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Presidential Address

MARITIME ENGINEERING AND THE MICROPROCESSOR

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Bryan Hildrew, now in his second year of office as President of the Institute of Marine Engineers, began his engineering career in 1936 as an apprentice at the North Eastern Marine Ltd, Sunderland. He studied initially at evening classes and subsequently full time at the Technical College, obtaining an external degree at London University. On completion of his apprenticeship he joined the Royal Navy and spent five years in sea-going appointments. Returning to England in 1946 he attended City and Guilds College carrying out research on the temperature stressing of turbine rotors and was awarded a Master's degree.

In 1948 he joined Lloyd's Register of Shipping and spent eight years carrying out field investigations into failures in ships and their machinery and measuring static and dynamic strain in heavy industrial plant and large steel structures. In 1956 he was seconded to the nuclear submarine project team first at Harwell and subsequently at Bath.

On his return to Lloyd's Register he established the computer department and in 1961 was appointed Principal Surveyor in charge of the Engineering Investigation Department. He succeeded Mr H. N. Pemberton as Chief Engineer Surveyor in 1967 and in 1977 became the Managing Director.

He is a founder Member of the Fellowship of Engineering, a past President of the Institution of Mechanical Engineers and was Chairman of the Council of Engineering Institutions in 1981–1982.

His involvement with the Institute began as a student member in 1940, and his association with world shipping has enabled him to appreciate the help and enjoy the company of Institute members in many countries.

Maritime Engineering and the Microprocessor

Historically, maritime engineering has evolved by accepting and adapting to its environment new technologies as they have developed. The address assesses the implications of utilizing microprocessor-based systems in the marine environment and reviews potential applications in the context of the ship and the offshore platform together with their associated machinery and equipment. The need for the engineer to accept such developments is underlined. The additional expertise required must be mastered and added to the many other facets of technology which will constitute the future maritime engineer.

INTRODUCTION

History and our individual experience as engineers show that most development will ultimately require adjustments to accommodate to it; and sometimes, when such adjustments are resisted, the consequence is disaster to individuals, to organizations and even to empires. In our particular world of maritime engineering, we should remember that the evolution from sail and wood to steam and steel, apart from creating maritime engineers, destroyed those who resisted. The marine engineer in his turn has shown a capacity to adapt as his industry has moved from rivetting to welding, from steam to internal combustion, from manual control to automatic control of machinery etc. All developments in the modern ship have resulted, and are resulting, in a greater variety of equipment on board.

It is the engineer's lot to be directly associated with such developments on land and at sea and to assess them for performance, safety and reliability. However, in judging the desirability of technological change and in conforming to the tradition of his predecessors by embracing such advances, he must make sound cogent judgements – thus avoiding the Scilla of unthinking opposition and the Charybdis of naive acceptance. Judgement must, of necessity, be made taking cognisance of technical feasibility and financial viability. Both of these requirements require a capability in terms of education, training and mental flexibility to understand the new technology, to assess its advantages — and its disadvantages — and to judge its potential applications and the effect it will have upon maritime engineering.

The development of the microprocessor in electronic engineering and its impact upon all facets of mechanical and electrical engineering are proving to be a watershed; and on that watershed is a signpost which indicates that the professional maritime engineer needs to add a further competence to the many-faceted talents which are required to design, build and maintain the very varied structures which operate on, over or under the sea. Good engineering combines the qualities of common sense, good economics and elegant simplicity. Significant improvements in the latter two qualities are often found by stepping outside the boundaries of conventional engineering practices, which have evolved through optimization rather than by innovation. Many developments in engineering have been consequent upon embracing ideas born in parallel disciplines. Taking advantage of such new techniques may involve re-tooling and re-education of large sectors of an industry. It is only by such adjustment and adaptation that an industry can survive and sell its products and competence in the world market-place.

