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TRANSACTIONS (TM)

FUEL MEASUREMENT AND FUEL ECONOMY IN SHIPS

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Fuel Consumption Measurement in Ships

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SYNOPSIS

Fuel consumption measurement on merchant ships has generally been an inaccurate process and the results are often viewed with distrust by shipowners. This paper reviews some of the recording methods used at sea and surveys a recent attempt to improve the information available to ships' officers in an effort to persuade them to make better decisions about the operation of their ship by reacting to ambient conditions and thus reduce main-engine fuel consumption. It is hoped to build up a long-term data base showing the characteristics of a particular vessel for reference purposes to indicate possible fuel economies.

INTRODUCTION

Fuel consumption are the two most emotive words in the marine industry today, and the concept is the subject of vast advertising programmes by engine builders and of many international conferences and seminars. It has also stimulated engine builders and their ancillary manufacturers to invest large sums of money in design and development. The economics of re-development programmes which aim to achieve the last 2–3 g/hp h are questionable, especially when, considering the present state of the industry, the costs must be spread over very few manufactured units.

First it is necessary to define fuel consumption as it concerns the cost effectiveness of owners' and charterers' ships. The fuel consumption figures quoted by engine builders are to ISO standard 3046/1, ie air temperature at turbocharger inlet 27 °C, cooling water temperature 27 °C, atmospheric pressure 1000 mbar and lower calorific value of the fuel 42 700 kJ/kg. Ideal conditions with a high calorific fuel, ie gas oil, would be no purifiers, no tank heating, no sulphur, straight mineral lub oil and reduced maintenance.

At present the majority of diesel main engines are operated on IFO 180 cSt or 1500 second Redwood No. 1 fuels, the latter of which does not seem to be in general use. If the average 1984 built diesel-engined ship is considered, the fuel consumption claimed by the engine builder is of the order of 135 g/hp h at the above ISO rating. Note that this is an average engine, not two stroke, not four stroke, not long stroke, not even super long stroke but average.

From the cost effectiveness of the actual consumption, it is necessary to take the difference between the fuel over the ship's rail and the final thermal value at the time of combustion. This gives the true effective fuel consumption cost value.

In general an increase in the ambient temperature will lead to an increase in the scavenge air temperature and hence an increase in the fuel consumption. An increase of 10 °C in the scavenge air temperature will give an increase of about 1 g/hp h, depending on the engine manufacturer. A variation in the atmospheric pressure or humidity has a lesser effect on the fuel consumption.

When burning heavy grade fuels it is unwise to keep the scavenge air temperature at the ISO standard of 27 °C as the dew point will be reached and cause the sulphur within the fuel to form sulphuric acid, leading to corrosion of liners and values etc. Further cold corrosion can occur in the upper cylinder liner area. The recent improvement in turbocharger efficiency has reduced the losses that occur when the ambient temperature rises. Indeed, turbochargers for the marine industry should be matched at test-bed trials to an inlet temperature of the order of 45 °C.

Henry Robert Selby completed his full-time education at Woolwich Polytechnical College before becoming an indentured apprentice at the Blackwell yard of R. & H. Green & Silley Wiers Ltd. He served at sea from 1953 until 1966 with first Shaw Savill Line and then Union Castle Mail Steamship Co., obtaining a Second Class MOT Certificate in 1956 and a combined First Class Certificate in 1959. He was promoted to Chief Engineer in 1961. From 1967 Mr Selby worked at Lloyd's Register of Shipping as a Ship and Engineer Surveyor and in 1974 he joined Hart Fenton where he is now Deputy Managing Director.

George Smith served an apprenticeship under the Alternative Training Scheme for Marine Engineers with Port Line Ltd and then attended Surrey University, obtaining a BSc in Mechanical Engineering in 1967. After this he served at sea with Fyffes Ltd and as Second/Chief Engineer with Canadian Pacific Steamships on cargo and passenger ships. He was later Assistant Technical Superintendent with Sugar Line/Tate & Lyle Shipping responsible for the operation of a number of bulk carriers and an associated ship repair company, obtaining a Diploma in Management Studies and a Certified Diploma in Accounting and Finance. In 1979 he joined Hart Fenton and was recently appointed Principle Marine Engineer. He has been involved in the design, specification, plan approval and supervision of a number of new buildings, principally container ships, and has supervised various drydockings, repairs and conversions of existing vessels. He has also been involved in fuel saving and shipboard computer projects.

