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# THE PRESIDENTIAL ADDRESS

of

G. McNee, B.Sc., C.Eng., F.I.Mar.E.

Read on 4 October 1977, at the Institute

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**G. McNEE, B.Sc., C.Eng., F.I.Mar.E.**

After attending Allan Glen's School, in Glasgow—the former pupils of which school would read like a marine engineer's Who's Who—Mr. McNee combined an apprenticeship at Barclay Curle's North British Engine Works with a degree course at the University of Glasgow from which he graduated with a B.Sc.(Hons.) in mechanical engineering.

On completion of his apprenticeship he went to sea as an Engineer Officer with the Union-Castle Mail Steamship Co., and obtained the B.O.T. First Class Certificate. He was appointed Assistant to the Superintendent Engineer, The Union-Castle Mail Steamship Co., employed on passenger and cargo ship operation and new construction, together with work carried out in the company's repair works at Blackwall. Subsequently Mr. McNee became Superintendent Engineer at London and then at Southampton where he was responsible for supervising repairs to the company's Mail vessels.

When his company merged with Clan Line Steamers to form British & Commonwealth Shipping Company he returned to London as Superintendent Engineer, Union-Castle vessels, supervising the operation of all the Union-Castle vessels. Some seven years later he was appointed Technical Manager, British & Commonwealth Shipping Company, to supervise the operation of the combined fleets of all Group companies. In 1972 Mr. McNee accepted an invitation to join the boards of Clan Line Steamers Ltd. and the Union-Castle Mail Steamship Co. Ltd.

In June 1976 he retired from service with British & Commonwealth Shipping Co., but was invited to remain on the board of Union-Castle Mail Steamship Company.

In July of the same year he was invited to form a new British ship management company, which has no connexion with British & Commonwealth, and he is now Managing Director of Newgate Shipping Company Ltd.

It will be seen from the foregoing that Mr. McNee brings to the office of President a very wide range of technical and managerial experience. His knowledge of Institute matters is also extensive. Since joining the Institute in 1960 he has been active on Committees—particularly the Membership and By-Laws Committees and the Technical Committee. He has served on Council from 1972 to date, being elected a Vice-President of Council in 1975, and Deputy President of the Institute in 1976.

# PRESIDENTIAL ADDRESS

*of*


## G. McNEE, B.Sc., C.Eng., F.I.Mar.E.


Amongst the celebrations of this Jubilee year I hope that one sad note has not escaped your attention, I refer to the disappearance of the South African Mail Service.

This service has been in existence since the 15th of September 1857, when the *Dane* sailed from Southampton bound for Cape Town, where she was due some forty-two days later. From that day on, despite vicissitudes of the companies involved, the service has continually improved its standard of service and reliability and it has only been wars which have interrupted its steady progress.

Whilst the operation of such a service has been a team effort, a considerable part of its success has been due to the effort of the marine engineer, and, with the ending of the service to which he has contributed so much, some record of this service should be recorded in this, his professional Institute.

On this occasion the record can be no more than a brief outline of milestones passed over the one hundred and twenty years of operation but, even so, it can show the tremendous change which has taken place, the ability of the marine engineer in the design office to initiate change, and the ability of the marine engineer on board ship to adapt to that change.

Table I shows an outline of the development in size of vessel and, where possible, brief details of typical vessels in order that the reader can appreciate the changes which have taken place over the years.

In 1842, as is the case today, coal was expensive and difficult to obtain and a company, the Southampton Company, was formed to transport coal from the coalfields to Southampton. Later the company changed its name to the Union Steam Colliery Company and again to the Union Steamship Company.

The company built five ships which were named *Union, Briton, Saxon, Norman* and *Dane*—names which were to figure frequently over the next seventy years. Although the vessels were steamers, they also had sails and were rigged as schooners with square rig on the foremast.

The advent of the Crimean War removed the need for the use of these vessels in the intended service and after war service the company, which was now named the Union Steamship Company, tendered for the operation of a mail service to the Cape and the tender was accepted.

