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PRELIMINARY ANALYSIS OF LOG DATA FROM THE FIJI WINDSHIP 'CAGIDONU'

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## ABSTRACT

A preliminary analysis of log data from the Fiji Windship `Cagidonu` is made to assess fuel savings from its sail rig. Limited data, collected in a random fashion, during normal ship operation, have been analysed using techniques developed for larger vessels. Data are not fully representative of all sailing conditions. For the sailing conditions recorded, fuel savings are around 37% with all sails and 21% with mizzen and jib only. Recommendations are made regarding future data acquisition.

A comparison is made between `Cagidonu` and a similar vessel `Na Mataisau` which was extensively analysed prior to her loss. This comparison suggests that many results for `Na Mataisau` may be factored and used for `Cagidonu`.

ACKNOWLEDGEMENT

This preliminary investigation has been made possible by the assistance and sponsorship of the following organisations:

1. The Science and Engineering Research Council (Marine Technology Directorate)

2. The Asian Development Bank.

3. The Government of Fiji.

4. The crew of `Cagidonu`.

5. MacAlister Elliott and Partners.

6. The Department of Ship Science, University of Southampton.

## INTRODUCTION

The Fiji wind-assisted ship `Na Mataisau` was studied at some length prior to its loss early in 1985. Its rig was salvaged and fitted to the vessel `Cagidonu`, with some modifications to sails. Special logs were prepared for `Na Mataisau`, to monitor fuel savings, and these were transferred to `Cagidonu` to continue data collection.

The aims of the present report are to analyse log data from `Cagidonu` with a view to finding out how much fuel is being saved, and the extent to which fuel saving predictions made for `Na Mataisau` are likely to be applicable to `Cagidonu`.

Data were collected during the normal operation of the vessel and not according to any pre-arranged method. This has limited the conclusions that can be drawn and necessitated the use of voyage analysis techniques originally developed for much larger vessels. Initial impressions are that the sails are working well but that there is insufficient data to draw any conclusions about general levels of fuel savings. However, available data suggests that in conditions where full sail can be used, fuel savings amount to 36.5%

## DATA ACQUISITION

Methods of data acquisition are essentially as described for `Na Mataisau` in ref (1) and will be summarised here.

Ship Speed:
Ship speed was measured by a through-hull paddle wheel.

Apparent Wind:
Apparent wind speed and direction was measured by a vane-type anemometer, mounted on a 1.5m pole, above the main mast.

Fuel Flow:
Fuel flow was measured by a system of differential flow meters,

one measuring the fuel going into the injection pump, and the other the fuel returned to the tank after cooling the injection pump.

Displacement:
Displacement was assessed from the draught marks and hydrostatics by MacAlister Elliott and Partners.

METHODS OF DATA ANALYSIS

Data for `Cagidonu` have been acquired in the manner described, by a number of observers, in a variety of weather conditions and with various degrees of hull fouling. Interpretation of the data needs to be within the framework of a good physical model. Voyage data for large vessels are often very variable, due to the effects of random winds and seas. Smaller vessels like `Cagidonu` are more susceptible to these effects and so considerable scatter must be expected in voyage data. This scatter requires special attention, to ensure that any trends are correctly assessed. Techniques for voyage analysis were developed in the 1950`s refs (2) and (3), and remain in use, largely unchanged, to the present day.

In the case of `Cagidonu` fuel flow is the quantity of primary interest, and needs to be related to ship speed, wind speed and direction, displacement and fouling. Fouling is related to days out of dock. Fuel flow variation with all of these quantities has been investigated for larger vessels and expectations are as follows:

1. Fuel flow/ship speed

For displacement vessels, effective power varies as (ship speed)$^3$. Propeller efficiency and engine SFC may vary slightly, but the normal expectation would be for fuel flow to vary as (ship speed)$^3$. At the highest speeds recorded (10 knots +) `Cagidonu` is almost certainly operating at an overdriven speed, where fuel flow is likely to vary according to the fourth or fifth power of ship speed. Somewhere within the ship speed range of 7-9 knots the cubic relationship between power and speed begins to break down, to be gradually replaced by a higher index appropriate to the overdriven mode.

2. Fuel flow/weather

Fuel flow - weather variation is difficult to analyse accurately. Wave effects can be different for two identical true wind speeds. Resistance increases due to waves may be compounded by individual helmsman`s or autopilot`s methods of steering. Windship theory shows wind energy available to depend on ship speed, true wind speed ($V_t$) and direction ($\gamma$), as well as the sail configuration. Classical voyage analysis techniques e.g. ref (3) make use of a single weather factor variable `W` which is read off a graph for different wind directions and Beaufort Numbers. Examination of this chart shows that

$$W \doteqdot .0517 \cdot V_t^{1.5} (1+\cos\gamma) \qquad 0 < \gamma < \pi/2$$
$$\doteqdot .0517 \cdot V_t^{1.5} (1+.75 \cos\gamma) \qquad \pi/2 < \gamma < \pi \qquad (1)$$

where $V_t$ is in knots and $\gamma$ in radians.

Such weather factors are derived from experience with large vessels and there is the possibility that some other $V_t$ - $\gamma$ variation is more appropriate for smaller vessels such as `Cagidonu`. Unfortunately, there is insufficient data available to investigate this question, as sails were used whenever possible, leaving a considerable gap in the data for the sails-furled configuration whenever $\gamma$ values exceeded $\pi/4$ radians ($45^o$).

3. Fuel flow/displacement

To a first order, resistance and effective power will normally increase as $(\text{displacement})^{2/3}$. However, propeller efficiency may fall if resistance is increased due to higher displacement, and there may ultimately be an argument for relating fuel flow to some power of displacement that is greater than two thirds. In this preliminary analysis the conventional figure of two thirds will be adhered to.

4. Fuel flow/days out of deck

When a vessel spends time at sea, the hull fouls and resistance increases. Rate of fouling can depend on location and water temperature, and many possible variations between fuel flow and days out of dock exist. It is suggested in ref (3) that a linear variation is usually a good average of the possible ways in which fuel flow can vary with days out of dock.

Once the form of the (fuel flow) v. (ship speed, weather, displacement, days out of dock) relationship is known then a multiple regression technique might be applied to obtain a least-squares fit between the data points and the constants required for the relationship. These techniques are applicable when a random sample of data points are available. In the present case for example, power setting is fairly constant, which makes it difficult to establish a fuel flow/ship speed relationship. If the ship goes slowly, it will usually be for reasons of weather or fouling, and not because engine power (and hence fuel flow) has been reduced. With the present data sample, multiple regression is not applicable, although one opportunity for single regression has been found. Log data is presented in Appendix I.