The main factor in fuel consumption is the calorific value of the fuel. Taking fuel of 1500 second Redwood (British Standard M6 IFO 180), the lower calorific value can easily vary between 38 500 and 41 000 kJ/kg, depending on the method of cracking and blending. An average good-quality fuel of this viscosity would be expected to have a lower calorific value of 40 200 kJ/kg.

Heavy fuel, paid for by weight, has the following losses before the combustion point in the engine compared with the ISO standard:

1. Allowable water content 1 vol% or 1.04 wt% (CIMAC 6).
2. Purifier losses in sludge, solids and working process 1%.
3. Lower calorific value about 40 200 kJ/kg.

Therefore the ISO standard specific fuel consumption should be multiplied by the following constant to give an average realistic fuel consumption when using heavy oil:

$$\frac{1}{0.989} \times \frac{1}{0.99} \times \frac{42\,700}{40\,200} = 1.0844.$$

An average engine with specific fuel consumption quoted by the builders of 135 g/hp h, will have a true heavy oil consumption of 135 × 1.0844 = 146.39 g/hp h. At the lower end, a quoted figure of 124 g/hp h will have a true consumption of 134.46 g/hp h. This difference is greater than the 3% allowed by the ISO standard.

Note that when costing fuels in the heavier grades, cost differentials are often less than the calorific value differential. The cost differential between IFO 180 and IFO 380 is normally of the order of £3 per ton, say 2%. The calorific value differential between the same fuels can be of the order of 1700 kJ/kg, say 4.2%.

After considering additional heating and the chances of higher impurities in the heavier grades, there is no commercial advantage, and a similar philosophy must be followed when burning MDO.

ECONOMIC ENGINE RATINGS

Most engine builders quote two specific fuel consumption ratings:
1. Maximum continuous rating (MCR).
2. Economic rating (ECR, normally 80–85% MCR).

The engines are set up (timing, turbocharger nozzle ring configuration, injection pump settings etc.) to either MCR or ECR. This means that the MCR of the economic engine is 80–85% of the MCR of the standard engine. In most cases the economic rating will reduce the fuel consumption by about 4 g/hp h.

If it is assumed that in Europe the average slow-speed two-stroke engine costs £134 per horsepower and IFO 180 is £125 per ton, then for a vessel requiring 8000 hp, and allowing a 17% sea and weather margin to the MCR, we have:
1. Normal rated engine, 9600 hp MCR.
   Specific fuel consumption (ISO) 129 g/hp h.
   Normal service 8000 hp, 83% MCR.
   Cost per day = 8000 × 129 × 1.0844 × 24 × 125 = £3357.
2. Economic rated engine, 9600 hp ECR or 11 612 hp MCR.
   Specific fuel consumption (ISO) 125 g/hp h.
   Normal service 8000 hp, 83% ECR.
   Cost per day = 8000 × 125 × 1.0844 × 24 × 125 = £3253.

The economic rated engine produces a fuel saving of £103 per day. The difference in capital cost of the installed engine is equal to 11 612 hp minus 9600 hp, which is equal to 2012 hp. Since the cost of the engines in the same range is hp × £, extra costs will be 2012 × 134, which is equal to £269 703.

Pay back time is therefore of the order of 2618 sea days or about 10 years, without taking account of additional lub-oil consumption for larger engines, extra maintenance and cargo deadweight loss.

This example uses a five-cylinder engine in the MCR format and the same bore seven-cylinder engine for the ECR system. Possibly increasing the bore would achieve the same result at less capital cost. However, the calculation does show what can happen when chasing grammes.

SHAFT-DRIVEN ALTERNATORS

Shaft-driven alternators have become popular over the last five years and are thought by some to cut, or even eliminate, the cost of electric power generation. There are presently three methods for power take off from the main engine:
1. Constant main engine speed with controllable-pitch propellers.
2. Electric solid-state rectifier/inverter systems to maintain constant frequency.
3. Variable-speed input/constant-speed output gearbox drives.