This contract demanded a monthly service out and home with a passage time of not more than forty-two days from Southampton to Cape Town. The only two vessels which could hope to meet these conditions were *Dane* and *Norman* and even they could not hope to meet the time without the use of sails in addition to their machinery. The company, therefore, purchased three other vessels which were named *Phoebe, Celt* and *Athens.*

Particulars of the vessels are scarce, but it is known that *Celt* was built at Lungleys of Deptford and was engined at Summers and Day, at what is today probably the site of Vosper Thornycroft's Northam Yard. The engine ran at about thirty-six revolutions per minute and was geared up to the propeller shaft. The bunker capacity was sufficient for about forty-five days' steaming which would indicate a consumption of about eleven tons per day as the bunker capacity was about five hundred tons.

The first vessel specifically designed for the Cape trade was the *Cambria* which came into service in 1860. Sails were still carried. Again the vessel was built at Lungleys and engined at Southampton.

It was about this time that the use of superheated steam came to the fore. Lamb and Summers developed their quaintly called superheating apparatus which was extensively used by P & O. and the Union Steamship Company (Mr. Lamb was the Superintendent Engineer of P & O.)

It was also about this time that the use of compound steam engines came into vogue. The original patent for Hornblower's compound engine was dated 1781, but it was not really developed for marine use until the 1860's. The marine development was under Elder and Randolph's patent of 1853. The two leading shipowning companies using this machinery were P.S.N.C. and P. & O.

TABLE I

| Year | 1855 | 1857 | 1860 | 1882 | 1891 | 1898 |
|---|---|---|---|---|---|---|
| Vessel | *Dane* | *Celt* | *Cambria* | — | *Scot* | *Carisbrooke Castle* |
| Length (feet) | 165 | — | 245 | — | — | 485 |
| Gross Tonnage | 530 | 514 | 1055 | — | 6884 | 7594 |
| Number of screws | 1 | 1 | 1 | 1 | 2 | 1 |
| Engine Size and Type | — | trunk 34" x 34" / 90" | — | compound 50" x 90" / 60" | Triple 34½" x 57½" x 92" / 60" | Quadruple 35¾" x 51¼" x 73½" x 105" / 69" |
| Horsepower | Nominal 60 | — | Nominal 130 | i.h.p. 4000 | — | i.h.p. 8500 |
| Number of Boilers | — | 1 | — | 3 D.E. | 6 D.E. | 3 D.E. 2 S.E. |
| Boiler Pressure lb/sq. in. | — | 12 | — | 80 | 170 | 205 |
| Speed (Knots) | 7½ | 9 | 10 | 12 | 18½ | 16¼ |
| Number of Crew in Engine Room | — | — | — | — | — | — |

S.E.=Single-ended boiler

The first mail contract expired in 1862 and it was followed by another covering the same monthly service, but the passage time was now to be thirty-eight days and as trade with South Africa increased the service was altered to fortnightly in 1868, which was in time for the Diamond Rush which was in full swing by 1870.

During this period there had been some competition from a short-lived Diamond Line, the Cape of Good Hope Line, and more serious competition from the Cape and Natal Line. It was due to the financial difficulties which the latter company experienced that provided for the entry of Castle Mail Packets Company into the service. This was an already established company trading to India and it was now to provide serious competition to the Union Company.

In 1872 Castle Packets chartered the *Penguin* which made the passage in twenty-five days and later in the same year the first vessel in the Cape trade with a Castle name—*Walmer Castle*—entered service. In 1873, *Windsor Castle* entered service and made a passage of twenty-three days.

The competition was such that, when a new mail contract was negotiated in 1876, the service was divided between the two companies, each taking alternate sailings. The passage time was now reduced to twenty-six days and, later in the same year, the first Castle Line vessel designed for the trade—*Dunrobin Castle*—entered service and immediately broke the record held by *Windsor Castle* by twelve hours. *Dunrobin Castle* was followed by *Balmoral Castle, Dublin Castle, Warwick Castle* and *Conway Castle.*

The "Castle" colours of dove-grey hull with red funnel with a black top became established about this time and the subsequent change from dove-grey to lavender for the hull took place about 1900.

By 1882 Castle Packets were building compound engines of 4000 i.h.p. at John Elder's on the Clyde—later to become Fairfields. This fact is shown in Table I, but as some of the vessels were not necessarily used in the mail service, no vessel's name is shown in the table.