Data analysis is simplified if some of the variables are removed by making use of expected physical relationships between variables. Instead of dealing with fuel flow, a normalised fuel flow may be defined which can reduce the effects of displacement and ship speed.

$$\text{Normalised Fuel Flow} = \text{fuel flow} / (\text{displacement})^{2/3} \times (\text{ship speed})^3$$

The definition of normalised fuel flow is chosen for a displacement vessel, with constant SFC and propeller efficiency, where fuel flow (gall/hr) is normalised for one tonne of displacement and one knot of ship speed. It can be argued that such a definition is inappropriate to `Cagidonu` at its higher speeds, where fuel flow may be expected to vary as to the fourth or fifth power of speed. Ideally, fuel flow might be related to ship speed through some power law that was itself a function of speed. However, for the present data, the implication of the cubic power law in equation (2) is that the fuel equivalent of the power provided by the sails may be under-estimated, as associated high ship speeds under sail are not correctly related to fuel flow. Consequently the adoption of a cubic relationship between fuel flow and ship speed should result in a conservative estimate of the benefits of sail.

Use of the normalised fuel flow concept leaves only the effects of weather, time out of dock and sail configuration still to be analysed.

It is useful to appreciate the spread of data with the variables introduced so far. Fig 1 shows the range of speeds for which normalised fuel flow can be computed. Comments in the legend of Fig 1 should be carefully read. Fig 2 shows the variation of normalised fuel flow with time out of dock, which shows considerable scatter but no physically-realistic trend. Fig 3 shows the variation of normalised fuel flow with weather factor (defined by equation (1)) for the case when sails are furled. A linear relationship between normalised fuel flow and weather factor is obtained by a least-squares fit of the data. This is shown by a dotted line on Fig 3. This provides a datum for comparing normalised fuel flows under sail with those obtained under power. Fig 4 shows normalised fuel flows obtained with the two sail configurations tested, as well as the datum from Fig 3, for normalised fuel flows obtained with the sails furled.

## INTERPRETATION OF DATA

Fig 1 appears to show that normalised fuel flow increases with decreasing ship speed. However, examination of the log data in

Appendix I shows that a fairly constant fuel flow (and power setting) may result in many different speeds, which suggests that the trend in Fig 1 is showing the effect of fouling or added resistance due to weather. A reduction in speed due to these causes will also cause a reduction in propeller advance ratio, and normally a lowering of propeller efficiency, which then raises the normalised fuel flow. Fig 1 must therefore be interpreted with great care and clearly does not show the variation of normalised fuel flow with speed when engine power is varied. Odd points are available at low engine power settings with sails furled, and these give much lower normalised fuel flows than might be inferred from the general pattern of the data.

Fig 2 shows data points for normalised fuel flow plotted against time out of dock. Most data are within a 30 day period and influenced by other factors. Given the scatter in the data and shortness of the period, it is too soon for firm conclusions.

Fig 3 shows normalised fuel flow for the vessel with sails furled, plotted against weather factor. Limitations of the weather factor concept have already been discussed, but, in the absence of information required for a better analysis, this concept probably offers as good a basis as any for the interpretation of the data. However, any such interpretation must be tempered by the knowledge that relationships governing weather factor, true wind speed and true wind direction may not be accurate. Data interpretation using a general weather factor (eq. 1) can only be tentative and specific weather factor-relationships for `Cagidonu` could usefully be sought. Within these limitations Fig 3 shows a great deal of scatter, but a trend for normalised fuel flow to increase with increase in weather factor. A least-squares line going through this data is defined by:

$$\text{Normalised fuel flow} = (4.949 + 0.4501 \cdot W) \times 10^{-4} \qquad (3)$$

in terms of gallons/hour/(tonne of displacement)$^{2/3}$/knots$^3$ and is shown by a dotted line on the figure. This line is also shown on Fig 4 where normalised fuel flow is plotted against weather factor for two sailing configurations. This plot provides a clear indication that sail produces substantial fuel savings.

Examination of log data also shows that many potentially good sailing conditions are not represented, which means that a general conclusion about the level of fuel savings from sail cannot be made. The only conclusion that can be drawn is specific to the data available.

Within the limitations referred to so far, Fig 4 provides the most equitable basis for assessing sail fuel savings for this data. The dotted line provides a datum for fuel usage without sail, and the data points an indication of fuel usage with sail. Fractional savings can be calculated by assessing the differences between datum line and data points, and then dividing by datum fuel usage. Mean fuel savings obtained in this way can then be expressed as percentages. Table 1 summarises both sail utilisation and percentage fuel savings, for the log data available.

Table 1

WIND ASSIST FUEL SAVINGS

| | Utilisation % | Fuel Saving % |
|---|---|---|
| Sails furled | 62 | 0 (DATUM) |
| Main, mizzen & jib | 23 | 36.5 |
| Mizzen & jib only | 15 | 21.2 |

The technique used to prepare Table 1 is based on the concept of a saving in normalised fuel flow and may yield conservative answers for these data because of the limitations of the assumed cubic law relating fuel flow and ship speed. Log data clearly shows `Cagidonu` being operated under motor sail at high ship speeds, where the benefit of the sails is used to increase speed, rather than to save fuel. This mode of operation is believed to be common around Christmas time in Fiji, where peak traffic creates a shipping capacity shortage that is alleviated by an increase in ship speed. It would be useful to continue the fuel monitoring exercise to include other data appropriate to lower ship speeds, where the benefits of sail are used to save fuel.

## FUTURE DATA ACQUISITION

Data collected so far have not been ordered so as to investigate specific effects, but were accumulated during the normal course of daily operations. It was originally intended that towing tests and other investigations carried out for `Na Mataisau` would be used to help prepare datum curves of fuel flow v. ship speed, from which wind-assist fuel savings could be assessed. Such datum curves are now required by `Cagidonu` and a method is proposed whereby they might be obtained with minimal expense.

Mention has been made of the problems of using a generalised weather factor, and the absence of data in certain (mathematical) regions. These can be alleviated by the careful acquisition of more specific data. A series of experiments are needed in a variety of (steady) weather conditions, to be carried out as follows:

"Furl the sails, and go to windward at a low engine power setting, take log readings and then repeat the log readings for progressively increasing power settings. Repeat the experiment at nine different headings, with an increment of $20^{o}$ between the headings. Then hoist the sails and repeat the experiment for all but the windward heading."

If this experiment is carried out, on an opportunist basis, in a variety of weather conditions, in a reasonably short space of time, it is likely that a much better interpretation of the data could be made, and the government of Fiji might be provided with performance graphs for `Cagidonu`. This in turn would enable the Marine Department to conduct their own voyage monitoring exercise, using the graphs as a datum. Such a monitoring exercise would enable the Department to ensure that the sails are used for maximum benefit. It is worth noting that continual monitoring of energy usage normally results in savings of 5%, and there is every reason to suppose that at least this level of additional fuel saving can be achieved through optimal operation of `Cagidonu`. Experience with `Na Mataisau` suggests that operational circumstances can arise where pure sail is required for emergency propulsion. It is therefore proposed that a series of pure-sail log readings are taken throughout the range of feasible apparent wind angles, with a view to providing the vessel with a pure-sail performance graph. Such a graph might be used to compute the times to different landfalls, in critical situations.

