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Control Engineering

MARINE AUTOMATION—PRESENT AND FUTURE

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There has been a notable increase in the fitting of marine control systems in the last six or seven years culminating in the present state where a considerable number of ships either built or building are so arranged that they can be operated with the machinery spaces unattended. Such arrangements should result in certain operational savings.

In the future it may be possible to carry this one stage further by the linear programming of all activities concerned with ship operation. This will involve the use of on-line process control in the ship. Six ships are already so fitted and three research projects are currently in hand as feasibility studies.

The difficulties encountered with marine control equipment in recent years are usually associated with environmental conditions, lack of adequate testing and failure to appreciate the requirements. Reliability should be much improved by adequate type testing and this may lead to the production of standard systems.

Although the technical problems will be great the human problems may be greater, and a good deal of re-education will be necessary if progress is to be maintained.

INTRODUCTION

In the past 100 years there has been a dramatic fall in the real costs of sea transport. This has come from three sources, namely, bigger ships, more efficient propulsion units and reduction in crew numbers per ton. The tendency, in certain quarters today, is to think in terms of automation as the source of further crew reductions but the spectacular reductions in the past were caused by the change from sail to steam and then from coal firing to oil firing. Today, one crew member is, on average, required for every 115 tons of British shipping, whereas 100 years ago the figure was one man for less than 60 tons.

The application of control engineering in the marine field has sometimes been likened to the change from sail to steam. If this contains any element of truth then it may be fair to state that the ultimate development in the control engineer's mind will be the integration by automatic control of all or most of the processes concerned with ship operation. This will involve the linear programming of ship operation and maintenance together with control of spares and ship fixing.

If this is feasible then such control should result in greater output per unit of capital and per man hour, lower maintenance and a further reduction in the real cost of transporting cargo. On-line process control should result in less working capital due to better control of capital assets, stocks and purchases, more correct information regarding maintenance and greater output due to better ship fixing.

The technical problems will be great but the human problems will be greater. Operating skills will be less important, promotion ladders will be altered, management decisions will be transferred to the centre and wholesale re-education will be necessary for this change to be accepted by those concerned and to be carried out without disruption.

THE PRESENT STATE

Control equipment has been at sea in various forms for about the last 30–40 years. Since 1961, however, there has been a dramatic rise in the amount of control equipment fitted per ship. The reasons for this development have been sufficiently highlighted elsewhere and it would be pointless to reiterate them here. Sufficient to record that, at the present time, there is a considerable number of ships at sea and a large number building which are so designed that the machinery spaces may be left unattended whilst the ship is in open water.

The recording of such ships is of comparatively recent origin but, as an indication of the rate of rise in the fitting of control equipment, the number of ships classed with Lloyd's Register of Shipping and which possess a fair amount of control equipment is given in Table I.

TABLE I—GROWTH OF AUTOMATION

	Motor			Steam		
	Automated	Total	Per cent	Automated	Total	Per cent
1960	1	575	0·17	—	74	—
1961	5	509	0·98	—	52	—
1962	8	483	1·6	—	39	—
1963	6	492	1·2	—	46	—
1964	22	511	4·3	3	37	8·1
1965	150	527	28·4	15	26	58
1966	177	499	36·5	18	24	75
1967	269	503	53·5	10	11	90

A special notation in the Register Book "UMS" was introduced by Lloyd's Register of Shipping in January 1968 signifying that the ship is suitable for operation with unattended machinery spaces. In the 11 months subsequent to this date approximately 23 steam turbine ships and 205 Diesel ships either built or building qualify for such a notation. A more detailed breakdown is contained in Table II.

* Lloyd's Register of Shipping.