A vessel powered by a main engine of 15 000 MCR with a normal electrical load of 500 kW, fitted with a power take off of 600 kW, has the following costs for the three systems.

Constant engine speed

Generator, 600 kW	£90 000
Gearbox drive	£50 000
Switchboard	£20 000
	£160 000
Financed over 8 years	£270 970

Daily fuel costs at sea for the power take off system, 500 × 1.362 × 146 × 24 × 125 = £298.2 per day. Daily fuel cost using auxiliary diesel engines burning MDO for the same purpose, 500 × 1.362 × 160 × 24 × 160 £418.4 per day plus spares, maintenance, labour and lub oil at £15 per day gives £433.3 per day. Using auxiliary diesels on IFO 180 the daily cost would be £326.8 per day.

This means the saving on a shaft-driven generator over auxiliaries on MDO is £135.2 per day and £28.6 per day if burning IFO. When related to the capital cost of the shaft-driven alternator the pay back time is 1997 or 9474 sea days, ie 7.68 or 36.4 years.

The main disadvantage of this system is that in maintaining constant speed the pitch normally has to be reduced for service operation. This can cause a loss in propeller efficiency of up to 6%, and hence an overall loss of 600–800 hp under normal service conditions. This cancels out any advantages of the shaft-driven system for power generation.

Constant frequency

Total at £500 per kW	£300 000
Financed over 8 years	£508 000

For the same conditions as above, pay back will be 3757 or 17 762 sea days, ie 14.4 or 68.3 years.

Constant output speed from gearbox

Total at £484 per kW	£291 000
Financed over 8 years	£492 830

Pay back will be 3643 or 17 231 sea days, ie 14.0 or 66.2 years.

Use of shaft-driven alternators

This arrangement has many advantages on specialist ships such as ferries and diving support vessels, where very high electric loads are required for manoeuvring using lateral thrusters. The alternative would be to install high-powered auxiliary engines. Normally, no capital cost can be saved by reducing the number of auxiliary engines and therefore a shaft-driven alternator must be shown to be an economic alternative before one is installed.

THE NEED TO MEASURE FUEL CONSUMPTION AT SEA

About a year ago one of our clients purchased two 1100 TEU twin-screw container vessels (see Fig. 1). They were built in 1973 at 23 000 dwt with a maximum service speed of 23 knots. The ships were introduced into a round the world service, with an average service speed of 17–19 knots, and quickly built up a reputation as 'gas guzzlers'. As the owner was associated with the charterer, and therefore directly involved in the purchase of the fuel, it was decided to reduce the daily fuel consumption and costs.

The vessels had been painted with self-polishing antifouling coatings and the propellers polished etc. at the sale drydocking. Generally the main engines had been well maintained and were already operating on 3500 second fuel. As the service speed and often arrival times at the various ports were set in advance, little scope remained for fuel consumption savings.

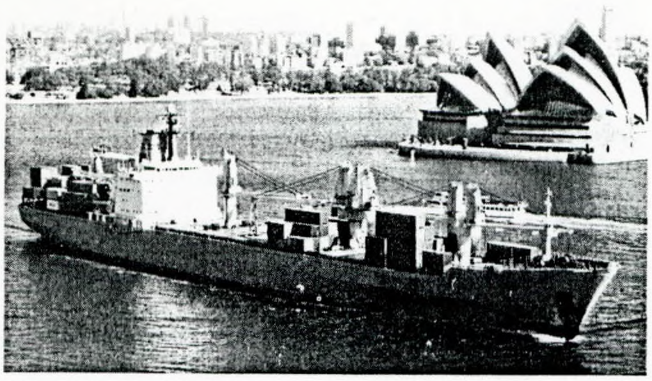

FIG. 1: MV *Nagara*, which is fitted with the system, in Sydney Harbour

It was felt, however, that an investigation of shipboard practices and operation should be carried out and that changes in these could produce some savings. In order to do this it would be necessary to fit additional instrumentation on the vessels. An on-line instantaneous readout of fuel consumption was required, which would hopefully lead to operational changes and watchkeeper reaction to vary the trim, the ships' heading, adjust shaft speed etc. The operator's actions are an important factor in obtaining better fuel consumption.