## A COMPARISON OF `NA MATAISAU` AND `CAGIDONU`

Theoretical and practical work carried out for `Na Mataisau` ref (1) may have applications for `Cagidonu` and a comparison of the two vessels is made to investigate this possibility.

Basic particulars of the two vessels are listed in Table 2. Wind energy extracted from the rig may be shown to be proportional to a power assistance coefficient ($C_{EP}$) and rig area ($S_{ER}$). $C_{EP}$ increases with increasing draught, but reduces with reducing rig aspect ratio. Average values of $C_{EP}$ are likely to be the same for both vessels, as Cagidonu`s improvement due to her draught will tend to be negated by her lower aspect ratio rig. If specific fuel consumption (SFC), quasi propulsive efficiency ($\eta D$) and transmission efficiency ($\eta T$) are assumed to be the same, then fuel savings should vary only as the ratio of rig areas. On this basis, the absolute fuel saving for `Cagidonu` should be 9% more than for `Na Mataisau`. However, if there are thought to be substantial differences in SFC, $\eta D$ or $\eta T$, then those differences can be accounted for by simple laws of proportionality. The 9% improvement in absolute fuel saving for `Cagidonu` pre-supposes that all routes and frequencies are the same for both vessels.

TABLE 2

PARTICULARS OF `NA MATAISAU` AND `CAGIDONU`

| ITEM | SYMBOL | NA MATAISAU | CAGIDONU | UNIT |
|---|---|---|---|---|
| Approx LWL | LWL | 27.8 | 26.7 | m |
| Max Beam | B | 7.32 | 7.0 | m |
| Max Draught | T | 2.8 | 3.2 | m |
| Typical Displacement | $\Delta$ | 262.5 | 274 | tonne |
| Rig Area | Ser | 219.7 | 240 | $m^2$ |
| Hull form | | multi-chine | multi-chine | |

## CONCLUSIONS

Log data for `Cagidonu` covered a limited period around Christmas 1985, when the vessel was being operated at fairly high speeds. Table 1 shows that the majority of the log readings are for the sails- furled configuration, and examination of Appendix I shows that some good sailing conditions are not represented in the data.

Lack of background information on Cagidonu has hindered interpretation of the data and necessitated the use of the two concepts of a weather factor and a normalised fuel flow. Both of these concepts can lead to errors of interpretation, although where such errors can be appraised, they are shown to give conservative answers for the fuel savings from sail.

Against this background of limited, variable data, with problems of interpretation, Table 1 summarises the fuel savings obtained. These are seen to be around 37% with all sails and 21% with the mizzen and jib only.

It is recommended that some simple experiments are conducted to acquire more specific data, which should lessen the need for assumptions in data interpretation. Execution of these recommendations could lead to reliable performance graphs for the vessel, which might provide a datum for future voyage monitoring. With such a monitoring programme, the sails are more likely to be used to best advantage and fuel usage is likely to be further reduced.

It is further recommended that some pure-sail log data is acquired to provide any master of `Cagidonu` with an operational graph, from which he could estimate sailing times to possible landfalls, in emergency conditions.

A comparison has also been made between `Na Mataisau` and `Cagidonu` with a view to examining the applicability of the forecast fuel savings for `Na Mataisau` to `Cagidonu`. This comparison suggested that absolute forecast fuel savings for `Na Mataisau` might be increased by around 9% and applied to `Cagidonu` when operating on similar routes, with similar frequencies and with similar engine/propeller characteristics.

## REFERENCES


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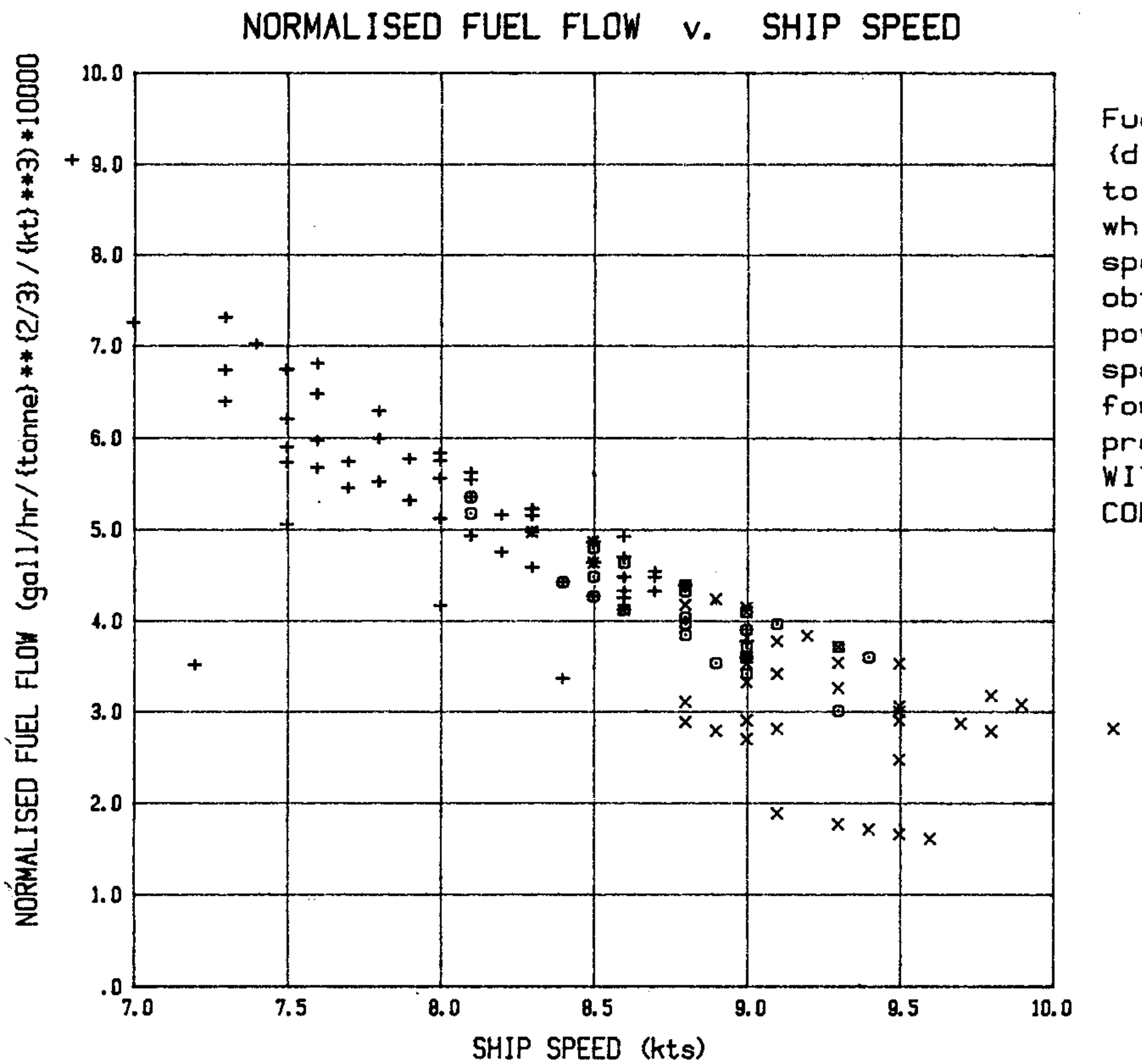
2. Burrill, L.C. `The Analysis of Trial Trip and Voyage Data`. Extrait de L`Annuaire de L`Union Belge des Ingeuieurs Navals Quatrieme Volume 1954-56, pp 1-29.

