Paper read at the Institute on Tuesday, 27 November, 1973

Mr. Duell

A METHOD OF PLANNED MAINTENANCE APPLIED TO A LARGE TANKER FLEET

R. P. Duell*, C.Eng., F.I.Mar.E.

The reasons for requiring a planned maintenance system are briefly discussed, together with the main benefits which could be expected to follow. Comparison is made between past and present approaches to shipboard maintenance, to show the changes in attitudes. Development of a basic system of calendar maintenance is described, giving an outline of the initial investigations necessary and the establishing of the administrative procedures which followed.

Various features necessary to operate the system are described, including the assessment of maintenance requirements and the development of routine instructions from these requirements. Some of the preliminary work in estimating available manpower and the balancing of planned workloads is covered, and this leads on to an outline of the on-board planning procedures which have been developed.

Since a comparatively large number of ships were to be covered by these maintenance procedures, it was decided to utilize computer facilities which were available. This required the development of reporting procedures that would be compatible with the specially written computer programmes. This would then further provide the administering office with sufficient information to compile and interpret existing maintenance data.

The chosen method of monitoring work done is described, together with examples of the resulting data and ways in which it could be used.

This method of maintenance met due requirements at the time of its development, but it is recognized that such a system of calendar maintenance is open to improvement. New areas are therefore being investigated, including scheduling work on a basis of machinery running hours and procedures for monitoring machinery condition before establishing maintenance intervals.

INTRODUCTION

In the past when a chief engineer joined a vessel he would expect to be there for a period of 12 to 18 months, sometimes even longer. Consequently, he could and did evolve his own plan of maintenance.

One would have been sure that all items of auxiliary machinery had some measure of maintenance during his service on board. However, with the advent of longer leave and shorter tours of duty some plan had to be evolved to ensure continuity of maintenance. If this was not done one could be faced with a situation where some machinery was over maintained and other items would receive no attention until they virtually collapsed. In fact, it was getting to the point where the machine was dictating the hour when maintenance was required, and this usually at the most inconvenient times. The problem then was how best to assist chief engineers to overcome the difficulties associated with lack of continuity whilst still maintaining the flexibility that is essential to tanker operations.

The conclusion was that it would be to the benefit of all if the company head office undertook the responsibility for scheduling maintenance, and advised each successive chief engineer of the particular portion of the programme for which he would be responsible. Chief engineers could then be assured that a definite programme did exist and was being adhered to. This, together with the sophistication of modern machinery, the continued growth of our fleet, and plain economics provided the motivation to develop the BP system of planned maintenance. The attendant benefits of the system are considerable, and those that we seek in particular are:

a) increased ship reliability factor;
b) the highlighting of breakdowns between maintenance stages; allowing the causes to be carefully analysed;
c) more accessible records of maintenance.

DEVELOPMENT OF THE SYSTEM

In 1967 it was decided to introduce a system of planned maintenance to the fleet. Various systems were investigated, none providing the complete answer to the problems. Eventually a system was devised to suit these particular requirements, and in January 1968 it was introduced to the m.v. *British Ivy*, a 19 000 dwt tanker. Today there are 79 ships involved in the system, and each new vessel entering service is immediately included.

Before considering any of the various systems, there was one overriding rule which governed the final decision—simplicity of operation. This decision was given to the development of a system based on a continuous cycle of five years which corresponds to the survey cycle required by Lloyds Register of Shipping.

The five year cycle was divided into 20 three-monthly maintenance periods, although at any time only 3 three-monthly periods would be presented to the ship. (One "current" programme, and two "forward" programmes for advance planning.)

* B.P. Tanker Co. Ltd.

Details of each successive maintenance programme are forwarded to the ship six months in advance of the commencement date so that spares may be checked and ordered if necessary.

When the problem of planned maintenance was first approached it was necessary to take three basic steps for each ship:

a) to compile an index of all equipment on board which required maintaining, including full manufacturer's details of the equipment;
b) to prepare maintenance routines to meet the requirements of each piece of equipment;
c) to set out a programme of maintenance covering the five year cycle, for each item in the equipment index.

To formulate the maintenance routines, some 130 firms were approached for suggestions and recommendations on both the level and frequency at which maintenance of equipment was considered to be necessary. Of those approached only nine replied, and one of them suggested that their equipment never, ever required maintenance! The last statement could not be agreed with, since previous reports from ships indicated otherwise.

It must be stated here that this was in 1967 and one finds that the same attitude does not now exist. Considerable co-operation is obtained from most manufacturers, particularly from those whose equipment is being fitted in new ships.

In the absence of manufacturers' recommendations, the specifications, drawings and parts lists were carefully analysed in conjunction with knowledge available to personnel in the office. The existing information was in the form of personal experience, ships' reports, spare gear indents, repair lists and unscheduled maintenance reports. It is obvious that information was only available concerning equipment already in service, so it is equally obvious that more problems arise when creating maintenance routines, when entirely new equipment is fitted.

In all cases our aim was to estimate the minimum practical requirement for maintenance whilst ensuring an acceptable level of reliability between maintenance stages. Our initial aim was to achieve a reliability factor of 85–90 per cent on each piece of equipment.

Estimating these requirements was a difficult but nonetheless necessary task. During the development stages of the system, maintenance routines were drafted in the office and finalized during voyages made on a random sample of ships. In consultation with the senior staff of these ships, the feasibility of the proposals was considered and, in the light of practical experience, modifications were made to the initial routines.

To enable some control to be exercised over a vessel's work load, it was also necessary to estimate simultaneously the manhours required to perform each level of maintenance. (These times were later amended after some experience.)

Having decided what work was required it was necessary to ensure that sufficient labour was available on board to cope with the work. The majority of the work load within the planned maintenance system falls to the engineering staff. For this reason their time was the main consideration when calculating the hours available for maintenance. It was reasoned, and still is, that if sufficient manpower was available for the engineering work, then there would also be sufficient manpower in the other "trades" to cope with the work load.

Each class of ship is considered individually when assessing the available manhours, and this takes into account:

a) engineers who may be on daywork;
b) a percentage of engineers' watchkeeping time which can be devoted to planned or unscheduled maintenance;
c) times when ships' staff will not be able to devote any time to maintenance, such as "stand-by" and repair periods.

Figure 1 shows a diagrammatic breakdown of how available manhours were estimated for one particular class of ship. It was calculated that a total of 9490 manhours/year (i.e. 365-days 26 manhours/day) would be theoretically available. The 26 manhours/day was arrived at from the fact that one engineer

Total available time: 9490 man-hours/year					
Annual docking/repair period, voyage repairs etc.: 676 M.H.	Deducted for standby and pilotage duties, etc.: 442 M.H.	Weekdays at sea: 3536 M.H.	Weekdays in port: 3276 M.H.		Saturdays and Sundays
		Time available for maintenance: 8372 M.H.			
		Estimated average of 25% of total available time for maintenance is expended on unscheduled or breakdown maintenance. 2093 M.H.	Available time for planned maintenance 6279 M.H.		
			Regular repetitive daily, weekly and monthly routines: 1164 M.H.	Average time expended in completing calendar based routines: 1600 M.H.	'Float' 3515 M.H. (allows for variations in planned and unscheduled estimates)

FIG. 1—*Average figures for 19 000 dwt motor vessels*

would be on day-work and so contributing eight hours/day; and also that each of the six eight-manhour watches could contribute three manhours each to maintenance.

From the total of 9490 manhours, must be deducted the average time spent in drydocks or repair ports (or any time when demarcation agreements preclude the ship's staff from doing any maintenance), and also the average amount of time spent on piloted passages when stand-by conditions also impose limitations. Of the remaining 8372 manhours, 25 per cent (about 2100 hours) is anticipated to be used on breakdown or unscheduled maintenance, leaving 6279 manhours for planned maintenance. Of this it is estimated that 1164 manhours (14 per cent) would be absorbed by regular weekly and monthly routines, and 1600 manhours for the main planned maintenance routines. Thus leaving a float of 3515 manhours per year (41 per cent).

One of the aims of the system is to achieve a balanced work load over the five-year cycle, and unless estimated job-times are arrived at this would be impossible. The average number of routines scheduled for a three-month period is 130 and it would obviously be possible to allocate 130 with a work content of no more than ½ to 1 hour each—a total of little more than 100 hours work in three months. This might result in a situation where one crew joins a ship and for six months has very little scheduled work to do. On the other hand, during subsequent periods, tasks with a work content of eight hours or more might be scheduled and the resultant work load would be more than the staff could be reasonably expected to cope with. A most undesirable state of affairs.

By estimating the times for each maintenance routine it is possible to adjust the maintenance cycle of each piece of equipment relative to the others and so achieve reasonably balanced conditions—even allowing for inaccuracies in the estimated job times. This is done manually within head office, taking account of survey or statutory requirements, staggering of major overhauls on duplicated machinery, and routines which can only be completed with the vessel out of service. The information concerning maintenance on each unit, and details of each ship are fed to our computer files to produce a bar chart of the balanced five-year cycle.

The effect of unbalanced work loads is shown in Fig. 2(a). By estimating the time a job will take, it is possible to balance the work load and achieve such reasonable forward planning

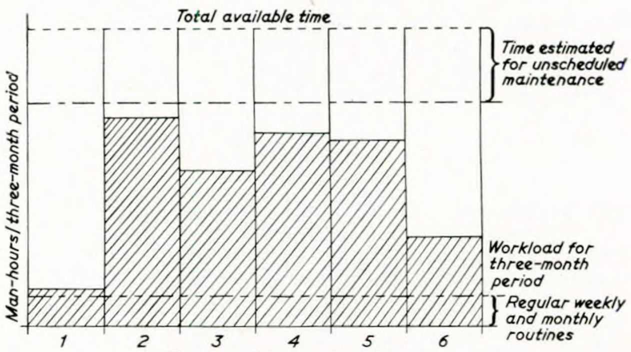

FIG. 2(a)—*Typical unbalanced "workload barchart"* conditions as illustrated in Fig. 2(b). Fig. 2(c) is a representation of an actual computer printout and is part of the final balanced work load bar chart from which the ship's maintenance programme is produced.

The computer programme was devised to eliminate the obviously large amount of clerical work involved in administering such a system, and to create facilities for accepting feedback from ships in order to provide historical and statistical records for analysis and future reference.

Having decided upon the maintenance requirements, the time required and the time available, and having balanced the five-year work load within acceptable limits, the next step was to develop "on-board" procedures that would be easy to follow and simple to operate.

Each ship is provided with two basic items of equipment, a manual of maintenance routines and visual display "planning boards".

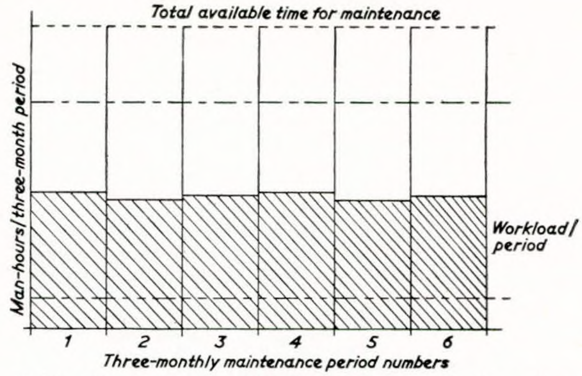

FIG. 2(b)—*Typical "workload barchart", balanced within acceptable limits*

SHIPPING DEPARTMENT　　PLANNED MAINTENANCE BAR CHART RIGHT SIDE RUN NO 15　　14 APR 73　　PAGE 336

C—11—507　　BRITISH -------

[I]	[II] 38	39	40	41	42	43	44	45	46	47
9—77—1827—90008—01—0 p SAFETY EQUIPMENT	011 3·0 [III] 8·0	020 2·0 20·0	011 3·0 8·0	031 4·0 26·0	011 3·0 8·0	020 2·0 20·0	011 3·0 8·0	031 4·0 26·0	011 3·0 8·0	020 2·0 20·0
9—83—0018—90014—01—0 p BREATHING APPARATUS			010 0·0 D 0·0				010 0·0 D 0·0			
9—83—0300—00562—01—0 LIFEBOAT DAVITS	020 1·0 4·0	010 1·0 4·0	041 10·0 70·0	010 1·0 4·0	020 1·0 4·0	010 1·0 4·0	020 1·0 4·0	010 1·0 4·0	020 1·0 4·0	010 1·0 4·0
9—83—0409—00385—01—1 LIFEBOAT ENGINE			121 3·0 2·0				121 3·0 2·0			
9—83—0409—00385—01—2 LIFEBOAT ENGINE			221 3·0 2·0				221 3·0 2·0			
9—83—2003—00724—01—0 LIFEBOAT HOIST AIR MOTOR	010 0·0 0·5	020 3·0 1·0	010 0·0 0·5	010 0·0 0·5	010 0·0 0·5	010 0·0 0·5	020 3·0 1·0	010 0·0 0·5	010 0·0 0·5	010 0·0 0·5
9—84—0011—00206—01—2 p EMERGENCY ALTERNATOR FWD			010 3·0 2·0				010 3·0 2·0			
9—84—0524—90010—01—0 p FIREFIGHTING EQUIPMENT	020 4·0 6·0	010 4·0 6·0	030 0·0 D 0·0	010 4·0 6·0	020 4·0 6·0	010 4·0 6·0	030 0·0 D 0·0	010 4·0 6·0	020 4·0 6·0	010 4·0 6·0
9—84—1554—00034—01—1 PUMP(SUMP) AIR SALVAGE	110 0·0 0·5	110 0·0 0·5	110 0·0 0·5	120 4·0 0·0	110 0·0 0·5	110 0·0 0·5	110 0·0 0·5	120 4·0 0·0	110 0·0 0·5	110 0·0 0·5
9—84—1554—00034—01—2 PUMP(SUMP) AIR SALVAGE	210 0·0 0·5	210 0·0 0·5	210 0·0 0·5	220 4·0 0·0	210 0·0 0·5	210 0·0 0·5	210 0·0 0·5	220 4·0 0·0	210 0·0 0·5	210 0·0 0·5
TOTAL OFFICER-HOURS TOTAL RATINGS-HOURS	363·5 294·5	399·5 336·5	358·0 327·5	362·0 284·0	362·0 305·5	367·5 286·0	288·5 199·0	351·0 270·0	295·5 246·5	390·5 316·0

AVERAGE OFFICER—HOURS 348 PER PERIOD
AVERAGE RATINGS—HOURS 282 PER PERIOD

FIG. 2(c)—*Computer printout of "workload barchart"*

The manual of maintenance routines takes the form of a library of cards showing the maintenance required on each item of equipment on board the vessel, together with the estimated time for its completion. There might be up to four levels of maintenance on each unit, ranging from the lower stage 1, which may be a routine inspection and lubrication check, up to a fourth level which covers a complete overhaul and possibly a Lloyds survey. Figs. 3 and 4 show examples of the general layout and content of the maintenance routine cards.