We were asked to study the performance of the vessels and review the fuel consumption monitoring equipment available on the market and then fit the most suitable. The chosen equipment had to meet some basic requirements:

1. Simple to install with no disruption to the vessel's schedule.
2. Easily understood information.
3. Reliability.
4. Inexpensive.

Generally, the practice of recording the fuel consumption of the main engines of merchant ships has been entirely the responsibility of the Chief Engineer, and the information, sometimes 'laundered', is then sent to the Master, usually some hours after the 24 h recording period has passed. This, of course, is after the event and far too late for corrective action to be taken to improve the situation or investigate trends in the consumption rate.

The bunker tanks are fitted with either remote reading gauges or sounding pipes and the Fourth Engineer would operate the gauges or dip the tanks to record the amount of fuel remaining. This would be done either prior to noon each day or, on some less efficient vessels, once a week. Depending on the trim of the vessel or design of the tank, calibration tables have to be referred to in order to correct the recorded level of oil to give the volume remaining.

Some remote reading gauges often do not allow very precise readings to be obtained and many engineers have had to read a tape on deck in wet conditions or with a torch in order to establish what is in the tank. The results are often unreliable, especially for those tanks that are always 'difficult to dip'. Movement of the vessel in seas setting up motion of the oil in the tanks makes measurement even more difficult.

The fuel is transferred to the settling tanks, purified to the service tank and then supplied to the main engines. These tanks usually have local or remote reading gauges, eg some sort of float gauge or sounding pipes, but fortunately are of a more reasonable shape and more meaningful measurements can be made. This is assuming that the gauge works, the tank fitting is not blocked by sludge, the float gauge wire has not snapped, the indicator is not wrongly positioned, and the sounding pipe is not full of 'lost' sounding tape weights.

The engineer records these levels once a watch and before noon, but often not at the same time each day. The figures are subtracted from the previous day's or individual watch consumptions and added up to give a daily rate. Unfortunately purifying, transferring, sludging/losses and consumption from the service tank have occurred during the period and it is not possible to record the consumption accurately.

The figures should be added up over a longer period, checked against the fuel remaining in the bunkers, and averaged out, when some consensus should emerge. Only if steady steaming and engine conditions are present over a reasonable period of time can any real sense be made of the figures. If the conditions vary considerably, misleading information is obtained and then recorded in the log book.

Some vessels also have fuel flowmeters fitted in the supply to the engine, but frequently these have long since ceased to function or be relied upon and generally only record a totalized figure. Other vessels have high- and low-level alarms and transfer pump trips fitted to the settling/service tanks, where the levels are often used as the basis of consumption. Service tanks with constant purification and overflow to the settling tank make it more difficult to record fuel consumption accurately.

RESEARCH AND SELECTION OF THE MONITORING SYSTEM

Before fuel consumption could be reduced, equipment for on-line monitoring had to be investigated. It was felt that if such equipment was located in the wheelhouse, fuel savings could be achieved by optimizing the consumption rate by altering the ship's speed, trim, heading etc. to suit the ambient conditions. If the purchase price of the equipment is reasonable, then relatively minor savings in fuel consumption could soon recover the cost of the equipment and lead to savings in daily running costs.

Equipment from 12 suppliers was initially investigated and was very soon reduced to six, ranging from a local reading flowmeter through various degrees of sophistication to equipment offering digital presentation of the current fuel consumption rate in l/h or with additional sensors to show specific fuel consumption, power, shaft speed, trim, slip, fuel consumed per nautical mile, distance travelled, accumulated fuel consumption etc. The additional sophistication requires additional sensors or interface equipment between the processor and existing sensors.

It was then necessary to decide on the extent of information required in the wheelhouse. Information should be presented to the watchkeeping officer in such a way that he is aware of how the ambient conditions are affecting the fuel consumption, and hence what needs to be done to reduce it. The basic system would require the following minimum features:

- Two flowmeters, including pulse transmitters and local non-resettable totalizers.
- Power input and amplification system.
- Digital indicators in the wheelhouse and control room for port and starboard engines' fuel consumption rates (l/h).

If this is all that is required, then much of the remaining equipment could be eliminated. However, the refinements for optimising trim, specific fuel consumption, speed, distances etc. require trim indicators, torquemeters and connections to the ship's speed log. The vessels did not have suitable trim indicators or torquemeters fitted and it was decided that the additional information available from these sensors would not greatly assist the ship's officers, and possibly introduce the chance of error or confusion and only supplement an alternative source of the data.