3. Clements, R.E. `A Method of Analysing Voyage Data`. Trans. North East Coast Institution of Shipbuilders and Engineers, Vol. 73, pp 197-230.

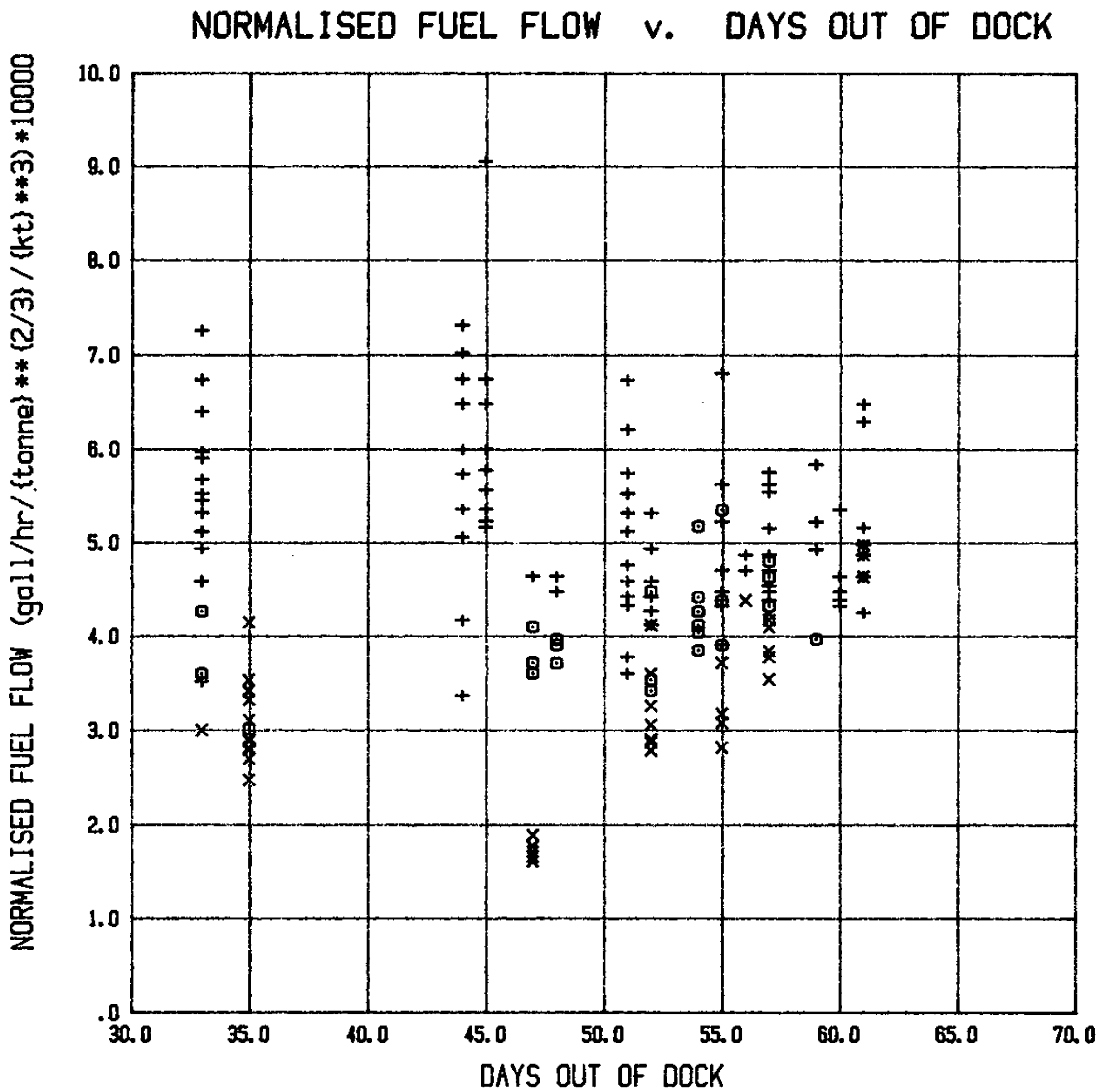



*LEGEND*

Fuel flow is divided by (displ.)**(2/3) and (spd.)**3 to obtain a normalised value which is plotted against ship speed. Data presented is mostly obtained with a near-constant power setting, where low ship speeds reflect the effects of fouling and weather. The trend produced is ONLY APPLICABLE WITH DATA COLLECTED AT CONSTANT POWER SETTING.