Even in those early days, the ground work was being laid for design for efficiency and easy maintainence which was essential to provide the reliability of such a service. This was to continue throughout the life of the service and it is interesting to observe the following requirements:

H.P. piston valve. L.P. slide valve.
Crankshaft in Vickers steel in two identical halves.
Spare half shaft with template bored couplings and tried in both positions.
Main bearings lined with Stones No. 2 whitemetal, the bottom halves being renewable without lifting the shaft.
Connecting rods and tunnel shafting to be forged from best rolled scrap iron. Tailshaft hollow, 18 inches outside diameter and 10 inches inside diameter.

About 1886 an early model of the recently developed triple expansion engine was fitted to a small Union Line coaster, the *African* and the result was such that both lines began to triple their existing compound engines. The first vessel to be converted was the Union Steamship Company's *Moor* and it was noteworthy that at the same time full electric lighting was fitted. Previously electric lighting had been confined to the dining rooms of one or two vessels.

In 1890, *Dunnotter Castle* was launched at Fairfields and on the 28th October arrived at Cape Town after an outward passage of seventeen days twenty hours and, on the homeward passage, sixteen days fourteen hours was accomplished. The vessel was about 5600 tons gross and had two funnels and three masts.

Not to be outdone the Union Line ordered a new vessel from Denny's—the *Scot.* This was the first vessel in the mail service to use twin screws. On the maiden voyage the passage time was fifteen days, nine hours and fifty-two minutes, but unfortunately this was only achieved at the cost of an extremely high fuel consumption and in practical terms the vessel was never a profitable proposition. In 1893 this vessel again broke the record, making a passage in fourteen days, eighteen hours and fifty-seven minutes, but notwithstanding the good publicity received from these record-breaking passages, the fortunes of the Union Company were slowly deteriorating and in 1895 there were quite a number of board changes and one of the partners in Harland and Wolff Ltd. joined the board. Thereafter all vessels for the Union Line were built by Harland and Wolff.

The first result of this co-operation was the 7500 ton *Norman* which came into service in 1894. It provided an entirely new concept of a mail steamer and caused some headaches for the Castle Line management. This was followed by a 10 000 gross ton *Briton* and the Castle Packets' reply was the *Carisbrooke Castle* followed by *Kinfauns Castle* and *Kildonan Castle* which appeared to have copied some of the Union Line's ideas.

Up till this time, the mail contract had specifically stated that there must be no merger of the companies, but with a new contract due in 1900 the South African Government asked for tenders for the provision of the whole service by one company and in 1900 the two companies amalgamated and the

| 1899 | 1903 | 1921 | 1927 | 1936 | 1960 |
|---|---|---|---|---|---|
| *ildonan Castle* | *Armadale Castle* | *Arundel Castle* | *Carnarvon Castle* | *Stirling Castle* | *Windsor Castle* |
| 515·4 | 570 | 630 | 630 | 725 | 783 |
| 9698 | 12 973 | 18 973 | 20 141 | 25 550 | 36 123 |
| 2 | 2 | 2 | 2 | 2 | 2 |
| Quadruple<br>28" x 39¾" x 57½" x 83½"<br>60" | Quadruple<br>32" x 46" x 66½" x 96"<br>60" | double-reduction turbines | diesel<br>8cyl, 840 mm bore, 4cycle, d/a | diesel<br>10cyl, 660mm bore, 2cycle, d/a | double-reduction turbines |
| i.h.p. 9800 | i.h.p. 12 000 | s.h.p. 14 500 | i.h.p. 23 000 | i.h.p. 27 000 | s.h.p. 45 000 |
| 4 D.E.<br>2 S.E. | 6 D.E.<br>4 S.E. | 9 D.E.<br>2S.E. | — | — | 3W.T. |
| 210 | 220 | 220 | — | — | 600 |
| 16¼ | 16¼ | 17 | 17 | 19½ | 22½ |
| — | — | 124 | 45 | 43 | 42 |

.E.=Double-ended boiler W.T.=Water-tube boiler

Union-Castle Mail Steamship Company Ltd. came into being.

As the Boer War was in progress, it was not until 1902 that the integrated service started and the ships used were *Saxon, Briton, Norman* and *Scot* ex Union Line and *Kildonan Castle, Kinfauns Castle, Carisbrooke Castle* and *Dunvegan Castle* ex the Castle Line.