It is relatively easy to summarize the development of maritime equipment. If we take steering gear as an example, the technology has advanced from simple manually operated tillers, through automatic electro-hydraulic systems, to the complex micro-based automatic dynamic positioning systems we have today. This technology could feasibly continue to advance to automatic navigation and berthing systems and lead eventually to the totally automatic ship. Strong economic reasons have been at the root of all past developments and will continue to be so in the future. The engineer needs to understand these economic pressures and he ignores them at his peril.

IMPLICATIONS

The principal features of microprocessor-based systems are size, speed of operation and standardization of hardware. Each of these features has advantages but it is also necessary to accept attendant disadvantages.

Size

The small size of the semiconductor components (chips) in a microprocessor system is well known. Even when all the necessary packaging, mounting and connection of components are included, together with stabilized power supply units, the total hardware assembly is only a fraction of the volume of a system executed in 'traditional' technology. A similar reduction in weight is also achievable.

Generally speaking also, the loads imposed on the power supplies of micro systems are less than those for other types of system, but in some cases there may be additional incidental requirements such as local air conditioning. The low energy level of signals within a micro system renders it vulnerable to the effects of electromagnetic interference (EMI) but measures can be taken to protect it and there are well-established protection techniques available to the system designer when required.

The small size of units allows them to be installed close to the machinery being controlled or monitored. Thus some of the control, alarm or safety functions can be distributed away from the central control station, so that they are not all at risk from a single hazard such as a fire or flood. A distributed system also has the advantage of requiring fewer long cable connections than does a centralized system and thus material and installation costs, and potential repair costs, are greatly reduced.

Speed of operation

The cycle times for the various microprocessor operations are measured in terms of microseconds. Many measurements can be taken and calculations made in each second. This capability can be further enhanced by combining together more than one microprocessor. With a distributed system, for instance, much of the signal processing can be done by the local units, thus reducing the work-load of the central unit. It is the speed of operation of microprocessors and their interfacing devices which allows them to communicate quickly with each other over fibre optic, cable or satellite links. Data are transmitted as a rapid series of pulses which are generated at the transmitting unit and decoded at the receiver.

It is this ability to multiplex data from many sources into a single link which gives rise to the reduction in cabling costs. It may be found financially viable to install micro systems solely for the purpose of multiplexing control and instrumentation signals where cable runs would be long with many bulkhead penetrations.

The high operating speed of microprocessors has a disadvantage when system fault-finding is required. Sophisticated test equipment, such as high speed oscilloscopes and logic analysers, is necessary. A preferable alternative is to incorporate self-testing routines into the system's program but this may result in a considerable increase in system complexity.

Standardization of hardware

The feature of microprocessor-based systems that has the most far-reaching consequences is the general purpose nature of the standardized hardware. This results in low hardware costs, since the chips are made by the million for use in domestic and entertainment equipment. As the digital hardware cost may account for a small proportion of the system cost, enhanced reliability may be achieved without greatly increasing the overall cost, either by redundancy arrangements or by specially selected components.

In order to be able to standardize the hardware, the manufacturers have to design it to be highly versatile. The functions carried out by a particular micro system are determined by its software program. This allows for great flexibility in the design of the system, and ease of adaptation to incorporate new functions or to change set points as the need arises. Because of this adaptability, steps have to be taken to ensure that system modifications can only be made by qualified personnel.

The cost of developing programs for particular applications of microprocessors can be very high and where the size of the market for the specialized system is not large, as is the case with most marine systems, the unit cost of the software may be prohibitive. To overcome this problem, the programmable logic controller (PLC) has been developed. The concept of these devices, available from several manufacturers, is that all the necessary functions of a general purpose control system have been pre-programmed into them so that they need only to be called up in their required order and allocated to the appropriate machinery signal connections to configure a particular application. PLCs are usually designed so that they can be programmed by control system designers without previous digital system experience.