The planning boards are used to assist in the forward planning of routines on the ships as indicated by the programmes forwarded to them from the head office, and they also provide a visual display of progress. Identifying details are taken from the programmes and routine cards and transferred to index strips attached to the boards. The routine card contents are checked to see if spares are required, and indicator pegs placed in the appropriate position on the board to indicate that the routine is either ready to be carried out at any time or whether spares are required before proceeding. A typical extract from a vessel's planned maintenance programme is shown in Fig. 5.

The estimated time given on the routine cards themselves should assist in the on-board planning of work. One would clearly not undertake routines with high work content when only a little time is available—either due to general conditions or to vessel trading requirements.

Once the plan has been established on board, the routine cards themselves are given to those allocated the various jobs. The cards are then placed in plastic envelopes which ensure they remain clean and re-usable, and also allows for comments and notes to be made on them with wax pencils.

The progress of the work is shown on the planning board, using the indicator peg to identify when work is scheduled to begin, to chart its progress and its completion.

To derive the maximum benefit from such a system a reporting and feedback procedure is essential. This is usually the responsibility of the senior officers, but to minimise their clerical work load a procedure was developed which requires the person doing the job to make out the report.

MAINTENANCE ROUTINE	FUNCTION	SYSTEM	UNIT	ROUTINE No.	
	1	11	1505	130 ~~230~~ ~~330~~ ~~430~~	60

UNIT DESCRIPTION	MAKER AND TYPE	SERIAL No.	ESTIMATED MAN HOURS FOR TASK	O	ORP
CARGO PUMP	16"x27"x16"x24" Horz. Duplex Compound			R	

Oil End Fit spare (reconditioned) valve/valve plate assemblies
Renew valve plate joints.
Replace defective retaining studs and stopper pins.
Overhaul relief valve, renew joint.
Renew valve cover joints, including intermediate joint.
Examine bucket rods for wear in way of gland - dress as required, renew neck bush and gland collar as necessary. NOTE rod diameter reduction not to exceed $\frac{1}{8}$". Calibrate liners at ends and centre. Liner to be rebored if barrelling exceeds 0.150". Liner bore must not exceed 16.25". Measure bucket ring clearance at smallest part of liner (acceptable clearance 0.030" min - 0.100" max.) Ensure bucket rod nuts and split pins are secure.
Repack bucket rod glands. Renew end cover joints.

Steam End Lap steam slide valve faces adjust valve clearances (top clearance 0.003" - 0.005", side clearance 0.010" - 0.012"). Adjust valve travel to makers settings (total lost motion $1\frac{1}{8}$" - $1\frac{1}{4}$").
Repack valve spindle glands. Renew piston rings. Dress piston rods as required, renew neck bushes and gland collars as necessary (piston rod reduction not to exceed $\frac{1}{8}$" on diameter). Repack piston rod glands, including metallic packing between cylinders.
Renew cylinder cover joints.
Overhaul steam inlet and steam byepass valves.
Overhaul valve gear, adjust bearing clearances (limit 0.010" - 0.015")
NOTE: Suction and Delivery valve/valve plate assemblies to be overhauled for future use. Dimensions must remain within following limits.
Max. width of valve face - $\frac{1}{2}$" (width new $\frac{1}{4}$")
Min. thickness of valve plate - $\frac{3}{8}$" in way of valve.
Min. free length of valve spring - 15/16" (19/16" new).

SEE REVERSE FOR SPARES AND TOOLS

FIG. 3—*Typical basic maintenance routine instruction card showing work scheduled at a high level*

MAINTENANCE ROUTINE	FUNCTION	SYSTEM	UNIT	ROUTINE No.	
	9	77	1827	012	3

UNIT DESCRIPTION	MAKER AND TYPE	SERIAL No.	ESTIMATED MAN HOURS FOR TASK	O	6
SAFETY EQUIPMENT	90008-01			R	10

Megger test navigation light cables.

Ensure that doors to navigation side lights open freely and are adequately greased.

Check that N.U.C. shapes are in good condition, and ensure N.U.C. lights are operating correctly.

Inspect lifejackets, ensure all are in good condition with whistles properly attached.

Check condition and dates of L.S.A. Pyrotechnics. (Lifeboats, Ship's Rockets, Bridge Wing Markers, Line Throwers).

Ensure floodlights and embarkation lights are clean, free to traverse normal area, and that pivots are greased.

Renew fresh water in lifeboat tanks. Renew torch batteries. Air sails and exposure covers of lifeboats.

Inspect inflatable liferaft containers for any signs of damage and/or deterioration. Check liferaft Certificate dates and if near twelve months old advise Head Office.

If fitted with forward 6-man raft, check condition of man rope, torch and batteries, renewing if any signs of deterioration.

SEE REVERSE FOR SPARES AND TOOLS

FIG 4—*Typical basic maintenance routine instruction card showing work scheduled at a low level. (Mainly inspection procedures)*

The maintenance report form was produced for this purpose (Fig. 6), and the report also serves as an input document for the computer programme.

The report requires, firstly, basic information regarding manhours, date completed, whether the work was planned or unscheduled. It also gives provision for detailing work carried out in excess of normal requirements, any difficulties, or suggestions and comments which may lead to improvements and updating of routines. The availability of a computer, which is an I.C.L. 1904, for processing, allows for easier collation and analysis of data received from ships in these reports. Because reports are submitted for all maintenance, both planned and

SHIPPING DEPARTMENT — PLANNED MAINTENANCE PROGRAMMES RUN No 40

C–14–600 BRITISH ________ — PROGRAMME FOR PERIOD 3 — DEC/FEB 1972

EQUIPMENT CODE AND SERVICE ROUTINE		DESCRIPTION	REMARKS
0–03–0115–90000–01	010	BOTTLESCREWS	
0–03–0229–00562 –01	010	CRANE, ENGINE ROOM STORES	
0–03–0230–00562– 01	010	CRANE, PROVISIONS HANDLING	
0–03–2105–00714– 01	010	WASK AUTO VENTS	
0–76–0531–90003–01	010	FREEBOARD EQUIPMENT	PRIORITY
1–04–0717–90005– 01	010	CARGO TANK HATCHES	
1–05–2104–00250–01	010	TANK GAS VENTING SYSTEM	PRIORITY
1– 11– 1505–00702–02	120	CARGO PUMP	
1– 11– 1505–00702–02	210	CARGO PUMP	
1– 11–1505–00702–02	310	CARGO PUMP	
1– 11 – 1505–00702 –02	410	CARGO PUMP	
1– 11– 1506–00468– 01	420	PUMP, CARGO PUMP PRIMING	
1– 11– 1510–00248–01	010	PUMP, CARGO STRIPPING	
1– 11– 1561–00248–01	010	PUMP, PUMPROOM BILGE	
1– 19– 0513–00222–01	110	FAN, PUMPROOM VENTILATING	
1– 19–0513–00222–01	210	FAN, PUMPROOM VENTILATING	
1–48–0814–90016– 01	020	INERT GAS SYSTEM	
1–69–0228–00562– 01	020	CRANE, CARGO OIL HOSE	
1–72–0603–00690–01	010	GAUGES, CARGO TANK	

CONTINUED —

FIG. 5—*P.M. programme printout*

MAINTENANCE REPORT — **S.S/M.V.**

IDENTITY	SHIP CODE (CLASS, NUMBER)	EQUIPMENT CODE (FU, SYST., UNIT, MANUFACTURER)	SERVICE ROUTINE	PERIOD No.	UNIT DESCRIPTION
1 0 0 5		0 0 0 0 0			
1–4	5–9	10–21	22–24	25–26	

ACTUAL MAN-HOURS TAKEN (TO NEAREST .5 OF AN HOUR) — OFFICERS / RATINGS	COMPLETION DATE (Y, M, D)	STOPPAGE/DELAY CAUSED BY THIS TASK (TO THE NEAREST WHOLE HOUR)	OP			CARD CLASS
			1	PLANNED	Delete 'OP Code' not applicable	0 5
			4	UNSCHEDULED		
27–29, 32	33–38	39–42	78			79–80

BRIEF DETAILS OF WORK CARRIED OUT (IF UNSCHEDULED/BREAKDOWN MAINTENANCE, OR IF WORK REQUIREMENT IS IN EXCESS OF MAINTENANCE SCHEDULE)

LIST OF ALL SPARE GEAR USED, COMPLETE WITH PART NUMBERS ETC:-

COMMENTS (BASIC CAUSE OF BREAKDOWN OR UNSCHEDULED MAINTENANCE – DIFFICULTIES ENCOUNTERED – SUGGESTED MODIFICATIONS ETC. – ALSO INDICATE IF WORK WAS CARRIED OUT BY SEA-GOING MAINTENANCE TEAM, MAKERS REPRESENTATIVES, DRYDOCK OR REPAIR PORT PERSONNEL)

TO BE COMPLETED BY CHIEF ENG./CHIEF OFF. (SEE NOTES 8 & 9 INSIDE COVER)		FOR HEAD OFFICE USE ONLY
DEFECTS NOTED ON REPAIR LIST DATED:-		
REPLACEMENTS ORDERED	YES/NO	
DATE OF INDENT		

SIGNATURE OF PERSON PERFORMING MAINTENANCE/REPAIR WORK — RANK

SIGNATURE OF CHIEF ENGINEER/CHIEF OFFICER

NOTE:- *All spare gear used must be listed on front of this form, complete with part numbers etc.
Immediately upon completion of work, the person who carried out the maintenance or repairs must complete all boxes on the report and append his signature.
WHITE COPIES TO BE FORWARDED TO HEAD OFFICE FROM FIRST AVAILABLE PORT. YELLOW COPIES TO BE FILED ON BOARD FOR MACHINERY HISTORY RECORD.

FIG. 6—*Maintenance report form*

unscheduled, it is now possible to investigate the maintenance history of any one machine or piece of equipment in any ship, and also to compare the effectiveness and maintenance labour requirements of one make of machine with any other on identical services.

Some 8000 reports are now received in the head office each month. The basic data on all reports are immediately fed into the computer files, and those reports which contain no useful data other than the basic information are destroyed after this processing. This ensures that files manually compiled contain only information which the computer files cannot assimilate. Reports containing comments are scrutinised and may require immediate action in some respect; others are filed for future reference when updating further maintenance routines.

From the data received in these reports, records are updated as necessary and equipment maintenance master data information files are amended as required.

MAINTENANCE RECORDS

Each hour of maintenance reported, whether planned or unscheduled, is plotted on a histogram.

The area of the histogram represents the estimated total manhours available for maintenance. Planned work is plotted from the bottom, and unscheduled work from the top. The amount of outstanding work is also plotted, thus giving an immediate visual display of the trend of maintenance and work load on the vessel. Any undue overloading of work or excessive unscheduled work can immediately be seen. Any appropriate action can then be taken as necessary, either by reprogramming the ship's future work or by providing assistance to the ship's staff in the form of sea-going maintenance teams.