TABLE II: NUMBERS OF SHIPS ELIGIBLE FOR U.M.S. NOTATION (AT 10TH DECEMBER 1968)

	Ships completed										Ships under construction																	
Flag \ Country of Build	Denmark	Finland	Germany (W)	Italy	Japan	Netherlands	Norway	Sweden	U.K.	Total Completed	Australia	Belgium	Denmark	Finland	France	Germany (W)	Greece	Iceland	Italy	Japan	Netherlands	Norway	Poland	Sweden	U.K.	Yugoslavia	Total under Construction	Grand Total
Australia											1									1							2	2
Belgium												4															4	4
Bermuda			1							1						2											2	3
Brazil																2											2	2
Denmark	11		1		2	2		3	1	20			8			1					2	1					12	32
Eire																									1		1	1
Finland		4								4				1	2												3	7
Germany (W)			2						1	3						1											1	4
Greece																	1										1	1
Iceland																		1									1	1
India																1											1	1
Israel					2				1	3												6			1		7	10
Italy				5						5									2								2	7
Kuwait																				2							2	2
Liberia						1			1	2						2			2	4	1			2	1		12	14
Mexico																							1			2	3	3
Netherlands						10			1	11											3						3	14
Norway					4		1	9		14		2								2							4	18
Sweden		3	2					14		19				1	1	1					1	1		9			14	33
U.K.	1		2		1	4		2	13	23						6				5	8	1		3	23		46	69
Total	12	7	8	5	9	17	1	28	18	105	1	6	8	2	3	16	1	1	4	14	15	9	1	14	26	2	123	228
Steamships										5	Steamships																18	23
Motor Ships										100	Motor Ships																105	205

The control arrangements in ships capable of operating with the machinery spaces unattended vary considerably from ship to ship. Certain basic safety requirements must be met and in addition certain shut-down services must be provided for faults such as loss of lubricating oil, loss of water, loss of flame or failure of air supply.

It is after these essential requirements have been met that the variations between installations occur.

In the simplest installation once the basic safety requirements have been met, arrangements are such that a machinery fault is indicated by an alarm leaving subsequent action to a duty engineer.

In the more extensive installations the shipowner may require minimum interruption of services in which case, in addition to alarm indication, automatic change over to the stand-by unit is provided. This is frequently accompanied by extensive automatic logging arrangements.

Capital investment and possible financial savings are the questions which inevitably spring to mind when such arrangements are being discussed. Little or no published information on this subject has appeared. The following figures have been supplied by an old established shipowner and refer to two series of ships which have been in service for between two and three years.

Case 1

Refrigerated cargo ship, Diesel propulsion, about 8000 dwt.

With watchkeepers a crew of 32 required employing one engineer and one greaser per watch. Ship designed for unattended machinery spaces (18 hours/day) and a crew of 29.

Total cost of ship: £1·6 × 10^6.

Total annual wage bill: £90 000.

a) Extra costs involved (expressed as percentage of total cost of ship)

Propulsion control and manoeuvring equipment; c.p. propeller; bridge control, etc.	1·24
Expanded alarm system; control room, etc.	0·32
Increased automatic logging arrangements; telegraph recorder, etc.	0·30
Fire detection; extension of internal communications	0·20
Increased alarm and control equipment for refrigeration machinery	0·25
Improved paint protection	0·12
Improved mooring equipment	0·34
Flume tank arrangement	0·87
Crew comforts: swimming pool, improved furnishings, etc.	0·56
Total extra costs	4·20
	(£67 000)

b) Estimated Savings (expressed as percentage of annual wage bill)

Three greasers used for maintenance instead of watchkeeping	6·0
Engineers on day work instead of watchkeeping	6·8
Reduction in wage bill due to reduced crew	6·0
Increased reliability of machinery (not possible to assess as yet)	
Reduced upkeep and cleaning in accommodation (not possible to assess as yet)	
Total estimated savings	18·8
	(£16 900)

Case 2

Oil tanker, steam turbine propulsion, about 100 000 dwt.

With watchkeepers a crew of 36 required employing one engineer and one greaser per watch. Ship designed for unattended machinery spaces (18 hours/day) and a crew of 30.

Total cost of ship: £3·5 × 10^6.

