	11.03	4	4	3	2	2	0	1	0.5	1	2/3
107	82.02	4.241	19.34	20.22	92.9	25200	24700	18.74	-0.88	0.60	-1.48	7.572	301				4	2	4	4	2	0	1	0.5	1	4
108	81.06	4.243	19.10	19.95	90.6	23800	23300	18.08	-0.85	1.02	-1.87	7.493	315	11.0	11.30	11.15	4	2	4	4	2	0	1	0.5	1	4
109	70.85	3.541	20.01	20.30	93.0	25300	24800	18.75	-0.29	1.26	-1.55	7.791	308	11.08	11.24	11.16	4	3	2	3	3	0	1	0.5	1	3

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. Δ DHP	25 DRAUGHT CORR. Δ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
1	22.87	22.59	37800	– 1900	+ 1000	36900	10.699	10.450
2	22.18	21.90	38200	– 2100	+ 1000	37100	10.702	10.400
3	22.12	21.84	38200	– 1700	+ 1000	37500	10.717	10.525
4	23.06	22.78	38200	– 100	+ 1000	39100	10.522	10.765
5	22.84	22.56	37900	0	+ 1000	38900	10.609	10.883
6	22.49	22.21	37200	+ 400	+ 1100	38700	10.287	10.693
7	23.51	23.23	36500	+ 600	+ 1100	38200	10.139	10.603
8	23.13	22.85	36200	+ 1000	+ 1100	38300	10.121	10.696
9	22.41	22.13	32800	+ 800	+ 1000	34600	9.493	10.002
10	22.53	22.25	32500	+ 500	+ 1100	34100	9.360	9.811
11	22.69	22.41	32300	+ 100	+ 1100	33500	9.338	9.678
12	22.17	21.89	32500	+ 100	+ 1100	33700	9.372	9.710
13	22.70	22.42	33100	0	+ 1100	34200	9.521	9.831
14	22.19	21.91	33100	+ 300	+ 1100	34500	9.574	9.970
15	22.61	22.33	33100	+ 700	+ 1100	34900	9.511	10.017
16	22.36	22.08	33200	+ 500	+ 1200	34900	9.522	10.000
17	22.35	22.07	33100	– 100	+ 1200	34200	9.542	9.852
18	22.33	20.05	33500	– 100	+ 1200	34600	9.575	9.883
19	22.10	21.82	33900	– 100	+ 1200	35000	9.617	9.923
20	22.37	22.09	33500	+ 200	+ 1500	35200	9.616	10.094
21	22.64	22.36	33500	+ 400	+ 1600	35500	9.518	10.074
22	22.70	22.42	33500	+ 300	+ 1600	35400	9.523	10.051
23	21.97	21.69	33100	0	+ 1600	34700	9.642	10.098
24	22.06	21.78	33200	+ 300	+ 1700	35200	9.667	10.237
25	22.10	21.82	33300	+ 400	+ 1700	35400	9.705	10.304
26	23.78	23.50	35300	+ 1100	+ 3000	38400	10.239	11.403
27	23.35	23.07	35200	+ 400	+ 3000	38600	10.167	11.129
28	23.04	22.76	35100	– 400	+ 3000	37700	10.139	10.875
29	22.97	22.69	35000	+ 400	+ 3100	38500	10.100	11.090
30	23.54	23.26	35300	+ 600	+ 3100	39000	10.086	11.122
31	23.52	23.24	35300	+ 400	+ 3100	38800	10.102	11.085
32	23.44	23.16	35600	0	+ 3100	28700	10.168	11.036
33	23.16	22.88	35400	+ 700	+ 3400	39500	9.838	10.957
34	22.84	22.56	33000	+ 600	+ 3200	36800	9.477	10.545
35	22.28	22.00	32800	+ 500	+ 3200	36500	9.414	10.454
36	22.00	21.72	32900	+ 500	+ 3200	36600	9.411	10.447
37	22.74	22.46	32700	+ 700	+ 3300	36700	9.514	10.654
38	22.63	22.35	32800	+ 800	+ 3300	36900	9.427	10.579
39	22.60	22.32	32700	+ 800	+ 3400	36900	9.437	10.621
40	22.48	22.20	32600	+ 800	+ 3400	36800	9.423	10.612
41	22.50	22.22	32700	+ 800	+ 3400	36900	9.383	10.563
42	22.83	22.55	32800	+ 500	+ 3600	36900	9.427	10.579

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. △ DHP	25 DRAUGHT CORR. △ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
43	21.98	21.70	32600	+ 100	+ 3600	36300	9.481	10.535
44	19,25	18.97	21200	0	+ 2200	23400	7.405	8.160
45	19.56	19.28	21200	- 200	+ 2200	23200	7.360	8.042
46	19.33	19.05	21200	- 200	+ 2200	23200	7.334	8.014
47	19.69	19.41	21200	+ 200	+ 2200	23600	7.404	8.227
48	20.35	20.07	21300	+ 400	+ 2200	23900	7.384	8.268
49	21.77	22.05	31300	- 2400	+ 1100	30000	9.042	8.674
50	21.19	21.47	31300	- 2400	+ 1100	30000	9.064	8.695
51	21.39	21.67	31100	- 1500	+ 1100	30700	8.967	8.854
52	21.26	21.54	31200	- 1300	+ 1100	31000	8.933	8.877
53	19.85	20.13	31200	- 1500	+ 1100	30800	8.913	8.801
54	20.03	20.31	31200	- 1000	+ 1100	31300	8.909	8.937
55	20.93	21.21	31100	- 1100	+ 1100	31100	9.045	9.045
56	21.23	21.51	31200	- 1100	+ 1200	31300	9.052	9.081
57	21.08	21.36	30400	- 1100	- 300	29000	9.115	8.702
58	21.38	21.66	31100	- 1400	- 300	29400	9.070	8.582
59	21.43	21.71	31300	- 1800	- 300	29200	9.095	8.497
60	21.24	21.52	31200	- 1700	- 400	29100	9.198	8.591
61	20.96	21.24	31200	- 1700	- 500	29000	9.099	8.470
62	20.33	20.61	31400	- 1700	- 500	29200	9.076	8.451
63	19.74	20.02	31400	- 1700	- 500	29200	9.106	8.479
64	20.35	20.63	31400	- 1100	- 400	29900	9.106	8.679
65	20.54	20.82	31400	- 1300	- 400	29700	9.110	8.626
66	20.25	20.53	31200	- 1300	- 400	29500	9.100	8.614
67	20.68	20.96	31100	- 1500	- 400	29200	9.165	8.616
68	20.56	20.84	31100	- 1500	- 500	29100	9.233	8.651
69	20.06	20.34	29300	- 1000	- 600	27000	8.723	8.256
70	20.06	20.34	29200	- 1000	- 600	27600	8.706	8.239
71	20.65	20.93	29300	- 1500	- 600	27200	8.721	8.108
72	20.49	20.77	29400	- 2300	- 600	26500	8.730	7.886
73	19.65	19.93	28900	- 1400	- 500	27000	8.841	8.271
74	19.55	19.83	28900	- 1200	- 500	27200	8.736	8.233
75	20.32	20.60	29200	- 1000	- 500	27900	8.763	8.325
76	20.44	20.72	26900	-	- 400	26500	8.485	8.361
77	19.48	19.76	24800	- 1100	- 300	23400	8.303	7.844
78	19.48	19.76	25100	- 900	- 300	23900	8.335	7.944
79	19.86	20.14	25300	- 800	- 300	24200	8.345	7.990
80	19.75	20.03	25200	- 900	- 300	24000	8.459	8.064
81	19.82	20.10	25500	- 1100	- 200	24100	8.466	8.010
82	20.00	20.28	26700	- 900	- 300	25500	8.696	8.312
83	20.56	20.84	26900	- 500	- 300	26100	8.640	8.388

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. △ DHP	25 DRAUGHT CORR. △ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
84	20.21	20.49	26900	- 800	- 300	25800	8.623	8.277
85	20.86	21.14	31100	- 2400	- 200	28500	9.278	8.516
86	20.79	21.07	30100	- 1900	- 300	27900	9.103	8.450
87	20.44	20.72	29300	- 1000	- 400	27900	8.961	8.541
88	20.57	20.85	29400	- 1100	- 400	27900	8.973	8.525
89	29.50	20.78	28600	- 700	- 400	27500	8.876	8.542
90	20.98	21.26	29700	- 700	- 400	28600	8.928	8.604
91	20.59	20.87	29100	- 700	- 400	28000	8.876	8.547
92	20.86	21.14	29300	- 500	- 300	28500	8.655	8.417
93	20.73	21.01	28700	- 300	- 300	28100	8.649	8.472
94	20.35	20.63	28500	- 700	- 300	27500	8.633	8.336
95	20.25	20.53	29200	- 100	- 300	28800	8.729	8.612
96	21.29	20.57	28800	- 500	- 200	28000	8.770	8.532
97	20.93	21.21	27300	- 900	- 200	26200	8.266	7.940
98	20.58	20.86	26600	+ 200	- 200	26600	8.048	8.048
99	10.17	10.45	26500	+ 200	- 200	26500	7.984	7.984
100	20.81	21.09	26600	+ 200	- 200	26600	8.002	8.002
101	20.75	21.03	26800	- 200	- 200	26400	8.168	8.048
102	20.49	20.77	27600	- 900	- 100	26600	8.324	8.029
103	19.97	20.25	26200	- 700	- 100	25400	7.835	7.601
104	19.39	19.67	25200	- 700	- 100	24400	7.697	7.458
105	19.22	19.50	24900	0	- 100	24800	7.611	7.581
106	19.65	19.93	24900	+ 600	0	25500	7.577	7.756
107	19.34	19.62	24700	- 1000	0	23700	7.572	7.271
108	19.10	19.38	23300	- 900	- 300	22100	7.493	7.115
109	20.01	20.29	24800	0	- 300	24500	7.791	7.699

TABLE (A-21)

SUMMARY OF MONITORING DATA FOR SHIP E, SECOND EXPERIMENT

Column Configuration as for Table (A-18)

1	2	3	4	5	6	7	8	9	10	11	12	13		14			15		16			17		18		19
												FUEL CONS.		DRAUGHTS			WIND		SWELL			MOTION		CURRENT From Charts		
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D. -LOG	t/hr	g/shp hr	For'd	Aft	Mean	Beauf No.	Dirn	Perd	Hgt	Dirn	Pitch	Roll	Speed	Dirn	SEA STATE
1	46.93	2.512	18.68	18.07	90.2	21500	21100	18.78	0.61	-0.10	0.71	7.357	342	10.11	10.96	10.54	4	3	3	3	3	1	1	0.5	5	2
2	53.37	2.996	17.81	18.02	89.4	21500	21100	18.38	-0.21	-0.57	0.36	7.173	331				4	1	2	2	3	1	1	0.5	5	3
3	76.85	4.212	18.25	18.43	89.5	21700	21300	18.34	-0.18	-0.09	-0.09	7.290	336				4	1/2	2	2/3	2/3	1	1	0.5	5	3
4	63.88	3.531	18.09	18.88	89.6	21900	21500	18.31	-0.79	-0.22	-0.57	7.356	336				4	1/2	2/3	3, 4	1/2	1	1	0.5	5	3
5	102.96	5.484	18.77	18.84	90.0	22300	21900	18.36	-0.07	0.41	-0.48	7.295	327	10.16	10.89	10.53	4/3	1/2	3	4	2	1	1/2	0.5	5	3/2
6	105.16	5.675	18.54	19.03	90.1	22000	21600	18.52	-0.49	0.02	-0.51	7.266	330				2	2	2	3	2	1	2	0.5	5	2
7	79.92	4.261	18.79	18.72	90.4	22100	21700	18.64	0.07	0.15	-0.08	7.229	327				1/0	1	4	3	3	1	2	0.5	5	1/0
8	63.44	3.308	19.18	19.07	91.0	22200	21800	18.90	0.11	0.28	-0.17	7.183	324				1	2/3	3	3	3	1	1	0.5	5	1
9	83.81	4.416	18.98	19.05	90.4	21800	21400	18.76	-0.07	0.22	-0.29	7.054	324	10.07	10.88	10.48	3	4	2/3	2/	3/4	1	1	0.5	5	2
10	63.98	3.416	18.73	18.71	90.8*	22200	21800	18.80	0.02	-0.09	0.07	7.213	325				1	3	0	0	0	0	0	0.5	5	0
11	83.94	4.488	18.70	18.55	90.4*	22100	21700	18.64	0.15	0.06	0.09	7.286	330				1	3	0	0	0	0	0	0.5	5	0
12	103.06	5.255	19.61	18.59	90.8*	22500	22100	18.69	1.02	0.93	0.09	7.291	324				2/3	3	0	0	0	0	0	0.5	5	2
13	91.85	4.775	19.24	18.61	91.0*	21300	20900	19.25	0.63	-0.01	0.64	7.312	343				1	2	1	0	1	0	0	0.5	5	1
14	127.65	6.853	18.63	18.48	89.0*	21300	20900	18.25	0.12	0.38	-0.26	7.337	344	9.95	10.81	10.38	1/2	1/2	1/2	1/2	3	0	0	0.5	5	1
15	94.20	5.098	18.48	18.48	92.5*	21100	20700	20.0	0.00	-1.52	1.52	7.297	346				2	3	1	0	3	0	0	0.5	5	1
16	64.06	3.383	18.91	18.66	90.3*	22000	21600	18.64	0.25	0.27	-0.02	7.261	330				3/4	5	1/2	1/2	5	0	0	0.5	5	2
17	69.36	3.633	19.09	18.72	91.9*	22800	22300	19.14	0.36	-0.05	0.42	7.447	327	9.98	10.75	10.36	4	4	1/2	1/2	5	0	0	0.5	5	2
18	80.51	4.171	19.30	18.98	92.0*	22800	22300	19.18	0.32	0.12	0.20	7.447	327				3/4	4	1	1	5	0	0	0.5	5	2
19	78.92	4.125	19.13	18.94	91.6*	22700	22200	19.02	0.19	0.11	0.08	7.426	327				3	4	1	1	5	0	0	0.5	5	2
20	81.24	4.275	19.01	18.93	91.7*	22800	22300	19.03	0.08	-0.02	0.10	7.483	328				3	4	1	1	5	0	0	0.5	5	2
21	98.43	5.190	18.97	18.73	91.6*	22600	22100	19.06	0.24	-0.09	0.33	7.479	331				3	4	1	1	4	0	0	0.5	5	2
22	82.75	4.308	10.21	18.70	91.7*	22600	22100	19.11	0.51	0.10	0.41	7.494	332				4	3	2	1	3	0	0	0.5	5	2
23	54.59	2.884	18.93	18.70	91.5*	22600	22100	19.00	0.23	-0.07	0.30	7.429	329	10.02	10.66	10.34	3	5	1	1	5	0	0	0.5	5	2
24	80.52	4.139	19.45	18.86	91.8*	22500	22000	19.21	0.59	0.24	0.35	7.429	330				3	5	1	1	5	0	0	0.5	5	2
25	74.86	3.857	19.41	—	89.9	2100	20600	18.84	—	0.55	—	7.415	353	10.11	11.50	10.30	2/3	5	2/1	1	5	0	0	0.5	5	2/1
26	60.70	3.241	18.73	—	90.1	21100	20700	18.90	—	-0.17	—	7.449	353				1	5	1	0	5	0	0	0.5	5	1