Fig. 7 shows a trend of reducing unscheduled maintenance

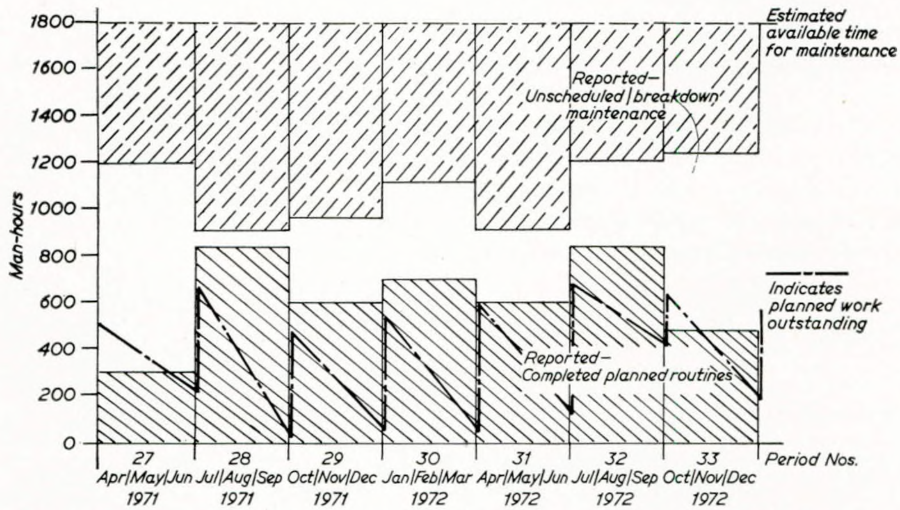

FIG. 7—*Histogram of reported planned and unscheduled maintenance (19 000 dwt motor vessel)*

on m.v. *British Poplar* (19 000 dwt) whereas Fig. 8 shows the opposite apparent trend on a VLCC and this seems to be accounted for due to the vessel being new at the introduction of planned maintenance and reports received not being representative of normal "in service" conditions. Periods 9, 10 and 11 probably indicate a more realistic level.

Fig. 9 shows a different picture occurring on m.v. *British Fern*. The unscheduled work has been extensive and in some instances actually overlapping the reported planned work. An investigation disclosed that 80 per cent of the unscheduled work was expended on maintaining the evaporation/distillation unit, and subsequently this was removed and replaced by a different

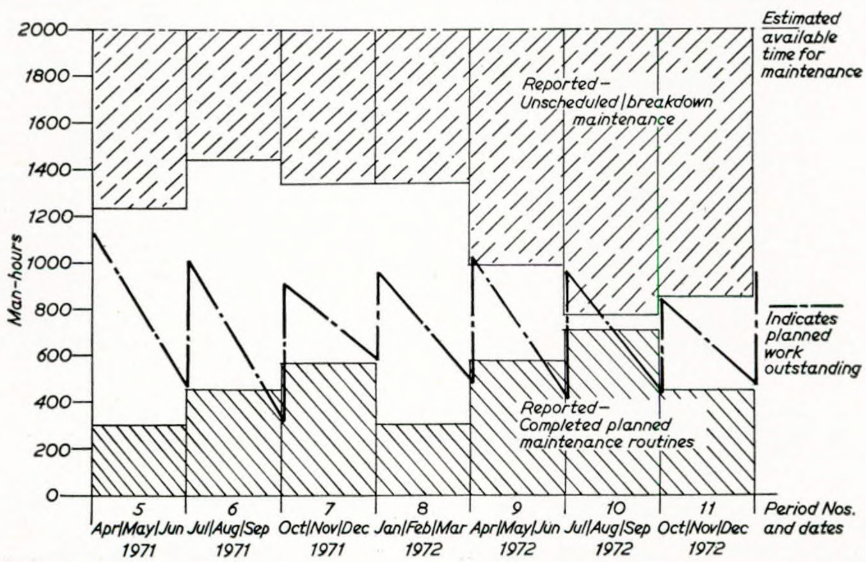

FIG. 8—*Histogram of reported planned and unscheduled maintenance (200 000 dwt steam vessel)*

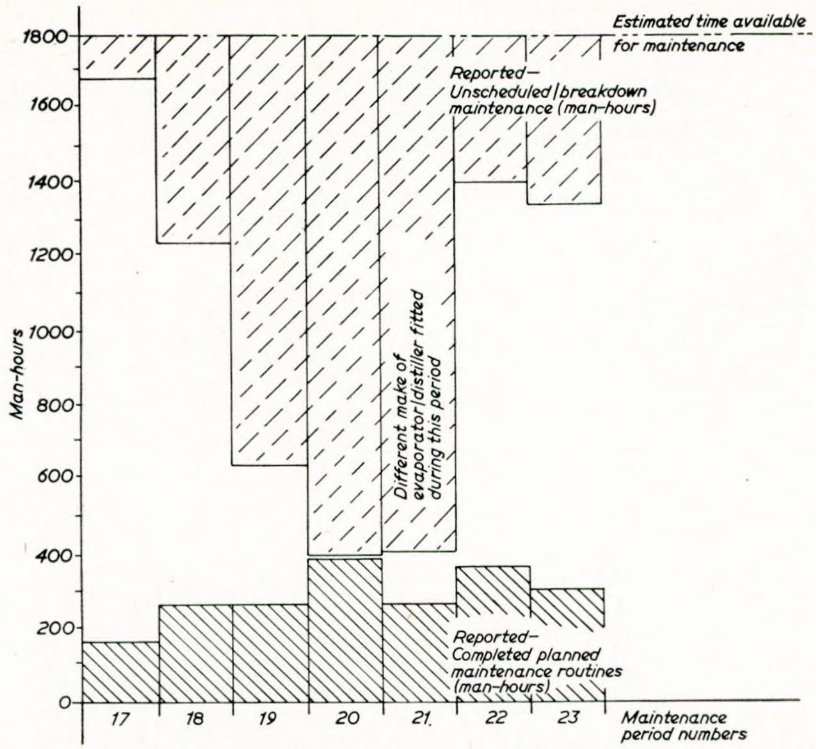

FIG. 9—*Histogram of reported planned and unscheduled maintenance indicating value of maintaining record of trends in workloads, thus enabling investigations to be made and action taken when workloads become excessive*

make. A similar effect, though not to the same extent, was noted on similar vessels in the same class with identical equipment.

The immediate effect was to restore a balance between planned and unscheduled work, and a further development was that similar action was taken on other vessels of this class.

A substantial proportion of the programmes are completed and the majority of staff are apparently working well within their capabilities.

Fig. 10 illustrates recent figures for VLCC.

The information obtained is, of course, only as accurate as the reports allow. When the scheme first started it was evident that some engineers were very reluctant to submit unscheduled maintenance reports, and they were equally reluctant to record the actual time taken to do the job. As with most of us there is an obvious reluctance to deal with paperwork.

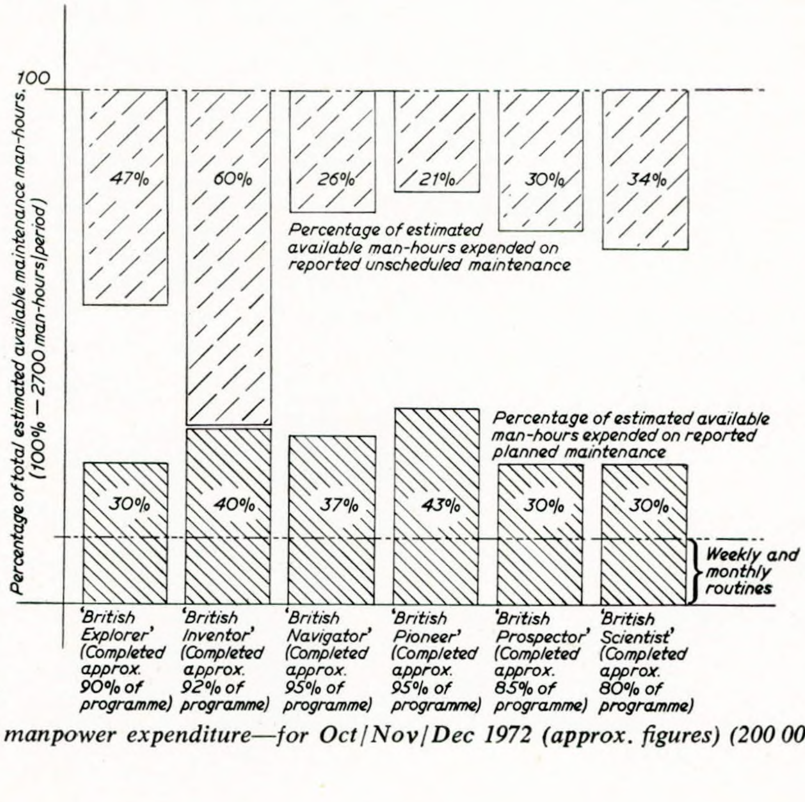

FIG. 10—*Reported manpower expenditure—for Oct/Nov/Dec 1972 (approx. figures) (200 000 dwt steam vessel)*

PLANNED MAINTENANCE REVIEW RUN NO 72 14 MAY 72

BRITISH ADMIRAL MAN-HOURS AVAILABLE THIS MONTH 800

SERVICE ROUTINE	DESCRIPTION	PERIOD	MAINTENANCE—MAN-HOURS ACTUAL	MAINTENANCE—MAN-HOURS PLANNED	BREAKDOWN MAN-HOURS	STOPPAGE SHIP-HOURS
010	CRANE, PROVISIONS HANDLING	05	1.5	1.0		0
110	TANK DOM. FRESH WATER	05	1.0	1.0		0
110	FAN, PUMPROOM VENTILATING	05	1.5	1.5		0
210	FAN, PUMPROOM VENTILATING	05	1.5	1.5		0
210	INERT GAS FAN MOTOR	05	1.0	1:0		0
000	CARGO TANK GAUGES	05			10.0	0
220	FAN, ER VENT EXHAUST	05	5.0	5.0		0
010	COMP. EMERGENCY AIR START	05	2.0	2.0		0
130	STM. STM. GEN FEED PUMP	05	12.0	12.0		0
120	BOILER FEED PUMP	05	6.0	6.0		0
010	SCRUBBING TOWER CW PUMP	05	1.0	0.5		0
040	AIR COND SW CIRC PUMP	05	10.0	8.0		0
210	DOMESTIC SW PUMP	05	6.0	2.0		0
230	EVAP AND DIST PLANT	05	24.0	24.0		0
100	COIL DRAIN PUMP	05			8.0	0
210	MAIN TURBO ALTERNATOR	05	19.0	6.0		0
210	TURBO ALT EXT PUMP	05	0.5	0.5		0
210	TURBO ALT SW CIRC PUMP	05	0.0	2.0		0
520	WINCH, AFT MAINDECK	05	24.0	24.0		0
620	WINCH, AFT MAINDECK	03	20.0	24.0		0
020	SUEZ CANAL SEARCHLIGHT	05	3.0	3.0		0
020	GALLEY PANTRY EQUIPMENT	05	12.0	8.0		0
010	DISH WASHER	05	1.0	1.0		0
010	MACHINE, POTATO PEELING	05	0.5	0.5		0
131	MAIN REFRIGERATOR	05	4.0	10.0		0
100	MAIN REFRIGERATOR	04			20.0	0
210	MAIN REFRIGERATOR	05	1.5	1.0		0
110	LIFEBOAT ENGINE	05	1.0	1.0		0
210	LIFEBOAT ENGINE	05	1.0	1.0		0
TOTALS:			160.0	147.5	38.0	0

OUTSTANDING WORK TO BE COMPLETED BY END OF PERIOD 5 = 786·0 MAN-HOURS
FLOAT LAST MONTH = 602 MAN-HOURS

FIG. 11—*Representation of P.M. review from computer output listing*

Sufficient data is now available, however, to warrant the use of computer data for analysis, and this is available in various forms (Fig. 11). The "Planned Maintenance Review" is obtained each month and lists all planned and unscheduled work reported. In this case it was estimated that 800 manhours would be available for maintenance and, according to the reports, a total of 198 manhours had been expended—160 on planned work and 38 on unscheduled work—the balance or "float" being 602 hours. The outstanding work to be completed by the end of the three-month maintenance period is 786 hours, and as the period in question started in March it means that only one month remains in which to complete the outstanding work. Without the benefit of other information this figure could be misleading, since it could also include work outstanding, for various reasons, up to twelve or even fifteen months previously. As with all historical data, careful interpretation must be given to avoid being misled by tabulated figures.

The "equipment performance report" is produced as required for any type of machinery. It details the total number of hours absorbed by planned or unscheduled tasks, and is relative to one specific type of equipment fitted on any ship throughout the fleet.

It is sometimes useful to compare one type of machine with another, of different manufacture, to determine which has the better service record. The equipment performance report print-out in Fig. 12 is for cargo pumps fitted on an Italian-built 35 000 dwt class of steamship. The planned and unscheduled maintenance manhours are detailed for the elapsed time indicated, together with the number of unscheduled reports received (indicates number of unscheduled incidents).

The "Unit Maintenance History" shows the amount of maintenance carried out on any one piece of equipment on any one ship. It lists the time taken at each stage and the dates on which maintenance was necessary. The information given in

PLANNED MAINTENANCE--EQUIPMENT PERFORMANCE REPORT--RUN NO 72

CODE 1–11–1505–00637–01 CARGO PUMP AND TURBINE FROM JAN 1969 TO MAY 1970

SHIP-NAME	MULT	MAINTENANCE—MAN-HOURS ACTUAL	MAINTENANCE—MAN-HOURS PLANNED	UNSCHEDULED MAN-HOURS	NUMBER OF UNSCHED REPORTS
BRITISH BEACON	1	0.0	82.0	61.5	6
	2	36.0	82.0	54.0	2
	3	18.0	52.0	129.5	4
BRITISH COMET	1	30.0	72.0	12.0	2
	2	84.0	56.0	0.0	0
	3	74.0	54.0	0.0	0
BRITISH LANTERN	1	44.0	88.0	14.5	4
	2	71.5	62.0	13.5	4
	3	54.0	42.0	24.0	6
BRITISH LIGHT	1	99.0	138.0	71.0	8
	2	79.0	62.0	7.0	4
	3	20.0	92.0	7.5	3
BRITISH SIGNAL	1	45.0	72.0	0.0	0
	2	4.0	56.0	1.0	1
	3	16.0	42.0	0.0	0
BRITISH STAR	1	76.0	62.0	3.0	1
	2	123.0	32.0	1.0	1
	3	58.0	40.0	0.0	0

FIG. 12—*Representation of "equipment performance report"*

such listings can be augmented as required by reference back to the original report. (Reports containing any valid written comment are retained for future reference.)