After considering all the factors it was decided that a summator and multiplier were needed to indicate in digital form the total combined daily consumption (m^3/day) of the port and starboard engines for instant comparison and resettable indicators were needed for the total fuel volume used. A graphic recorder was also required to record trends or sudden changes in the fuel consumption rate occurring over a given period and to record the combined consumption rate in m^3/day (see Fig. 2).

These features were not available exactly in this form and so several manufacturers were asked to custom build the monitoring unit. Two suppliers offered the components to make up the basic system and allowed a number of options to be added. These manufacturers did not specifically market a packaged system aimed at the marine market, whereas the manufacturers that did required a higher price. The supplier who had manufactured the existing flowmeters was finally selected as he offered simple installation of new meters and the instrumentation requirements packaged in a suitable panel (see Fig. 3).

The monitored information needs to have one feature that stands out above all the others, and that is the combined consumption in m^3/day. The ship's officers can easily understand this information, either from the requirements of the charter party or when compared with previous log readings. As this figure indicates the current situation, the officer would realise that if the vessel/ambient conditions remained constant, then the consumption for the 24 h period would be that indicated and he could then decide if it was acceptable.

With experience in the use of the monitor and the recording of data in the form of permanent graphs, coupled with the officer's experience of the vessel and conditions, fuel savings can be achieved within any service restraints that may be present.

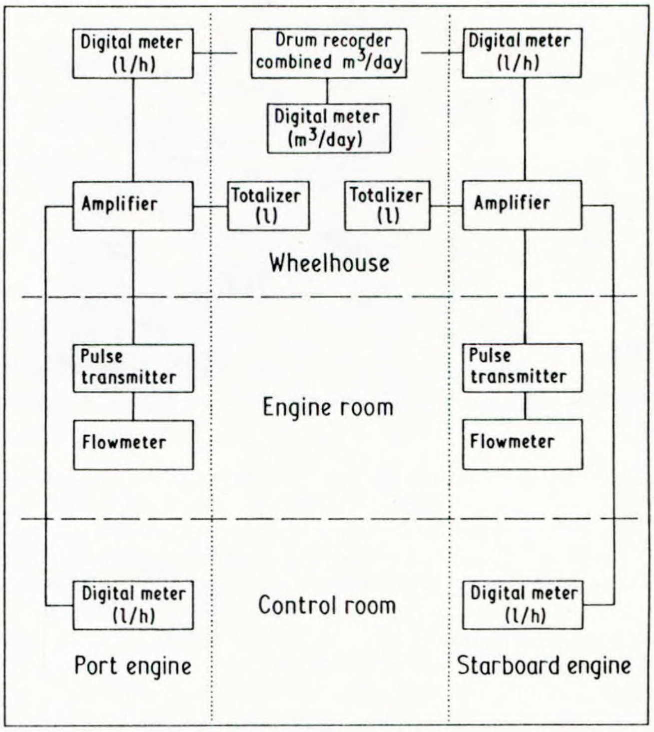

FIG. 2: Modified fuel consumption monitoring system

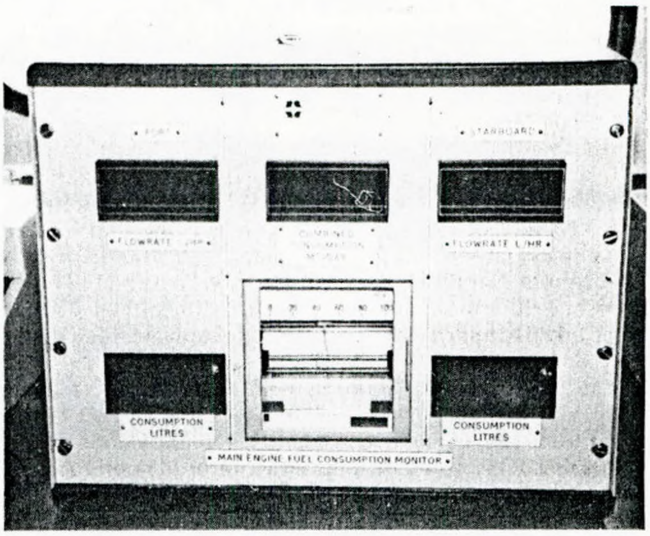

FIG. 3: Fuel consumption monitor fitted in the wheelhouse

INSTALLATION AND USE OF THE FUEL CONSUMPTION MONITOR

The chosen system was required to give an immediate indication of the daily fuel consumption rate to enable the watchkeeping officer to compare it with the ship's condition. Significant fuel savings are possible by suitable variation of the ship's speed, trim, heading etc. and comparison with previous similar conditions.