Total annual wage bill: £119 000.

a) Extra costs involved (expressed as percentage of total cost of ship)

Bridge control of propulsion; increased capacity of emergency generator, etc.	0·49
Expanded alarm system; control room, etc.	0·26
Increased automatic logging arrangements; telegraph recorder	0·27
Fire detection; extension of internal communications	0·12
Cargo handling system; priming system, etc.	0·75
Increased cargo pump capacity; alteration to cargo and ballast lines; additional drainage in cargo tanks; flume tank arrangement; certain improvements in machinery standards	0·52
Improved paint protection	0·20
Improved mooring equipment	0·45
Lift (elevator); overhead crane	0·25
Labour saving equipment: dishwashers, cleaning machines, etc.	0·19
Crew comforts: swimming pool, improved furnishings, sound insulation, etc.	0·22
Total extra costs	3·72
	(£130 000)

b) Estimated Savings (expressed as percentage of annual wage bill)

Three greasers used for maintenance instead of watchkeeping	4·7
Engineers on daywork instead of watchkeeping	7·4
Reduction in wage bill due to reduced crew	5·0
Increased reliability of machinery (not possible to assess as yet)	
Reduced upkeep and cleaning in accommodation (not possible to assess as yet)	
Total estimated savings	17·1
	(£20 300)

In Case 1 an annual saving of £16 900 has resulted from an increased capital investment of £67 000.

If money were borrowed at the normal market rates it is probable that a net rate of interest for such borrowing, after allowance for the appropriate taxation relief thereon, may be as low as 4·5 per cent. On the basis of 4·5 per cent per annum over a period of 15 years then an annual saving of £16 900 would justify an immediate investment of £180 000 whereas the actual investment was only £67 000.

Similarly in Case 2 an annual saving of £20 300 would justify an immediate investment of £210 000 whereas the actual investment was only £130 000.

Thus the extra capital expenditure in these ships would appear to be a viable proposition.

THE FUTURE

A small number of computers have been at sea for the past few years but, so far as is known, these computers were installed for reasons other than ship operation, e.g. in some survey vessels they were installed for use by the scientific staff carried on board. In such ships where the computing ability was made available for ship operation this was by way of a fringe benefit; to the best of the author's knowledge these instruments have all been used off-line.

In 1967 and later, Hamburg-Südamerikanische Dampfschifffahrts-Gesellschaft took delivery of six refrigerated cargo ships fitted with on-line process control computers. These computers were applied to both the refrigerating machinery and the propulsion machinery.

In Japan the Ship Bureau of the Transport Ministry has authorized, as a research project, the installation of an on-line computer in a large tanker, the keel of which is to be laid in 1970.

In Norway a government sponsored research project is to install an on-line computer in a dry cargo ship of about 22 000 dwt at present being built in Japan for Wilhelm Wilhelmsen, Oslo.

In Sweden, it is the intention to install an on-line computer in a large tanker currently being built by Kockums, Malmo.

Possible areas of application in such ships could include:

a) control of propulsion machinery including combustion control;
b) logging;
c) direct digital control of a number of closed loops;
d) steering control;
e) navigational computations;
f) sequence control of cargo loading and unloading;
g) strain computations of the hull;

h) administration;

i) self testing of the computer.

The results of these exercises will be of considerable interest for the future. It may not be out of place also to mention that the cost of preparing suitable programmes may be comparable with the capital cost of the computer itself. Early estimates of the cost of preparing programmes for the areas mentioned above have varied from two to eight man-years. In addition the programmes finally prepared will have a marked influence on the size of the computer, measured in terms of core memory.

BASIC REQUIREMENTS FOR ON-LINE PROCESS CONTROL

What then are the basic requirements which must be satisfied if on-line process control is ever to be successful?

Firstly, records must be accurate. This involves the reliability of sensing devices and accuracy of logging. Extensive use of logging and analysis of the data so received should bring to light errors in sensing devices, for until these are put right it will be very difficult to improve operational standards. Automatic data logging is often regarded as the preliminary to the installation of an on-line computer but the experience of many industries has shown that the installation of a data logger may be all that is necessary to prove that operational practices can be greatly improved by more attention to the sensing devices.

The second important point is that variations between performance of almost identical machinery installations are common, not because of variations in machinery or fuel but because of variations in operational practice. To require standard operational practices would require great discipline but only if standard practices are adhered to is it possible to decide by planned experiment in what degree they can be varied with advantage.