The versatility of a microprocessor-based system enables many extra features to be designed in. A machinery control system could also incorporate self-test facilities such as cable continuity and input signal validation. It also becomes possible to display much more data about the process under control, such as historical parameter data (trends). Automatic optimization of fuel consumption or other variables could also be included. Because of the complexity of micro systems it becomes very difficult to test them adequately. Systems may be shown to perform correctly in response to expected input conditions, but difficulty arises in trying to prove that the system will not maloperate as a result of some unforeseen combination of input conditions.

The complexity and relative novelty of micro systems necessitate special training for maintenance personnel, unless systems are designed with internal self-test facilities which can locate hardware faults for repair by replacement. The stock of spares required to implement such a maintenance policy can represent quite a large investment but, if the same type of hardware is installed to perform several functions on the same vessel, one set of spares can serve several systems.

Having said this, the rapid development of microprocessor technology brings to the fore one of the main disadvantages that the engineer as an end-user has long had to cope with in the field of automation. Manufacturers have to remain competitive, which requires them to keep apace with changes in techniques and design methodology. Consequently, it becomes necessary for them to change their equipment as improvements are made, so rendering previous equipment obsolete. In these circumstances the end-user is faced with the major problem of obtaining adequate spares for equipment which is no longer manufactured. The time-scale for such obsolescence can be frighteningly short and, with today's rate of development, cases have been recorded where equipment has become unavailable in as little time as 2 years.

Rules and regulations

Rules and regulations play an important role in all aspects of marine engineering in defining standards of workmanship and safety. Contrary to popular belief, Rules are not formulated to be restrictive but rather to provide the basis of a sound engineering approach to construction and operation.

As yet, there are no IMO or IACS requirements relating specifically to programmable systems. Lloyd's Register of Shipping is at present augmenting the current Rules for Control Engineering Systems. The purpose of the new Rules will be to supplement the existing general requirements for control, alarm and safety systems by addressing aspects unique to programmable systems. These are principally the need for protection of data and programs from loss of power and unauthorized alteration, and the provision of fault location facilities to enable maintenance to be carried out without specialist training. The 'single fault' philosophy basic to the Society's present control engineering Rules is expressed in the requirement that system design should be such that control, alarm and safety functions for any item of machinery should not be able to fail simultaneously as a result of a single hardware or software fault.

APPLICATIONS

Microprocessors will find many applications in the shipping and offshore industries, from the design and construction stages through to the operation of the ship or installation. Their impact will be felt not only in terms of engineering technology but also in areas which utilize the engineer's management ability and sea-going skills.

Micro-based systems are already rapidly gaining acceptance in the design and construction stages and include:

(i) Design aids from initial conception.
(ii) Design analysis for performance, manufacture and cost.
(iii) Production of drawings.
(iv) Control of manufacture with feedback to management regarding status of the manufacturing process, stock control etc.

The technology to provide such systems is already available; it is the application of the technology which lags behind, and major efforts are now being made to rectify this situation. The constraints which delay the introduction of these systems to our industry are the need for re-education, changes in working practices and the cost of their introduction. It is the responsibility of the shipbuilding industry to ensure that the advantages which can be realized in terms of optimized design, performance and cost of the finished product are not outweighed by the disadvantages.

The application of micros to automated machine tools and welding processes etc. is well established in our industry and is largely taken for granted. The next logical stage would be the introduction of robotic techniques to the manufacturing process. This might well prove to be difficult, since we are not generally involved with repetitive processes which lend themselves more easily to robotics; however, if we dismiss the possibility out of hand at this stage of the technology, it is highly likely that in the future we will once more have to run very fast to stand still.

Figure 1 shows conceptually those areas where micro-based systems are rapidly gaining acceptance.

(i) Navigation: weather routing; traffic control.
(ii) Communications: distress signals; data transfer.
(iii) Administration: spares control; crew wages; cargo booking; maintenance and repair scheduling.
(iv) Cargo control: trim and stability; shear forces; bending moments.
(v) Machinery control and monitoring: alarm and safety systems; optimization of machinery efficiency; condition monitoring; survey scheduling.

It is this wide spectrum of shipboard use that will expedite the wider introduction of the microprocessor, which will result in economic advantage, and it is the last itemized group which is of major interest to the maritime engineer.