- \+ sails furled
- × main , mizzen & jib
- ⊙ mizzen & jib only

FIG 1

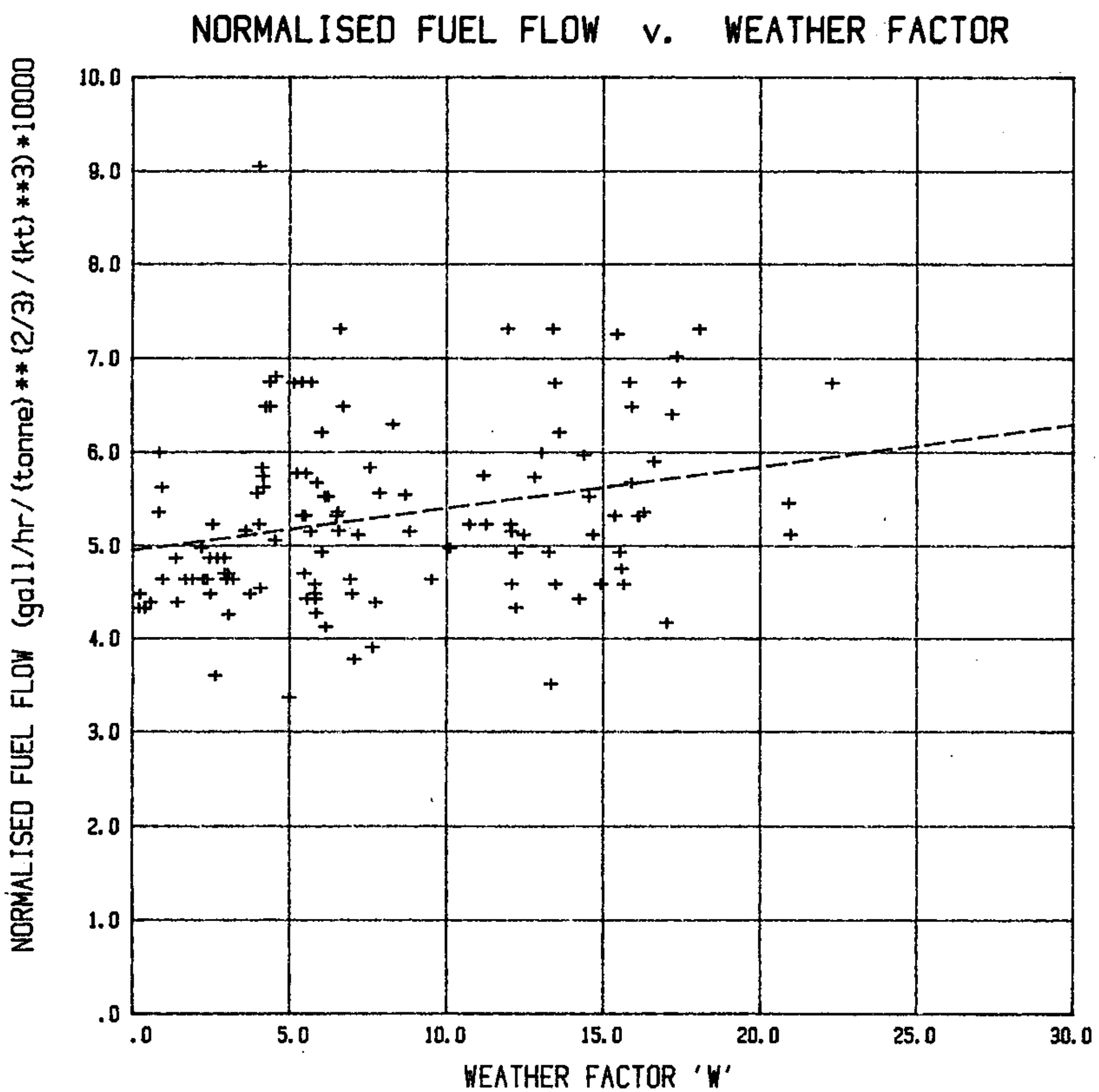



*LEGEND*

Normalised fuel flow is plotted against days out of dock for all configurations.

+ sails furled
× main , mizzen & jib
⊡ mizzen & jib only

FIG 2



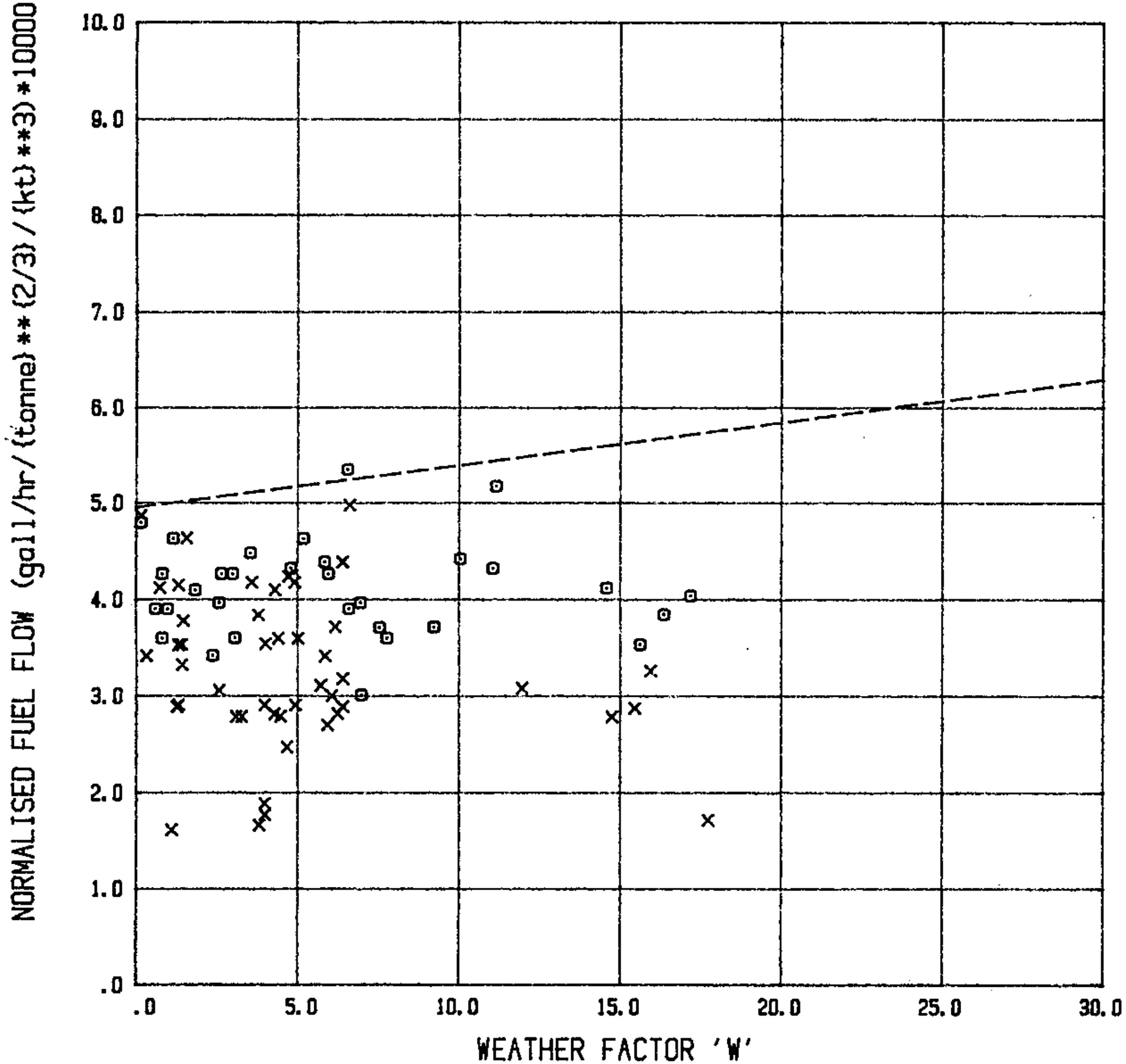

*LEGEND*

Normalised fuel flow is plotted against weather factor for the sails furled configuration. The dotted line shows a linear regression of the data.