Thirdly, standard practices for maintenance; if more accurate figures for machinery failure were logged and analysed, and standard practice regarding maintenance were laid down, the availability of machinery should be much increased. Among the points which would benefit from maintenance analysis are the re-design of items which have failed, the variation of maintenance practice based on information from other ships and the omission of wasteful planned maintenance stops which are not required. It is important to realize that an on-line computer which can save maintenance and reduce time off-hire for maintenance may be as important as one which increases the efficiency of the ship during operation.

OBSTACLES IN THE WAY

Before considering marine difficulties it may be as well to look at shoreside industry where control engineering has had a much longer history.

Some four to five years ago the Steel Company of Wales undertook a feasibility study with a view to using an on-line computer to achieve maximum consistency of its products from the hot strip mill. The sum sanctioned was £2·4 $\times$ 10^6. Of this sum only £0·85 $\times$ 10^6 was actually devoted to the computer. The remainder was devoted to improving the plant plus its existing control equipment. Thus without any computer in operation, and after the machinery modifications had been effected, it was possible to produce, with manual operation, a more consistent product than was possible before.

This pattern of studying the process and removing obstacles to efficient operation seems to repeat itself wherever the use of on-line computers is being considered. In fact it may almost be described as a by-product of the on-line computer and may be producing results equal in value to the operation of the computer itself.

Once again the sensing devices have to be reliable and the records must be accurate. The difficulties which have emerged from all plants within the Steel Company of Wales, which have attempted to use on-line computers, have been caused by the unreliability of sensing devices and the difficulty of logging all the variables which finally affect the issue without first making modifications to the plant.

This then has been the experience in an industry using control engineering techniques for a very long time.

What types of failures have occurred in the marine field and what lessons can be learned? The following lists some of the failures which have been reported from ships in recent years:

i) ultra violet flame scanner which failed to operate with an ambient temperature in excess of 50°C (122°F);

ii) oxygen analyser which failed to operate when the ambient temperature exceeded 45°C (113°F);

iii) automatic voltage regulator which failed to operate when the ambient temperature exceeded 45°C (113°F);

iv) a system of bridge control for a main turbine with the feed-back potentiometer mounted on top of the manoeuvring valve; in this state the system operated for only 2·5 days in 14 months;

v) various data loggers which failed to operate satisfactorily in the ambient temperatures encountered in service;

vi) fracture of stainless steel bellows in a level transmitter;

vii) bursting of Bourdon tubes and bellows;

viii) chain-driven tacho-generators; broken chains;

ix) failure of indicator lamps; a single lamp failure, in itself, is not an important event, but when a great number of lamps is involved and the efficiency of the display is jeopardized by continual lamp failure, this is more than a nuisance, it affects safety;

x) plastic indicator plates which would not remain adhered;

xi) air drier of insufficient capacity so that in the Persian Gulf flapper/nozzle systems were fouled up and control was lost;

xii) a control scheme which allowed the turbine to remain stopped with 180 lb/in^{2}g steam on;

xiii) manoeuvring valve spindle sheared in three ships; with this design there was a jump in steam pressure to the hp turbine (200–400 lb/in^{2}g) coinciding with the lift of the main valve;

xiv) a control scheme which allowed the Diesel to run at a critical speed;

xv) automatic control scheme for Diesel generators using unscreened cable resulting in spurious start up and connexion of generating sets due to pick-up of unwanted signals;

xvi) automatic control of Diesel generators with a test push for the alarm lamps; a switch had to be turned to "TEST" before operating the test push; the switch was badly located and not clearly visible, an engineer pressed the test push without operating the switch resulting in all generating circuit breakers opening and total loss of electrical power;

xvii) control valves installed the wrong way round and no external indication of flow provided; in one ship such a condition applied to Piston C.W., Jacket C.W. and L.O. systems and the ship was stopped for four hours whilst the causes of trouble were located and rectified;

xviii) bridge alarm panels not fitted with dimmers so that some ships were at sea for a time, fitted with paper masks to reduce illumination at night;

xix) a turbine control system which allowed both ahead and astern manoeuvring valves to be open because the position feedback originated from the bell crank layshaft position and not from the valve spindle; also because the adjusting sleeves of both manoeuvring valves were incorrectly fitted;

xx) a centralized control room fitted with air conditioning and designed for a maximum ambient temperature of 35°C (95°F). Due to the physical configuration of the consoles installed, there was no air circulation in one area containing electronic units. After failure had occurred it was discovered that certain printed circuit boards in close proximity to power supplies had a surface temperature of more than 80°C (176°F).