* One shaft only

1	2	3	4	5	6	7	8	9	10	11	12	13		14			15		16			17		18		19
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D -LOG	FUEL	CONS.	DRAUGHTS			WIND		SWELL			MOTION		CURRENT		SEA STATE
												t/hr	g/shp hr	For'd	Aft	Mean	Beauf No.	Dirn	Perd	Hgt	Dirn	Pitch	Roll	Speed	Dirn	
27	66.37	3.578	18.51	18.51	89.3	21000	20600	18.54	0.04	0.01	0.03	7.429	354				2	4	1	0	4	0	0	0.5	5	1
28	80.32	4.398	18.26	18.50	89.1	21100	20700	18.40	-0.24	-0.14	-0.10	7.332	347				2	4	1	0	4	0	0	0.5	5	1
29	98.03	5.143	19.06	18.67	89.4	21300	20900	18.47	0.39	0.59	-0.20	7.469	351				3	3/4	1	1	3/4	0	0	0.5	5	2
30	56.08	2.998	18.70	—	89.9	21600	21200	18.57	—	0.13	—	7.446	345				4	3	1	1	3	0	0	0.5	5	3
31	80.15	4.125	19.43	18.38	90.1	21700	21300	18.65	1.05	0.78	0.27	7.500	346	10.31	10.45	10.28	5	3	1	2	4	0	1	0.5	5	3
32	88.94	4.635	19.19	18.76	90.1	21500	21100	18.69	0.43	0.50	-0.07	7.416	345				3	4	1	0	4	0	0	0.5	5	2
33	56.13	3.006	18.67	18.38	89.6	21200	20800	18.60	0.29	0.07	0.22	7.376	348				2	4/5	0	0	0	0	0	0.5	5	1
34	71.86	3.784	18.99	18.60	90.8	21500	21100	19.07	0.39	-0.08	0.47	7.486	348	9.90	10.62	10.25	2	5	0	0	0	0	0	0.5	5	1
35	84.32	4.349	19.39	18.96	89.6	21600	21200	18.44	0.43	0.95	-0.52	7.486	347	9.53	10.84	10.21	2/3	4	0/1	0/1	4	0	0	0.5	5	2/1
36	73.26	3.784	19.36	19.11	90.2	22100	21700	18.55	0.25	0.81	-0.56	7.536	341	9.35	11.00	10.18	2	3	1	1	3	0	0	1.0	5	2
37	60.24	3.057	19.69	18.91	90.1	21900	21500	18.57	0.78	1.12	-0.34	7.423	339				2	4	1	1	4	0	0	0.5	5	1/2
38	71.85	3.826	18.78	18.80	90.4	22000	21600	18.68	-0.02	0.10	-0.12	7.412	337				3	5	2	2	4	0	0	1.0	5	2
39	106.78	5.866	18.20	18.76	90.7	21700	21300	18.93	-0.56	-0.73	0.23	7.420	342	9.45	10.98	10.21	2	3	1/2	1/2	4	0	0	1.00	5	1/2
40	153.38	8.267	18.55	18.69	91.1	22100	21700	18.97	-0.14	-0.42	0.28	7.539	341	9.40	10.90	10.19	3	5	3	3	4	1	3	0.5	5	3
41	103.88	5.233	19.85	20.02	94.5	25000	24500	19.58	-0.17	0.27	-0.44	8.149	326				5	5	3	4	5	1	3	0.5	5	4
42	75.90	3.941	19.26	20.38	95.7	25700	25200	19.91	-1.12	-0.65	-0.47	8.329	324				5	4	3	4	5	1	3	0.5	5	4
43	80.15	4.071	19.69	20.31	95.2	25800	25300	19.63	-0.62	0.06	-0.68	8.311	322				4	4	3	4	4	1	3	0.5	5	4
44	70.67	3.614	19.55	20.38	95.6	26000	25500	19.76	-0.83	-0.21	-0.62	8.386	323				4	4	3	3/4	4	1	3	0.5	5	4
45	108.71	5.498	19.77	20.26	96.0	25600	25100	20.10	-0.49	-0.33	-0.16	8.282	324				4	4	3	3	4	1	2	---	-	4
46	92.45	4.773	19.37	20.06	94.7	25400	24900	19.54	-0.68	-0.17	-0.51	8.228	324				3/4	4	2	2/3	3/4	0	2	---	-	2/3
47	86.65	4.426	19.58	19.88	95.8	25800	25300	19.93	-0.30	-0.35	0.05	8.416	326	9.92	10.39	10.17	3	3	2	3	3	0	2	---	-	2/3
48.	112.35	5.147	21.83	21.33	102.9	31700	31100	21.97	0.50	-0.14	0.64	9.731	307	9.26	9.79	9.53	3/4	4/5	2	2	4	0	0	0.5	5	3
49	138.76	6.390	21.71	21.16	103.7	31500	30900	21.93	0.55	-0.22	0.77	9.592	304				4	4	2	2	4	0	1	0.5	5	3
50	74.07	3.510	21.10	21.09	102.4	31200	30600	21.41	0.01	-0.31	0.32	9.419	302				5	4	2	2	4	0	2	0.5	5	3
51	75.80	3.610	21.00	20.17	98.2	27100	26600	20.66	0.83	0.34	0.49	8.655	319				4	4	2	3	4	0	3	1.0	5	4
52	93.16	4.249	21.93	20.33	98.0	27000	26500	20.59	1.60	1.34	0.26	8.592	318	9.23	9.78	9.51	4	5	2	3	5	0	2	1.0	5	4
53	79.25	3.908	20.28	20.42	97.1	27500	27000	19.98	-0.14	0.30	-0.44	8.802	320				1	4	1	1	5	0	0	1.0	5	1
54	112.733	5.431	20.76	20.69	101.7	28500	27900	21.41	0.07	-0.65	-0.72	8.986	315	9.18	9.80	9.49	1	4	0	0	0	0	0	1.0	5	1

1	2	3	4	5	6	7	8	9	10	11	12	13		14			15		16			17		18		19
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D. -LOG	FUEL t/hr	CONS. g/shp hr	DRAUGHTS For'd	Aft	Mean	WIND Beauf No.	Dirn	SWELL Perd	Hgt	Dirn	MOTION Pitch	Roll	CURRENT From Charts Speed	Dirn	SEA STATE
55	154.66	6.331	24.43	24.41	119.0	50400	49400	24.57	0.02	-0.14	0.16	13.372	265	9.87	10.11	9.99	2	1	2	2	1	0	1	1.0	1	1/2
56	97.48	4.026	24.21	24.58	119.3	50800	49800	24.61	-0.37	-0.40	0.03	13.376	263				4	2	2/3	2/3	2	0	0	0.5	1	3/4
57	73.56	3.308	22.24	21.25	109.3	39100	38300	22.54	0.99	-0.30	1.29	10.923	279	11.24	11.24	11.24	5	2	3	5	2	2	2	0.5	5	4
58	124.16	5.606	21.20	20.83	104.1	37500	36800	20.36	0.37	0.84	-0.47	10.520	281	11.08	11.31	11.20	5	2/3	3	4	1/2	2	2	0.5	1	4
59	85.67	4.223	20.26	21.33	108.0	38300	37500	22.12	-1.07	-1.86	-0.79	10.675	279	11.14	11.10	11.13	4/5	2	3	3/4	2	1	2	0.5	1	4
60	74.74	3.673	20.35	21.59	109.2	38400	37600	22.69	-1.22	-2.32	1.10	10.676	278	11.18	11.02	11.10	4	1/2	3	3	2	0	2	1.0	1	4
61	95.10	4.159	22.87	23.32	113.9	44000	43100	23.56	-0.45	-0.69	0.24	11.763	267	11.19	11.92	11.06	3/4	1	2	3	1	1	1	0.5	1	3
62	113.96	4.857	23.46	23.51	113.9	43900	43000	23.59	-0.05	-0.13	0.08	11.792	269				3	1	2	2	1	1	1	0.5	1	2
63	115.57	4.959	23.30	23.45	113.7	43800	42900	23.50	-0.15	-0.20	0.05	11.806	270				3	2	2	2	2	0	0	0.5	1	2
64	84.76	3.806	22.27	23.45	114.3	43700	42800	23.82	-1.18	-1.55	0.37	11.893	272	11.07	10.98	11.03	1	1	3	2	1	1	1	0.5	1	1
65	85.85	3.661	23.45	22.60	113.3	43900	43000	23.29	0.85	0.16	0.69	11.873	270	10.91	11.05	10.98	3/4	2	2/3	2/3	2/1	0/1	1/2	0.5	1	2
66	108.64	4.767	22.78	22.65	114.0	44400	43500	23.52	0.13	-0.74	0.87	11.868	267				4	2	2/3	3/4	2	1/2	1/2	0.5	1	2/3
67	112.96	5.045	22.39	22.10	112.4	44100	43200	22.75	0.29	-0.36	0.65	11.787	267				5	2	2	4	2	1	2	0.5	1	4
68	85.21	3.735	22.81	22.10	112.4	44000	43100	22.78	0.71	0.03	0.68	11.750	267	10.78	11.10	10.94	5	2	2	4	2	1	2	0.5	1	4
69	89.22	3.861	23.11	22.26	113.4	44000	43100	23.31	0.85	-0.20	1.05	11.785	268				5	3	3	5	3	0	2	0.5	1	4
70	150.11	6.351	23.64	23.68	114.5	42900	42000	24.10	-0.04	-0.46	0.72	11.702	273	10.64	11.15	10.89	0	0	0	0	0	0	0	1.0	1	0
71	117.76	5.116	23.02	23.81	113.9	43000	42100	23.83	-0.79	-0.81	0.02	11.654	271				0	0	0	0	0	0	0	1.0	1	0
72	94.38	4.261	22.15	22.40	108.3	37000	36300	22.60	-0.25	-0.45	0.20	10.559	285				3	1	0	0	0	0	0	0.5	1	0
73	104.56	4.835	21.63	21.96	105.0	38200	37400	20.66	-0.33	0.97	-1.30	10.781	282	10.59	11.07	10.83	4	1	2	2	1	0	0	0.5	1	4
74	114.71	5.206	22.04	22.12	109.3	40200	39400	22.24	-0.08	0.20	0.12	11.204	279				4/5	1	2	3	1	0	0	0.5	1	4
75	115.09	5.116	22.50	22.55	110.4	41300	40500	22.48	-0.05	0.02	-0.07	11.213	271				4	1	2	3	1	0	0	0.5	1	3
76	123.41	5.526	22.34	22.30	110.0	41200	40400	22.31	0.04	0.03	0.01	11.195	272				4/5	1	2	3	1	0	0	0.5	1	3/4
77	68.87	2.925	23.55	24.13	115.8	41700	46100	23.76	-0.58	-0.21	-0.37	12.632	269	10.52	11.22	10.87	4	2	3	2	2	0	0	0.5	1	2
78	99.14	4.159	23.83	24.03	115.8	47300	46400	23.71	-0.20	0.12	-0.32	12.695	269				4	2	3	2	2	0	0	0.5	1	2
79	108.48	4.632	23.42	24.00	115.7	47300	47200	23.63	-0.58	-0.11	-0.37	12.563	266				3/4	2	2	3	2	0	0	0.5	1	2
80	138.56	5.749	24.10	24.25	116.8	48200	47200	24.00	-0.15	0.10	-0.25	12.636	262				3	2	2	2	2	0	0	0.5	1	2

1	2	3	4	5	6	7	8	9	10	11	12	13		14			15		16			17		18		19
RUN No.	OBS. DIST.	TIME	OBS. SPEED	LOG SPEED	RPM	SHP	DHP	G.P.D. SPEED	OBS. -LOG	OBS. G.P.D.	G.P.D. -LOG	FUEL t/hr	CONS. g/shp hr	DRAUGHTS			WIND		SWELL			MOTION		CURRENT From Charts		SEA STATE
														For'd	Aft	Mean	Beauf No.	Dirn	Perd	Hgt	Dirn	Pitch	Roll	Speed	Dirn	
81	138.56	5.749	24.10	24.25	116.8	48200	47200	24.20	0.24	0.20	0.04	12.784	265	10.40	11.24	10.82	0	0	1	1	3	00	0	0.5	1	1
82	112.00	4.590	24.40	24.16	117.2	48700	47700	24.28	0.38	0.37	0.01	12.764	262	10.32	11.26	10.78	4	5	1	1	5	0	0	0.5	1	2
83	109.94	4.251	24.45	24.23	117.7	48700,	47700	24.34	0.22	0.11	0.11	12.782	262				3	5	0	0	0	0	0	0.5	1	1
84	95.54	4.008	23.84	24.36	117.7	48900	47900	24.28	-0.42	-0.44	0.02	12.777	262				3	5	1	1	5	0	0	0.5	1	1
85	91.10	3.700	24.62	24.30	117.6	48700	47700	24.28	0.32	0.34	-0.02	12.777	262	10.24	11.26	10.75	4/5	4/5	2	2	5	0	0	0.5	1	2
86	102.63	4.274	24.01	24.23	115.4	48600	47600	23.18	-0.22	0.83	-1.05	12.649	260				3	5	0	0	0	0	0	0.5	1	2
87	58.08	2.471	23.51	23.82	117.2	48900	47900	24.03	-0.31	-0.52	0.21	12.682	259	10.16	11.28	10.72	4	1	3	1	1	3	1	0.5	1	4
88	137.00	5.512	24.86	24.36	122.8	58600	57400	24.55	0.50	0.31	0.19	13.719	251	10.30	10.19	10.74	2/3	3	4	5	2	3	2	0.5	1	2/3

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. △ DHP	25 DRAUGHT CORR. △ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
1	18.68	18.59	21100	0	+ 900	22000	7.357	7.665
2	17.81	17.72	21100	− 1100	+ 900	20900	7.173	7.107
3	18.25	18.16	21300	− 1000	+ 900	21200	7.290	7.256
4	18.09	18.00	21500	− 1000	+ 900	21400	7.356	7.322
5	18.77	18.68	21900	− 900	+ 1000	22000	7.295	7.328
6	18.54	18.45	21600	− 300	+ 1000	22300	7.266	7.497
7	18.79	18.70	21700	− 100	+ 1000	22600	7.229	7.523
8	19.18	19.09	21800	0	+ 1000	22800	7.183	7.507
9	18.98	18.89	21400	+ 300	+ 1000	22700	7.054	7.475
10	18.73	18.64	21800	0	+ 1200	23000	7.213	7.603
11	18.70	18.61	21700	0	+ 1200	22900	7.286	7.682
12	19.61	19.52	22100	0	+ 1200	23300	7.291	7.680
13	19.24	19.15	20900	− 100	+ 1200	22000	7.312	7.689
14	18.63	18.54	20900	− 200	+ 1200	21900	7.337	7.681
15	18.48	18.39	20700	0	+ 1200	21900	7.297	7.712
16	18.91	18.82	21600	+ 500	+ 1200	23300	7.261	7.822
17	19.09	19.00	22300	+ 500	+ 1300	24100	7.447	8.036
18	19.30	19.21	22300	+ 400	+ 1300	24000	7.447	8.003
19	19.13	19.04	22200	+ 300	+ 1300	23800	7.426	7.949
20	19.01	18.92	22300	+ 300	+ 1300	23900	7.483	8.008
21	18.97	18.88	22100	+ 300	+ 1300	23700	7.479	8.009
22	19.21	19.12	22100	0	+ 1300	23400	7.494	7.926
23	18.93	18.84	22100	+ 500	+ 1300	23900	7.429	8.021
24	19.45	19.36	22000	+ 500	+ 1300	23800	7.429	8.023
25	19.41	19.32	20600	+ 400	+ 1300	22300	7.415	8.015
26	18.73	18.64	20700	+ 100	+ 1300	22100	7.449	7.943
27	18.55	18.46	20600	+ 200	+ 1300	22100	7.429	7.966
28	18.26	18.17	20700	+ 200	+ 1300	22200	7.332	7.853
29	19.06	18.97	20900	+ 200	+ 1300	22400	7.469	7.996
30	18.70	18.61	21200	+ 300	+ 1300	22800	7.446	7.998
31	19.43	19.34	21300	0	+ 1300	22600	7.500	7.950
32	19.19	19.10	21100	+ 300	+ 1300	22700	7.416	7.968
33	18.67	18.58	20800	+ 300	+ 1300	22400	7.376	7.933
34	18.99	18.90	21100	+ 300	+ 1400	22800	7.486	8.078
35	19.39	19.30	21200	+ 300	+ 1500	23000	7.486	8.111
36	19.36	19.27	21700	0	+ 1600	23300	7.536	8.082
37	19.69	19.60	21500	+ 200	+ 1600	23300	7.423	8.033
38	18.78	18.69	21600	+ 500	+ 1600	23700	7.412	8.120
39	18.20	18.11	21300	0	+ 1500	22800	7.420	7.933