Fig. 13 is an example of a "Unit Maintenance History" detailing the maintenance life of No. 1 cargo pump on s.s. *British Light*. The details are an extension of the equipment performance report shown in Fig. 12.

FUTURE DEVELOPMENTS

Having covered briefly a system of planned maintenance, and the information that one is now able to derive from it, it can be seen that as records grow so one is able to be more selective in our choice of equipment for future building programmes. Apart from the auxiliary plant which has been fully incorporated into this system, routines are now being introduced and improved for main engine maintenance on motor vessels.

At present, methods of improving this planned maintenance system are being investigated. As previously explained, when the present scheme was devised one could not set the maintenance pattern of machinery on a running-hours basis. Every ship has its own peculiarities and the trading patterns differ widely. There are some product carriers on coastal trading and using cargo pumps every three or four days, and there are VLCC trading between the U.K. and Persian Gulf using cargo pumps perhaps once every six weeks. Cargo pumps and main engines are, however, particular exceptions, as most of the auxiliary machinery on any tanker will be running almost continuously no matter what the trading.

To achieve a reasonably balanced work load with the advantage of positive forward planning, the existing system was therefore based on clearly defined maintenance procedures to be carried out on a calendar basis.

However, present investigations are looking to methods of "health-monitoring"—or maintenance "on condition"—using ultrasonic aids and inspections before deciding when a machine requires maintenance.

Methods of maintaining on an "hours-run" basis are also being investigated, particularly with regard to cargo pumps and main engines where there can be considerable variations in usage during the ship's life.

Maintenance of some equipment can, of course, be carried out purely on a "breakdown" basis. Equipment not affecting the running efficiency of the ship or pumping of cargo might be considered as suitable for inclusion under this heading. In these cases it could be feasible to carry out maintenance and renewal of parts only on failure of the machine, providing that planning has been carried out to the extent of providing spares for such an eventuality.

CONCLUSION

Whatever steps are taken to improve this system, one aspect must be borne in mind. The available manpower on a ship is limited and so some degree of control must still be imposed over maintenance requirements in order to maintain a reasonably balanced work load. Although sea-going maintenance teams and other outside assistance can be used to supplement the ship's staff, it is an expensive procedure.

With the experience gained over the past five years from all the methods in the present system and with the introduction of new methods in the future, the writer is certain that an efficient and workable compromise will be arrived at.

PLANNED MAINTENANCE--UNIT MAINTENANCE HISTORY--RUN NO 72

SHIP CODE B-22-390 EQUIPMENT CODE- 1-11-1505-00637-01
BRITISH LIGHT DESCRIPTION CARGO PUMP AND TURBINE

MAINTENANCE	PLANNED				UNSCHEDULED		
COMPLETION DATE	SCHEDULED PERIOD	MAN-HOURS PLANNED	MAN-HOURS ACTUAL	ROUTINE	COMPLETION DATE	PERIOD	MAN-HOURS
09/02/69	01	6.0	7.0	110			
					09/04/69	02	5.0
NOT DONE	02	0.0		110			
ARREARS	02	60.0		130			
06/07/69	03	6.0	6.0	110			
					14/07/69	03	4.0
					06/08/69	03	15.0
					06/08/69	03	8.0
					07/08/69	03	8.0
					08/08/69	03	9.0
25/06/69	03	60.0	80.0	140			
					09/09/69	04	2.0
28/02/70	05	6.0	6.0	110			
					17/01/70	05	20.0
TOTALS		138.0	99.0				71.0

HOURS EXPENDED 170.0

FIG. 13—*Representation of "unit maintenance history"*

Discussion

MR. R. E. WILSON, F.I.Mar.E., said that he thought that Mr. Duell's paper had clearly explained the basic idea behind planned maintenance and the procedure they had employed to put this into practice. He agreed with the basic ideas presented, i.e. that there was a need for shore-controlled long term planning to offset the lack of continuity afloat which existed today due to the relieving system.

The planned maintenance had to be based on the ship's survey cycle, and the ship's programme had to be known at least six months in advance to allow for spares to be ordered. However, it was better to maintain a spares norm on board, as unusual requirements would not be found until the planned maintenance was carried out. Mr. Duell's three basic steps were the ideal approach.

It was a cause for some concern that today ship's engineer officers were expected to do fitting work two or three hours per day during their watch. Was not most damage and failure in engine rooms due, not to shoddy work, but to poor watch-keeping? This did not apply to those ships sailing unmanned, with alarms, etc.

The first chart showed 8372 maintenance hours, with 3306 allocated to weekdays at sea and 3276 to weekdays in port, the remainder for Saturdays and Sundays being 1160. The planned maintenance float of 3500 included this weekend work. Was it possible in 1973 and 1974 to get workers, especially day workers, to put in eight hours during a weekend? Also, the port time was high. With quick turnrounds, engineers were busy with cargo pumps, looking after the superintendent's whims, and had very little spare time. Also, most tanker ports frowned on work being carried out while the vessel was in port. What percentage of the sea staff's work had finally to be attended to by shore labour?

The principle of estimating job times was very good, but initially very time-consuming. Could not these be identified as major, intermediate and minor, and allocated accordingly when putting out the work? Planned maintenance was often overtaken by events, e.g. those dealt with when rectifying a fault, and the fact that the engineer could or could not undertake his own survey work.

Did this involve a re-run in the main work balancing programme? If so, did that programme take into consideration the last time that these levels of maintenance work were completed, so as to avoid over- or under-maintenance? Could not a five-year vessel programme work more easily than the computer system? This could be organized by the ship's staff themselves.

As to the ship's planning board, did this show the labour allocated to the job, or was it the individual officer's estimate which went on to it? Was it the ship's staff who said the hours they put in, or did they put in the work which had been allocated in the office? This system could be used to justify a poor state of engine room, as cards could be produced to show that so many of the staff had been busy on so many hours of work, which would not be the case.

The histogram showed up the unnecessary unscheduled maintenance. Presumably a computer print out was needed to show where the unnecessary work originated. Would the maintenance forms have to be unearthed before the cause of the unnecessary work was found?

In the investigation of individual machinery, how did the ship's maintenance superintendent get to know which particular piece of machinery required excessive maintenance?

Although the system was obviously working within Mr. Duell's organization, it appeared to rely very heavily on man-hours, and there was the possibility that it could give the wrong picture—either inflated or deflated—due to various factors such as maintenance men who were new to the job, unusual difficulties, machine tools in use elsewhere, no spares, etc. There were many reasons why it was possible to get the wrong hours.

The computer print-out did not show the cause of the difficulty nor how to distinguish between important and unimportant defects. There was also the excessive time taken, so the original document would have to be retrieved before a proper investigation could start. How many man-hours a month were spent in the Head Office, on the planned maintenance system, and was the outlay proving its worth?

There was little said about defect reporting, which appeared to be a separate system altogether. Was there any system whereby the office was aware of the actual defects on the ship and could allocate the man-hours needed to repair them? Also, were these carried out within the float hours, as described in Fig. 1?

MR. J. GOLDIE, F.I.Mar.E., said that in view of earlier remarks, perhaps he should make it clear from the outset that his experience was as a consultant, but in the military rather than the mercantile marine field. It was pleasing to see that there were those who would venture. It was even more pleasing to infer from this paper that they had won—in this case a greater ability to control what was, after all, one of their factors of production, i.e. the maintenance of essential equipment in efficient operation.

At policy level the need for flexibility was obviously appreciated, vide the fact that improvements were still in order after five years. Flexibility was just as important at lower levels, however, and it was on this count that a purely Calendar-based preventive maintenance programme fell down. It was costly because it was inflexible. Men were deployed on a Calendar basis but the maintenance needs of equipment—certainly those of high work content—arose more generally on a basis of hours-run. The purely Calendar system could place too little emphasis on establishing that the maintenance need had arisen when the task was carried out and too much on the availability of time or men to do the work. Health monitoring was the ideal outcome—and it would come. Meantime in order to minimize the maintenance load, and defects arising therefrom, it was necessary to:

1) establish periodicity of major tasks on an hours-run basis, within the scope of existing knowledge;
2) Execute these tasks only when the hours had been run, as far as operational demands permitted;
3) Optimize periodicity on the basis of proven reliability/unreliability, that was, monitor and adjust the maintenance plan as a living thing.

Did Mr. Duell include the retrieval of hours-run for individual equipments and their use to reduce rather than balance the work load, among the improvements which he foresaw?

The value of any analysis did not exceed the accuracy of the input data—i.e. the "rubbish in—rubbish out" principle of computer technology. Reporting was a difficult area, since ship's staff had other—to them—more important and more interesting functions to perform. What were Mr. Duell's experience and views on the reliance which could be placed on the reporting aspect? If data were accurately and comprehensively reported, had he considered "reporting by exception" (i.e. only incompleted routine tasks plus corrective tasks, of course) to minimize the effort and computer time involved?

The use of maintenance assistance teams, whether in port or at sea, involved expense, but was this approach inherently more expensive than carrying a full maintenance team as permanent ship's staff? With (i) the possibility of reducing complement which arose with centralized control; (ii) the increasing sophistication of ships' equipment and specialist skills demanded; and (iii) the high cost of downtime and loss of earnings, use of the minimum ship's staff consistent with regulations and the ability to accomplish routine servicing, plus mobile highly skilled maintenance teams to effect longer term tasks, could prove cost-effective.

Finally, there was one point in the paper which distilled in essence to a defect in need of repair. In referring to Fig. 9 on page 7, Mr. Duell had stated ". . . 80 per cent of the unscheduled work was expended on . . ." and he had used the word "maintaining" which, on the speaker's opinion, should be "repairing".

MR. W. M. STEFFEN agreed with Mr. Duell that during the past the term "Planned Maintenance" and what lay behind it was sometimes neglected or underestimated by manufacturers. It was more or less left with the ship-operators. They had to introduce appropriate measures under the pressure of rising maintenance costs and scarcity of trained technical ship staff, particularly for highly sophisticated equipment.

Even when some time ago engine manufacturers began to state maintenance periods, life expectation and time involved for inspection and repair work, this was very much used, and regrettably was still in use, as a weapon against strong competition. Information offered by the manufacturers about operation data, engine wear and lifetime had very often been interpreted as an indication of reliability or unreliability.

The approach to reaching a realistic consideration had now been made by one of the leading medium speed diesel engine manufacturers, together with Professor Mau of the Research Institute for Marine Operation Technique in Flensburg.

Developed on the theoretical basis found by the Institute and the experience of the speaker's company in the field of the sophisticated medium speed diesel engines, a system comprising planned maintenance and maintenance contracts could be offered to ship-operators.

The main idea was:

1) To make maintenance and servicing costs a calculable part in ship operation costs;
2) To provide either side with data for "health monitoring";
3) To provide highly skilled and experienced engineers for maintenance, service, and repair on a regular basis, depending upon the type of contract, and
4) To provide either side with data for decision making on ships' operation respectively for improvement in the design engines and future development.

The Maintenance Contracts were fixed price contracts in roughly three variations:

1) Supervision contract only, with checking and ascertainment of the engine installation at regular intervals;
2) Maintenance and servicing contract with servicing work

according to maintenance schedule, including contract stage 1; and

3) Maintenance and repair contract with or without spare parts supply including contract stages 1 and 2.

MR. K. GRANT said that firstly, regarding the expected breakdown figure of 25 per cent, when the system was planned, what were the figures produced since? Were they about 45–50 per cent?

Secondly, were the estimates for man-hours on individual jobs made by the company's own staff, or were outside estimators used?

Thirdly, a "Reliability Factor" was mentioned. How was this measured? Had they used (a) breakdown rates, (b) comparison between individual machines or ships, (c) time to repair, or (d) any statistical measurements?

Fourthly, the speaker's company had had planned maintenance for seven years, and their system was similar to that used by B.P. The figures showed that 75/80 per cent of all maintenance time and cost was spent on main engines, boilers and cargo systems. These were the areas where most of the time should be spent, in administration, work force and money.

One or two other points: had some stock control system been thought of in B.P.? Had the performance of the planned maintenance system been measured? If so, how had this been done, e.g. had it reduced downtime? Had there been benefits in reduced repair costs, etc., or was it a very sophisticated Second Engineer's work book, as some of our fellow engineers had suggested?

MR. T. BAKKE said that as a Scandinavian he was very glad to hear the comments made about the Scandinavian shipowners and staff. With regard to the attitude of the Scandinavians to the maintenance problem, he pointed out the basic idea in this field. When the new generation of diesel engine was designed, namely the K90GF, which was presented here some years ago by Mr. Smith Sorensen, reliability and easy maintenance together with low installation costs and low production costs were the main points.