Machinery control

Currently there are ships at sea in which their well-proven analogue control system has been replaced, or is being replaced, by a digital system. In the process of so doing, a considerable size reduction is achieved.

An actual installation, shown in Fig. 2, demonstrates this size reduction quite dramatically. The reason that the vessel has both systems fitted is one of caution. The original analogue system was retained in order to provide well-proven back-up until sufficient experience had been gained with the new system.

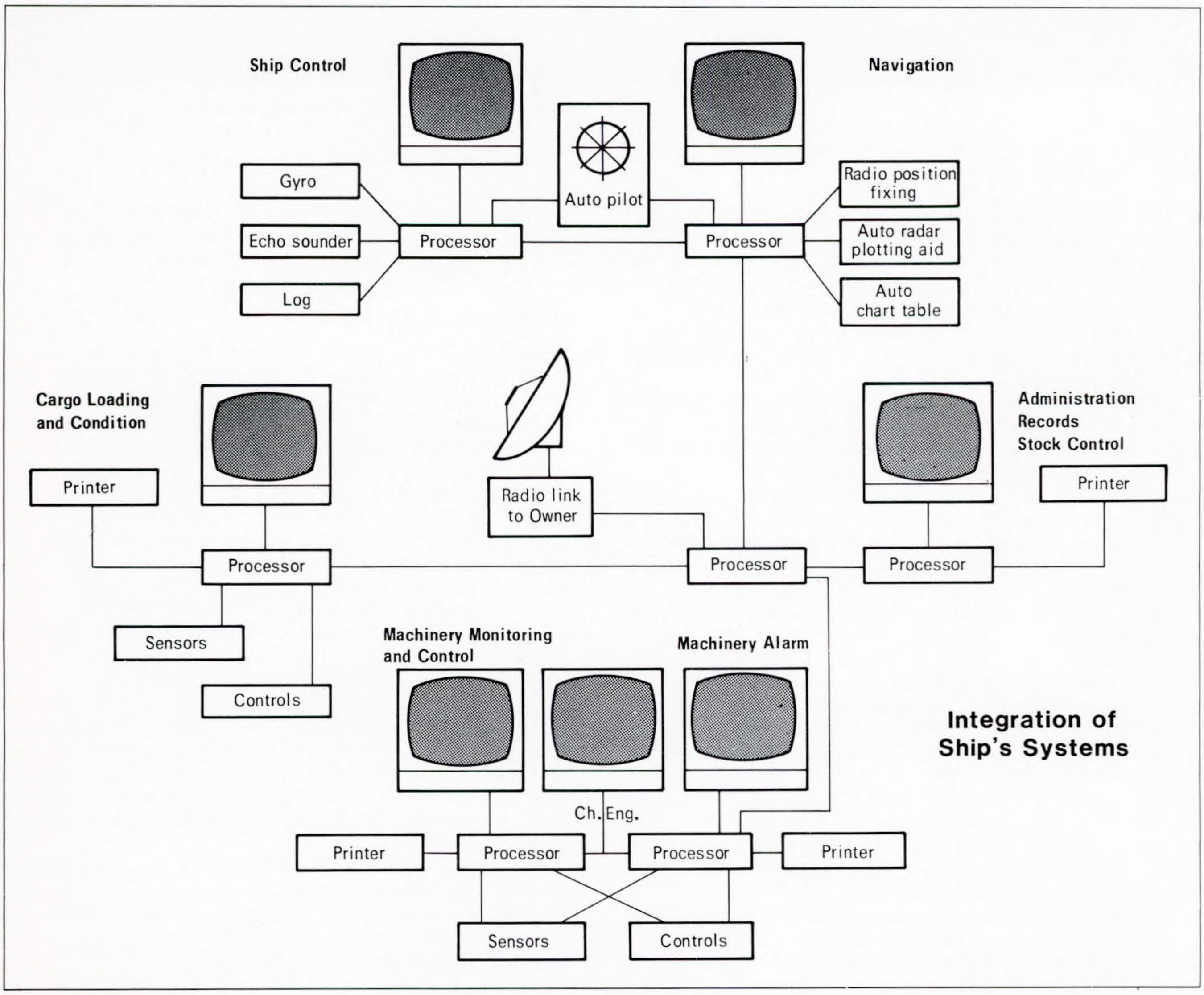
The similarity to analogue information can be seen in the use of readily familiar indicators, which in this system are produced by light emitting diodes (LEDs).