\+ sails furled

FIG 3

NORMALISED FUEL FLOW v. WEATHER FACTOR




*LEGEND*

Normalised fuel flow is plotted against weather factor for two sail configurations. The dotted line shows a least-squares linear regression of data for the furled sails configuration.

× main , mizzen & jib

⊡ mizzen & jib only

FIG 4

APPENDIX I

LOG DATA FROM `CAGIDONU`

| displ. tonnes | days out of dock | ship speed kts | apparent wind spd. kts | apparent wind ang. degrees | config | fuel flow gall/hour |
|---|---|---|---|---|---|---|
| 310.0 | 33. | 7.2 | 20. | 10. | 0. | 6. |
| 310.0 | 33. | 8.1 | 19. | 10. | 0. | 12. |
| 310.0 | 33. | 8. | 18. | 10. | 0. | 12. |
| 310.0 | 33. | 8. | 21. | 10. | 0. | 12. |
| 310.0 | 33. | 8.3 | 20. | 15. | 0. | 12. |
| 310.0 | 33. | 8.3 | 18. | 15. | 0. | 12. |
| 310.0 | 33. | 8.3 | 22. | 15. | 0. | 12. |
| 310.0 | 33. | 7.9 | 23. | 10. | 0. | 12. |
| 310.0 | 33. | 7.6 | 21. | 10. | 0. | 12. |
| 310.0 | 33. | 7.9 | 22. | 10. | 0. | 12. |
| 310.0 | 33. | 7.9 | 22. | 10. | 0. | 12. |
| 310.0 | 33. | 7.9 | 26. | 20. | 0. | 12. |
| 310.0 | 33. | 7.3 | 25. | 20. | 0. | 12. |
| 310.0 | 33. | 8. | 30. | 15. | 0. | 12. |
| 310.0 | 33. | 7.3 | 31. | 10. | 0. | 12. |
| 310.0 | 33. | 7. | 23. | 10. | 0. | 11.4 |
| 310.0 | 33. | 7.3 | 26. | 15. | 0. | 11.4 |
| 310.0 | 33. | 7.6 | 24. | 15. | 0. | 11.4 |
| 310.0 | 33. | 7.7 | 29. | 10. | 0. | 11.4 |
| 310.0 | 33. | 7.6 | 24. | 5. | 0. | 11.4 |
| 310.0 | 33. | 7.5 | 24. | 10. | 0. | 11.4 |
| 310.0 | 33. | 7.8 | 25. | 5. | 0. | 12. |
| 310.0 | 33. | 9. | 10. | 120. | 2. | 12. |
| 310.0 | 33. | 8.5 | 12. | 120. | 2. | 12. |
| 310.0 | 33. | 8.5 | 11. | 130. | 2. | 12. |
| 250.0 | 33. | 9.5 | 10. | 130. | 1. | 10.2 |
| 250.0 | 35. | 9.1 | 10. | 130. | 1. | 10.2 |
| 250.0 | 35. | 9. | 8. | 150. | 1. | 10.2 |
| 250.0 | 35. | 9.1 | 9. | 170. | 1. | 10.2 |
| 250.0 | 35. | 8.9 | 10. | 165. | 1. | 7.8 |
| 250.0 | 35. | 8.8 | 7. | 160. | 1. | 7.8 |
| 250.0 | 35. | 9. | 6. | 160. | 1. | 7.8 |
| 250.0 | 35. | 9. | 8. | 165. | 1. | 8.4 |
| 250.0 | 35. | 9.1 | 9. | 165. | 1. | 8.4 |
| 250.0 | 35. | 9. | 8. | 150. | 1. | 8.4 |
| 250.0 | 35. | 9.5 | 8. | 140. | 1. | 8.4 |
| 250.0 | 35. | 8.8 | 8. | 180. | 1. | 8.4 |
| 250.0 | 35. | 8.8 | 8. | 150. | 1. | 7.8 |
| 250.0 | 35. | 9.5 | 11. | 150. | 1. | 12. |
| 250.0 | 35. | 9. | 11. | 150. | 1. | 12. |

notes :

1) sail config. value of 0.0 corresponds to sails furled.

2) sail config. value of 1.0 corresponds to all sails in use.

3) sail config. value of 2.0 corresponds to jib and mizzen only.

| displ. tonnes | days out of dock | ship speed kts | apparent wind spd. kts | apparent wind ang. degrees | config | fuel flow gall/hour |
|---|---|---|---|---|---|---|
| 250. | 35. | 9.3 | 10. | 180. | 2. | 9.6 |
| 274.0 | 44. | 8.4 | 8. | 90. | 0. | 8.4 |
| 274.0 | 44. | 8. | 24. | 10. | 0. | 9. |
| 274.0 | 44. | 7.5 | 20. | 0. | 0. | 9. |
| 274.0 | 44. | 7.5 | 19. | 10. | 0. | 10.2 |
| 274.0 | 44. | 7.8 | 19. | 10. | 0. | 12. |
| 274.0 | 44. | 7.3 | 20. | 10. | 0. | 12. |
| 274.0 | 44. | 7.6 | 23. | 10. | 0. | 12. |
| 274.0 | 44. | 7.5 | 19. | 30. | 0. | 12. |
| 274.0 | 44. | 7.6 | 23. | 30. | 0. | 12. |
| 274.0 | 44. | 7.3 | 23. | 30. | 0. | 12. |
| 274.0 | 44. | 7.5 | 23. | 10. | 0. | 12. |
| 274.0 | 44. | 7.5 | 25. | 10. | 0. | 12. |
| 274.0 | 44. | 7.4 | 25. | 10. | 0. | 12. |
| 274.0 | 44. | 7.3 | 26. | 10. | 0. | 12. |
| 274.0 | 44. | 7.3 | 18. | 10. | 0. | 12. |
| 274.0 | 44. | 8.1 | 23. | 10. | 0. | 12. |
| 274.0 | 45. | 7.5 | 20. | 30. | 0. | 12. |
| 274.0 | 45. | 7.5 | 19. | 30. | 0. | 12. |
| 274.0 | 45. | 7.9 | 18. | 30. | 0. | 12. |
| 274.0 | 45. | 7.9 | 18. | 30. | 0. | 12. |
| 274.0 | 45. | 7.9 | 19. | 30. | 0. | 12. |
| 274.0 | 45. | 7.5 | 22. | 20. | 0. | 12. |
| 274.0 | 45. | 6.8 | 21. | 20. | 0. | 12. |
| 274.0 | 45. | 7.6 | 22. | 20. | 0. | 12. |
| 274.0 | 45. | 8.1 | 22. | 30. | 0. | 12. |
| 274.0 | 45. | 8.2 | 18. | 20. | 0. | 12. |
| 274.0 | 45. | 8.3 | 20. | 20. | 0. | 12.6 |
| 274.0 | 45. | 8. | 20. | 20. | 0. | 12. |
| 274.0 | 45. | 7.8 | 24. | 25. | 0. | 12. |
| 274.0 | 45. | 8. | 26. | 30. | 0. | 12. |
| 274.0 | 47. | 9.5 | 26. | 70. | 1. | 6. |
| 274.0 | 47. | 9.3 | 27. | 70. | 1. | 6. |
| 274.0 | 47. | 9.1 | 27. | 70. | 1. | 6. |
| 274.0 | 47. | 9.6 | 26. | 50. | 1. | 6. |
| 274.0 | 47. | 9.4 | 26. | 40. | 1. | 6. |
| 274.0 | 47. | 8.5 | 30. | 30. | 0. | 12. |
| 274.0 | 47. | 9. | 14. | 70. | 2. | 12.6 |
| 274.0 | 47. | 9.4 | 22. | 70. | 2. | 12.6 |
| 274.0 | 47. | 9.3 | 16. | 90. | 2. | 12.6 |