They had tried to look into the total situation from the beginning by analysing what it was necessary to maintain on an engine, based on previous experience; to put the engine into service; to get some feedback; to tell the shipowner what to maintain, how to use some observation points as guidance; that meant not only to use a strict, planned maintenance system. The ship's engineer on board should be responsible for the ship and the service, so that if a problem turned up he would be there and have sufficient knowledge to take the precautions he ought to take. So there should not be a strict, planned maintenance that might take the initiative away from the people on board the ship.

One of the first things mentioned in the paper was about questions to manufacturers. The speaker did not know how many of the ships, which used the P.M.-system had their type of engine installed, but based upon an article in a Norwegian newspaper in 1968 they had asked B.P. if they could assist them in building-up the P.M.-system for the main engine. They said that they would make contact at the beginning of 1969, but nothing was ever heard. In their system, did BP calculate with feedback to the manufacturing company, because some of the points specified in the computer program shown could have been avoided if there had been a feedback to the manufacturers and knowledge had been obtained about possible altered components which could have been included as spares, whereby further troubles would have been avoided. Was B.P. still interested in co-operating with a manufacturing company?

Had B.P. incorporated in their P.M.-system a feedback system to the manufacturers, so that they both got better ideas about what happened with the engines in service?

If shipowners had knowledge of the reason for any trouble and reported this back to the manufacturers, this could be absolutely basic to the manufacturing company in developing new components in order to avoid similar breakdowns in the future, and it was vital that the manufacturer should know about this. Some of the largest shipping companies in Denmark and Norway were co-operating in this respect by having open-minded meetings with discussions about service troubles as well as systematic analysis concerning service conditions and so on. A computer system was used to deal with all these observations and then the information obtained was applied in the development of new engines. By using a one-side service contract—which would be very costly, because the service company had to include enough overheads to cover their total costs—it was better to develop one's own planned maintenance system based upon performance monitoring system; that was, based upon the service conditions by using a condition-check which clearly defined what to maintain at the next step. It was therefore very important to give sufficient knowledge to the people on board the ship, and this could be done by using performance sheets which would make it easy to analyse the service conditions to obtain information about what precautions should be taken. This performance system had been used during the last six or seven years, and, if the company wanted to be a little advanced, they could use a computer to obtain the actual service condition compared with the condition on the testbed. This was better than the planned maintenance system, because the work could be reduced to only that which was necessary.

Was B.P. willing to pay for equipment for facilitating the maintenance job, more than what was usual nowadays?

What did B.P. mean about the difficulties in getting qualified engineers for the job on board the ship, and what kind of training programme was used within the company for keeping up with all the new technology?

MR. A. N. S. BURNETT, F.I.Mar.E., said that he had one very quick item, which had already been partly raised by the other speakers. In the conclusions, the author's views were given regarding the use of outside technical assistance. There was at least one Scandinavian and one U.K. company which supplied these expert sea-going maintenance service teams. Surely they would not still be in business if they were not useful to the owners who used them? Therefore it was likely that this type of service would expand rather than contract; and as a result maintenance should be planned around this system rather than ignoring it and resisting its presence. So why did B.P. not consider using such sea going teams, now that they were used profitably, mainly by Scandinavian owners? As far as was known, B.P. did use some outside assistance for their automation work. Would the author please comment?

Correspondence

MR. J. B. HILL, F.I.Mar.E., wrote that Mr. Duell's lucid account of how B.P. had organized and operated their scheme provided valuable guidance and encouragement to those who might be contemplating a re-organization of maintenance procedures in their own fleets.

The introduction of centrally controlled planned maintenance (as distinct from schemes developed on board ship), appeared to be relatively recent in this country. Pioneered by some of the major oil companies a number of years ago, it had been slow to perculate through the British Shipping Industry. Possibly tanker companies with lack of ready access to their ships and quick turnround times, felt the necessity for planning to be more pressing than other organizations. On the other hand, the general adoption of Classification five-year continuous machinery survey cycles undoubtedly played its part in making superintendents conscious of the advantages of long term planning.

Whilst it was difficult to determine standards adopted by other countries, Scandinavian shipowners (from personal knowledge), did seem to have embraced the planned maintenance concept more readily than their British counterparts; but again this might have been because their ships traded largely overseas and in these circumstances, it was not practical to maintain close technical surveillance over them.

Various other reasons had been propounded for the introduction of planning, not least of which was that pointed out by Mr. Duell in his remarks concerning frequency of sea-staff changes necessitated by ever-increasing leave entitlements.

It could also be added that the complexity of modern ships' engine rooms made planning very desirable, if some items of equipment were not to be overlooked until they made their presence felt by actually breaking down!

Planning as outlined by Mr. Duell played another important part in these days of staff shortages, and increasingly sophisticated machinery installations. To name but a few components now regarded as standard aboard ships today, there were alarm systems, remotely controlled values, automatic purifiers, etc., and one wondered how often young engineers found themselves called upon to maintain machinery with which they were only vaguely familiar. A full planning system which included job-cards, explaining how each piece of equipment was to be overhauled, which clearances were to be measured, etc., offered an excellent means of teaching junior staff. Even if job-cards were studied only once and all instructions fulfilled, one felt that at least the engineers were acquiring a sound basis on which to carry out future maintenance.

Mr. Duell's paper had raised one aspect of planning schemes which concerned many shipowners at this moment. Namely, should one develop a scheme within a company as Mr. Duell had done, or was it advisable to draw on the experience of consultants? One feature of the Scandinavian scene was the apparent readiness to adopt sophisticated schemes, developed by consultants, and the willingness of owners to accept the cost of these services.

Amongst British owners, one had the impression that they had traditionally avoided the employment of consultants and preferred, if at all possible, to introduce their own schemes.

No doubt some owners felt that it was better to create a system from within, so that it dovetailed reasonably well into existing office procedures.

As far as sea staff were concerned, there could be some resistance to schemes brought in from "Outside", so to speak, although visits to Scandinavian vessels did not give this impression, and indeed one felt that the engineers accepted planning wholeheartedly and took pride in keeping their filing systems up to date.

The paper had not mentioned any difficulties arising from the scheme operated by B.P., but it would be of interest if Mr. Duell could say how the sea staff reacted when planning was introduced and if there was any problem in obtaining a regular flow of information from the vessels.

Mr. Duell had given the impression that every effort had been made to keep the system of planning as simple as possible and in this respect there was a contrast compared with some of the schemes offered by consultants.

Furthermore one felt that B.P. had been at pains to develop and introduce their planning system gradually, so as not to risk overwhelming sea staff with paperwork—which could well doom any system to failure.

Some consultants on the other hand, tended to view planning as an overall operation, which could benefit the shipowner not only in the day-to-day running of his ships, but also in the field of spare parts, accounts, cost analysis, etc.

To introduce such a radical change could well be beneficial in the long run, but would naturally be beyond the ability of the normal technical department; in fact, to adopt one of the more comprehensive schemes would almost certainly necessitate the employment of consultants, both ashore and at sea for a fairly lengthy period.

Ultimately, one felt that all large shipping companies would be obliged to plan their operations along the more comprehensive lines suggested. The advent of the computer left little alternative, but how long the period of transitions would be in this country was difficult to assess.

In Scandinavia, some very comprehensive planning and ship operating schemes appeared to work quite successfully, but were they introduced in their present form, or did they emerge from modest beginnings, as had the B.P. scheme?

Consultants would argue that to be successful, all office departments should change their systems together (including the accounts department), in order that a uniform method of coding, costing, etc., could be put into operation, but how many shipping companies would be prepared to undergo such an upheaval, unless economic circumstances made it essential.

Perhaps Mr. Duell would care to give his opinion upon the best way to introduce a planned maintenance scheme and in particular how the extra demands made upon the technical department were coped with, especially in the initial stages.

Once in operation, it would be useful to know the number of staff, technical and clerical, required to maintain a scheme such as that outlined in the paper. Mention was made of 8000 reports being received at head office per month (i.e. about 400 per day, assuming a five-day week) and one wondered how this large number of returns was effectively scrutinized, to ensure that no vital information was overlooked. Even accepting the part played by a computer, the task appeared to be formidable.

The histograms shown in the paper were most interesting, particularly as it appeared that time spent on unscheduled maintenance frequently exceeded planned maintenance time. Was this regarded as normal, or was it hoped, with closer control of maintenance, to reduce time spent dealing with unscheduled breakdowns?

One or two Norwegian owners had claimed that only about 20–30 per cent of the man-hours available need be reserved for unplanned work and indeed inspection of records seemed to bear this out.

As ships grew older, one would have thought that the number of unscheduled repairs was likely to increase. Was this the case in practice, and if so, were maintenance schedules reviewed at intervals throughout the life of each ship? For example, pipework should require no more than cursory attention until a ship was at least six or seven years old, but an increasing number of man-hour requirements might be anticipated after this lapse of time, particularly with regard to repairing and renewing pipes in sea water service.

There seemed to be definite advantages in adopting the author's proposals to change to an "hours-run" basis, when calculating machinery maintenance intervals and in this respect it was gratifying to note the co-operation presently being obtained from the majority of equipment manufacturers.

However, one had to guard against the tendency of some firms to advise inspection of components much too frequently. There was a lot to be said for the old maxim that if equipment was running well, leave it alone, but this was not necessarily the best advice and in reality operating experience must be the basis from which maintenance schedules were derived. The data which B.P. were accumulating in their computer records would be invaluable in this respect.

Finally, could the author state what steps had been taken to integrate spare parts and maintenance systems and whether the computer was used in connexion with the former. Also to what extent maintenance data and the computer were used in the preparation of forward operating cost estimates.

Author's Reply

Referring to Mr. Burnett's comments about sea-going maintenance teams, Mr. R. P. Duell said that he considered them to be expensive. There were many contractors offering teams and they were used frequently both for emergency maintenance work and to reduce any backlog of repairs. This service was not ignored as a means of completing repairs while keeping a ship in service, but it was still considered an expensive procedure when so many of the jobs they were used for could be avoided with a little more careful planning.

Regarding Mr. Bakke, it was certainly not his Company that said their machinery did not need maintenance. At that time in the development of their system they concentrated on auxiliary plant rather than main machinery, because at that time this was where their own particular problems were, and the area where quickest results could be expected.

In reply to Mr. Wilson, about the man-hours used to operate the system, the B.P. system of planned maintenance for ship's machinery was operated by one section leader, two Technical Assistants, and two Clerical Assistants. He thought that the returns were well worth the time expended.

Regarding the man-hours on the ship, he felt sure that they were not asking the ship's staff to do anything they should not have been doing in the past. They were asked to maintain the machinery, but in a uniform manner throughout the Fleet, and in a far more organized way.

Mr. Grant raised the point of the breakdown figure of 25 per cent. It was anticipated that the percentage of the total available time taken up by unscheduled/breakdown maintenance would be in the region of 25 per cent. Retaining their present level of P.M. this percentage in fact averaged at about 35 per cent over the whole Fleet of 85 ships. Increasing the frequency of P.M. or planning for more work to be done at the present intervals was not necessarily the answer when trying to reduce this figure. If it was assumed that a failure rate of say 15 per cent should be applied to overhauled equipment, then increasing the frequency of maintenance was likely to increase the amount of unscheduled maintenance (because of the failure rate applied to newly overhauled equipment). It was more likely that the unscheduled work would reduce if the present system was modified to allow for greater use of "health monitoring" to determine maintenance requirements.

A reliability factor of 85/90 per cent was mentioned. By this was meant that some failures were expected before the planned event occurred. If the equipment was in use from one P.M. routine to the next without failures (and without amendments to the schedule) then it could well be that one was over-maintaining. The ideal would of course be if one aimed at, say, twelve months between maintenance intervals knowing the equipment would fail if left to twelve months plus one day.

With reference to spares usage, this was being looked at very carefully. Apart from the feedback in the form of the maintenance reports, which identified spares used in conjunction with a maintenance routine, there was also an extensive project developed to control and monitor stocks and spares usage of all purposes.

*The following talk was then given by Mr. R. D. Cooper**

PLANNED MAINTENANCE FOR MERCHANT SHIPS

Planned maintenance for merchant ships is the subject but ever since I started to collect my thoughts on how I might best interest you in this business I have been continuously confirmed in my conviction that a resumé or summary of a number of maintenance systems could not avoid a number of failings.

To collect and compare different solutions to the maintenance problem would be of only passing interest in that it would present a number of possible answers with no relevance to any particular situation.

One could be much more specific and recount in detail the components and workings of a particular system used by an anonymous company but this would, I think, lack the authority of real identification and, more important, I am fairly sure from my experience, that there would be parts of any system that individual listeners would not accept, and they would tend therefore to refuse the whole. I wish to avoid presenting you with a curate's egg, rather I am aiming to make a case for planned maintenance and to show, very briefly, how it may be carried out as efficiently as possible within any operating conditions. I accept, even insist, that the details of a system that suits one company may be quite irrelevant to another.

I intend therefore to discuss some principles that should, I am sure, be incorporated in any system for getting work done and I shall assume your acceptance of these principles before going on to discuss the means whereby the principles may be met in practical terms.