RELIABILITY

A study of the above list of failures would indicate that the primary causes of unsatisfactory performance fall under the following broad headings:

1) failure to appreciate the environmental conditions to which the equipment would be subjected in service;
2) lack of adequate testing to prove the design of the equipment;
3) failure to appreciate the requirements of the equipment;

Many of the hardware items which have appeared in ships in recent years have been in industrial use for a sufficiently long time to have established their reliability in such applications. It may also be stated that many of the items quoted in the previous section as having failed would fall into this category. There are some marine engineers who see no reason why such industrial equipment should not be "marinized" so that they may be applied in ships with equal success.

In the opinion of the author this is an attitude which is fraught with danger. In many cases "marinizing" is just not possible; frequently complete re-design is necessary. It is relevant to note that in the discussion to a paper recently presented at this Institute the representative of a famous firm of marine electronic engineers stated that a sum of about £250 000 had been required for research and development in order to produce a display, alarm and data processing system suitable for marine service. In other words re-design was required and not marinizing of existing equipment.

What then is required in order to achieve reliability? The basic requirements are probably as follows:

4) a full specification of the requirements of the design which must be clearly understood by everyone concerned with the production of the constituent parts and the complete end product;
5) a satisfactory design of equipment thoroughly proved by adequate type testing in order to establish its reliability under the conditions to which it will be subjected in use;
6) manufacturing processes that are capable of meeting these requirements;
7) acceptance by production departments of the responsibility for meeting the standards set by the specification;
8) a check that the equipment conforms with the specification; this is required to protect the customer, to safeguard the reputation of the manufacturer and to provide essential information regarding failure to conform;
9) instruction manuals for the equipment;
10) a study of user experience, feedback to the manufacturer concerned and rapid remedial action.

The foregoing amounts to no more than is implied by "Total Quality Control", a subject on which many papers have been written.

The evolution of the specification and the quality of the original design is of far greater importance than is usually supposed. Of basic importance to the specification is the defining of environmental conditions and of operational requirements. Only after this has been done is it possible for the designer to commence his work. It is also important to realize that it is not appropriate for the specification writer to insert clauses which impinge on detail design.

As regards environmental conditions it is most unfortunate, and a matter of personal regret to the author, that the various regulatory bodies such as classification societies, national standardizing organizations, governmental bodies and the like, have not reached agreement. The environmental conditions, particularly those relating to ambient temperatures, vibration, humidity, inclination and variations in power supplies are basic to the production of a specification. In the absence of such agreement the author can only suggest that reference be made to the marine clauses of Defence Specification DEF 133 "Climatic, Shock and Vibration Testing of Service Equipment", but omitting the clauses which are peculiar to the operation of warships, e.g. those relating to shock due to enemy action. This, at least, should provide a basis for design and type testing of the product.

As regards operational requirements, in the opinion of the author, a regulatory body can only indicate broad areas where protection, in the form of control, may be required. The detail requirements will come best from the designer of the machinery being controlled. It is interesting to note that this fact has been appreciated by at least one section of the industry; in the field of the large slow running Diesel engine standard control schemes for each design of engine are almost the rule. Such a state of affairs possesses technical competence and is technically desirable. In such cases considerable collaboration has been effected between the control scheme designer and the machinery designer; the combination of machinery plus controls has been thoroughly type tested on the test bed and not in the ship.

Such an approach enables the manufacturer to produce equipment in which inherent faults are removed before production rather than appearing after some time at sea; it should ensure that the transition from development to production will not introduce potential faults; it should facilitate the maintenance of a standard of reliability and should guard against the introduction of faults which may be caused by changes in manufacturing techniques both at the production works and with component suppliers.