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. △ DHP	25 DRAUGHT CORR. △ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
40	18.55	18.46	21700	+ 500	+ 1500	23700	7.509	8.221
41	19.85	19.76	24500	+ 700	+ 1900	27100	8.149	8.997
42	19.26	19.17	25200	+ 700	+ 1900	27800	8.329	9.171
43	19.69	19.60	25300	+ 500	+ 1900	27700	8.311	9.084
44	19.55	19.46	25500	+ 500	+ 1900	27900	3.386	9.161
45	19.77	19.68	25100	+ 500	+ 1900	27500	8.282	9.060
46	19.37	19.28	24900	+ 400	+ 1900	27200	8.228	8.973
47	19.58	19.49	25300	- 100	+ 1900	27200	8.416	9.035
48	21.83	21.74	31100	+ 700	+ 4400	36200	9.731	11.297
49	21.71	21.62	20900	+ 700	+ 4400	36000	9.592	11.142
50	21.10	21.01	30600	+ 900	+ 4400	35900	9.419	11.020
51	21.00	20.91	26600	+ 600	+ 3800	31000	8.655	10.059
52	21.93	21.84	26500	+ 700	+ 3900	31100	8.592	10.055
53	20.28	20.19	27000	+ 100	+ 3900	31000	8.802	10.082
54	20.76	20.67	27900	+ 100	+ 3900	31900	8.986	10.246
55	24.43	24.52	49400	- 600	+ 5000	53800	13.372	14.538
56	24.21	24.30	49800	- 1400	+ 5000	53400	13.376	14.323
57	22.24	22.33	28200	- 1800	- 600	35900	10.923	10.253
58	21.20	21.29	36800	- 900	- 500	35400	10.520	10.127
59	20.26	20.35	37500	- 1400	- 300	35800	10.675	10.201
60	20.35	20.44	37600	- 1500	- 300	35800	10.676	10.176
61	22.87	22.96	43100	- 1400	- 200	41500	11.762	11.335
62	23.46	23.55	43000	- 1100	- 200	41700	11.792	11.442
63	23.30	23.39	42900	- 900	- 200	41800	11.806	11.509
64	22.27	22.36	42800	- 200	- 100	42500	11.893	11.811
65	23.45	23.54	43000	- 1100	+ 100	42000	11.873	11.603
66	22.78	22.87	43500	- 1400	+ 100	42200	11.868	11.521
67	22.39	22.48	43200	- 1900	+ 200	41500	11.787	11.333
68	22.81	22.90	43100	- 1900	+ 300	41500	11.750	11.323
69	23.11	23.20	43100	0	+ 300	43400	11.735	11.865
70	23.64	23.73	42000	0	+ 500	42500	11.702	11.838
71	23.02	23.11	42100	0	+ 500	42600	11.654	11.789
72	22.15	22.24	36300	- 1000	+ 500	35800	10.559	10.416
73	21.63	21.72	37400	- 1500	+ 700	36600	10.781	10.555
74	22.04	22.13	39400	- 2100	+ 700	38000	11.204	10.813
75	22.50	22.59	40500	- 1500	+ 800	39800	11.213	11.023
76	22.34	22.43	40400	- 2100	+ 800	39100	11.195	10.841
77	23.55	23.64	46100	- 1300	+ 700	45500	12.632	12.471
78	22.83	23.32	46300	- 1300	+ 700	45700	12.695	12.534
79	23.42	23.51	46400	- 1100	+ 800	46100	12.563	12.483
80	24.10	24.19	47200	- 900	+ 900	47300	12.636	12.636

20 RUN NO.	21 OBS. SPEED	22 CORRECTED OBS. SPEED	23 DHP	24 WIND CORR. △ DHP	25 DRAUGHT CORR. △ DHP	26 CORRECTED DHP	27 FUEL CONSUMPTION	28 CORRECTED FUEL CONS.
81	24.40	24.49	47200	0	+ 1000	48200	12.784	13.049
82	24.65	24.74	47700	+ 1100	+ 1200	50000	12.764	13.367
83	24.45	24.54	47700	+ 800	+ 1200	49700	12.782	13.306
84	23.84	23.93	47900	+ 800	+ 1300	50000	12.777	13.327
85	24.62	24.71	47700	+ 1200	+ 1400	50300	12.777	12.458
86	24.01	24.10	47600	+ 800	+ 1400	49800	12.649	13.221
87	23.51	23.60	47900	- 1800	+ 1500	47600	12.682	12.604
88	24.86	24.95	57400	0	+ 1800	59200	14.719	15.171

Appendix B

TABLES OF RESULTS FROM HULL ROUGHNESS ANALYSIS (CHAPTER 1)

AND

COST AND STATISTICAL INFORMATION FOR CASE STUDIES

(CHAPTERS 3 AND 4)

TABLE (B-1) AVERAGE HULL ROUGHNESS FOR NEW SHIPS

SHIP TYPE	BUILDING PLACE	AHR (μm)
LPG CARRIER	ST. NAZAIRE, FRANCE	140
ULCC	ST. NAZAIRE, FRANCE	157
BULK CARRIER	SUNDERLAND, U.K.	113
GENERAL CARGO	SUNDERLAND, U.K.	135
CONTAINER	DEVON, U.K.	110
CONTAINER	DEVON, U.K.	89
CONTAINER FEEDER	TYNE, U.K.	78
CONTAINER	DEVON, U.K.	121
GENRAL CARGO	SUNDERLAND, U.K.	120
CONTAINER	DEVON, U.K.	100
CONTAINER	BREMEN, GERMANY	125
CONTAINER	U.S.A.	124
CONTAINER	U.S.A.	141
CONTAINER	U.S.A.	165
CONTAINER	U.S.A.	131
CONTAINER	U.S.A.	123
CONTAINER	U.S.A.	124

TABLE (B-2) CHANGE IN ROUGHNESS DURING DRYDOCKING

SHIP TYPE	INDOCKING AHR (μm)	OUTDOCKING AHR (μm)	CHANGE IN AHR (μm)
GENERAL CARGO	470	455	-15
VLCC	125	156	+31
VLCC	155	222	+67
GENERAL CARGO	317	352	+35
REFRIG. CARGO	558	575	+17
VLCC	397	422	+25
CONTAINER	159	166	+ 7
VLCC	212	225	+13
REFRIG. CARGO	544	527	-17
PASSENGER	629	638	+ 9
PASSENGER	669	649	-20
GENERAL CARGO	109	138	+29
REFRIG. CARGO	513	522	+ 9
GENERAL CARGO	351	340	-11
PASSENGER	152	194	+42
GENERAL CARGO	178	214	+36
PASSENGER	147	143	-4
PASSENGER	145	181	+36
CONTAINER	124	138	+14
VLCC	128	198	+70
REFRIG. CARGO	163	160	-3
PRODUCT CARRIER	271	293	+22
PRODUCT CARRIER	422	426	+ 4
CONTAINER	172	168	-4
CONTAINER	109	107	-2
GENERAL CARGO	253	271	+18
CONTAINER	124	133	+ 9
CONTAINER	158	188	+30
CONTAINER	430	379	-51
CONTAINER	453	415	-38
VLCC	166	183	+17
VLCC	113	161	+48
CONTAINER	147	153	+ 6
CONTAINER	156	182	+26
BULK CARRIER	130	140	+10
RO RO	345	264	-81
CONTAINER	377	342	-35
CONTAINER	131	139	+ 8
CONTAINER	146	191	+45
CONTAINER	140	155	+15
CONTAINER	164	243	+79
CONTAINER	131	150	+19
CONTAINER	123	154	+31
CONTAINER	124	161	+37

TABLE (B-3) CHANGES IN HULL ROUGHNESS WITH TIME IN SERVICE

SHIP TYPE	AGE (MONTHS)	AHR (μm)	AVERAGE INCREASE IN AHR IN SERVICE (μm/MONTH)
GENERAL CARGO	158	470	+1.79
VLCC	27	125	-0.91
VLCC	42	156	-0.41
GENERAL CARGO	51	317	+3.10
REFRIG. CARGO	70	655	+7.73
VLCC	41	303	+3.27
VLCC	63	397	+3.72
CONTAINER	33	159	+0.20
VLCC	18	183	+3.33
REFRIG. CARGO	172	1083	+6.92
PASSENGER	227	669	+3.72
GENERAL CARGO	12	109	-1.08
REFRIG. CARGO	61	639	+8.45
GENERAL CARGO	34	351	+6.19
PASSENGER	26	152	+0.18
GENERAL CARGO	15	178	+3.67
PASSENGER	34	145	-0.85
VLCC	112	351	+1.37
VLCC	84	128	-1.17
VLCC	13	135	+0.92
REFRIG. CARGO	54	595	+8.56
PRODUCT CARRIER	182	376	+0.70
PRODUCT CARRIER	22	271	+5.92
GENERAL CARGO	83	337	+1.82
CONTAINER	74	172	-0.30
BULK CARRIER	114	429	+2.18
GENERAL CARGO	89	407	+2.62
PASSENGER	150	782	+5.45
PASSENGER	115	524	+3.12
CONTAINER	114	241	+0.15
VLCC	121	432	+2.06
PRODUCT CARRIER	82	561	+5.07
CONTAINER	16	158	+2.19
CONTAINER	14	124	+0.07
VLCC	78	609	+6.05
GENERAL CARGO	30	253	+3.63
VLCC	48	244	+1.66
CONTAINER	192	430	+1.11
CONTAINER	12	174	+4.25
PRODUCT CARRIER	121	505	+2.81
CONTAINER	84	453	+3.43
VLCC	122	315	+0.76
PRODUCT CARRIER	42	420	+6.47
CONTAINER	79	228	+0.52
CONTAINER	84	725	+7.28
PASSENGER	174	800	+4.80
GENERAL CARGO	111	820	+6.63
CONTAINER	118	534	+3.21
BULK CARRIER	123	720	+4.99
BULK CARRIER	16	130	+0.44
RO RO	98	996	+10.16
RO RO	54	345	+3.49
CONTAINER	84	377	+2.38
RO RO	94	544	+4.11
CONTAINER	58	285	+1.83
CONTAINER	102	283	+0.67

TABLE (B-4) PAINT COSTS AND APPLICATION RATES (1981)

	WORLDWIDE COST/LITRE	DISCOUNT	NET COST/ LITRE	APPLICATION RATE LITRE/m²	COST/m²
1 BLAST PRIMER OR HOLDING PRIMER @ 25µm/coat	$10.00	30%	$ 7.00	8.5	$ 0.82
2A VINYL PITCH ANTICORROSIVE 3 COATS @ 75µm/coat	$ 5.00	30%	$ 3.50	3.8 5.7 #	$ 2.76 $ 0.61 #
2B PITCH-EPOXY 2 COATS @ 125µm/coat	$ 6.00	30%	$ 4.20	3.7	$ 2.27
3A ECONOMICAL ANTIFOULING 2 coats @ 50µm ON SIDES	$ 8.00	30%	$ 5.60	7.2	$ 1.56 } 1.24*
1 coat @ 50µm ON FLATS					$ 0.78 } 1.24*
3B PREMIUM CONVENTIONAL ANTIFOULING 2 coats @ 75µm ON SIDES	$13.00	30%	$ 9.10	5.0	$ 3.64 } 2.91*
1 coat @ 75µm ON FLATS					$ 1.82 } 2.91*
3C SELF POLISHING ANTIFOULING 3 coats @ 100µm OVERALL	$20.00	40%	$12.00	3.0	$12.00
4 coats @ 100µm OVERALL					$16.00

* BASED ON 60% SIDES AND 40% FLATS

USED AS SEALER

TABLE (B-5) REVIEW OF DRYDOCKING CHARGES (1981)

	PORTUGAL	HONG KONG	SINGAPORE	KOREA	DENMARK	BAHREIN	AVERAGE
REBLAST SA 2.5	13.00	11.00	12.00	7.00 (sand)	12.50	11.36	12.00
GRITSWEEPING	7.00	9.00	6.50	-	4.00	-	6.50
PAINT APPLICATION - PRIMER		-	-	-			
- ANTICORROSIVE	0.47	0.48-0.75	0.50-0.65	0.30-0.44	0.32 0.44*	0.32	0.50 0.60*
- CONVENTIONAL ANTIFOULINGS		0.55-0.86 *	-	0.36-0.53	0.40		0.50
- SELF POLISHING ANTIFOULING	0.66	0.65-1.00	1.00	0.60-0.90	0.54	-	0.75
TOUCHING UP COATS OF PAINT	0.75	0.50	0.45-0.50	0.30-0.36	-	0.55	0.50
HIGH PRESSURE WASHING	0.73	0.52	1.00	-	0.63	0.55	0.70
LOW PRESSURE HOSING	0.19	0.09	0.20	-	-	-	0.16

ALL COSTS ARE EXPRESSED IN U.S. DOLLARS/m^2

TABLE (B-6) PAINT SYSTEM COSTS 1981

	PREMIUM CONV. 10% SPOT BLAST	PREMIUM CONV. 20% SPOT BLAST	PREMIUM CONV. FULL REBLAST	SELF POLISHING 10% SPOT BLAST		SELF POLISHING 20% SPOT BLAST		SELF POLISHING FULL REBLAST		SELF POLISHING 10% SPOT BLAST + GRIT SWEEP	
				3COATSYST	4COATSYST	3COATSYST	4COATSYST	3COATSYST	4COATSYST	3COATSYST	4COATSYST
HIGH PRESSURE WASH	0.70	0.70		0.70	0.70	0.70	0.70			0.70	0.70
BLAST 10% BLAST 20% FULL REBLAST	1.80	3.60	12.00	1.80	1.80	3.60	3.60	12.00	12.00	1.80	1.80
GRIT SWEEP										6.50	6.50
TOUCH UP MATERIALS - APPLICATION	0.55 0.30	1.10 0.60		0.55 0.30	0.55 0.30	1.10 0.60	1.10 0.60			0.45 0.36	0.45 0.36
PRIMER FULL COAT			0.82					0.82	0.82		
ANTICORROSIVE MATERIALS - APPLICATION			2.76 1.50					2.76 1.50	2.76 1.50	0.76 0.60	0.76 0.60
SEALER FULL COAT - APPLICATION	0.61 0.50	0.61 0.50									
ANTIFOULING MATERIALS - APPLICATION	2.91 0.80	2.91 0.80	2.91 0.80	12.00 2.25	16.00 3.00	12.00 2.25	16.00 3.00	12.00 2.25	16.00 3.00	12.00 2.25	16.00 3.00
TOTAL COST	8.17	10.82	20.79	17.60	22.35	20.25	25.00	31.33	36.08	25.42	30.17

ALL COSTS ARE U.S. DOLLARS/m^2

FIGURE (B-1)
PRICE DEVELOPMENTS FOR 180 cst MARINE FUEL OIL 1972-1983
BASED ON 5/6 WORLD PORTS IN JANUARY/FEBRUARY OF EACH YEAR
[SOURCE: "PETROLEUM ECONOMIST", "MOTOR SHIP" & "OECD ECONOMIC OUTLOOK"]