notes :

1) sail config. value of 0.0 corresponds to sails furled.

2) sail config. value of 1.0 corresponds to all sails in use.

3) sail config. value of 2.0 corresponds to jib and mizzen only.

| displ. tonnes | days out of dock | ship speed kts | apparent wind spd. kts | apparent wind ang. degrees | config | fuel flow gall/hour |
|---|---|---|---|---|---|---|
| 274.0 | 47. | 9.4 | 13. | 90. | 2. | 12.6 |
| 274.0 | 48. | 8.6 | 12. | 105. | 0. | 12. |
| 274.0 | 48. | 8.5 | 17. | 80. | 0. | 12. |
| 274.0 | 48. | 9. | 17. | 100. | 2. | 12. |
| 274.0 | 48. | 8.8 | 12. | 90. | 2. | 11.4 |
| 274.0 | 48. | 9. | 13. | 90. | 2. | 11.4 |
| 310.0 | 51. | 9. | 8. | 60. | 0. | 12.6 |
| 310.0 | 51. | 8. | 24. | 30. | 0. | 12. |
| 310.0 | 51. | 7.9 | 22. | 30. | 0. | 12. |
| 310.0 | 51. | 7.8 | 21. | 30. | 0. | 12. |
| 310.0 | 51. | 7.5 | 21. | 30. | 0. | 12. |
| 310.0 | 51. | 7.9 | 24. | 15. | 0. | 12. |
| 310.0 | 51. | 7.7 | 21. | 20. | 0. | 12. |
| 310.0 | 51. | 7.3 | 21. | 15. | 0. | 12. |
| 310.0 | 51. | 7.5 | 21. | 15. | 0. | 12. |
| 310.0 | 51. | 7.8 | 22. | 15. | 0. | 12. |
| 310.0 | 51. | 8.2 | 23. | 15. | 0. | 12. |
| 310.0 | 51. | 8.3 | 23. | 15. | 0. | 12. |
| 310.0 | 51. | 8.4 | 20. | 10. | 0. | 12. |
| 310.0 | 51. | 9. | 11. | 20. | 0. | 12. |
| 310.0 | 51. | 8.6 | 19. | 40. | 0. | 12.6 |
| 310.0 | 52. | 8.4 | 22. | 5. | 0. | 12. |
| 310.0 | 52. | 8.4 | 23. | 5. | 0. | 12. |
| 310.0 | 52. | 8.4 | 23. | 5. | 0. | 12. |
| 310.0 | 52. | 8.5 | 23. | 5. | 0. | 12. |
| 310.0 | 52. | 8.5 | 23. | 5. | 0. | 12. |
| 310.0 | 52. | 8.3 | 23. | 0. | 0. | 12. |
| 310.0 | 52. | 7.9 | 22. | 5. | 0. | 12. |
| 310.0 | 52. | 8.6 | 24. | 5. | 0. | 12. |
| 310.0 | 52. | 8.1 | 24. | 5. | 0. | 12. |
| 310.0 | 52. | 8.1 | 22. | 10. | 0. | 12. |
| 310.0 | 52. | 8.9 | 20. | 60. | 2. | 11.4 |
| 310.0 | 52. | 9. | 18. | 70. | 2. | 11.4 |
| 310.0 | 52. | 9.5 | 10. | 80. | 1. | 11.4 |
| 310.0 | 52. | 9. | 9. | 80. | 1. | 12. |
| 310.0 | 52. | 9. | 11. | 80. | 1. | 12. |
| 310.0 | 52. | 8.6 | 21. | 50. | 1. | 12. |
| 310.0 | 52. | 9.3 | 20. | 60. | 1. | 12. |
| 310.0 | 52. | 9.8 | 18. | 60. | 1. | 12. |
| 310.0 | 52. | 9.5 | 19. | 70. | 1. | 12. |
| 310.0 | 52. | 9.8 | 22. | 70. | 1. | 12. |

notes :

1) sail config. value of 0.0 corresponds to sails furled.

2) sail config. value of 1.0 corresponds to all sails in use.

3) sail config. value of 2.0 corresponds to jib and mizzen only.