Further benefits from the use of such standard products should accrue to the shipowner. The purchase price of a standard equipment should not be inflated by a high percentage of R and D costs as would be the case with a custom built or "one-off" equipment; thus it should represent better value. In addition, standard equipment should produce greater familiarity with maintenance requirements for seagoing personnel, in an owner's fleet, as well as easing the problem of maintaining depot spares by the owner's headquarters.

Accuracy of instruments is another factor in reliability. Unfortunately, there appears to be little quantitative data available on the reliability of instruments. However, the U.K. Atomic Energy Authority recently carried out an analysis of a number of transistorized equipments and concluded that instruments showing the lowest failure rates used comparatively small numbers of components. The trend is illustrated in Fig. 1.

Trends for other performance parameters such as accuracy, stability, sensitivity, etc., may be the inverse of Fig. 1. For example, if high accuracy is needed more components are usually required. Fig. 2 shows how accuracy is related to complexity for the same equipments as were used for obtaining the trend shown in Fig. 1.

Considering Figs. 1 and 2 together it is clear that accuracy and other performance parameters should not be over specified, as otherwise it may be difficult to obtain the required reliability.

Finally, redundancy must be mentioned. In this imperfect world, where nothing is 100 per cent reliable, redundancy in one form or another is the final way to improve reliability in the interests of safety. That this is widely accepted is shown by the use of redundancy in aircraft

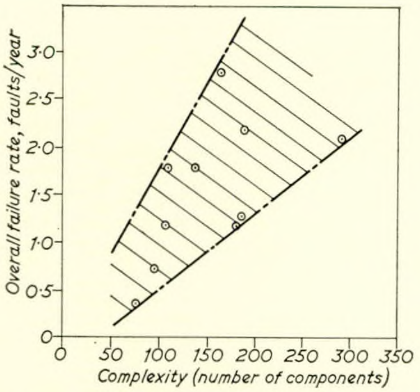

Fig. 1—Failure rates for transistor equipments

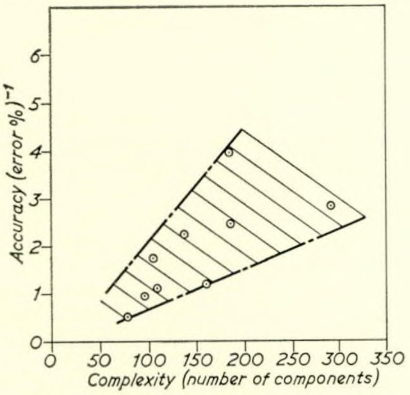

Fig. 2—Accuracy of electronic equipments

control systems, nuclear reactor safety systems and space vehicles.

At present the decision on where to use redundancy is usually made on the basis of past experience. Some equipment is regarded as so reliable and the probability of failure so small that the risk is accepted economically. As examples of this the average ship has one rudder, one main engine and one propeller. The difficulty comes in deciding where redundancy of auxiliary machinery should begin and end. Such items as steering systems, steam generating plant, electric generating plant, engine service pumps, refrigeration compressors, to name but a few, are normally duplicated.

As far as control systems are concerned, at the present time, and in ships operating with unattended machinery spaces, the final redundancy is always provided in the shape of local controls for the machinery, i.e. the ship can revert from an unattended engine room to an attended engine room. In addition, the alarm system usually contains a certain amount of built-in redundancy, e.g. a high and low temperature alarm for the exhaust gas not only protects the exhaust gas system but also, to some extent, protects the scavenge air system and the oil fuel system, since a fault in the scavenge air coolers will eventually cause variation in the exhaust gas temperature.

What type of redundancy will be required if on-line process control is installed? In the six ships previously mentioned fitted with a process computer, redundancy is provided in the shape of a permanently wired (i.e. non-adjustable) stand-by computer controlling the most essential machinery of the ship. This would appear to be perfectly reasonable. In the author's view, however, this could be regarded as one solution to a "two fault philosophy". With such a philosophy one would accept that a state of emergency or hazard can exist only after two faults have occurred. Thus, with an on-line process control system fitted as the primary means of control, redundancy should be provided in the shape of one of the following:

a) a second on-line process controller;

b) conventional remote controls as currently fitted;

c) local hand controls.