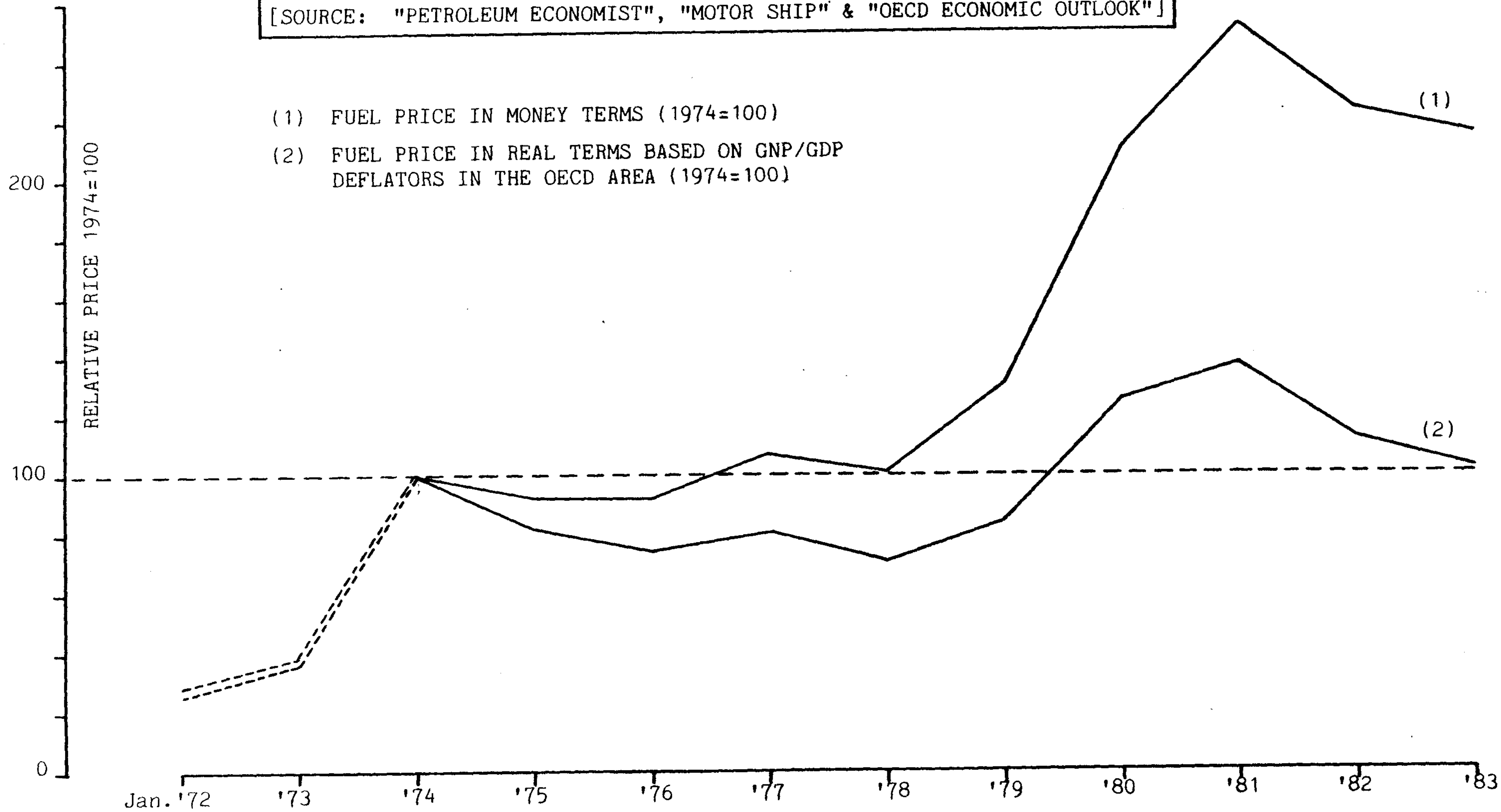
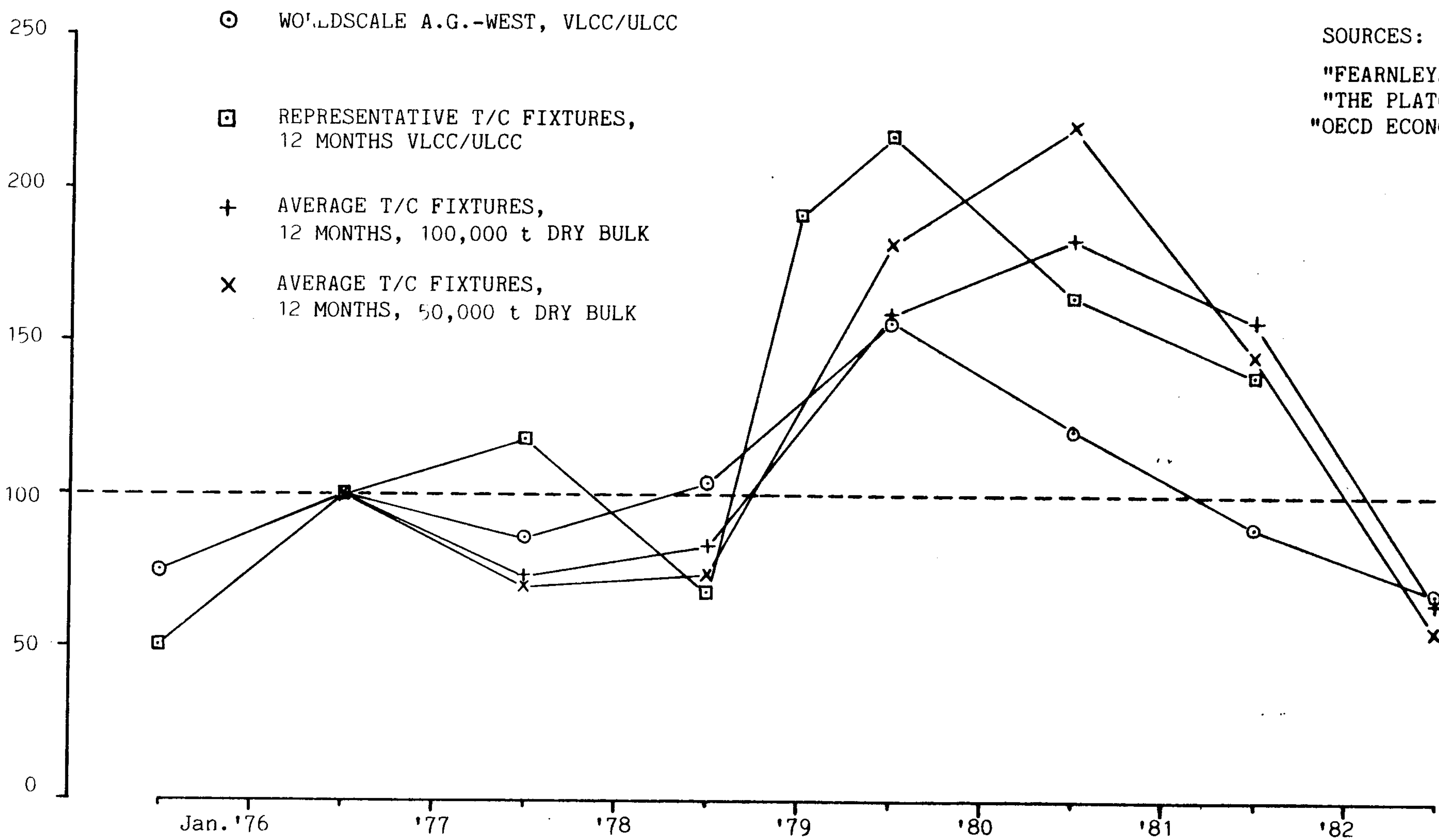


FIGURE (B-2)
RELATIVE MOVEMENTS IN THE CHARTER AND VOYAGE CHARTER RATES IN REAL TERMS, 1976=100



SOURCES:

"FEARNLEYS REVIEW"
"THE PLATOU REPORT"
"OECD ECONOMIC OUTLOOK"

Appendix C

TABLES OF RESULTS FROM CASE STUDIES (CHAPTER 3)

TABLE (C-1)

CASE STUDY 2.1

SHIP A

PERIOD OF CALCULATION		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200µm	300µm	400µm	500µm	600µm	700µm	800µm
2 years	NPV	19.3	321.4	572.6	788.6	982	1156	1315
	PROF/ INV	0.120	2.001	3.565	4.910	6.115	7.198	8.188
4 years	NPV	287.5	805	1241	1622	1963	2273	2558
	PROF/ INV	1.790	5.012	7.727	10.10	12.22	14.15	15.93
6 years	NPV	474.8	1148	1723	2229	2685	3102	3486
	PROF/ INV	2.956	7.148	10.73	13.88	16.72	19.32	21.71
8 years	NPV	608.5	1399	2078	2681	3226	3726	4189
	PROF/ INV	3.789	8.711	12.94	16.69	20.09	23.20	26.08
10 years	NPV	708.3	1584	2344	3021	3636	4201	4725
	PROF/ INV	4.410	9.863	14.60	18.81	22.64	26.16	29.42

NPV = Difference in net present value between alternative hull maintenance strategies ($1000)

PROF/ INV = Discounted profit to investment ratio

TABLE (C-2)

CASE STUDY 2.1

SHIP B (1)

PERIOD OF CALCULATION		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200μm	300μm	400μm	500μm	600μm	700μm	800μm
2 years	NPV	30.1	116.6	186.79	246.4	298.3	344.7	386.6
	PROF/INV	0.335	1.300	2.083	2.747	3.327	3.843	4.311
4 years	NPV	107.6	254.8	376.4	481	573	655	730
	PROF/INV	1.199	2.841	4.197	5.361	6.386	7.306	8.142
6 years	NPV	160.7	351.7	511.5	650	773	883	984
	PROF/INV	1.792	3.922	5.703	7.248	8.616	9.851	10.98
8 years	NPV	198.5	421.6	610	775	921	1054	1175
	PROF/INV	2.213	4.701	6.804	8.639	10.27	11.75	13.11
10 years	NPV	226	473	683	868	1033	1183	1321
	PROF/INV	2.52	5.275	7.620	9.679	11.52	13.19	14.73

NPV = Difference in net present value between alternative hull maintenance strategies ($1000)

PROF/INV = Discounted profit to investment ratio

TABLE (C-3)

CASE STUDY 2.1

SHIP B (2)

PERIOD OF CALCULATION		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200µm	300µm	400µm	500µm	600µm	700µm	800µm
2 years	NPV	-89.1	-1.7	69.2	129.4	182.0	228.8	271.2
	PROF/INV	-0.966	-0.018	0.751	1.403	1.974	2.482	2.941
4 years	NPV	-10.8	137.9	260.7	366.2	459.1	542.4	618.1
	PROF/INV	-0.117	1.496	2.828	3.972	4.979	5.883	6.704
6 years	NPV	49.2	235.7	397.0	536.9	660.8	772.5	874.6
	PROF/INV	0.465	2.556	4.306	5.832	7.167	8.379	9.486
8 years	NPV	81.8	306.2	496.5	662.5	810.5	944.5	1067
	PROF/INV	0.887	3.321	5.385	7.185	8.792	10.24	11.57
10 years	NPV	108.8	358.0	570.2	756.4	923.1	1074	1213
	PROF/INV	1.180	3.883	6.184	8.204	10.01	11.65	13.16

NPV = Difference in net present value between alternative hull maintenance strategies ($1000)

PROF/INV = Discounted profit to investment ratio

TABLE (C-4)

CASE STUDY 2.1

SHIP C

PERIOD OF CALCULATION		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200µm	300µm	400µm	500µm	600µm	700µm	800µm
2 years	NPV	-282.9	-164.5	-69.0	11.5	81.6	143.8	199.8
	PROF/ INV	-0.672	-0.391	-0.164	0.027	0.194	0.342	0.475
4 years	NPV	-176.5	24.5	189.6	330.7	454.4	564.9	665.0
	PROF/ INV	-0.419	0.058	0.450	0.786	1.079	1.342	1.580
6 years	NPV	-104	156.3	373.0	559.9	724.9	873.1	1007.9
	PROF/ INV	-0.247	0.371	0.886	1.330	1.722	2.074	2.394
8 years	NPV	-52.8	250.9	506.3	728.1	925.1	1103	1265
	PROF/ INV	-0.125	0.596	1.203	1.729	2.197	2.620	3.005
10 years	NPV	15.7	320.3	604.9	853.4	1075	1275	1459
	PROF/ INV	-0.037	0.761	1.437	2.027	2.553	3.029	3.466

NPV = Difference in net present value between alternative hull maintenance strategies ($1000)

PROF/ INV = Discounted profit to investment ratio

TABLE (C-5)

CASE STUDY 2.1

SHIP D

PERIOD OF CALCULATION		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200µm	300µm	400µm	500µm	600µm	700µm	800µm
2 years	NPV	-69.6	12.0	77.7	133.2	181.4	224.3	262.9
	PROF/ INV	-0.503	0.087	0.562	0.963	1.312	1.622	1.901
4 years	NPV	3.7	142.3	256.0	353.2	438.3	514.5	583.4
	PROF/ INV	0.027	1.029	1.851	2.554	3.169	3.720	4.218
6 years	NPV	53.8	233.2	382.4	511.2	624.8	726.9	819.7
	PROF/ INV	0.389	1.686	2.765	3.696	4.518	5.256	5.927
8 years	NPV	89.2	298.4	474.3	627.2	762.8	885.2	996.9
	PROF/ INV	2.645	2.158	3.430	4.535	5.516	6.401	7.208
10 years	NPV	114.8	346.3	542.3	713.6	866.3	1005	1132
	PROF/ INV	0.830	2.504	3.921	5.160	6.264	7.267	8.185

NPV = Difference in net present value between alternative hull maintenance strategies ($1000)

PROF/ INV = Discounted profit to investment ratio

TABLE (C-6)

CASE STUDY 2.2 SHIP A

OUTDOCKING AHR AFTER REBLAST	DIFFERENCE IN NPV RELATIVE TO AN OUTDOCKING AFTER REBLAST OF 125 µm				
	2 YEARS	4 YEARS	6 YEARS	8 YEARS	10 YEARS
125 µm	-	-	-	-	-
150	-121.8	-200	-253	-291	-318
175	-232.3	-384	-488	-561	-616
200	-333.7	-554	-707	-816	-896
225	-427.8	-714	-913	-1056	-1161
250	-515.6	-864	-1107	-1283	-1414

All NPV values are $1000

TABLE (C-7)

CASE STUDY 2.2 SHIP B

OUTDOCKING AHR AFTER REBLAST	DIFFERENCE IN NPV RELATIVE TO AN OUTDOCKING AFTER REBLAST OF 125 µm				
	2 YEARS	4 YEARS	6 YEARS	8 YEARS	10 YEARS
125 µm	-	-	-	-	-
150	-36.7	-59.5	-74.8	-85.5	-93.2
175	-69.6	-133.6	-143.4	-164.4	-179.5
200	-99.5	-163.3	-206.9	-237.7	-260.1
225	-127.1	-209.5	-266.2	-306.5	-335.9
250	-152.6	-252.7	-322.0	-371.5	-407.7

All NPV values are $1000

TABLE (C-8)

CASE STUDY 2.2 SHIP C

OUTDOCKING AHR AFTER REBLAST	DIFFERENCE IN NPV RELATIVE TO AN OUTDOCKING AFTER REBLAST OF 125 μm				
	2 YEARS	4 YEARS	6 YEARS	8 YEARS	10 YEARS
125 μm	-	-	-	-	-
150	-50.4	-81.7	-102.6	-117.1	-127.6
175	-95.6	-155.4	-196.5	-225.0	-245.5
200	-136.5	-224.0	-283.3	-325.1	-355.4
225	-174.0	-287.0	-364.3	-419.0	-458.6
250	-208.8	-345.9	-440.2	-507.3	-556.2

All NPV values are $1000

TABLE (C-9)