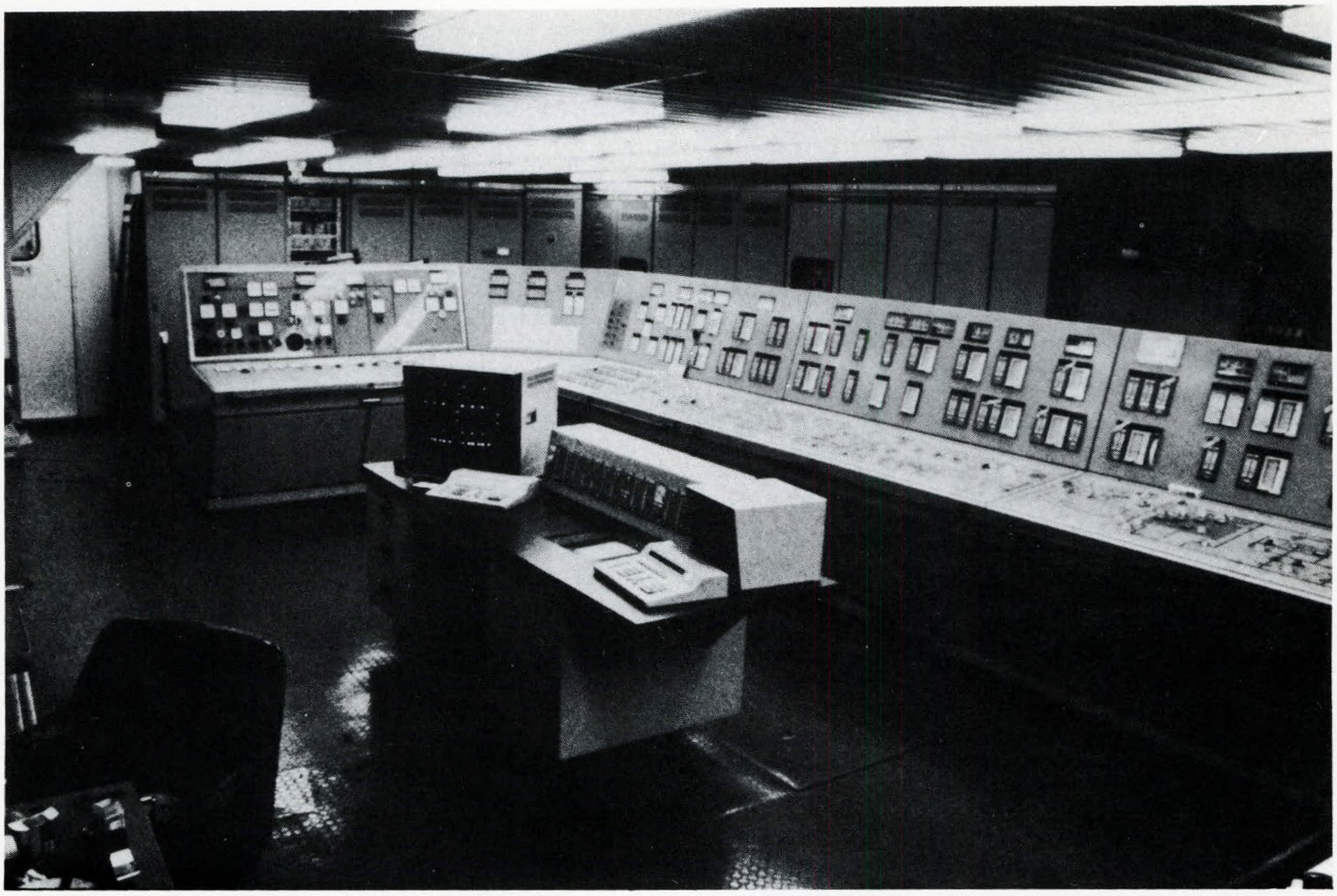
An advantage of the digital system, besides reduction in size, is its ability to make a programmed transition from throttle to boiler pressure control modes for enhanced fuel economy. This permits the turbine throttles to be fully open while full away to minimize losses, and control of the turbine's output to be maintained by means of boiler pressure control.