The extent and detail and format of these practical means of working systematically are, as I have implied, very much a matter for individual companies and I shall thus hope to avoid telling you what I think should be done but rather to suggest lines along which sound maintenance should proceed.

I shall inevitably slip, in the next few minutes or so, into talking about the management of maintenance and to forestall any doubts that this word may create I will define management as a function, that of "Getting things done through people in an organization".

In the present context we are concerned with getting maintenance done. Using this definition we can now reasonably talk about the management of maintenance as a shipboard activity and enlarge on the principles that should run through any system for such management, and against which any system should be judged.

The first and cardinal principle of management is clarity of purpose.

Without being clear at all levels about what is to be done, there can be no progress except by accident and no measure of accidental progress. Unless you know where you are at any time and what you have to do, you cannot know in what direction to proceed or how far you have gone. Neither principal nor subordinates can know.

The next principle is that of delegation of authority, which is a concise way of expressing the need for something more on the way of directive than telling someone to do something. The telling must be in clear terms and the delegator must be sure that the work can be done by the delegatee and that he is equipped with the necessary resources to carry out the work.

The third principle is motivation to work. This is sometimes regarded as a matter of cajolery at the worst or leadership at the best. It is also clearly related to clarity and delegation: people like to know what is expected of them and to be given a measure of authority.

The last principle is that of economy of effort which appears very obvious but this also depends on the others, as indeed they all do on each other. The units of economy are of manpower, of time, of opportunity and of material. Economy is what this is all about—either to get more done by the same people or to reduce the effort expended on the same work, in the circumstances of the moment.

Four straightforward principles have been given and now we must consider the components of a system for the management of maintenance that will embody them, and the form that these components should take.

I will offer some advice on the form of the components. This is because the value of systematic management is particularly high in the current arduous conditions brought about by rapid personnel changes within hard worked, complex ships and that being so, it is important to give the information within a system real permanance. That can only be done by writing it down because of the fragile nature of information left to the memory or passed on verbally.

Before considering the components of a system to embody our agreed principles it would be as well to be clear about what is meant by maintenance.

The actual work of preventive maintenance and surveys and defect rectification is very much the same sort. It is carried out by the same sort of men and competes for the other resources of time and opportunity. It thus seems reasonable to include them in the same system. If all maintenance is tackled within the same system, what is the least information required and by whom is it needed?

At some stage everyone from superintendent, and perhaps others at head office, to the least skilled worker will want to know what is to be maintained which leads quickly to a list of maintainable equipment within the ship.

*S. S. Stevenson & Partners Ltd.

The decision on what is actually included in the list need not be final but can first be limited, for example, to the equipment to be maintained by ship's staff. Nevertheless at this stage any future extension, to include gear subject to survey or cargo systems or underwater fittings for example, should be considered. This is because such a list is the starting point for the derivation of a lot of information which will need indexing and the index system chosen should serve without confusing alterations, no matter how wide the eventual scope of the maintenance system.

The right index will allow work to proceed in parallel on the equipment list and on the compilation of a schedule of maintenance for each selected piece of equipment. A maintenance schedule is a statement of what preventive maintenance work is recommended at which intervals.

The sources of schedule information are various but seldom produce, ready-made, the sort of information that can be used in the management of the work. Here, as always, it is important to look ahead and visualize the information in use. This broad look ahead at the problem will show the need for work to be scheduled in convenient tasks—convenient that is to the opportunities that will arise in practice for their execution.

All work should be included in the schedule so that even the oiling, greasing, filter changing, and the like is clear to the man on the spot—not to the man who has just gone on leave.

In the pursuit of clarity each conveniently sized job should be separately identified and this is best done in some self evident, numeric code. When this is done each item of maintenance will have a unique label.

In creating a maintenance schedule which covers the equipment fitted in the ship, a great deal of work has been formally defined—a large measure of clarity of the maintenance task has been achieved, to the benefit of shore and ship organization. It is vitally important that this work should be recognized by the shore staff before being made over to the ship and as a contribution towards delegation the ship's staff should be placed in no doubt about how this work is to be tackled. This cannot be stated in detail for no one knows what the future holds but someone, presumably the Chief Engineer, should be authorized to proceed with the maintenance as and when opportunity offers. Some such directive is better than one which says "Do it all" or "Do what you think fit". In the first case the task may be impossible in the event, in the second the effect is to make the Chief responsible for maintenance policy, which is not his job.

In brief the need is for guidance towards the implementation of policy by whoever is authorized to do this. Only in this way will continuity be provided and personal idiosyncrasies avoided.

So far so good—we have a list of equipment, coded for ease of reference. We have a policy document on preventive maintenance, which has been placed in the hands of the Chief Engineer for implementation.

How is the Chief Engineer to proceed to tackle this mass of work or, in other words, how is he, in his turn, to make the task clear in the environment in which he works and how is he to delegate the work and achieve motivation and economy of effort—it is reasonably certain that he is not going to achieve much without more help towards these principles.

Items of maintenance will occur at different frequencies from daily to five-yearly and it will be useful to separate the frequent items from the less frequent because the control and supervision of the work will tend to lie with different people or in different spheres—for example the more frequent items will individually tend to take less time and collectively, to be done by watchkeepers as part of their task.

A correlation between the less frequent items and the ship equipment list leads to a Master Plan grid for the next five years. Planning at this stage should be made on paper with the aim of accepting what has been completed to date, and, for the future, either ensuring an even loading of work or bunching the work where the trading pattern bunches the opportunity to work.

Such a plan is a broad statement of intention and will serve as a reminder of special requirements for spares, stores and personnel. When work is done, or not done, and the plan noted accordingly it will serve as a running account of work, for the information of all concerned.

In deciding what work is actually to be executed it is important to provide a mid-scale plan, over say three to four months to be more accurately related to what is known of ship movements and personnel availability. Such a plan should also embody any defect work outstanding so that priorities can be set and every opportunity taken to combine defect rectification in one place with preventive maintenance in another or the same machine, or system. In this manner a total bill of work outstanding is constantly presented for the information and decision of the ship's team.

Presented is the right word because, on this scale, planning should be visual. A very reasonable way of achieving this is by having a card representing, in as much detail as is convenient, each item of preventive maintenance and each defect of any significance; these can literally be moved in changing circumstances to advance or defer or combine work.

Finally the planning has to stop and someone has to do something—the work has to be delegated within the ship and sound delegation means being sure that the delegatee knows how to do the job and that he has the resources required. In fact, the information that should be available is quite extensive—tools required, spare gear likely to be needed, grade of lubricant needed and the time it will take, not to mention the safety precautions that must be included, before the correct procedure is carried out and given clearances restored and perhaps recorded.

If a job is started without this knowledge, its economic execution is virtually impossible—neither economic of itself in time and manpower nor economic of the opportunity that has arisen.

This sort of information is detailed and is normally supposed to be available to the "Man on the job"—it may be, if of sufficient familiarity by frequency of execution or past experience. On the other hand it may not be available to the man who ought to be on the job, or to anyone else, with the result that the senior officers tend to delegate only the simplest jobs. In this way they are overworked in the wrong field—they should be acting as engineers and managers not as mechanics while potential skills remain unused.

Without doubt there is a need for detailed work information and, where it is not available it must be generated—not in the memory of an individual, but in the written word accompanied by sketches, where its use will help delegation and economy. The motivation of the less skilled, following their being given something more than menial tasks, is considerable.

And so the work proceeds, making the best use of everything that is available in the way of skill, numbers, time, opportunity. This is whether the work is frequent or infrequent, by watchkeepers or in port, simple or complicated.

And does it all get done? What are the reasons why work does not get done? There are several possible reasons and it is worth while differentiating between them. There is what the Chief Engineer decides does not need to be done, what cannot be done because of missing spare gear, or tools, or because of sheer lack of time and opportunity. What then are the results of all this effort and who wants to know what they are and why do they want to know?

I should hope that head office wants to know how successfully their policy is being implemented and I hope they want to know why, in order to take some action. How would they know? What action can be taken? If the means by which work is put in hand are retraced, the day to day plans can be updated in the light of events and from these the weekly and monthly displays will show work completed to time or overdue. These peaks may settle themselves within a reasonable time but if they do not, the medium term work display boards will show this and the progress (or lack of it, more usefully) will appear on the Master Plan. From this an extract can be prepared at any frequency desirable. Perhaps at three monthly intervals, reports are forwarded to Head Office.

So far this will satisfy the minimum requirements of a system which will assist the ship's management to start with a clear objective, decide what use to make of the resources and opportunities that arise, ensure that this decision is implemented and inform the owner of their achievements.

We have therefore, for a successful system, a loop, as it were, of information: policy from Head Office, implementation of policy within the ship and a return of information to Head Office. Thus the relationship between Head Office and the ship is vital to the successful use of a system.

To start with the schedule must spring from Head Office—no matter who compiles it, it must have authority. To be taken seriously it must be credible, that is it should be necessary and, for practical purposes, its execution must be within reach of the ship's capacity. If the load is hopelessly impossible, nobody will attempt it but if it is fair and a good effort is made the results must be accepted for what they are: success or failure to achieve company policy, and action taken accordingly. Acknowledgment is probably the least action, if further reports are to be forthcoming. Further action can include the provision of additional resources either sooner, in the form of manpower, or opportunity, or later, during a docking period.

Maintenance state reports are the basis of maintenance costing and the means whereby dormant docking lists can be prepared. The provision of detailed work information is the means of achieving accurate figures whether the work is carried out by ship's staff or not.

Work information is also the means whereby the whole schedule may be costed and matched against numbers of men and trading pattern.

It is thus possible to develop information for use within a system that is essential for the full success of the system and which can be analysed and synthesized to show the cost of maintenance.

The benefits of exercising maintenance management are virtually impossible to foresee for it can be exercised well or badly. When exercised well the action taken by Head Office is critical both to its continuation and to its effectiveness, dependent on the action taken in support of the ship on receipt of factual information.

When all goes well nobody believes it was not going to anyway but a comparison of costs of voyage repairs and unplanned down time will show the well-managed ship in a better light than one in which there is a lack of policy and in which the effort and opportunity is frittered away through lack of a plan and the information to carry it through. A "before" and "after" comparison will do the same and many ships carrying out virtually no preventive maintenance at one time are now absorbing this load when they thought they were fully occupied without it.

Preventive maintenance is of course a lot of work which can, as I have said, be costed in manpower. The first approximation to the ideal maintenance schedule will only be as good as the information and experience that goes towards its complication and a management system of any sophistication will seek to improve itself by refinement of the schedule in the light of its effectiveness. This is best achieved by selecting the most expensive items of maintenance and recording the state of equipment upon examination, and adjusting the frequency until the examination calls for repair work.

*The following talk was then given by Mr. R. A. Lorge**

THE SYSTEMATIC REDUCTION OF ENGINEERING COSTS ON BOARD SHIPS

A scheme which at present may be in the forefront of developments in engineering repair and maintenance techniques is known as SEACOST. The initials of this word describe the scope of the scheme:

S ystematic
E quipment
A nalysis and
C ost
O ptimization
S canning
T echnique

*New Marine Systems, London

The scheme achieves cost reductions in two ways:

1) Improving cost-effectiveness of work that arises, by cost-optimizing such systems as Planned Maintenance. These systems are *not*—repeat *not*—self-optimizing.
2) Eliminating repair and maintenance costs *at source*, by locating and eliminating failure causes—provided each action is financially viable from the outset.

SEACOST thus covers virtually all cost reductions which can be achieved by technical engineering methods.

The second method of eliminating failure causes, usually by equipment or system modifications, is of course well known and practised widely. Nevertheless, its scope is still largely untapped and will remain so until a systematic approach is applied. Consider the advantages:

1) Repetitive work disappears permanently.
2) Certain ship delays are reduced or avoided altogether.
3) Equipment—and therefore ship—reliability is permanently improved.
4) Reliance on critical spares, specialist help in foreign ports, etc., is reduced.

What are the principal SEACOST features?

a) Firstly, that each failure elimination can be tested for profitability before implementation. (The sums can be quite staggering in some cases.)
b) SEACOST usually pays for itself within 9 to 12 months.
c) The essential data is obtained in a very simple and painless manner—on average within ten minutes per 24-hour day.
d) The data itself leads directly to the failure cause and its remedy.
e) Accurate feedback becomes available for designers, manufacturers, owners' project engineers, classification societies, etc.
f) Detailed and consistent plant records are maintained despite crew changes, at minimum cost.
g) Most important, overhaul times and work contents can be planned, systematically updated and improved with much greater precision and regularity.

The time allocated for this talk today is too limited for giving details but here are some facts which may be of interest:

1) Savings of 34 per cent were achieved within one year in a chemical plant.
2) A steel mill engineer in Germany achieved 20 per cent savings from a similar but more limited manual scheme. (SEACOST is computer-based.)
3) In its marine application, the cost of the scheme was recovered within six months, although the time scale for marine work is inevitably longer than ashore.
4) There is evidence that German shipowners have already introduced a scheme on similar lines.
5) A recent contract awarded by one of the power generating boards indicates the trend and level of interest shown in our approach.

There is no question that the scheme works well—the data is too simple and robust for any alternative. Yet data itself is not enough. Results can only be achieved through a properly constructed system working as a complete entity, in which every function in the chain—

Data—Evaluation—Decision—Action—Results Feedback

is closely controlled.