| displ. tonnes | days out of dock | ship speed kts | apparent wind spd. kts | apparent wind ang. degrees | config | fuel flow gall/hour |
|---|---|---|---|---|---|---|
| 310.0 | 52. | 9.7 | 19. | 60. | 1. | 12. |
| 310.0 | 52. | 9.8 | 23. | 70. | 1. | 12. |
| 310.0 | 52. | 8.5 | 25. | 70. | 2. | 12.6 |
| 310.0 | 54. | 8.8 | 22. | 60. | 2. | 12.6 |
| 310.0 | 54. | 8.6 | 19. | 60. | 2. | 12. |
| 310.0 | 54. | 8.4 | 17. | 65. | 2. | 12. |
| 310.0 | 54. | 8.8 | 21. | 60. | 2. | 12. |
| 310.0 | 54. | 8.5 | 22. | 70. | 2. | 12. |
| 310.0 | 54. | 8.5 | 20. | 70. | 2. | 12. |
| 310.0 | 54. | 8.1 | 15. | 60. | 2. | 12.6 |
| 274.0 | 55. | 8.3 | 16. | 60. | 0. | 12.6 |
| 274.0 | 55. | 8.3 | 17. | 40. | 0. | 12.6 |
| 274.0 | 55. | 8.8 | 19. | 30. | 2. | 12.6 |
| 274.0 | 55. | 8.6 | 18. | 30. | 0. | 12.6 |
| 274.0 | 55. | 8.1 | 14. | 30. | 0. | 12.6 |
| 274.0 | 55. | 9. | 12. | 65. | 0. | 12. |
| 274.0 | 55. | 8.6 | 15. | 45. | 0. | 12. |
| 274.0 | 55. | 8.7 | 16. | 50. | 0. | 12. |
| 274.0 | 55. | 7.6 | 8. | 90. | 0. | 12.6 |
| 274.0 | 55. | 9.3 | 14. | 80. | 1. | 12.6 |
| 274.0 | 55. | 9.8 | 14. | 80. | 1. | 12.6 |
| 274.0 | 55. | 9.9 | 14. | 85. | 1. | 12.6 |
| 274.0 | 55. | 10.2 | 13. | 80. | 1. | 12.6 |
| 274.0 | 55. | 8.8 | 9. | 135. | 0. | 12.6 |
| 274.0 | 55. | 9. | 11. | 90. | 2. | 12. |
| 274.0 | 55. | 9. | 11. | 100. | 2. | 12. |
| 274.0 | 55. | 8.1 | 22. | 30. | 2. | 12. |
| 274.0 | 55. | 8.6 | 22. | 45. | 0. | 12. |
| 274.0 | 56. | 8.5 | .6 | 180. | 0. | 12.6 |
| 274.0 | 56. | 8.6 | .8 | 160. | 0. | 12.6 |
| 274.0 | 56. | 8.8 | 7. | 160. | 1. | 12.6 |
| 274.0 | 56. | 8.8 | 7. | 160. | 1. | 12.6 |
| 274.0 | 57. | 8.8 | 4. | 130. | 1. | 12. |
| 274.0 | 57. | 9.3 | 6. | 140. | 1. | 12. |
| 274.0 | 57. | 9.1 | 6. | 150. | 1. | 12. |
| 274.0 | 57. | 8.8 | 8. | 130. | 1. | 12. |
| 274.0 | 57. | 9.2 | 4. | 130. | 1. | 12.6 |
| 274.0 | 57. | 9. | 6. | 130. | 1. | 12.6 |
| 274.0 | 57. | 8.9 | 4. | 160. | 1. | 12.6 |
| 274.0 | 57. | 8.1 | 4. | 170. | 0. | 12.6 |
| 274.0 | 57. | 8.5 | 3. | 170. | 0. | 12.6 |

notes :

1) sail config. value of 0.0 corresponds to sails furled.

2) sail config. value of 1.0 corresponds to all sails in use.

3) sail config. value of 2.0 corresponds to jib and mizzen only.

| displ. tonnes | days out of dock | ship speed kts | apparent wind spd. kts | apparent wind ang. degrees | config | fuel flow gall/hour |
|---|---|---|---|---|---|---|
| 274.0 | 57. | 8.8 | 4. | 120. | 0. | 12.6 |
| 274.0 | 57. | 8.7 | 3. | 160. | 0. | 12.6 |
| 274.0 | 57. | 8.6 | 2. | 90. | 0. | 12.6 |
| 280.0 | 57. | 8. | 17. | 15. | 0. | 12.6 |
| 280.0 | 57. | 8.3 | 19. | 30. | 0. | 12.6 |
| 280.0 | 57. | 8.5 | 9. | 50. | 2. | 12.6 |
| 280.0 | 57. | 8.6 | 4. | 75. | 2. | 12.6 |
| 280.0 | 57. | 8.8 | 7. | 90. | 2. | 12.6 |
| 280.0 | 57. | 8.8 | 17. | 40. | 2. | 12.6 |
| 280.0 | 57. | 8.6 | 17. | 30. | 2. | 12.6 |
| 280.0 | 57. | 8.1 | 13. | 15. | 0. | 12.6 |
| 280.0 | 57. | 8.3 | 13. | 15. | 0. | 12.6 |
| 280.0 | 57. | 8.3 | 18. | 15. | 0. | 12.6 |
| 280.0 | 57. | 8.7 | 13. | 50. | 0. | 12.6 |
| 274.0 | 59. | 8. | 12. | 40. | 0. | 12.6 |
| 274.0 | 59. | 8. | 17. | 5. | 0. | 12.6 |
| 274.0 | 59. | 8.6 | 19. | 40. | 0. | 13.2 |
| 274.0 | 59. | 9.1 | 15. | 45. | 2. | 12.6 |
| 274.0 | 59. | 8.3 | 16. | 45. | 0. | 12.6 |
| 274.0 | 59. | 8.3 | 16. | 10. | 0. | 12.6 |
| 274.0 | 60. | 8.8 | 12. | 0. | 0. | 12.6 |
| 274.0 | 60. | 8.5 | 9. | 20. | 0. | 12. |
| 274.0 | 60. | 8.7 | 7. | 0. | 0. | 12. |
| 274.0 | 60. | 8.5 | 10. | 20. | 0. | 12. |
| 274.0 | 60. | 8.6 | 9. | 10. | 0. | 12. |
| 274.0 | 60. | 8.1 | 22. | 50. | 0. | 12. |
| 274.0 | 61. | 8.5 | 14. | 20. | 0. | 12.6 |
| 274.0 | 61. | 8.5 | 15. | 0. | 0. | 12. |
| 274.0 | 61. | 8.5 | 9. | 30. | 0. | 12. |
| 274.0 | 61. | 8.2 | 8. | 60. | 0. | 12. |
| 274.0 | 61. | 8.3 | 16. | 40. | 0. | 12. |
| 274.0 | 61. | 8.3 | 8. | 60. | 1. | 12. |
| 274.0 | 61. | 8.5 | 11. | 50. | 1. | 12.6 |
| 274.0 | 61. | 8.5 | 12. | 70. | 1. | 12. |
| 274.0 | 61. | 8.3 | 9. | 20. | 0. | 12. |
| 274.0 | 61. | 8.5 | 15. | 70. | 0. | 12. |
| 274.0 | 61. | 8.5 | 2. | 30. | 0. | 12.6 |
| 274.0 | 61. | 8.5 | 2. | 90. | 0. | 12. |
| 274.0 | 61. | 8.5 | 4. | 0. | 0. | 12. |
| 274.0 | 61. | 7.8 | 12. | 10. | 0. | 12.6 |
| 274.0 | 61. | 8.6 | 8. | 30. | 0. | 11.4 |
| 274.0 | 61. | 7.6 | 5. | 10. | 0. | 12. |

notes :

1) sail config. value of 0.0 corresponds to sails furled.

2) sail config. value of 1.0 corresponds to all sails in use.

3) sail config. value of 2.0 corresponds to jib and mizzen only.