Machinery monitoring systems

Microprocessor-based systems are made by several manufacturers of machinery alarm systems. These monitor all the required parameters of the main propulsion and auxiliary machinery and may be either centralized or distributed systems. Extension alarms operate on the bridge and in the duty engineer's cabin in the event of a fault.

FIG. 1 Integration of ship's systems





(Courtesy of Shell International Marine Ltd)

FIG 2 ST *Lottia:* boiler and turbine control consoles

The inputs to these systems may be on/off signals from pressure, flow or temperature switches, or analogue voltage or current signals which are converted to digital form by the system, which also holds the alarm threshold set-point data.

It is the ability of these systems to compute data trends and give a diagnostic analysis of machinery performance which leads to the more exciting concept of condition monitoring and predictive maintenance techniques.

Condition monitoring systems can be on-line, depending on the extent of machinery to be monitored. A typical on-line configuration consists of a data acquisition system: sensors and processing modules for validation and signal conditioning. Validated data are fed to the central processing unit for comparison with preset performance curves and maintenance limits and are then entered into store. Excursions from the preset limits of acceptability indicate that maintenance action should be taken.

The central processing unit is capable of further diagnosis. It can indicate the possible causes of machinery deterioration and highlight areas where maintenance is necessary consequent to gradual deterioration. The allowable running time before maintenance action is necessary may also be computed.

One of the most valuable tools in a condition monitoring programme is vibration analysis. As an example, the vibration signature of an HP forward bearing of a main propulsion turbine will probably show the first and second order vibrations of the rotor. The recorded values are compared with the severity criteria of Verein Deutscher Ingenieure (VDI) Standard 2056 to determine whether or not the equipment is within a good operating condition range.

LR has developed survey procedures using a combination of condition monitoring and preventive maintenance to provide greater flexibility for owners and a more cost-effective survey format. These procedures reduce the number of surveyor's visits and permit owners to open out machinery when the condition monitoring data indicate that it is necessary. They are no longer tied down to fixed survey times.

High integrity safety systems

Examples of microprocessors being used in high integrity safety systems can be seen in offshore emergency shut-down (ESD) systems and fire and gas detection systems. The high degree of reliability required of such systems is achieved by two courses of action, component selection and system design.

Components of enhanced reliability are available which have been produced for military applications. These have been subjected to a 'burn-in' process by operation for several hours near their upper temperature limit. This acts as an accelerated life test and rejects the components which would fail in the initial stages of equipment operation. Integrated circuits selected by this process cost typically three times the price of unselected devices but may have reliability figures 100 times better.

System design for high reliability involves the provision of redundant systems — duplication or triplication. In the fields of nuclear and space technology, multiple redundancy is sometimes taken even further; and in defence applications some systems avoid the possibility of common-mode hardware and software failures by employing microprocessors of different types, programmed by different teams of designers for each subsystem.

Fire and gas detection systems for offshore installations and units are large and complex and are therefore obvious areas in which microprocessor technology can be applied to advantage.

Fire detectors have in the past all been wired back to a central monitoring panel, either individually, or collectively as zone loops. Similarly, gas detectors have also been individually wired. As several hundred detectors are typically involved, it can be seen that considerable weight and cost savings could be made by installing local signal processing units, each in the nearest safe area outside the zone being monitored, with the signals multiplexed to the central panel via duplicated links.