SEACOST is commercially available as a system package. It is the practical answer for the medium-sized shipowning company and also answers several of the pertinent questions raised in several articles.

Mr. A. N. S. Burnett then gave a talk on the same subject which included points from his booklet on *Ship Operators and Maintenance—The Examination of Maintenance Costs.**

*Published by International Marine Services, 30 Baker Street, London W1.

Discussion and Authors' Replies

MR. J. C. BLAXLAND said that in his talk, Mr. Cooper had said that his planned maintenance system covered a period of five years. What was the operational cycle of a tanker? How often would she have a refit? What were the docking cycles and frequencies?

MR. R. D. COOPER said that docking cycles and frequencies appeared to depend on opinion based on experience of underwater deterioration vis-à-vis the accumulated outstanding defects or scheduled work. The five-year planning period was linked with classification society surveys.

The frequency of scheduled work was initially a matter of experience in the combination of manufacturer's and user's ideas, but there were factors common to machines, such as the relation of running hours to expected trading patterns, that helped in the determination of frequency in calendar terms.

MR. A. N. S. BURNETT said that any planned maintenance programme had to be integrated to what the ship was to do. One might spend days at sea and call at South America whereas another was all over the place. These were only guides, and the operator had to take what the manufacturer said, in each case, and tailor it to his operation. The airlines had shown this. He had to plan his planned maintenance system accordingly. This was an essential requirement. Two ships of precisely the same type could be on entirely different cycles of work, and therefore the planned maintenance system had to be different for each one.

MR. R. A. LORGE said that the important point was that the manufacturer of the equipment did not operate it. He had to write his instruction books to cover a wide range of applications. If the equipment was very large, such as main engines, the manufacturer might rely on his early experience. But this might not be the application to which the user put the equipment. The manufacturer was doing his best but his word was not infallible.

MR. R. P. DUELL said that exception seemed to have been taken to performing maintenance on a calendar basis. They were reviewing this at present as had already been said. With the auxiliary machinery and equipment on a tanker it was found that as it was running more or less continuously it was fairly easy to tackle this on a calendar basis. Obviously the most variable items (in terms of running hours from ship to ship) were main engines and cargo handling equipment, and these should certainly be approached on an "hours-run" or monitored basis.

As regarded the main repairs, they scheduled the overhauling and repairing of the main machinery—boilers, turbines—to coincide with the normal docking programme, which, at the moment was at about 16 month intervals. A few days outside these intervals were not critical and there were no great problems.

MR. BAKKE said that the costs of the components, and also basing the design on experience, were important. If given time, the manufacturer could use workshop testing as the basis for a maintenance programme compared with testing in service afterwards, and this would be more helpful. The maintenance programme should be based on operation rather than on keeping up a tight maintenance system.

MR. A. N. S. BURNETT said that he agreed entirely, and that in fact Mitsoui had gone one step further. They had produced a very sophisticated maintenance system which did not require many man-hours, and had decided to present it to the ship industry, based on their experience of some of the maintenance failures aboard. The manufacturer had the choice of trying to be ahead of the market all the time or of trying to update. They had done the first, and had offered this for sale.

MR. T. BAKKE said that the overhauling procedure for an engine should take place with such simple tools and equipment that the time needed to keep up the maintenance equipment was reduced. This was what could be foreseen.

Mr. BURNETT replied that as soon as the shipowner started to analyse the cost and where his money was going, and got the total cost for a certain operation and then fed it back to the manufacturer, this provided the basis. The airlines were very keen on this. If one air liner was one minute late, there was a meeting the next day to find out the cause, e.g. if it was due to a bolt slipping, then the manufacturer was called in the next day. They treated the manufacturer as part and parcel of the total cost process. He had to be informed right away, if he was to produce better machines. This was happening all the time. But in the shipping industry, you would be lucky to get it to him within months. The turn-round times of aircraft were going up so much, compared even with a few years ago when they were already very good. This was done at director level, to decide what could be done the next morning, and it was not left until some director arrived back from Japan.

MR. B. L. HIDE asked how much it cost to collect the cost data, regarding SEACOST, and how long did it take?

Mr. A. N. S. BURNETT replied that it was between £1500 and £2000. One did not know quite what the very large schemes cost, but this was for a single to five ship basis.

MR. HIDE said this was using cost as a trigger.

Mr. BURNETT answered that this was very difficult to say. If there were 8–10 ratings in the engine room of the ship and they were reasonably well occupied, then one could be utilizing such a scheme very well. The experience where the scheme repaid itself in twelve months was in what the owner acknowledged was his best ship—and it certainly was. But even so the failures were still found which made it profitable within twelve months. He would get the benefit for the remaining life of the ship, which would be ten years.

MR. HIDE said it seemed neat and pat, but the practicalities seemed to be enormous.

Mr. BURNETT said that if one took dry dockings, the cost savings would be very high. If one included the engineers and not the ratings, etc., it could vary. But the implementation of the scheme did not take long, and he was talking in terms of days rather than weeks.

MR. G. R. SNAITH said that on the British Ship Research Association they had been looking at some material with regard to the matter of delegated instructions. It was important that the maintainor received adequate instructions. Recently they had looked at the system used by the Ministry of Defence in H.M.S. *Collingwood*, regarding maintenance of electronic systems. This seemed to be the most rational approach in giving adequate information and pitching it to the level of the chap doing the work. Many manufacturers' documents appeared to be prepared as an after-thought of the design activity rather than as a specific part of the maintenance.

There was the problem in the U.K. at present of the maintenance costs for equipment of high complexity being very great. The Engineering Equipment Users Association were currently preparing codes of practice to give advice to manufacturers on the support documentation which they should supply, e.g. regarding fault identification, repair and so on.

The system which he had got from the Ministry of Defence had already been taken up actively, and adapted and developed by companies in the U.K., and had been applied to electronic and mechanical equipment used in this country and maintained by a wide range of ability. We had to invest in this type of support activity, although it was doubtful if one could cut the time or the cost of maintaining equipment.

Mr. A. N. S. Burnett replied that in order to determine a particular aid, it was necessary to get the focus of the component in the first place, so as to find out which out of the many components needed attention. Where did one start? One could say that one would look at everything, as it could not be done with the limited resources of the shipowner. After that, once one had concentrated on the equipment, and the components on which you need to, one could then define the problem. If it was lack of information on how to do the job, these aids must be got. Depending on how much it was costing, not having these aids, as compared with what it would cost if one did have them, it was possible to decide whether or not they were justified.

Lieut. R. Franz (Mexican Navy) said that with regard to Mr. Duell's paper, he would like to know to what extent mathematical methods, i.e. maintenance theories, regression analysis and so on, were used in the planned maintenance system employed on B.P. ships, or was this a system which allowed for prevention of breakdown failures by probability forecasting?

Mr. R. P. Duell said that they had not used mathematical methods at all in the beginning. They had used data from all the available sources, and eventually devised the routine maintenance requirements and intervals from this data. Ships' staff were asked to feed back their comments, and as reports came back they were, and still were, able to adjust maintenance recommendations if necessary. It was not felt necessary to use mathematical methods at the present time, but this might well need to be considered later.

Mr. A. R. Murrison, F.I.Mar.E., said that there used to be talk of a subject called non-destructive testing, and part of the work produced a feedback from two linked similar machines one of which was in the process of being worn out. Had this sort of information been fed into the author's planned maintenance system so as to reduce the necessity for pulling things adrift in order to see why they worked so well? Were there any thoughts in this connexion with reference to vibration analysis techniques being useful in connexion with Planned Maintenance?

Mr. Cooper replied that in setting out a brand new maintenance system vibration analysis was very useful in establishing which of, say, four cargo pumps was most worn, and should therefore be programmed first for preventive maintenance.

In conducting a vibration survey recently on auxiliary machinery they had not been surprised to find fixed tranducers under each main engine bearing housing and feeding back to a console.

This could have been a monitoring system, or a warning system sounding alarms when fixed maxima of vibration were reached. Monitoring by portable equipment could indeed give evidence of machinery states which bore on the need for stripping equipment.

Mr. Duell said that he had said that they were looking for new methods. Health-monitoring was one, of which vibration analysis was one aspect. But the introduction of these techniques needed care. In one instance—according to meter readings—a machine was shown to be in a critical state; but it was found that the V.A. equipment was recording the movement of a handrail beside the machine.

In the paper he had talked about a proven system which they had developed and were using, but there were many other ideas which might be introduced in the not too distant future.

Mr. Burnett stated that if one started this cost-analysis process, one had to ask the question "why did that occur?" The second question was: "what can I do about it?" The answer was given, and the next question was: "is there a better way?" This introduced non-destructive testing. One of the dangers was that one must not introduce these things *per se* but as they answered one's questions. One did not go mad on NDT or health monitoring, but they were used because the cost-loop asked the questions "why, when, how", and this led quickly to NDT.

In conclusion, Mr. Duell said that there were still some points raised which had not been properly answered.

Mr. Wilson had questioned the man hours shown in Fig. 1. These were only a general guide to the total time that could be available for *any* maintenance (either planned or unscheduled). Weekend and in-port work would not necessarily be planned by Head Office, but this time was available for maintenance and would indeed be used for unscheduled work if the need arose. This time had therefore to be taken into account in the estimates.

It was agreed that tanker ports frowned on work being carried out while a vessel was in the port, but this generally applied to work that would immobilize the main engines or prevent the vessel from moving.

The percentage of work done by ship's staff that had later to be dealt with by shore labour was so small that it was hardly worth mentioning. His company had found their staff were efficient and competent to carry out the work asked of them. Some levels of maintenance were scheduled to be carried out by shore labour, but in these cases it was usually of a level where the man hours would be excessive for the on-board resources, or where a shut down of plant would be necessary in order to complete the work.

There was no reason why job times could not be identified as major, intermediate and minor, except that they tried to keep a balance in the planned work over the five-year cycle. To do this it did help to have reasonable estimates of the length of the jobs.

Of course P.M. was sometimes overtaken by other events—and in such cases the future schedules of maintenance on the items affected had to be, and were, adjusted so as to avoid over- or under-maintenance.

The planning board in use on board showed the estimated manpower requirements for each job (which could be updated from previous experience). When reporting completed work they asked that the actual time taken was reported and not the estimates. They did not find that the system was used to justify a poor state of engine room—but rather the opposite, a poor state of E.R. and heavy unscheduled work were used to justify incomplete P.M. programmes. In fact if the system was working well then the state of machinery spaces would generally improve anyway.

The unscheduled work shown on the histogram was obtained from a computer printout of all work done. The areas where unscheduled work was necessary could be identified from this, and the actual report forms used as a back up for detail information. An analysis of the computer print-outs enabled a tabulation to be made listing the most troublesome items of equipment. This would assist superintendents quickly to identify problem areas.

Concerning defect reporting, minor items were dealt with onboard—the Head Office being advised of the defect at the time of the reported maintenance for its correction. Major items were advised to the Office in the form of a list of required repairs which was used to compile a specification of work to be undertaken at docking and repair periods.

In answer to Mr. Goldie, it was acknowledged that a purely calendar based system was not entirely satisfactory. This system was used because of the ease with which it could be brought into operation.

As mentioned in the paper, however, they were looking to improvements in the system, maintenance based on hours run and "health monitoring" in particular. This would obviously produce a more economic system in terms of labour and spares usage, though whether a sufficiently balanced work programme would be maintained remained to be seen. Perhaps a combination of all three aspects would be the ideal. Although one should aim to reduce the work load through more accurate maintenance schedules (perhaps based on the retrieval of historical information), they still felt that a reasonably balanced workload must have a fairly high importance.

Reporting in the early stages was not particularly good, possibly because ship's staff did not properly appreciate the requirements—and also the company was not too sure what it should be looking for. Currently however, the feedback was excellent, though it was now felt that the method of compiling and analysing historical data needed to be improved.

"Reporting by exception" had been mentioned and although this might have advantages, the present view was that they should work towards compiling complete maintenance records for any real benefit to be obtained by the system, and for new design and development.

Mr. Goldie had referred to the terminology when referring to a defect requiring repair. Although some of the terms differed they had tried to use the B.S.I. terms as a guide. In this respect the word "maintenance" was used as meaning "work undertaken in order to keep or restore facilities to an acceptable standard".

Replying to Mr. Bakke, all manufacturers were certainly most co-operative these days compared with the attitude experienced six years ago. Now it was possible to get just about any information asked for.

There was still the point about feedback to manufacturers. This hardly existed, and was perhaps an area to be looked into—how this could best be achieved.

Mr. Duell's company had found that the equipments could be used on different services and would require different maintenance patterns. The manufacturer's recommendations, as far as intervals and level of maintenance were concerned, could therefore only be taken as a guide.

Finally, he would again say that this paper had dealt with a system which was developed for their own Fleet, and which had served and proved itself over the last six years. There were new ideas being developed to improve the P.M. procedures and these should be to the benefit of all.