At that time, two replacement vessels were ordered—*Armadale Castle* and *Kenilworth Castle*—which took the place of the *Scot* and *Dunvegan Castle*, the two latter vessels being laid up at Netley as reserve ships. Happy days when the Company could afford the luxury of reserve ships.

They were followed in 1908, by *Balmoral Castle* and *Edinburgh Castle*, of about 13 000 gross tons, which were to be the last of the mail vessels with reciprocating steam engines.

In 1912, the Union-Castle Line was taken over by the Royal Mail Steam Packet Company and, in the same year, a new mail contract which was to run for ten years was signed with a lowered passage time of sixteen days fifteen hours. At the same time, a freight contract came into being which—amongst other things—recognised the requirements of the South African fruit industry. Under this agreement the company had to provide 18 000 cubic feet of refrigerated space in each mail vessel.

The Great War interrupted the service once again until 1919 and the first post-war mail vessels, *Arundel Castle* and *Windsor Castle*, came into service in 1921 and 1922. These vessels were of a completely new design, the Scotch boilers were still there, but the propulsion machinery was double reduction turbines and, as was the custom of the period, the vessels had four funnels—three working and one spare, so to speak.

With the present day accent on safety, it is perhaps interesting to note that the life-saving equipment included a row of boats which lay across the full width of the ships abaft the after funnel. The mind boggles at the task of getting these boats into the water and it is perhaps fortunate that they never had to be used to save life.

By the mid-twenties, the diesel engine was beginning to make real progress and, in 1927, the *Carnarvon Castle*, the first of the big diesel engined mail vessels, came into service.

The engines were large and advanced for the period. They were eight cylinder, 840 mm bore, double-acting, four-stroke, with two air compressors at the forward end of the engines to provide the air for the blast type fuel injection. The i.h.p. per engine was about 11 500 at 122 revolutions per minute.

The vessel had four generators producing about 350 kilowatts at 150 revolutions per minute. They were single-acting and, to give some idea of their size, the flywheel weighed about 10 tons and the armature 7 tons.

Experience in service was a revelation and, notwithstanding the general lack of experience of diesel engines of any size, the reliability of these large engines was high.

One of the greatest benefits from the change was the cleanliness. The coaling of a passenger vessel was a very dirty process indeed and, no matter how much care was taken to screen the decks and shut doors and portholes, the coal dust penetrated the entire ship. The subsequent cleaning had to be extensive and very often carried out against the clock so that the ship would be ready for embarkation of passengers.

Another benefit was the large reduction in the number of the engine-room crew. Burning coal was labour intensive and although today the number of engineers who have sailed in coal-fired ships is comparatively small, those who have will commend the work of the trimmers and firemen. The trimmers for their work in wheeling barrow-loads of coal from bunkers to boilers, on the very unsteady platform of a ship in a seaway, and the firemen for depositing the coal at the right place in the furnaces through the not overlarge furnace door. It was a heavy job which was carried out in most cases with much good, if somewhat basic, humour.

A new mail contract was signed in 1928 following which two further vessels—*Warwick Castle* and *Winchester Castle*—were ordered. They were very similar to *Carnarvon Castle* and they also had diesel machinery of the same type.

The following years were probably the most serious in the Company's history as, with the collapse of the Royal Mail empire in the depression which started in 1928, the finances of the Union-Castle Line, in common with other companies in the group, were in poor shape. Much hard work was necessary to untangle the financial problems which were not finally cleared until about 1936.

Although the financial problems were severe, the company pushed ahead with the ordering of new mail vessels and, in 1936, *Stirling Castle* and *Athlone Castle* came into service.

Again there was a break with tradition and these vessels reverted more to the yachtlike lines of the early vessels in the Company's history.

These vessels were propelled by diesel machinery, 10 cylinder, 660 mm bore, two-stroke, double-acting engines with independent scavenge blowers. The i.h.p. was about 13 500 per engine. Five diesel generators, each producing 700 kW at 260 revolutions per minute were fitted.

In 1936, another mail contract was signed to run for ten years from January 1st 1937 which provided for a reduction of the passage time to fourteen days from the end of 1938.