The fuel consumption rate for each watch should be logged and plotted on suitable permanent graphs that can then be used for comparison purposes. If possible, references should be plotted from recordings made under clean hull and fair weather conditions. Optimum trim and speed should be readily obtainable using these graphs and any significant deterioration in the vessel's performance or deviation should be spotted.

Several manufacturers of fuel management systems claim to optimize trim etc. but in effect they only give a visual record of fuel consumption over a period of time as the trim is altered. Minimum fuel consumption would occur at a particular draught and trim. The optimum trim condition varies with the ship's speed and mean draught.

Further sophistication could have been obtained from computer software programs designed to interpolate initial data from model tank tests that have estimated power requirements at a number of speeds over a range of draughts and trims. The program would search the data and then indicate, for a specified speed, the best mean draught and trim for minimum fuel consumption.

The original model test data were not available and it would have cost about $10 000 to commission model tests, for which the owner was not initially prepared to pay. The alternative was to obtain actual service results and use these data as the basis of any comparison, accepting that the information would be influenced by many factors.

The log abstract forms in use on the vessels were found to be different for the two vessels and were not particularly helpful. A revised abstract form and fuel consumption monitor daily record form were devised for the Deck Officer to complete (see Figs 4 and 5). From these records the permanent graphs can be drawn and then used to obtain a comparison of present and new monitoring equipment measurement methods.

After initial calibration and testing at the suppliers (see Fig. 6), the system was fitted on the first vessel in June 1985. The package consisted of:

- Two flowmeters of the oval wheel, volumetric positive displacement type (see Fig. 7). The measuring element consists of two meshing oval wheels driven by the fluid. The number of revolutions of the wheels is directly proportional to the measured volume, and gearing transmits this to a mechanical register (six digit non-resettable). Additionally, inductive pulse transmitters were fitted.
- A metal panel measuring 20 × 16 × 14 in, which is internally wired and fitted with the following instruments, sited in the wheelhouse.
- Two pulse amplifiers with pulse scaler, scaled relay output and current output.
- Two electronic totalizing counters with manual reset reading directly in litres.
- Five digit panel meters as flowrate indicators (LED display at 4–20 mA input, with four in l/h and one in m^3/day). Two meters act as repeaters in the engine control room.
- One chart recorder of the fan fold type to take 2 × 4–20 mA inputs from amplifiers to give a summated flowrate for 0–100 m^3/day. The visible chart span covers $3\frac{1}{2}$ h.

From: Fremantle								To: Port Louis							Voyage: 101							
														Consumption								
						Revolutions (rev/min)		Wind		Weather / Sea				HO			DO		LO			
Date	Steaming time (h)	Distance run (nmiles)	Engine distance (nmiles)	Slip (%)	Average speed (knots)	Port	Stbd	Direction to vessel	Force		Mean draught (m)	Trim	Average fuel rack	Orig. ME	Monitor ME	Aux.	Aux.	ME	Cyl.	Aux.	Number of alternators	Total electrical load (kW)
31/8	18.8	350	404.5	13.48	18.61	99.5	99.1		3	Mod/Slt	9.4	0.1	5.5/5.4	55.0	60.8	4.5	2.9	—	360	75	3	150
1/9	25.0	496	558.1	11.11	19.84	102.4	103.6		4	Good/Mod	9.4	0.4	5.5/5.4	80.8	86.2	6.0	3.7	—	460	75	3	148
2/9	25.0	494	554.5	10.91	19.76	103.5	102.3		5	Good/Mod	9.4	0.4	6.0/5.6	77.3	82.0	6.3	3.8	—	460	75	3	158
3/9	24.0	487	542.2	10.18	20.29	103.7	104.8		3	Good/Slt	9.3	0.5	5.9/5.6	76.2	94.2	6.8	4.2	—	460	75	3	150
4/9	25.0	499	557.6	10.49	19.96	103.5	102.0		3	Good/Slt	9.4	0.5	5.8/5.0	77.3	96.2	5.3	3.3	3000	470	75'	3	150
5/9	25.0	497	556.3	10.65	19.88	103.4	102.0		2	Good/Slt	9.2	0.2	5.7/5.1	76.5	96.2	7.1	4.4	—	460	90	3	150
6/9	22.3	446	494.1	9.70	20.00	103.2	101.3		3	Good/Slt	9.2	0.2		71.0	86.4	4.5	3.0	—	420	60	3	165