Related Abstracts

The application of planned maintenance to steam turbine tankers

Organizing and developing a programme for the maintenance of a unit of capital equipment is not new, it is normal procedure in industry. A maintenance policy may be quite justifiably vague in outline, as for example, the outside painting of a building every five to seven years, or it may be comprehensive and detailed, on an operating time basis, as with aircraft maintenance. Within the shipping industry, there is a very wide variety of floating equipment, ranging from passenger vessels, through cargo carriers, tankers and speciality carriers, to estuarial craft, tugs and barges. Each is designed for a specific purpose, influenced by operating conditions, and having regulations applicable to the particular trade. For each, a maintenance policy will vary to meet the conditions of service. This paper was intended as an interim report, on a study covering a plan for the overall maintenance of a fleet of ocean-going, steam turbine driven, crude oil tankers, classed with Lloyd's Register of Shipping. The tentative conclusions drawn, therefore, apply only to this group of vessels, but the general outline and certain apparent principles could be applicable to other groups of vessels.

This study was considered necessary because within the previous decade, technological development in the size of these oil carriers, and in the design of equipment, had been significant. Loss of earnings, due to fall off in speed between drydockings, and time out of service for maintenance repairs, became of increasing importance, and was related directly to the increasing size of these vessels. Shipping in general was passing through a prolonged period of low freight rates and reduced earning potential, and in these highly competitive conditions, the cost factors, within the control of the operator, required more searching analysis. Lloyd's classification requirements for surveys had been amended, based on operating experience, and this permitted greater flexibility in the planning of maintenance.

Initially, this study is intended to examine the optimum period, between drydockings, solely for bottom cleaning and painting. Taken in conjunction with a system of planned maintenance by ship's staff, combined with continuous survey of machinery to meet classification requirements, the objective is to extend the periods between withdrawal of a vessel from service, for shipyard overhaul, possibly to a maximum of 24 months, during the first eight years' life of the vessel. Thereafter, the time in service between shipyard repair periods will be regulated by boiler survey requirements. The essential need for detailed ship and machinery performance records is stressed. Tentative conclusions are drawn, and areas requiring closer investigation are high-lighted.

Appendix A gives a very thorough example of a planned maintenance schedule, with time durations specified for the various operations, and with reference to Lloyd's Continuous Survey Schedule.—*Scott, J. and Vickerstaff, H., Trans.I.Mar.E. 1963 Vol. 75. pp. 177–204.*

The deviation concept: a tool for preventive maintenance of marine power plants

This paper describes a new computerized maintenance management system aboard ship, using a continuously monitoring reference comparison technique (deviation concept). Some detailed design goals and expected results are outlined. Appendices contain some details of the machinery lists, instrumentation installation, and analysis of equipment using this concept. Future uses of the system are described. —*Kramer A. R. etc. Marine Technology, October 1972, Vol. 9, No. 4, pp. 405–418.*

Preventive maintenance of electrical machinery on board ships

This paper gives a short introduction to maintenance of electric machinery and equipment in general. Problems relating to the preventive maintenance of this equipment on board ships are then dealt with in more detail. It is well known that the costs of maintenance in general have risen sharply.

Two of the main causes for the rise in costs are:

i) maintenance work is rather labour-intensive with ever-increasing wages for those who carry out the job;
ii) the equipment has become gradually of a more complicated nature which necessitates better trained, more highly educated personnel to carry out maintenance work on this equipment.

There seems very little chance that this trend will be reversed within a measurable space of time.—*Gameren, B. A. Van, et al. Europort 73 Conference.*

Investigation into reliability of ship machinery

This report gives results of an investigation into the reliability of ship machinery, carried out over four years by the research committee organized for the purpose, as one of the activities of the Japanese Ship Association.

The investigation was not intended to pursue the cause of individual machine failures experienced on board but to know their general character in such aspects as their whereabouts, occurrence, frequency and relations with maintenance as the first approach to reliability engineering, which would be not only available for designing and estimation, but would also contribute to operational management.

Two groups of as uniform samples as possible were selected, one consisting of sixteen motor cargo ships, the other of twelve motor tankers, each of similar design, construction and age and serving on the same lines. Precise information was gathered from each ship concerning any failures of machinery and records of maintenance continuously whether the ship was in service or in dock.

The results provide a body of knowledge about failures, their kinds and occurrence under present operating conditions and maintenance, for motor cargo ships and tankers, also how man-hours could be allocated to the repair of unexpected failures of various machinery and to the routine job of maintenance. Some features of failures experienced on board have been analysed.

The authors stress the need for additional data, citing as an example the lack of quantitative information concerning the effect of fuel quality or mean effective pressure on engine failure rate. The establishment of a permanent system of gathering field data regarding failure is urged.—*Koizumi, I. and Tamaki, J. Japan Shipbuilding and Marine Engineering, 1972, Vol. 6, No. 4, pp. 5–17.*

A-mar-Z package system

Sir Joseph W. Isherwood & Co. Ltd. have launched a novel package deal ship maintenance and repair management system. Designed to provide a wider range of facilities than existing planned maintenance systems, the service offers a support bureau and the facilities of a number of technical associates acting as approved contractors. The new system, called A-mar-Z, aims to provide a service for fleet managers, by identifying the total work load necessary to maintain ships in service and applying planning techniques to ensure that manpower is deployed in the most cost-effective manner.

Many modern vesels are highly sophisticated. Technical problems, however, aggravated by external factors, have resulted in an unprecedented increase in repair, maintenance and associated off-hire costs. In some cases planned maintenance schemes have been implemented in an endeavour to bring costs back under control. From their research, Isherwoods have concluded that the majority of these schemes are failing to produce the anticipated benefits, largely from too great emphasis being placed on office-bound systems and insufficient attention being paid to the job of effectively managing the whole range of maintenance and repair activities. For example, some VLCCs spend up to 40 days out of service in an 18 month period and total costs of £600 000 during such a period are not untypical. Given full support the A-mar-Z system, it is claimed, can reduce the total repair bill of £600 000 during an 18 month drydocking interval by some 33 per cent and on the basis of their quoted costs this gives a saving to cost ratio of the order of 6 : 1. A feature is the maximizing of at sea maintenance, inspection and repairs, performed by specialized contractors when beyond ship's staff resources.—*Shipping World & Shipbuilder, May 1973, Vol. 166, No. 3881, Supplement p. 41.*

Improving the reliability of diesel engines

For some years there has been discussion, in the various branches of industry, on reliability and planned maintenance. In the case of ship operation, the reasons for this include the following:

1) Increasing capital and overhead costs, lead to improvements in the ratio of sea-time to harbour-time, so that the time available in port for maintenance and repair work is getting less.
2) Frequent changes in ship's personnel, with their different qualifications, makes it difficult for maintenance and servicing to be co-ordinated with the specific needs of the engine.
3) The increasing degree of automation and complication results in a lower overall reliability for a given reliability of individual components, and there is an increasing amount of time spent on tracing faults.
4) The requirements for high-performance engines needing as little maintenance as possible, or "maintenance-free operation", places increasing demands on the reliability of the system.
5) Regarding spare parts, to avoid tying up a large amount of capital on the one hand, and to avoid the high cost of idle time due to lack of spares on the other hand, information must be available on parts subject to wear and on replacement intervals.

A plan for increased reliability can make a significant contribution towards the solution of these matters, and the work carried out at the Flensburg establishment for the study of ship-operation technology, as far as is known, was the first empirical and theoretical investigation on the whole field of marine technology from the reliability standpoint.

In heavy machinery construction it is, as a rule, not yet possible to determine by theoretical means the reliability and wear performance of a product. Only rarely is use of a test stand possible. As a foundation for research on reliability and for the planning of maintenance there remains only the analysis of data collected during ship operation.

For collecting wear data, two systems are available: on-line monitoring and "subsequent" data acquisition.

The quickest and most accurate method is data acquisition by means of measurement apparatus for the automatic collection of certain characteristic values from the engine during operation. Such a method is, however, dependent on the development of suitable measuring equipment and the clear interpretation of the measured values.

By subsequent data-acquisition is meant the noting down of failures, repairs, and measurements of worn parts after dismantling, etc. The present-day state of measurement technology allows, in general, only subsequent data-acquisition to be undertaken, this being done by ship's personnel. As examples of information carriers, the forms developed by the MAN company may be mentioned. The shipboard records hitherto made on the operational behaviour of the engine have been integrated into the system. This has the following advantages:

a) no duplicated recording of the same data by the shipowner and engine builder is necessary;
b) comprehensive analysis, taking all available data into account, is possible, leading to maximum information density and output capability;
c) ability to compare the data obtained from different ships.

The analysis of the weak points starts with the wear and repair data. Its aim is to determine the wear performance and the life of the engine components and assemblies, and to compare the results with the design concept, the customers' requirements, and the "normal" values, determined as an average from all the available values or by comparison. The "tool" used for weak-point analysis is statistics, and the following methods in particular are important.

The reliability of an engine is dependent on *repair frequency* and on *repair time*.

"Structural analyses" of these two characteristics show the frequency and time distribution of the various components and assemblies in the total amount of maintenance work.

The "order of merit" obtained in this way for the most damage-intensive and most repair-time intensive parts and assemblies is, however, not necessarily identical with the order for the parts responsible for the overall reliability of the engine. The frequency and time analysis of the repairs must be supplemented by an ABC analysis. Examples of this could be:

A-Components: parts causing a machinery shut-down

B-Components: parts making a power reduction necessary

C-Components: parts that must be repaired within the next 100 running hours.

Frequency, time and ABC analyses provide the starting points for the removal of the weaknesses.

Failures of parts, and wear phenonmena, cannot be described by idealized and definite laws, but only by probability distributions. Distributions of this sort are called life or durability distributions. They permit the quantative determination of reliability against elapsed time, and are therefore an important characteristic for design and maintenance. Empirically derived life distributions are an adequate substitute for theoretical distributions.

The third statistical method in reliability is the calculation of parameters. It investigates which factors influence wear.

The use of this method necessitates a very considerable effort in the collection of data, since the wear of a component is usually influenced by several factors whose intensity is in turn dependent on environmental and operational conditions.

The elimination of weaknesses follows the analysis of weak points, and is a design task. In addition to repair *frequency*, repair *duration* also affects the availability of the engine; efforts must be made to co-ordinate design with the needs of maintenance, by good accessibility to the components; simple assembly and dismantling; design measures against consequential damage, e.g. by providing safety devices, and co-ordination of the lives of the components belonging to an assembly.

The technical reliability of a ship's diesel engine in service is determined by its weak points and its wear performance, and thus cannot be influenced by the user. On the other hand, the costs incurred by this technical "unreliability" *can* be influenced.

i) The changing of a cylinder liner in port, with the aid of shore personnel, takes less time than changing it at sea. Further, the repair time does not involve costs for idle time if the ship is in port for other reasons.
ii) A broken piston-ring can lead to consequential damage not only to the cylinder liner but also to the turbocharger if broken pieces of the ring reach it through the exhaust duct.

These two examples show that high costs can be avoided by an appropriate timing of necessary maintenance work (during a stay in port for other reasons) and by preventive maintenance measures (avoidance of consequential damage and ensuring that spare parts are available).

These considerations are, of course, not new, but carrying them out in practical ship-operation is made difficult by insufficient knowledge of the wear behaviour of the parts. As it is not known when a part will fail, it is changed either too soon or only after a failure. Both of these procedures lead to avoidable costs!

Planned maintenance seeks to solve this problem, by specifying a repair time which is an optimum in relation to a selected criterion. For ship operation, the following two criteria are available:

1) total costs (minimization of costs for standstill time and maintenance);
2) maintenance costs for a specified maximum risk of failure.

The practicability of the two criteria is not the same. The exact determination of the standstill and repair costs may be possible in only a very few cases, since they are dependent on the utilization of the ship and on the availability of repair personnel, etc. On the other hand, the second optimization criterion is readily usable.—*Blaeser, H. and Weertz, K.: Shipping World and Shipbuilder, December 1972, Vol. 165, No. 3876, pp. 1375–1377.*

Optimizing ship repair and maintenance costs; a systematic approach

The major factors which contribute towards a reduction in maintenance and repair work are given as sound system design, adequate commissioning preparations, operating instructions and training, comprehensive planned maintenance, spare parts availability and performance feedback. There is evidence that during the development of the first generation of V.L.C.C.'s these conditions were not always met, resulting in operating delays and loss of revenue due to the introduction of complex equipment not fully understood by the operators, and to inadequate engineering of systems' interfaces by some manufacturers. The principal objective of a planned maintenance system is "The reduction of unscheduled repair arising from component failure", and the history of merchant marine programmes shows that very few are entirely successful. It is suggested that the reasons for this are the limitation of the system to rotating machinery (and in many cases to selected units), inflexibility whereby non-scheduled repair work cannot be carried out without completely disordering the P.M. system; the management of spare parts is often not included in the P.M. system; staff commitment to a P.M. system is often low; reports submitted by senior ship's officers to shore management do not stimulate constructive responses either in the form of advice or more tangible assistance; operators often do not have a clear understanding of the large financial incentives behind a P.M. system. There considerations give rise to a list of criteria for a system and two aspects, spare parts availability and performance feed back, are discussed further. Section II considers aspects of the cost control of repair and maintenance, which is dealt with at length, cost control areas being defined and such subjects as repair contractors' bids, de-commissioning and turnaround being covered, the latter with a comprehensive cycle flow plan.—*Bunnis, J. B.: Transactions, North East Coast Institution of Engineers and Shipbuilders, November 1973, Vol. 90, No. 1, pp. 9–18.*