CASE STUDY 2.2 SHIP D

OUTDOCKING AHR AFTER REBLAST	DIFFERENCE IN NPV RELATIVE TO AN OUTDOCKING AFTER REBLAST OF 125 μm				
	2 YEARS	4 YEARS	6 YEARS	8 YEARS	10 YEARS
125 μm	-	-	-	-	-
150	-34.7	-56.4	-70.7	-80.8	-87.9
175	-65.8	-107.4	-135.5	-155.0	-169.2
200	-94.0	-154.4	-195.4	-224.2	-245.0
225	-119.9	-197.9	-251.1	-288.8	-316.2
250	-143.8	-238.4	-303.4	-349.7	-383.3

All NPV values are $1000

TABLE (C-10)

CASE STUDY 2.3

DIFFERENCE IN NPV RELATIVE TO IMMEDIATE REBLAST		PRESENT (INDOCKING) AVERAGE HULL ROUGHNESS						
		200 μm	300 μm	400 μm	500 μm	600 μm	700 μm	800 μm
SHIP A	24 months delay	+59.1	-246	-500	-720	-914	-1091	-1252
	48 months delay	-203	-725	-1166	-1551	-1895	-2209	-2497
SHIP B	24 months delay	+13.2	-74.8	-146.1	-206.7	-259.6	-306.8	-349.4
	48 months delay	-66.4	-215.6	-339.0	-444.9	-538.2	-622.0	-698.0
SHIP C	24 months delay	60.9	-58.2	-154.2	-235.3	-305.8	-368.3	-424.7
	48 months delay	-12.1	-214.1	-380.0	-521.9	-646.2	-757.3	-857.9
SHIP D	24 months delay	+26.1	-56.2	-122.5	-178.5	-227.1	-270.3	-309.2
	48 months delay	-38.5	-178.0	-292.5	-390.4	-476.2	-541.4	-622.3

All NPV values are $1000

TABLE (C-11)

CASE STUDY 3.1

	SCENARIO	2 YEARS		4 YEARS		6 YEARS		8 YEARS		10 YEARS	
		NPV	PROF/ INV	NPV	PROF/ INV	NPV	PROF/ INV	NPV	PROF/ INV	NPV	PROF/ INV
SHIP A	1	17.3	0.175	298.4	1.695	711.9	2.919	1190	3.923	1691	4.760
	2	17.3	0.175	181.3	1.030	408.1	1.674	660.6	2.178	919.1	2.586
	3	-42.8	-0.434	-6.4	-0.037	62.0	0.254	145.3	0.479	234.0	0.659
	4	-98.7	-1	-176.1	-1	-243.9	-1	-303.3	-1	-355.4	-1
SHIP B	1	-31.2	-0.469	23.7	0.200	120.2	0.733	237.8	1.165	364.1	1.523
	2	-31.2	-0.469	-11.7	-0.098	28.9	0.176	79.4	0.389	133.4	0.558
	3	-49.5	-0.745	-68.0	-0.574	-74.1	-0.451	-73.15	-0.359	-68.3	-0.286
	4	-66.4	-1.000	-118.4	-1.000	-164.1	-1.000	-204.0	-1.000	-239.1	-1.000
SHIP C	1	-231.9	-0.826	-303.9	-0.607	-300.2	-0.433	-251.8	-0.292	-177.5	-0.176
	2	-231.9	-0.826	-253.3	-0.705	-428.0	-0.617	-473.6	-0.549	-500.3	+0.495
	3	-257.3	-0.916	-431.3	-0.861	-570.1	-0.822	-683.4	-0.792	-777.4	-0.769
	4	-280.8	-1.000	-500.9	-693.9	-693.9	-1.000	-863.0	-1.000	-1011	-1.000
SHIP D	1	-60.6	-0.643	-32.5	-0.193	38.15	0.164	131.2	0.453	234.6	0.692
	2	-60.6	-0.643	-66.5	-0.396	-49.7	-0.213	-21.2	-0.073	12.8	0.038
	3	-78.0	-0.828	-120.1	-0.715	-147.5	-0.634	-165.8	-0.573	-178.1	-0.527
	4	-94.2	-1.000	-168.0	-1.000	-232.8	-1.000	-289.5	-1.000	-339.2	-1.000

All NPV values are $1000

TABLE (C-12)

CASE STUDY 3.2

			SHIP A	SHIP B	SHIP C	SHIP C
10 YEARS	30 months 24 months	NPV	307.6	229.6	-5.7	35.7
		AW	47.8	35.7	-0.9	5.5
6 YEARS	36 months 24 months	NPV	548.4	341.0	291.6	153.6
		AW	125.9	78.3	66.9	35.2
4 YEARS	48 months 24 months	NPV	610.7	358.8	314.7	168.4
		AW	197.5	116.1	101.8	54.5
8 YEARS	48 months 24 months	NPV	1042	642.2	540.3	288.2
		AW	190.7	117.5	98.8	52.7

All NPV and AW values are $1000

months denotes drydocking intervals of alternatives 1 and 2 respectively

TABLE (C-13)

CASE STUDY 5

SHIP TYPE	SPEED LOSS WHEN FOULED	DIFFERENCE IN NPV ($1000)				
		2 YEARS	4 YEARS	6 YEARS	8 YEARS	10 YEARS
SHIP A	5%	260	515	709	893	1.067
	10%	575	1.142	1.569	1.976	2.361
SHIP B	5%	125	247	341	433	507
	10%	254	501	692	878	1.029
SHIP C	5%	120	234	338	432	518
	10%	241	470	679	868	1.040
SHIP D	5%	80	158	230	283	333
	10%	162	319	464	572	672

TABLES OF RESULTS FROM CASE STUDIES USING THE DYNAMIC PROGRAMMING MODEL

Path configuration is shown in Figure (2.15c)

Maintenance alternatives are described in Section 3.2.8

Reblast Alternative1 = first alternative coating system in Figure (2.15c)

Reblast Alternative2 = second alternative coating system in Figure (2.15c)

TABLE	IDENTI-FICATION CODE	SHIP	ROUGHNESS SCENARIO WITH SECOND ALT. COATING SYSTEM
C-14	3320	A	1
C-15	3321	A	2
C-16	3322	A	3
C-17	3323	A	4
C-18	2320	B	1
C-19	2321	B	2
C-20	2322	B	3
C-21	2323	B	4
C-22	4320	C	1
C-23	4321	C	2
C-24	4322	C	3
C-25	4323	C	4
C-26	5320	D	1
C-27	5321	D	2
C-28	5322	D	3
C-29	5323	D	4

CODE:3320

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:3:5:7:9:11	93982

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:4:6:8:10	69879
B 2	:4:6:8:10	69879
B 3	:5:7:9:11	70227

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:5:7:9	48755
C 2	:5:7:9	48755
C 3	:5:7:9	48755
C 4	:6:8:10	49060
C 5	:7:9:11	49060

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:6:8	30241
D 2	:6:8	30241
D 3	:6:8	30241
D 4	:6:8	30241
D 5	:7:9	30508
D 6	:8:10	30508
D 7	:9:11	30508

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:7	14015
E 2	:7	14015
E 3	:7	14015
E 4	:7	14015
E 5	:5	14057
E 6	:8	14249
E 7	:9	14249
E 8	:10	14249
E 9	:11	14249

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	23166
B 2	:2	23738
B 3	:3	23755

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	43382
C 2	:2:2	44619
C 3	:3:3	44559
C 4	:3:4	44574
C 5	:3:5	44923

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	61035
D 2	:2:2:2	62751
D 3	:3:3:3	62860
D 4	:3:5:4	63156
D 5	:3:5:5	63169
D 6	:3:4:6	63126
D 7	:3:5:7	63474

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	76458
E 2	:2:2:2:2	78525
E 3	:3:3:3:3	78751
E 4	:3:5:4:4	79195
E 5	:3:5:7:5	79454
E 6	:3:5:7:6	79465
E 7	:3:5:5:7	79428
E 8	:3:4:6:8	79385
E 9	:3:5:7:9	79733

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	69936
F 2	:2:2:2:2:2	92266
F 3	:3:3:3:3:3	92576
F 4	:3:5:4:4:4	93122
F 5	:3:5:7:5:5	93511
F 6	:3:5:7:9:6	93738
F 7	:3:5:7:9:7	93748
F 8	:3:5:7:6:8	93715
F 9	:3:5:5:7:9	93677
F10	:3:4:6:8:10	93634
F11	:3:5:7:9:11	93982

CODE:3321

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
A 1	:3:5:7:6:8	93325

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
B 1	:4:6:6:8	69426
B 2	:4:6:6:8	69426
B 3	:5:7:6:8	69570

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
C 1	:5:7:9	48517
C 2	:5:7:9	48517
C 3	:5:7:9	48517
C 4	:6:6:8	48607
C 5	:7:6:8	48522

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
D 1	:6:8	30160
D 2	:6:8	30160
D 3	:6:8	30160
D 4	:6:8	30160
D 5	:7:9	30271
D 6	:6:8	30160
D 7	:6:8	30160

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
E 1	:7	14015
E 2	:7	14015
E 3	:7	14015
E 4	:7	14015
E 5	:5	14057
E 6	:8	14169
E 7	:9	14104
E 8	:10	14049
E 9	:7	14015

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
B 1	:1	23166
B 2	:2	23738
B 3	:3	23755

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
C 1	:1:1	43382
C 2	:2:2	44619
C 3	:3:3	44559
C 4	:3:4	44574
C 5	:3:5	44803

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
D 1	:1:1:1	61035
D 2	:2:2:2	62751
D 3	:3:3:3	62860
D 4	:3:5:4	63036
D 5	:3:5:5	63049
D 6	:3:4:6	63021
D 7	:3:5:7	63165

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
E 1	:1:1:1:1	76458
E 2	:2:2:2:2	78525
E 3	:3:3:3:3	78751
E 4	:3:5:4:4	79075
E 5	:3:5:7:5	79144
E 6	:3:5:7:6	79156
E 7	:3:5:5:7	79216
E 8	:3:4:6:8	79114
E 9	:3:5:7:9	79195

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
F 1	:1:1:1:1:1	89936
F 2	:2:2:2:2:2	92266
F 3	:3:3:3:3:3	92576
F 4	:3:5:4:4:4	93002
F 5	:3:5:7:5:5	93201
F 6	:3:5:5:7:6	93221
F 7	:3:5:5:7:7	93231
F 8	:3:5:7:6:8	93325
F 9	:3:5:5:7:9	93320
F10	:3:4:6:8:10	93163
F11	:3:5:7:9:11	93198

CODE:3322

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:6	92897

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	69142
B 2	:2:4:4:6	69159
B 3	:5:4:4:6	69196

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:6	48277
C 2	:4:4:6	48277
C 3	:3:5:5	48338
C 4	:6:5:5	48370
C 5	:4:4:6	48277

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	30037
D 2	:5:5	30037
D 3	:5:5	30037
D 4	:4:6	30044
D 5	:7:6	30073
D 6	:5:5	30037
D 7	:5:5	30037

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	14005
E 2	:6	14005
E 3	:6	14005
E 4	:6	14005
E 5	:5	14057
E 6	:8	14082
E 7	:6	14005
E 8	:6	14005
E 9	:6	14005

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	23166
B 2	:2	23738
B 3	:3	23695

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	43382
C 2	:2:2	44619
C 3	:2:3	44542
C 4	:2:4	44505
C 5	:3:5	44614

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	61035
D 2	:2:2:2	62751
D 3	:2:3:3	62843
D 4	:2:2:4	62853
D 5	:2:2:5	62820
D 6	:2:4:6	62838
D 7	:3:5:7	62815

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	76458
E 2	:2:2:2:2	78525
E 3	:2:3:3:3	78734
E 4	:2:2:4:4	78892
E 5	:2:2:4:5	78832
E 6	:2:2:4:6	78803
E 7	:2:2:5:7	78868
E 8	:2:4:6:8	78790
E 9	:3:5:7:9	78674

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	89936
F 2	:2:2:2:2:2	92266
F 3	:2:3:3:3:3	92558
F 4	:2:2:4:4:4	92819
F 5	:2:2:4:5:5	92869
F 6	:2:2:4:4:6	92897
F 7	:2:2:4:4:7	92871
F 8	:2:2:4:6:8	92886
F 9	:2:2:5:7:9	92868
F10	:2:4:6:8:10	92689
F11	:3:5:7:9:11	92506

CODE:3323

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:6	92897

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	69142
B 2	:2:4:4:6	69159
B 3	:3:3:5:5	69142

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:6	46277
C 2	:4:4:6	48277
C 3	:3:5:5	48338
C 4	:4:4:6	48277
C 5	:4:4:6	48277

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	30037
D 2	:5:5	30037
D 3	:5:5	30037
D 4	:4:6	30044
D 5	:5:5	30037
D 6	:5:5	30037
D 7	:5:5	30037

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	14005
E 2	:6	14005
E 3	:6	14005
E 4	:6	14005
E 5	:5	14057
E 6	:8	14005
E 7	:6	14005
E 8	:6	14005
E 9	:6	14005

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	23166
B 2	:2	23738
B 3	:3	23639

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	43382
C 2	:2:2	44619
C 3	:2:3	44542
C 4	:2:4	44456
C 5	:3:5	44443

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	61035
D 2	:2:2:2	62751
D 3	:2:3:3	62843
D 4	:2:2:4	62853
D 5	:2:2:5	62777
D 6	:2:4:6	62689
D 7	:3:5:7	62507

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	78458
E 2	:2:2:2:2	78525
E 3	:2:3:3:3	78734
E 4	:2:2:4:4	78892
E 5	:2:2:4:5	78832
E 6	:2:2:4:6	78766
E 7	:2:2:5:7	78756
E 8	:2:4:6:8	78520
E 9	:3:5:7:9	78222

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	89936
F 2	:2:2:2:2:2	92266
F 3	:2:3:3:3:3	92558
F 4	:2:2:4:4:4	92819
F 5	:2:2:4:5:5	92889
F 6	:2:2:4:4:6	92897
F 7	:2:2:4:4:7	92538
F 8	:2:2:4:6:8	92771
F 9	:2:2:5:7:9	92631
F10	:2:4:6:8:10	92292
F11	:3:5:7:9:11	91911

CODE:2320

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:3:5:7:9:11	39479

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:4:6:8:10	29363
B 2	:4:6:8:10	29363
B 3	:5:7:9:11	29450

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:5:7:9	20497
C 2	:5:7:9	20497
C 3	:5:7:9	20497
C 4	:6:8:10	20573
C 5	:7:9:11	20573

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:6:8	12727
D 2	:6:8	12727
D 3	:6:8	12727
D 4	:6:8	12727
D 5	:7:9	12794
D 6	:8:10	12794
D 7	:9:11	12794

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	5935
E 2	:6	5935
E 3	:6	5935
E 4	:6	5935
E 5	:5	5938
E 6	:8	5976
E 7	:9	5976
E 8	:10	5976
E 9	:11	5976

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	9876
B 2	:2	10060
B 3	:3	10029

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	18508
C 2	:2:2	18881
C 3	:2:3	18677
C 4	:2:4	18850
C 5	:3:5	18996

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	26055
D 2	:2:2:2	26562
D 3	:2:3:3	26608
D 4	:3:5:4	26633
D 5	:3:5:5	26609
D 6	:2:4:6	26630
D 7	:3:5:7	26686

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	32656
E 2	:2:2:2:2	33261
E 3	:2:3:3:3	33340
E 4	:3:5:4:4	33406
E 5	:3:5:7:5	33458
E 6	:3:5:7:6	33437
E 7	:3:5:5:7	33428
E 8	:2:4:6:8	33448
E 9	:3:5:7:9	33504