MAINTENANCE AND REPAIR

With control systems, as fitted at present, a system of alarms pinpoints machinery faults.

The fear in the minds of many marine engineers, and especially with the use of electronic circuitry, is how to pin-point faults in the control system. Most items of equipment are now built on a modular basis so that repair by replacement can be carried out. Nevertheless, the faulty module must be located before such repair can be effected.

In addition, in a control system, as opposed to a unit of equipment, there are many interfaces between sensors, transducers, measuring and comparing devices, and actuators. The fault may lie anywhere in the system. The location of the fault may best be described as fault diagnosis. Once this has been effected fault repair can be carried out with comparative ease.

With manual fault diagnosis or, what is probably more appropriate "preventive maintenance routines", the only test to apply to a system is to see that the system operates in the manner intended. Such a system is illustrated in Fig. 3.

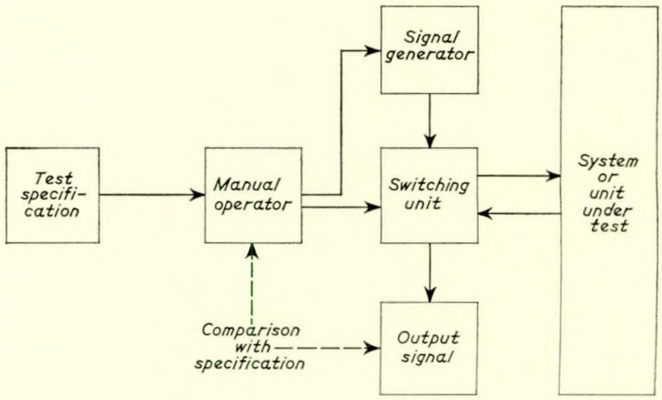

Fig. 3—Manual system testing

With a manual system a certain amount of integrity is required of the operator in that he should not interfere with circuit parameters in order to change an unsatisfactory output signal into a satisfactory output signal; also a certain amount of skill is required of the operator.

In the future, automatic test equipment may become available and a possible system is shown in Fig. 4.

Among the advantages of such an automatic test system would be:

i) reduced testing time;

ii) increased test integrity;

iii) reduced demand on skilled manpower;

iv) reduced time for fault diagnosis;

v) less human error;

vi) less interference with circuit parameters.

Undoubtedly the most difficult task will be the preparation of the programme and a possible sequence for programme production is shown in Fig. 5.

In the opinion of the author there would seem to be no reason why such automatic test equipment should not be applicable to any control medium, pneumatic, hydraulic or electrical/electronic.

Such equipment is already in use in the aircraft industry and it is understood that both Pan-Am and B.O.A.C. have reported that units of equipment tested in this manner return to the base workshops less frequently than when previously tested manually.