FIG. 4: Revised service abstract

From: Panama				To: Auckland		Date: 17/7/85		Voyage: 511				
		Port ME		Starboard ME							Wind	
Time	Remarks	Rate (l/h)	Totalizer (l)	Rate (l/h)	Totalizer (l)	Combined consumption (m³/day)	Fuel consumption (m³/day) (original method)	Mean draught (m)	Trim	Speed (knots)	Direction to vessel	Force
1600		975	3974	857	3671	44.4		8.75	0.5 A	16.3		3
2000		1055	7990	905	7341	47.5		8.75	0.5 A	16.2		1–2
2400		1071	12220	996	11043	50.8		8.75	0.5 A	16.1		2
0400		1035	16390	880	14777	47.7		8.75	0.5 A	16.0		2
0800		1021	20575	906	18518	46.7		8.75	0.5 A	16.2		2
1200		1026	24671	913	22193	46.0		8.75	0.5 A	16.1		3
Average reading		1030		910		47.1	46.5	8.75	0.5 A			2
Daily total consumption (l)			24671		22193							
Daily total consumption (m³)			24671	+	22193	=	46.764	Total consumption (m³)				
Daily total consumption (m³/day)						46.764						

FIG. 5: Daily record of fuel consumption monitor

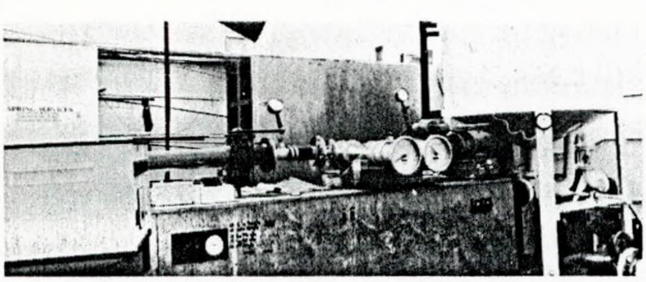

FIG. 6: Testing and calibration of flowmeters and monitor

Installation of the meters and new cabling between the engine room, wheelhouse and control room was completed in 24 h and tested on passage between Livorno and Barcelona. The monitoring instrument behaved perfectly and its accuracy and response to fuel rate changes was impressive. It reacted particularly well to the influences of wind on the vessel.

Regular checks were taken during the passage and engine speed varied or kept constant and the ship's heading altered to check the behaviour of the monitor. The response to ship and ambient conditions was very effective and sensitive to any changes. Consumption increased significantly with stronger head winds and also by turning the vessel through 360°: a difference in fuel consumption of 8% was found for winds of force 6 on the bow and on the stern.

It was also revealed that the port-side propeller had greater pitch than the starboard one in order to provide energy to the one waste heat economiser and freshwater generator fitted on the ship. At 20 knots and the same engine speed it consumed 4 t/day more than the starboard engine. By adjusting the engine speeds slightly, consumptions were more evenly balanced and fuel savings resulted.

The data presented to the ship's officers were correct and should be of considerable use to them. Generally the ship's officers have accepted the use of the monitor positively but some initial opposition was evident, with feelings expressed that the monitor should be positioned in the control room. There was also reluctance to divulge direct fuel consumption knowledge to the deck department. Old practices die hard, perhaps understandably, but the human factor is always present and a ship's staff have to be persuaded of the importance and benefits of the equipment.