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	38431
F 2	:2:2:2:2:2	39108
F 3	:2:3:3:3:3	39210
F 4	:3:5:4:4:4	39308
F 5	:3:5:7:5:5	39396
F 6	:3:5:7:9:6	39439
F 7	:3:5:7:9:7	39421
F 8	:3:5:7:6:8	39413
F 9	:3:5:5:7:9	39403
F10	:2:4:6:8:10	39424
F11	:3:5:7:9:11	39479

CODE:2321

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:6	39318

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	29257
B 2	:2:4:4:6	29258
B 3	:5:4:4:6	29278

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:6	20433
C 2	:4:4:6	20438
C 3	:3:5:5	20440
C 4	:6:5:5	20458
C 5	:4:4:6	20438

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	12710
D 2	:5:5	12710
D 3	:5:5	12710
D 4	:4:6	12710
D 5	:7:6	12726
D 6	:5:5	12710
D 7	:5:5	12710

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	5935
E 2	:6	5935
E 3	:6	5935
E 4	:6	5935
E 5	:5	5938
E 6	:8	5951
E 7	:6	5935
E 8	:6	5935
E 9	:6	5935

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	9876
B 2	:2	10560
B 3	:3	10029

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	18598
C 2	:2:2	18581
C 3	:2:3	18577
C 4	:2:4	18850
C 5	:3:5	18870

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	26055
D 2	:2:2:2	26562
D 3	:2:3:3	26608
D 4	:2:2:4	26608
D 5	:2:2:5	26534
D 6	:2:4:6	26598
D 7	:3:5:7	26593

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	32456
E 2	:2:2:2:2	33261
E 3	:2:3:3:3	33340
E 4	:2:2:4:4	33383
E 5	:2:2:4:5	33381
E 6	:2:2:4:6	33360
E 7	:2:2:5:7	33375
E 8	:2:4:6:8	33366
E 9	:3:5:7:9	33343

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	38431
F 2	:2:2:2:2:2	39108
F 3	:2:3:3:3:3	39210
F 4	:2:2:4:4:4	39283
F 5	:2:2:4:5:5	39318
F 6	:2:2:4:4:6	39318
F 7	:2:2:4:4:7	39300
F 8	:2:2:4:6:8	39311
F 9	:2:2:5:7:9	39307
F10	:2:4:6:8:10	39282
F11	:3:5:7:9:11	39245

CODE:2322

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
A 1	:2:2:4:4:6	39318

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
B 1	:3:3:5:5	29257
B 2	:2:4:4:6	29258
B 3	:3:3:5:5	29257

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
C 1	:4:4:6	20439
C 2	:4:4:6	20438
C 3	:3:5:5	20440
C 4	:4:4:6	20438
C 5	:4:4:6	20438

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
D 1	:5:5	12710
D 2	:5:5	12710
D 3	:5:5	12710
D 4	:4:6	12710
D 5	:5:5	12710
D 6	:5:5	12710
D 7	:5:5	12710

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
E 1	:6	5935
E 2	:6	5935
E 3	:6	5935
E 4	:6	5935
E 5	:5	5939
E 6	:6	5935
E 7	:6	5935
E 9	:6	5935
E 9	:6	5935

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
B 1	:1	9876
B 2	:2	10060
B 3	:3	10011

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
C 1	:1:1	18508
C 2	:2:2	18891
C 3	:2:3	18877
C 4	:2:4	18834
C 5	:3:5	18813

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
D 1	:1:1:1	26055
D 2	:2:2:2	26562
D 3	:2:3:3	26608
D 4	:2:2:4	26608
D 5	:2:2:5	26570
D 6	:2:4:6	26548
D 7	:3:5:7	26489

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
E 1	:1:1:1:1	32656
E 2	:2:2:2:2	33261
E 3	:2:3:3:3	33340
E 4	:2:2:4:4	33383
E 5	:2:2:4:5	33381
E 6	:2:2:4:6	33347
E 7	:2:2:5:7	33331
E 8	:2:4:6:8	33275
E 9	:3:5:7:9	33188

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
F 1	:1:1:1:1:1	38431
F 2	:2:2:2:2:2	39108
F 3	:2:3:3:3:3	39210
F 4	:2:2:4:4:4	39283
F 5	:2:2:4:5:5	39318
F 6	:2:2:4:4:6	39316
F 7	:2:2:4:4:7	39269
F 8	:2:2:4:6:8	39273
F 9	:2:2:5:7:9	39227
F10	:2:4:6:8:10	39147
F11	:3:5:7:9:11	39041

CODE:2323

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:6	39318

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	29257
B 2	:2:4:4:6	29258
B 3	:3:3:5:5	29257

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:6	20438
C 2	:4:4:6	20438
C 3	:3:5:5	20440
C 4	:4:4:6	20438
C 5	:4:4:6	20438

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	12710
D 2	:5:5	12710
D 3	:5:5	12710
D 4	:4:6	12710
D 5	:5:5	12710
D 6	:5:5	12710
D 7	:5:5	12710

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	5935
E 2	:6	5935
E 3	:6	5935
E 4	:6	5935
E 5	:5	5938
E 6	:6	5935
E 7	:6	5935
E 8	:6	5935
E 9	:6	5935

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	9876
B 2	:2	10060
B 3	:3	9994

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	18508
C 2	:2:2	18681
C 3	:2:3	18677
C 4	:2:4	18819
C 5	:3:5	18762

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	26055
D 2	:2:2:2	26562
D 3	:2:3:3	26608
D 4	:2:2:4	26608
D 5	:2:2:5	26557
D 6	:2:4:6	26504
D 7	:3:5:7	26398

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	32656
E 2	:2:2:2:2	33261
E 3	:2:3:3:3	33340
E 4	:2:2:4:4	33383
E 5	:2:2:4:5	33381
E 6	:2:2:4:6	33336
E 7	:2:2:5:7	33292
E 8	:2:4:6:8	33196
E 9	:3:5:7:9	33057

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	38431
F 2	:2:2:2:2:2	39108
F 3	:2:3:3:3:3	39210
F 4	:2:2:4:4:4	39283
F 5	:2:2:4:5:5	39318
F 6	:2:2:4:4:6	39318
F 7	:2:2:4:4:7	39279
F 8	:2:2:4:6:8	39238
F 9	:2:2:5:7:9	39157
F10	:2:4:6:8:10	39032
F11	:3:5:7:9:11	38869

CODE:4320

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:2:5:5	-7456

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:3:3	-5528
B 2	:2:2:5:5	-5379
B 3	:5:7:9:11	-5325

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	-3859
C 2	:2:5:5	-3844
C 3	:3:3:3	-3708
C 4	:6:8:10	-3720
C 5	:7:9:11	-3720

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	-2431
D 2	:5:5	-2431
D 3	:3:3	-2363
D 4	:4:4	-2264
D 5	:7:9	-2313
D 6	:8:10	-2313
D 7	:9:11	-2313

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	-1225
E 2	:2	-1157
E 3	:3	-1125
E 4	:4	-1085
E 5	:5	-1033
E 6	:8	-1080
E 7	:9	-1080
E 8	:10	-1080
E 9	:11	-1080

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	-2008
B 2	:2	-2077
B 3	:3	-2309

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	-3800
C 2	:2:2	-3612
C 3	:1:3	-3929
C 4	:1:4	-4032
C 5	:3:5	-3914

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	-5395
D 2	:2:2:2	-5025
D 3	:1:3:3	-5174
D 4	:2:2:4	-5207
D 5	:2:2:5	-5386
D 6	:1:4:6	-5438
D 7	:3:5:7	-5321

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	-6811
E 2	:2:2:2:2	-6308
E 3	:1:3:3:3	-6412
E 4	:2:2:4:4	-6396
E 5	:2:2:2:5	-6423
E 6	:2:2:2:6	-6579
E 7	:2:2:5:7	-6618
E 8	:1:4:6:8	-6671
E 9	:3:5:7:9	-6553

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	-8065
F 2	:2:2:2:2:2	-7465
F 3	:1:3:3:3:3	-7537
F 4	:2:2:4:4:4	-7471
F 5	:2:2:2:5:5	-7456
F 6	:2:2:2:2:6	-7533
F 7	:2:2:2:2:7	-7670
F 8	:2:2:2:6:8	-7659
F 9	:2:2:5:7:9	-7699
F10	:1:4:6:8:10	-7752
F11	:3:5:7:9:11	-7634

CODE:4321

DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:2:5:5	-7456

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:3:3	-5528
B 2	:2:2:5:5	-5379
B 3	:5:4:4:4	-5514

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	-3859
C 2	:2:5:5	-3844
C 3	:3:3:3	-3708
C 4	:4:4:4	-3859
C 5	:4:4:4	-3859

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	-2431
D 2	:5:5	-2431
D 3	:3:3	-2363
D 4	:4:4	-2264
D 5	:7:9	-2412
D 6	:5:5	-2431
D 7	:5:5	-2431

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	-1225
E 2	:2	-1157
E 3	:3	-1125
E 4	:4	-1085
E 5	:5	-1033
E 6	:8	-1114
E 7	:9	-1141
E 8	:10	-1163
E 9	:11	-1182

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	-2008
B 2	:2	-2077
B 3	:3	-2309

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	-3800
C 2	:2:2	-3612
C 3	:1:3	-3329
C 4	:1:4	-4032
C 5	:3:5	-3964

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	-5395
D 2	:2:2:2	-5025
D 3	:1:3:3	-5174
D 4	:2:2:4	-5207
D 5	:2:2:5	-5386
D 6	:1:4:6	-5432
D 7	:3:5:7	-5450

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	-6811
E 2	:2:2:2:2	-6308
E 3	:1:3:3:3	-6412
E 4	:2:2:4:4	-6386
E 5	:2:2:2:5	-6423
E 6	:2:2:2:6	-6579
E 7	:2:2:5:7	-6657
E 8	:1:4:6:8	-6784
E 9	:3:5:7:9	-6777

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	-8065
F 2	:2:2:2:2:2	-7465
F 3	:1:3:3:3:3	-7537
F 4	:2:2:4:4:4	-7471
F 5	:2:2:2:5:5	-7456
F 6	:2:2:2:2:6	-7533
F 7	:2:2:2:2:7	-7670
F 8	:2:2:2:6:8	-7693
F 9	:2:2:5:7:9	-7798
F10	:1:4:6:8:10	-7948
F11	:3:5:7:9:11	-7959

CODE:4322

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:2:5:5	-7456

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:3:3	-5528
B 2	:2:2:5:5	-5379
B 3	:3:3:3:3	-5528

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	-3859
C 2	:2:5:5	-3844
C 3	:3:3:3	-3708
C 4	:4:4:4	-3859
C 5	:4:4:4	-3859

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	-2431
D 2	:5:5	-2431
D 3	:3:3	-2363
D 4	:4:4	-2264
D 5	:5:5	-2431
D 6	:5:5	-2431
D 7	:5:5	-2431

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	-1225
E 2	:2	-1157
E 3	:3	-1125
E 4	:4	-1085
E 5	:5	-1033
E 6	:8	-1150
E 7	:9	-1191
E 8	:10	-1224
E 9	:6	-1225

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	-2008
B 2	:2	-2077
B 3	:3	-2334

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	-3800
C 2	:2:2	-3612
C 3	:1:3	-3829
C 4	:1:4	-4054
C 5	:3:5	-4043

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	-5395
D 2	:2:2:2	-5025
D 3	:1:3:3	-5174
D 4	:2:2:4	-5207
D 5	:2:2:5	-5405
D 6	:1:4:6	-5551
D 7	:3:5:7	-5593

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	-6811
E 2	:2:2:2:2	-6308
E 3	:1:3:3:3	-6412
E 4	:2:2:4:4	-6386
E 5	:2:2:2:5	-6423
E 6	:2:2:2:6	-6596
E 7	:2:2:5:7	-6717
E 8	:1:4:6:8	-6910
E 9	:3:5:7:9	-6990

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	-8065
F 2	:2:2:2:2:2	-7465
F 3	:1:3:3:3:3	-7537
F 4	:2:2:4:4:4	-7471
F 5	:2:2:2:5:5	-7456
F 6	:2:2:2:2:6	-7533
F 7	:2:2:2:2:7	-7585
F 8	:2:2:2:6:8	-7746
F 9	:2:2:5:7:9	-7908
F10	:1:4:6:8:10	-8134
F11	:3:5:7:9:11	-8240

CODE:4323

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:2:5:5	-7456

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:3:3	-5528
B 2	:2:2:5:5	-5379
B 3	:3:3:3:3	-5528

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	-3859
C 2	:2:5:5	-3841
C 3	:3:3:3	-3708
C 4	:4:4:4	-3659
C 5	:4:4:4	-3859

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	-2431
D 2	:5:5	-2431
D 3	:3:3	-2363
D 4	:4:4	-2264
D 5	:5:5	-2431
D 6	:5:5	-2431
D 7	:5:5	-2431

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	-1225
E 2	:2	-1157
E 3	:3	-1125
E 4	:4	-1085
E 5	:5	-1033
E 6	:8	-1181
E 7	:6	-1225
E 8	:6	-1225
E 9	:6	-1225

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	-2005
B 2	:2	-2077
B 3	:3	-2358

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	-3806
C 2	:2:2	-3612
C 3	:1:3	-3829
C 4	:1:4	-4075
C 5	:3:5	-4113

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	-5395
D 2	:2:2:2	-5025
D 3	:1:3:3	-5174
D 4	:2:2:4	-5207
D 5	:2:2:5	-5423
D 6	:1:4:6	-5613
D 7	:3:5:7	-5719

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	-6811
E 2	:2:2:2:2	-6308
E 3	:1:3:3:3	-6412
E 4	:2:2:4:4	-6396
E 5	:2:2:2:5	-6423
E 6	:2:2:2:6	-6612
E 7	:2:2:5:7	-6771
E 8	:1:4:6:8	-7020
E 9	:3:5:7:9	-7171

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	-8065
F 2	:2:2:2:2:2	-7465
F 3	:1:3:3:3:3	-7537
F 4	:2:2:4:4:4	-7471
F 5	:2:2:2:5:5	-7456
F 6	:2:2:2:2:6	-7533
F 7	:2:2:2:2:7	-7699
F 8	:2:2:2:6:8	-7793
F 9	:2:2:5:7:9	-8004
F10	:1:4:6:8:10	-8293
F11	:3:5:7:9:11	-8476

CODE:5320

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:3:5:7:9:11	4433

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:4:6:8:10	3273
B 2	:4:6:8:10	3273
B 3	:5:7:9:11	3443

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:5:7:9	2256
C 2	:5:7:9	2256
C 3	:3:5:5	2270
C 4	:6:8:10	2405
C 5	:7:9:11	2405

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	1386
D 2	:5:5	1386
D 3	:5:5	1386
D 4	:4:4	1417
D 5	:7:9	1496
D 6	:8:10	1496
D 7	:9:11	1496

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	620
E 2	:6	620
E 3	:6	620
E 4	:4	643
E 5	:5	679
E 6	:8	699
E 7	:9	699
E 8	:10	699
E 9	:11	699

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	973
B 2	:2	1051
B 3	:3	991

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	1804
C 2	:2:2	2059
C 3	:2:3	1972
C 4	:2:4	1919
C 5	:3:5	2028

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	2516
D 2	:2:2:2	2896
D 3	:2:3:3	2856
D 4	:2:2:4	2867
D 5	:2:2:5	2820
D 6	:2:4:6	2829
D 7	:3:5:7	2938

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	3127
E 2	:2:2:2:2	3599
E 3	:2:3:3:3	3590
E 4	:2:2:4:4	3641
E 5	:3:5:7:5	3645
E 6	:3:5:7:6	3604
E 7	:2:2:5:7	3617
E 8	:2:4:6:8	3626
E 9	:3:5:7:9	3735