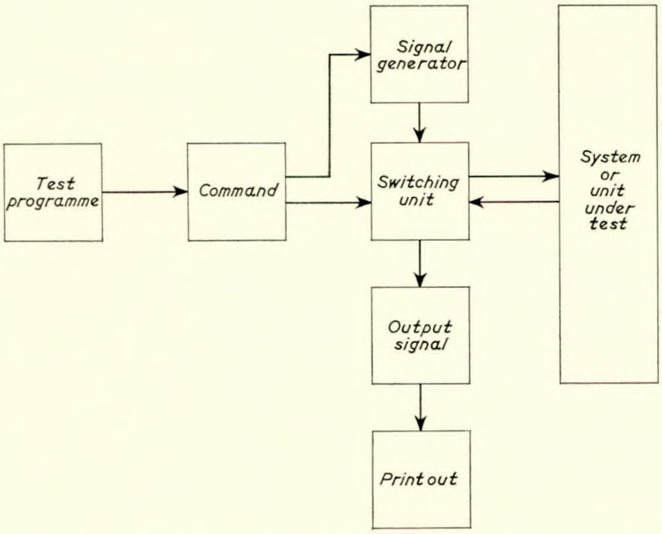

Fig. 4—Automatic system testing

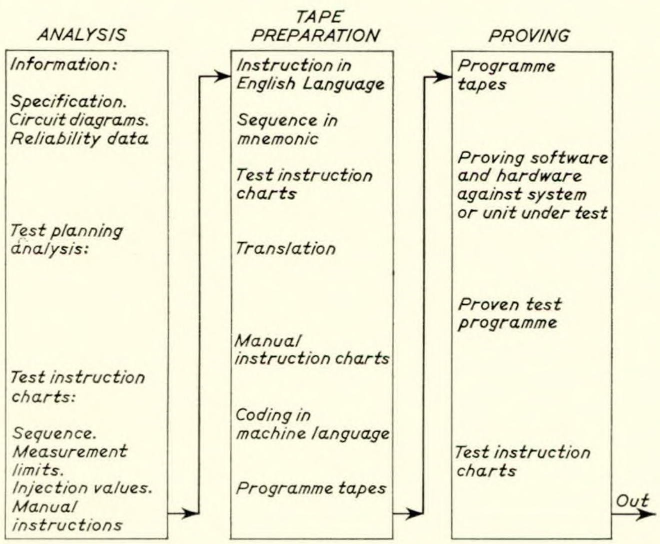

Fig. 5—A possible programme preparation for auto system testing

HUMAN PROBLEMS

One of the features of on-line process control is to move decision making to the centre of the organization. Many writers have inferred from this, that automation results in high employment for the favoured few and unemployment for the less well educated or mentally equipped. Nothing could be further from the truth. In 1964, Mr. Lyndon B. Johnson set up a committee to investigate the effects of automation on U.S. industry; this committee reported that with proper planning "automation can be a boon to working men and employees rather than a job destroyer". More recently at a T.U.C. conference, Mr. Frank Cousins said the same thing.

It seems to the author that designers of ships together with their machinery systems must realize that a cross section of the intelligence level of the community must be employed within the industry rather than picking out the high calibre and leaving the rest to rot. The author believes that this is possible for two main reasons. In the past sometimes brains have been wasted on jobs for which they were not required; secondly, some machinery systems have been so designed that brains were required to operate and maintain them when, by careful planning and design, reasonable compliance with instructions would have been adequate.

Indeed, the existence of these two features may be not unimportant factors in the current wastage rates of qualified seagoing personnel. In days of full employment men will usually do the type of work they want to do; the routine jobs will often be given up in favour of a job which represents a greater challenge. This is no more than "professionalism" and it exists throughout all industries and services today. Professionalism implies a commitment primarily to the values of a group of practitioners rather than to the values of an organization. A professional is more likely to be influenced by consideration of opportunities to exercise professional expertise, and by considerations of monetary reward, than by consideration of company loyalty. This trend is clearly evident among computer personnel at present—they tend to move from firm to firm, not only to increase their salaries but also in search of jobs which offer intrinsic satisfaction in programme writing.

Consequently the lower calibre man must be planned for in the total seagoing labour force and designers must produce equipment and machinery free from breakdown and easy to replace.

In addition, it seems to the author that large scale crew reductions may not be practicable. At the present time a tanker may take 31 days Europe to The Gulf and 34 days home. This represents about 70 days at sea. Many tanker captains have reported that their biggest problem is maintaining stable and happy personnel relations on board. For this reason a balanced community is required on board and opinion seems to be hardening that 30 appears to represent the minimum number of men to provide this in a long haul ship. The only other approach towards the solution of this problem is perhaps, the system being operated by one old-established tanker owner, by which men are at sea for two voyages and ashore for one voyage; i.e. 140 days at sea followed by 70 days ashore.

Finally, in all seagoing communities which are happy and stable there always seems to be at least one man who may be described as a "father figure". Such a man is not necessarily the captain or the chief engineer; he can be a junior officer or the chief steward. He provides stability in the community; he provides a receptive ear for men with domestic or other troubles. In most ships he appears by accident and not by design. In ships of the future it will be well to produce him by design; this will involve training in leadership for future officers.

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