The local units of such a distributed system may also be programmed to perform safety functions, such as the shutdown of the fuel supply or the ventilation equipment and the release of fire suppressant automatically when their detectors are activated. This can be made independent of the central panel so that each zone is autonomous, thus avoiding the risk of a total system failure resulting from a single fault.

In order to avoid false alarms, particularly where fire or gas signals are inputs to the ESD system, multiple detectors may be installed with a voting system. Two out of three signals will give an alarm; one out of three indicates a system fault. Some flame detectors may need to be installed in multiple combinations in order to eliminate false alarms due to background radiation sources. Microprocessors are ideally suited to the task of making the logical decisions required by multiple detector systems.

It is now possible to pin-point which fire detector on a particular zone loop has been activated. This is done by means of circuits in each detector base unit which emit digitally coded address signals unique to each device. This enables detailed information of the installation to be displayed at the fire control station, showing on a visual display which fire or gas detector has been activated and what subsequent safety functions have been put into effect.

The ESD systems for oil or gas production platforms must be high integrity systems. Failure to operate in an emergency can put the whole platform in jeopardy; but spurious shut-downs, due to maloperation of the system, risk the loss of considerable production revenue. They are invariably duplex or triplex systems.

An ESD system has to make logical decisions on its input signals, determine the level to which any shut-down must be carried out, then perform the appropriate sequence of operations and monitor their results. These are all functions well within the capabilities of micro systems.

Overall, in the past decade, the utilization of the computer for offshore work has grown and its functions presage further developments in the maritime industries. Because of the high cost of transporting men to offshore installations and of maintaining them offshore, as well as the hazards and problems of evacuation in an emergency, the trend is to control operations and functions remotely and to reduce offshore manning to as low a level as possible.

Dynamic positioning

More advanced machinery control systems can be seen in dynamic positioning applications, where the use of manual control would be quite ineffective for vessel station-keeping in critical operations such as diving.

Effective dynamic positioning requires simultaneous control of multithruster installations in response to inputs from position reference systems (e.g. taut wire, hydro-acoustic position reference systems, microwave (Artemis) systems, radar systems etc.) and environmental sensors such as gyrocompasses, wind sensors and vertical reference units. In fully automated systems, LR Class Notation DP (AA), electrical power management requirements are also controlled in response to thruster loads.

Dynamic positioning systems complying with DP(AA) have fully duplicated control computers, reference systems and environmental sensors, all arranged so that the standby systems can take over control without manual intervention in the event of a failure of the on-line equipment. The use of microprocessor-based systems makes this redundancy economically viable and enhances the safety of DP operation.

CONCLUSION

The Institute of Marine Engineers was founded in 1889 by men who spent the greater proportion of their working lives following the profession of 'sea-going engineer'. However, over the past two decades we have seen a steady decline in the number of engineers required afloat to service the world fleet, despite the present wide variety of ship types and the increasing complexity of equipment being fitted to ships to ensure a more economic unit.

Such developments require increasingly sophisticated control in order to safeguard and exploit the large investment and to perform the numerous tasks inherent in the total ship operation. Many of these tasks can be most effectively and accurately undertaken by a computer and it is inevitable that its fullest exploitation will include monitoring the integrity of the machinery. The potential to monitor and record the status of a ship from the land will further reduce the number of seafarers whilst demanding a wider competence from those who remain. At the same time, exploration for offshore oil and the land-based technological support required for the developing infrastructure are providing alternative employment for the qualified maritime engineer.

Thus the source of the Institute's membership is changing as the profession adjusts to different working practices and it is necessary for our members to recognize this. Historically, we have adapted to new and developing technologies in the maritime environment. The introduction of the microprocessor is but one more step in the development path up which we have no option but to go.

ACKNOWLEDGEMENT

I cannot close without thanking my colleague Mr J. L. Buxton for the considerable assistance given in assembling this address.

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