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	3653
F 2	:2:2:2:2:2	4192
F 3	:2:3:3:3:3	4205
F 4	:2:2:4:4:4	4284
F 5	:3:5:7:5:5	4324
F 6	:3:5:7:9:6	4355
F 7	:3:5:7:9:7	4319
F 8	:3:5:7:6:8	4303
F 9	:2:2:5:7:9	4316
F10	:2:4:6:8:10	4324
F11	:3:5:7:9:11	4433

CODE:5321

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:4	4284

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	3191
B 2	:2:4:4:4	3233
B 3	:5:7:5:5	3244

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	2225
C 2	:4:4:4	2225
C 3	:3:5:5	2270
C 4	:6:8:10	2270
C 5	:7:5:5	2241

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	1386
D 2	:5:5	1386
D 3	:5:5	1386
D 4	:4:4	1417
D 5	:7:9	1427
D 6	:8:10	1391
D 7	:5:5	1386

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	620
E 2	:6	620
E 3	:6	620
E 4	:4	643
E 5	:5	679
E 6	:8	675
E 7	:9	657
E 8	:10	641
E 9	:11	629

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	973
B 2	:2	1051
B 3	:3	991

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	1804
C 2	:2:2	2059
C 3	:2:3	1972
C 4	:2:4	1919
C 5	:3:5	1994

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	2516
D 2	:2:2:2	2896
D 3	:2:3:3	2856
D 4	:2:2:4	2867
D 5	:2:2:5	2820
D 6	:2:4:6	2798
D 7	:3:5:7	2849

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	3127
E 2	:2:2:2:2	3599
E 3	:2:3:3:3	3590
E 4	:2:2:4:4	3641
E 5	:2:2:2:5	3604
E 6	:2:2:2:6	3563
E 7	:2:2:5:7	3591
E 8	:2:4:6:8	3548
E 9	:3:5:7:9	3580

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	3653
F 2	:2:2:2:2:2	4192
F 3	:2:3:3:3:3	4205
F 4	:2:2:4:4:4	4284
F 5	:2:2:2:5:5	4283
F 6	:2:2:4:4:6	4261
F 7	:2:2:4:4:7	4225
F 8	:2:2:2:6:8	4238
F 9	:2:2:5:7:9	4247
F10	:2:4:6:8:10	4169
F11	:3:5:7:9:11	4209

CODE:5322

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
A 1	:2:2:4:4:4	4284

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
B 1	:3:3:5:5	3191
B 2	:2:4:4:4	3233
B 3	:5:4:4:4	3191

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
C 1	:4:4:4	2225
C 2	:4:4:4	2225
C 3	:3:5:5	2270
C 4	:6:5:5	2233
C 5	:4:4:4	2225

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
D 1	:5:5	1386
D 2	:5:5	1386
D 3	:5:5	1386
D 4	:4:4	1417
D 5	:5:5	1386
D 6	:5:5	1386
D 7	:5:5	1386

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV ($1000)
E 1	:6	620
E 2	:6	620
E 3	:6	620
E 4	:4	643
E 5	:5	679
E 6	:8	651
E 7	:9	622
E 8	:6	620
E 9	:6	620

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
B 1	:1	973
B 2	:2	1051
B 3	:3	973

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
C 1	:1:1	1804
C 2	:2:2	2059
C 3	:2:3	1972
C 4	:2:4	1904
C 5	:3:5	1940

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
D 1	:1:1:1	2516
D 2	:2:2:2	2896
D 3	:2:3:3	2856
D 4	:2:2:4	2867
D 5	:2:2:5	2807
D 6	:2:4:6	2751
D 7	:3:5:7	2750

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
E 1	:1:1:1:1	3127
E 2	:2:2:2:2	3599
E 3	:2:3:3:3	3590
E 4	:2:2:4:4	3641
E 5	:2:2:2:5	3694
E 6	:2:2:2:6	3551
E 7	:2:2:5:7	3549
E 8	:2:4:6:8	3461
E 9	:3:5:7:9	3434

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV ($1000)
F 1	:1:1:1:1:1	3653
F 2	:2:2:2:2:2	4192
F 3	:2:3:3:3:3	4265
F 4	:2:2:4:4:4	4284
F 5	:2:2:2:5:5	4283
F 6	:2:2:4:4:6	4261
F 7	:2:2:4:4:7	4215
F 8	:2:2:2:6:8	4202
F 9	:2:2:5:7:9	4171
F10	:2:4:6:8:10	4061
F11	:3:5:7:9:11	4016

CODE:5323

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
A 1	:2:2:4:4:4	4284

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
B 1	:3:3:5:5	3191
B 2	:2:4:4:4	3233
B 3	:3:3:5:5	3191

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
C 1	:4:4:4	2225
C 2	:4:4:4	2225
C 3	:3:5:5	2270
C 4	:4:4:4	2225
C 5	:4:4:4	2225

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
D 1	:5:5	1386
D 2	:5:5	1386
D 3	:5:5	1386
D 4	:4:4	1417
D 5	:5:5	1386
D 6	:5:5	1386
D 7	:5:5	1386

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
E 1	:6	620
E 2	:6	620
E 3	:6	620
E 4	:4	643
E 5	:5	679
E 6	:8	629
E 7	:6	620
E 8	:6	620
E 9	:6	620

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
B 1	:1	973
B 2	:2	1051
B 3	:3	957

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
C 1	:1:1	1804
C 2	:2:2	2059
C 3	:2:3	1972
C 4	:2:4	1890
C 5	:3:5	1891

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
D 1	:1:1:1	2516
D 2	:2:2:2	2896
D 3	:2:3:3	2856
D 4	:2:2:4	2867
D 5	:2:2:5	2794
D 6	:2:4:6	2709
D 7	:3:5:7	2664

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
E 1	:1:1:1:1	3127
E 2	:2:2:2:2	3599
E 3	:2:3:3:3	3590
E 4	:2:2:4:4	3641
E 5	:2:2:2:5	3604
E 6	:2:2:2:6	3541
E 7	:2:2:5:7	3512
E 8	:2:4:6:8	3386
E 9	:3:5:7:9	3309

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
F 1	:1:1:1:1:1	3653
F 2	:2:2:2:2:2	4192
F 3	:2:3:3:3:3	4205
F 4	:2:2:4:4:4	4284
F 5	:2:2:2:5:5	4283
F 6	:2:2:4:4:6	4261
F 7	:2:2:4:4:7	4206
F 8	:2:2:2:6:8	4170
F 9	:2:2:5:7:9	4105
F10	:2:4:6:8:10	3951
F11	:3:5:7:9:11	3853

Appendix D

VARIABLE DESCRIPTIONS AND SAMPLE OUTPUTS

TABLE (D-1)	Variable descriptions for deterministic and dynamic programming model
TABLE (D-2)	Description of additional variables in probabilistic cash flow simulation model
SAMPLE (D-1)	Output from deterministic model
SAMPLE (D-2)	Output from dynamic programming model
SAMPLE (D-3)	Output from probabilistic cash flow simulation model

TABLE (D-1)

VARIABLE	DESCRIPTION
CODE	four digit code number serving as identification of each case study evaluation
TR1	trigger for maintenance alternative 2 if TR1=1 then ON, otherwise OFF if TR1=0 in dynamic programming routine, then in- service period prior to first drydocking
TR2	trigger for fouling alternative if TR2=1 then ON, otherwise OFF
TR3	trigger for propeller deterioration if TR3=1 then ON, otherwise OFF
TR4	trigger for sensitivity analysis if TR4=1 then ON, otherwise OFF
TR5	trigger for speed/power operation of alternative 1 if TR5=0 then constant power operation TR5=1 then constant speed operation TR5 1 then constant optimal speed operation
TR6	trigger for drydocking procedure for alternative 1 if TR6=0 then NO reblast or change in paint system TR6=1 then ONE reblast and/or change in paint syst. TR6 1 then MORE THAN ONE reblast and/or change in paint system
LIFE	remainder of ship life or period for which calculation is required
TR7	trigger for speed/power operation of alternative 2 - optional values as for TR5
TR8	trigger for drydocking procedure for alternative 2 - optional values as for TR6
TR9	trigger for fouling option with alternative 1 if TR9=0 then no fouling TR9=1 then fouling with first paint system TR9 2 then fouling with first and following systems
TR10	trigger for fouling option with alternative 2 - optional values as for TR9
VL	ship speed in laden (or average) condition [knots]
VB	ship speed in optional ballast condition [knots]

POWERL	shaft power corresponding to VL [kW]
POWERB	shaft power corresponding to VB [kW]
EXPO	exponent to speed/power curve of the form $P=kV^n$
ROUGHBASE	hull roughness corresponding to speed/power description
FUELRATE	specific fuel consumption at POWERL [g/kW hr]
AUXTPD	daily auxiliary fuel consumption at sea [tonnes/day] (given as heavy fuel oil equivalent)
TPDP	daily fuel consumption in port [tonnes/day]
QPC	propulsive coefficient (including transmission losses)
AREAL	wetted surface area in laden condition [m^2]
AREAB	wetted surface area in ballast condition [m^2]
L	ship length between perpendiculars [m]
FACTOR	multiplication factor used to increase/decrease the power penalty predicted by the ITTC correlation formula for hull roughness
MAXCARGO	maximum cargo carrying capacity [tonnes or units]
LOADF	loadfactor
SR	stowage rate (applies to volume carriers only)
MILES	length of roundtrip voyage [n. miles]
DISTLOAD	% of roundtrip distance in laden condition [%]
PTDAYS	number of days in port per roundtrip
OFFH	number of days off hire per annum
CREW	crew costs per annum [$1000]
CRCR	annual escalation in crew costs give as fraction
UPKEEP	upkeep costs per annum [$1000]
UPKCR	annual escalation in upkeep costs (fraction)
FIX	fixed costs per annum [$1000]
FIXCR	annual escalation in fixed costs (fraction)
FUEL	fuel cost per tonne (H.V.F.) [$/tonne]
FUELCR	annual escalation in fuel costs (fraction)

PORT	port charges per roundtrip [$1000]
PORTCR	annual escalation in port charges (fraction)
CARGO	cargo handling charges [$/tonne or unit]
CACR	annual escalation in cargo handling charges (fraction)
FRATE	freight rate [$/tonne or unit]
FRCR	annual escalation in freight rate (fraction)
DR	discount rate used in present value calculations (fraction)
ESC	inflation rate (fraction)
FIRST ALTERNATIVE :	
PAINTCOST1	cost of first coating system [$/m^2]
PAINTCOST2	cost of optional second coating system [$/m^2]
PAINTCR	annual escalation in coating system costs (fraction)
DOCKHIRE	total daily cost of hire of drydock [$/day]
CLEANCOST	additional cost of special hull cleaning/preparation prior to application of optional second coating system
DOCKCR	annual escalation in docking charges (DOCKHIRE & CLEANCOST) given as fraction
ININVEST	initial single capital investment in year 0 [$1000]
NEW1	initial AHR with first coating system [μm]
MINCS1	monthly increase in AHR in service with first coating system [μm]
INCDA1	slope of regression line for roughness increase in drydock, first system
INCDB1	constant term for roughness increase in drydock, first system
NEW2	initial AHR with second coating system after reblast or equivalent hull surface treatment [μm]
MINCS2	monthly increase in AHR in service with second coating system [μm]
INCDA2	slope of regression line for roughness increase in drydock, second system

INCDB2	constant term for roughness increase in drydock, second system
DOCKINT1	interval between drydockings with first coating system [months]
DOCKINT2	interval between drydockings with optional second coating system [months]
NEXTDOCK	number of months until next drydocking
DOCKDAYS	number of days in drydock
XTRADAYS	additional number of days required in drydock for reblast or equivalent hull surface treatment
NEXTBLAST	number of drydockings until reblast and change of coating system (if NEXTBLAST=1 then at next dryd.)
BLASTINT	number of drydockings between reblasts or equiv. (i.e. if BLASTINT=2 then at every second drydocking following NEXTBLAST)
NEXTSURV	number of drydockings until next classification survey in drydock
SURVINT1	number of drydockings between classification surveys in dock with first coating system (if SURVINT1=1 then at every drydocking)
SURVINT2	number of drydockings between classification surveys in dock with second optional coating system
NOFOUL1	time period from outdocking free from fouling with first coating system [months]
NOFOUL2	time period from outdocking free from fouling with second optional coating system [months]
SATFOUL	time period from initial fouling settlement to reach saturation growth [months]
FOULOSS	speed loss with fouling when saturation growth has been reached [knots]
SECOND ALTERNATIVE :	
PAINTCOST1 ↓ ININVEST	same variable descriptions as for alternative 1

NEW1 ↓ SURVINT2	same variable descriptions as for alternative 1
PERCHANGE	%change in variables in sensitivity analysis
NOFOUL ↓ FOULOSS	same variable descriptions as for alternative 1

TABLE (D-2)

VARIABLE	DESCRIPTION
CASES	number of variables described in terms of a probability distribution function
PARNUM(1) ↓ to PARNUM(CASES)	code number of each of the variables described in terms of a probability distribution function
DISTPAR(*,1)	code number for distribution shape, (1) implies single half or part of truncated normal distribution, (2) implies a combination of two truncated halves
DISTPAR(*,2)	if code=1 then: mean value of normal distribution from which truncated part is obtained if code=2 then: mean value of actual variable
DISTPAR(*,3)	if code=1 then: limiting ordinate at non-continuous end of distribution if code=2 then: standard deviation of lower truncated half of normal distribution
DISTPAR(*,4)	if code=1 then: standard deviation of normal distribution from which truncated part is obtained if code=2 then: standard deviation of upper truncated half of normal distribution
above sequence for DISTPAR repeated for all CASES	

NSIM	number of repeat simulations required
REPEAT	trigger for random number generation if REPEAT=1 then identical sequence of random numbers produced for every programme run, otherwise starting point is random and the following sequence of random numbers is non-repeatable
K2	specifies (number+1) of equally spaced groups for histogram and frequency distribution of the final net present value of the investment
C	the negative of the minimum acceptable net present value of the investment, used in calculating the certainty equivalent assuming a logarithmic utility function

SAMPLE (D-1)

```
******************************
*                            *
*  TECHNO ECONOMIC ANALYSIS  *                    CODE:   0
*                            *
******************************
```

INPUT-DATA : TECHNICAL

SHIP SPEED LADEN CONDITION:	15.0 knots	CORRESPONDING POWER LADEN:	9400 kW
SHIP SPEED BALLAST CONDITION:	16.7 knots	CORRESPONDING POWER BALLAST:	9400 kW
EXPONENT TO THE SPEED/POWER CURVE:	3.216		
AHR CORRESPONDING TO SPEED/POWER DATA:	125		
SPECIFIC FUEL CONSUMPTION:	218 g/kWhr	EXPONENT TO S.F.C. CURVE:	0.000
AUXILLIARY FUEL CONSUMPTION:	4.0 t/day	FUEL CONSUMPTION IN PORT:	5.0 t/day
WETTED SURFACE AREA LADEN:	10500 sq.m	WETTED SURFACE AREA BALLAST:	7660 sq.m
PROPULSIVE COEFFICIENT:	0.66		
SHIP LENGTH (B.P.):	214.5 m		

INPUT-DATA : OPERATIONAL

LENGTH OF ROUNDTRIP:	16380 N.M.		
DISTANCE LADEN:	64 %	DISTANCE IN BALLAST:	36 %
NUMBER OF DAYS IN PORT PER ROUNDTRIP:	12.0 days		
NUMBER OF DAYS OFF HIRE PER ANNUM:	0.0 days		
MAXIMUM CARGO CARRYING CAPACITY:	60000		
LOADFACTOR:	0.50		

INPUT-DATA : FINANCIAL

CREW COST ($1000):	1000	ANNUAL ESCALATION:	10.0%
UPKEEP COST ($1000):	500	ANNUAL ESCALATION:	10.0%
FIXED COST ($1000):	1500	ANNUAL ESCALATION:	10.0%
PORT CHARGES (PER ROUNDTRIP, $1000):	45	ANNUAL ESCALATION:	10.0%
FUEL COST ($/TONNE):	185	ANNUAL ESCALATION:	10.0%
FREIGHT RATE ($/TONNE OR UNIT):	18.00	ANNUAL ESCALATION:	10.0%