Since then, despite some operational problems with the system on both vessels, the ships' staffs have advised positively

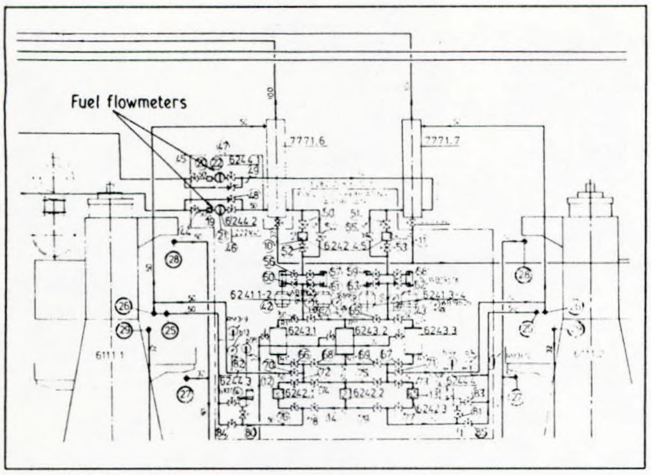

FIG. 7: Main-engine fuel system showing where fuel flowmeters are fitted

on the use of the monitor. Wind and sea have a marked effect on consumption, with much higher consumption in deteriorating weather. The charterer's requirements for firm ETAs etc. and the need to meet operational deadlines have dictated fuel consumption to a large extent, but awareness of direct fuel consumption has been heightened. Masters have commented that the use of accurate satellite positioning and weather forecasting equipment, combined with the fuel monitor, should improve the situation.

Both vessels have recently reported problems with the equipment but it is felt that this may well be because of faults with fuel pressure setting valves passing excess fuel back to the mixing tank and overflowing to the service tank and from blockages of filters. Sufficient information has not yet been received to allow full graphs to be drawn or enough experience gained to predict confidently conditions from previous results (see Fig. 8).

However, in time the officers will gain confidence in the use of the monitor and important fuel savings will result. It will also enable rapid assessment of repainting and propeller cleaning to be carried out. Finally, the system has been considered for two new buildings.

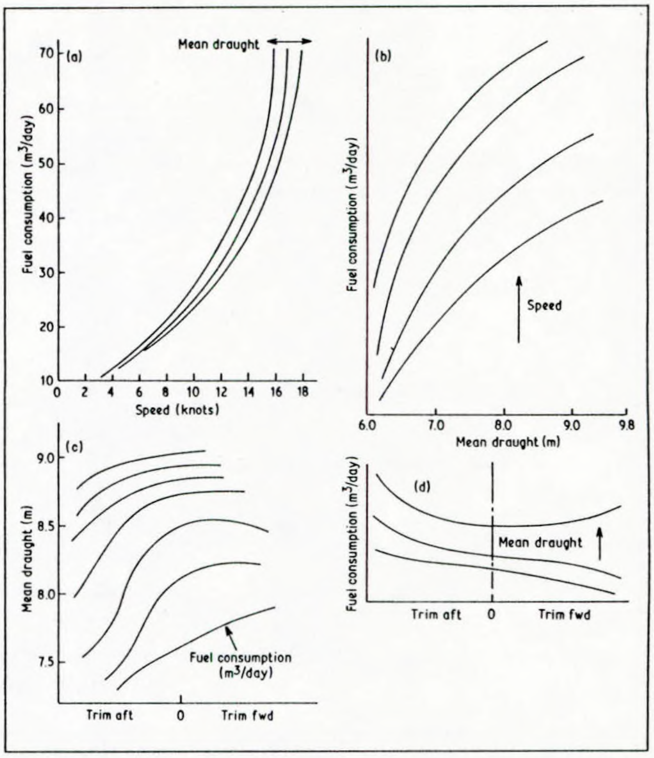

FIG. 8: Recorded graphs: (a) fuel consumption against ship's speed, (b) fuel consumption against mean draught, (c) mean draught against trim and (d) fuel consumption against trim

CONCLUSION

Prior to selection of fuel measurement equipment, careful evaluation of the ship's engines and systems must take place or savings will not be made.

One approach to the measurement of fuel consumption at sea has been outlined. It may not be the best, but it has been productive and a significant improvement on the previous systems available. Fuel consumption measurement on ships has never been good and the present state of the art is far from ideal, with most systems having some chance of error.