INPUT-DATA : ALTERNATIVE HULL MAINTENANCE STRATEGIES

	ALTERNATIVE1	ALTERNATIVE2
PRESENT HULL ROUGHNESS (AHR):	500 um	500 um
MONTHLY INCREASE IN AHR IN SERVICE:	1.85 um	1.85 um
INCREASE IN AHR IN DRYDOCK:	-0.094*(AHR)+37 um	-0.094*(AHR)+37 um
DRYDOCK INTERVAL WITH PRESENT SYSTEM:	24 months	24 months
NEW AHR AFTER REBLAST OR EQUIV.:	150 um	***
NEW MONTHLY INCREASE IN AHR IN SERVICE:	1.85 um	***
NEW INCREASE IN AHR IN DRYDOCK:	-0.094*(AHR)+37 um	***
DRYDOCK INTERVAL WITH NEW SYSTEM:	24 months	***
NEXT DRYDOCKING TO TAKE PLACE IN:	0 months	0 months
DAYS IN DRYDOCK:	7 days	7 days
EXTRA DAYS IN DRYDOCK FOR REBLAST:	5 days	***
NEXT REBLAST TO TAKE PLACE AT:	1ST. DRYDOCKING	***
NEXT CLASS. SURVEY TO TAKE PLACE AT:	1ST. DRYDOCKING	1ST. DRYDOCKING
CLASS. SURVEY TO TAKE PLACE AT EVERY:	1 DRYDOCKING	1 DRYDOCKING
CLASS. SURVEY WITH NEW SYSTEM AT EVERY:	1 DRYDOCKING	***
PAINT SYSTEM COST WITH PRESENT SYSTEM:	8.17 $/sq.m	8.17 $/sq.m
PAINT SYSTEM COST WITH NEW SYSTEM:	8.17 $/sq.m	***
ANNUAL ESCALATION OF PAINT SYSTEM COST:	10.0%	10.0%
DAILY COST OF HIRE OF DRYDOCK:	12000 $	12000 $
ADDITIONAL COST OF REBLAST OR EQUIV.:	12.62 $/sq.m	***
ANNUAL ESCALATION OF DRYDOCK CHARGES:	10.0%	10.0%
ADDITIONAL INVESTMENT IN YEAR 0 ($1000):	0	0

INPUT-DATA : MISCELLANEOUS

SHIP LIFE (OR PERIOD OF CALCULATION):	6 years
DISCOUNT RATE USED IN CALCULATIONS:	17.5%
ANNUAL RATE OF INFLATION:	10.0%
% CHANGE IN VARIABLE IN SENSITIVITY ANALYSIS:	10%
% CORRECTION TO ITTC CORRELATION FORMULA:	-40%

*** CALCULATIONS MADE FOR TWO ALTERNATIVE HULL MAINTENANCE STRATEGIES

*** THE EFFECT OF HULL FOULING NOT INCLUDED

*** THE EFFECT OF PROPELLER ROUGHNESS AND FOULING NOT INCLUDED

*** SENSITIVITY ANALYSIS ON MAJOR PARAMETERS IS INCLUDED

*** SIMULATION OF SHIP OPERATION FOR ALTERNATIVE1 BASED ON CONSTANT POWER

*** SIMULATION OF SHIP OPERATION FOR ALTERNATIVE2 BASED ON CONSTANT POWER

*** HULL MAINTENANCE ALTERNATIVE1 INCLUDES ONE REBLAST OR CHANGE IN PAINT SYSTEM

*** HULL MAINTENANCE ALTERNATIVE2 INCLUDES NO REBLAST OR CHANGE IN PAINT SYSTEM

* ALTERNATIVE 1 *

YEAR	ROUNDTRIPS PER ANNUM	SPEED ON 1ST ROUNDTRIP IN THE YEAR	POWER ON 1ST ROUNDTRIP (KW)	ANNUAL FUEL COSTS (THOUSANDS)	NET CASH FLOW EXCLUDING CAPITAL CHARGES	COSTS ALLOCATED TO PAINT SYSTEM
1	6.299	14.94	9400	2799	418	299
2	6.498	14.89	9400	3186	912	0
3	6.349	14.81	9400	3440	712	104
4	6.460	14.78	9400	3860	1047	0
5	6.320	14.73	9400	4167	812	126
6	6.432	14.69	9400	4675	1215	0

THE NET PRESENT VALUE OF THE OPERATING ACCOUNT (EXCLUDING CAPITAL CHARGES) IS ($1000): 2829

THE NET PRESENT VALUE OF THE COSTS ALLOCATED TO THE PAINT SYSTEM IS ($1000): 375
WHICH IS EQUIVALENT TO AN ANNUAL WORTH ESCALATING AT 10 % PER ANNUM OF ($1000): 86

ALL PRESENT VALUE CALCULATIONS ARE USING A DISCOUNT FACTOR OF 17 %

* ALTERNATIVE 2 *

YEAR	ROUNDTRIPS PER ANNUM	SPEED ON 1ST ROUNDTRIP IN THE YEAR	POWER ON 1ST ROUNDTRIP (KW)	ANNUAL FUEL COSTS (THOUSANDS)	NET CASH FLOW EXCLUDING CAPITAL CHARGES	DIFFERENCE IN NCF BETWEEN ALT1 AND ALT2	COSTS ALLOCATED TO PAINT SYSTEM
1	6.236	14.48	9400	2855	459	-41	86
2	6.351	14.46	9400	3203	728	184	0
3	6.227	14.45	9400	3436	543	169	104
4	6.342	14.43	9400	3877	867	180	0
5	6.219	14.43	9400	4183	644	168	126
6	6.334	14.41	9400	4692	1035	180	0

THE NET PRESENT VALUE OF THE OPERATING ACCOUNT (EXCLUDING CAPITAL CHARGES) IS ($1000): 2388

THE DIFFERENCE IN NPV BETWEEN THE OPERATING ACCOUNTS OF ALT1 AND ALT2 IS ($1000): 440
WHICH IS EQUIVALENT TO AN ANNUAL WORTH ESCALATING AT 10 % PER ANNUM OF ($1000): 101

THE NET PRESENT VALUE OF THE COSTS ALLOCATED TO THE PAINT SYSTEM IS ($1000): 193
WHICH IS EQUIVALENT TO AN ANNUAL WORTH ESCALATING AT 10 % PER ANNUM OF ($1000): 44

THE RATE OF RETURN ON THE ADDITIONAL INVESTMENT CAN NOT BE CALCULATED

DISCOUNTED PROFIT TO INVESTMENT RATIO FOR THE INCREMENTAL INVESTMENT IS: 3.184

ALL PRESENT VALUE CALCULATIONS ARE USING A DISCOUNT FACTOR OF 17.5 %

```
**************************
*                        *
*  SENSITIVITY ANALYSIS  *
*                        *
**************************
```

	NPV OF ALTERN. 1 (EXCL. CAPITAL CH.)	NPV OF ALTERN. 2 (EXCL. CAPITAL CH.)	DIFFERENCE IN NPV BETWEEN ALT. 1&2	CHANGE IN DIFFERENCE AS % OF BASIS	YIELD OF ADDITIONAL INVESTMENT	CHANGE IN YIELD COMPARED WITH BASIS
BASIS CONDITION	2829	2388	440	0.00	**	0.00
IMPROVE PROPULSION EFFICIENCY BY10%	827	815	11	2.55	**	**
SPECIFIC FUEL CONSUMPTION DECR. BY 10%	1125	1134	-9	-2.04	**	**
VOYAGE DISTANCE DOUBLED (F.R. COMP.)	-41	-113	72	16.26	**	**
FUEL PRICE INCR. BY 10% (F.R. COMP.)	-16	-46	30	6.81	**	**
FUEL PRICE INCR. BY 10% (NO F.R. COMP.)	-1247	-1256	9	2.09	**	**
FUEL ESC. INCR. BY 10% (F.R. COMP.)	-98	-160	61	13.90	**	**
FUEL ESC. INCR. BY 10% (NO F.R. COMP.)	-2960	-2972	12	2.74	**	**
FREIGHT RATE INCR. BY 10%	3008	2957	51	11.53	**	**
FREIGHT RATE ESC. INCR. BY 10%	7108	6987	122	27.62	**	**
COST OF PAINT INCR. BY 10%	-19	-19	0	-0.00	**	**
HIRE OF DRYDOCK INCR. BY 10%	-15	-12	-3	-0.58	**	**
COST OF HULL PREP. INCR. BY 10%	-11	0	-11	-2.56	**	**
DOCKINT. OF ALT.1 INCR. BY 12 MONTHS	168	0	168	38.23	**	**
ALL DOCKINT. INCR. BY 12 MONTHS	168	138	30	6.83	**	**
DAYS IN DRYDOCK INCR. BY 2 FOR ALT.1	-74	0	-74	-16.78	**	**
DAYS IN DRYD. INCR. BY 2 FOR BOTH ALT.	-74	-72	-2	-0.38	**	**
EXTRA DAYS IN DRYDOCK INCR. BY 2	-28	0	-28	-6.38	**	**
IMPORTANCE OF ROUGHNESS DECR. BY 10%	33	91	-57	-12.93	**	**

	PRESENT WORTH OF DIFFERENCE BETWEEN ALT. 1&2 AT VARIOUS DISCOUNT RATES							
YEAR	0%	5%	10%	20%	30%	40%	50%	75%
0	0	0	0	0	0	0	0	0
1	-41	-39	-37	-34	-32	-29	-27	-23
2	184	167	152	128	109	94	82	60
3	169	146	127	98	77	62	50	31
4	180	148	123	87	63	47	35	19
5	168	132	105	68	45	31	22	10
6	180	134	102	60	37	24	16	6
NPV	840	688	571	406	300	229	178	104

CODE: 0

SAMPLE (D-2)

***** DYNAMIC PROGRAMMING OF OPTIMAL HULL MAINTENANCE STRATEGIES *****

RESULTS OF BACKWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 1(A) YEAR 0 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
A 1	:2:2:2:5:5	4174

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
B 1	:3:3:5:5	3104
B 2	:2:2:5:5	3158
B 3	:5:7:5:5	3159

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
C 1	:4:4:4	2171
C 2	:2:5:5	2171
C 3	:3:5:5	2213
C 4	:6:8:10	2216
C 5	:7:5:5	2184

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
D 1	:5:5	1348
D 2	:5:5	1348
D 3	:5:5	1348
D 4	:4:4	1390
D 5	:7:9	1391
D 6	:8:10	1361
D 7	:5:5	1348

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH FROM	OPTIMAL ROUTE	NPV (S1000)
E 1	:6	600
E 2	:6	600
E 3	:3	607
E 4	:4	632
E 5	:5	664
E 6	:8	657
E 7	:9	641
E 8	:10	629
E 9	:11	618

RESULTS OF FORWARD DYNAMIC PROGRAMMING

DRYDOCKING NUMBER 2(B) YEAR 2 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
B 1	:1	918
B 2	:2	1016
B 3	:3	952

DRYDOCKING NUMBER 3(C) YEAR 4 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
C 1	:1:1	1707
C 2	:2:2	2003
C 3	:2:3	1907
C 4	:2:4	1851
C 5	:3:5	1928

DRYDOCKING NUMBER 4(D) YEAR 6 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
D 1	:1:1:1	2387
D 2	:2:2:2	2826
D 3	:2:3:3	2772
D 4	:2:2:4	2784
D 5	:2:2:5	2734
D 6	:2:4:6	2706
D 7	:3:5:7	2763

DRYDOCKING NUMBER 5(E) YEAR 8 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
E 1	:1:1:1:1	2975
E 2	:2:2:2:2	3518
E 3	:2:3:3:3	3493
E 4	:2:2:4:4	3542
E 5	:2:2:2:5	3510
E 6	:2:2:2:6	3467
E 7	:2:2:5:7	3484
E 8	:2:4:6:8	3438
E 9	:3:5:7:9	3480

DRYDOCKING NUMBER 6(F) YEAR 10 :

PATH TO	OPTIMAL ROUTE	NPV (S1000)
F 1	:1:1:1:1:1	3482
F 2	:2:2:2:2:2	4105
F 3	:2:3:3:3:3	4100
F 4	:2:2:4:4:4	4174
F 5	:2:2:2:5:5	4174
F 6	:2:2:4:4:6	4141
F 7	:2:2:4:4:7	4103
F 8	:2:2:2:6:8	4124
F 9	:2:2:5:7:9	4125
F10	:2:4:6:8:10	4066
F11	:3:5:7:9:11	4098

SAMPLE (D-3)

```
****************************
*                          *
*  MONTE-CARLO SIMULATION  *                                    CODE:   0
*                          *
****************************
```

ALTERNATIVE 1

```
MEAN OF DISTRIBUTION=   3127

STANDARD DEVIATION  =   2885

SKEWNESS            =   0.81

KURTOSIS            =   0.27

NUMBER OF CASES     =    400

   C L A S S        FREQUENCY

 UP TO     -1059.8       0      !
-1059.8 -    176.1      62      !********************
  176.1 -   1411.9      84      !****************************
 1411.9 -   2647.7      55      !******************
 2647.7 -   3883.6      56      !******************
 3883.6 -   5119.4      49      !****************
 5119.4 -   6355.2      33      !***********
 6355.2 -   7591.1      32      !**********
 7591.1 -   8826.9      12      !****
 8826.9 -  10062.7       9      !***
10062.7 -  11298.5       5      !*
11298.5 -  12534.4       1      !
12534.4 -  13770.2       2      !
13770.2  AND ABOVE       0      !

                          EACH * = 3 OBSERVATIONS
```

ALTERNATIVE 2

```
MEAN OF DISTRIBUTION=   2607

STANDARD DEVIATION  =   2823

SKEWNESS            =   0.81

KURTOSIS            =   0.20

NUMBER OF CASES     =    400

   C L A S S        FREQUENCY

 UP TO     -1511.3       0      !
-1511.3 -   -317.9      54      !******************
 -317.9 -    875.4      86      !****************************
  875.4 -   2068.7      56      !******************
 2068.7 -   3262.0      50      !****************
 3262.0 -   4455.4      60      !********************
 4455.4 -   5648.7      27      !*********
 5648.7 -   6842.0      35      !***********
 6842.0 -   8035.3      14      !****
 8035.3 -   9228.6       9      !***
 9228.6 -  10422.0       5      !*
10422.0 -  11615.3       2      !
11615.3 -  12808.6       2      !
12808.6  AND ABOVE       0      !

                          EACH * = 3 OBSERVATIONS
```

INCREMENTAL INVESTMENT

MEAN OF DISTRIBUTION= 521

STANDARD DEVIATION = 231

SKEWNESS = 0.63

KURTOSIS = 1.15

NUMBER OF CASES = 400

CLASS		FREQUENCY	
UP TO	-20.2	0	!
-20.2 -	122.8	8	!**
122.8 -	265.8	42	!**********
265.8 -	408.8	77	!*******************
408.8 -	551.8	112	!****************************
551.8 -	694.8	78	!*******************
694.8 -	837.8	47	!***********
837.8 -	980.8	22	!*****
980.8 -	1123.8	11	!**
1123.8 -	1266.8	2	!
1266.8 -	1409.8	0	!
1409.8 -	1552.8	0	!
1552.8 -	1695.8	1	!
1695.8	AND ABOVE	0	!

EACH * = 4 OBSERVATIONS

CERTAINTY EQUIVALENT OF INCREMENTAL INVESTMENT = 487

BASED UPON A MINIMUM TOLERABLE NPV OF -250

SUM OF PROBABILITIES = 1.00000000