As only two vessels could meet this reduced passage time, a slightly larger vessel—*Capetown Castle*—was ordered and arrangements were made to re-engine the other mail vessels. *Carnarvon Castle, Warwick Castle* and *Winchester Castle* were fitted with two-cycle, double-acting machinery, which could be fitted into the same space as the original four-stroke machinery, and *Arundel Castle* and *Windsor Castle* were fitted with high pressure, single-reduction turbines, steam being provided by four water-tube boilers, two of the original Scotch boilers being retained for low pressure steam requirements.

During the re-engining, the two funnels of the older motor vessels were replaced by a single funnel and the four funnels of the two steamers were replaced by two funnels.

This programme was completed in 1938 and the last vessel to sail in the old mail service was *Edinburgh Castle* on 15th December 1938. The new service was started by *Athlone Castle* on 22nd December 1938 and it was then that perhaps the seeds of the most successful advertisements were sown—"Every Thursday afternoon at 4 o'clock a Union-Castle vessel leaves Southampton".

War again intervened and, from 1939 until 1945, the mail vessels were otherwise engaged, *Windsor Castle* and *Warwick Castle* being lost by enemy action.

The return of peace brought in its wake another heavy reconditioning programme and the building of *Pretoria Castle* and *Edinburgh Castle* to replace the two vessels which had been lost. The other vessels went to Belfast in turn to convert them from troopships to passenger vessels and for a much needed major refit, as the vessels had been heavily worked during the war years. As a result it was not possible to re-institute a full mail schedule until 1950.

*Pretoria Castle* and *Edinburgh Castle* were built with steam machinery, not because the Company was dissatisfied with diesel, but because at the time of ordering there was no diesel machinery of proven reliability available for ships of this size.

In 1956, the Union-Castle Company was again taken over, this time by Clan Line Steamers and, as a result, British and Commonwealth Shipping Company was formed to merge the two companies.

One of the first fruits of the merger was an assessment of the mail service in view of the age of the older vessels. There was an urgent need to order replacements and a decision was made to build new ships which would take two days off the existing fourteen day schedule and thus enable the service to be maintained with seven ships instead of eight.

One new vessel was building at the time of the merger—*Pendennis Castle*—and this was altered on the stocks by increasing the length and increasing the machinery power.

Subsequently, *Windsor Castle, Transvaal Castle, Southampton Castle* and *Good Hope Castle* were ordered, the first two being passenger vessels with turbine machinery and the second two being cargo vessels with diesel machinery. *Windsor Castle* was the largest vessel built for the mail service.

With the advent of these vessels, the scene was set for what was to be the grand finale of a service which had survived wars, mergers, financial difficulties for over a hundred years and, with the sailing of *Southampton Castle* in mid-September this year, the curtain comes down for the last time after one hundred and twenty years.

During those one hundred and twenty years, there has been steady progress and continual improvement. At times, to the outsider, that progress may have appeared to be somewhat slow, but the proof of the correctness of the policy of gradual advance has been in the way new ships have been built, passed their trials, have gone into service for as long as required.

One interesting fact is the long run which the steam reciprocating engine had, the last mail steamer with the machinery going out of service in 1938 and, in fact, if the company as a whole is considered, it was 1952 before the last vessel with this type of machinery went out of service, a period of about ninety-eight years in the company's history.

Perhaps the most difficult period for the marine engineer, whether ashore or afloat, was the first change from steam to diesel. It began with the building of the first three new ships with four-cycle, double-acting machinery and continued with the very fast change-over to the larger two-cycle, double-acting machinery in the late thirties. It should be remembered that there were few teachers then, designers, builders and operators had to learn while they worked.

For the Chief Engineer, the time scale for learning was extremely short. A man who had spent a lifetime with the reliable and well-known reciprocating steam engine, perhaps had a spell at the builders' works, about six months at sea, took the examination for the diesel endorsement to his First Class Certificate, and back to Chief Engineer with a fearsome bag of tricks in his charge.

It must have been a traumatic experience for them, but, with the help of the middle rankers, who by this time had gained reasonable proficiency with diesel engines, it is to their eternal credit that the change-over was made so easily. There were problems, as there normally are with any new type of machinery, but they were solved, or, if not solved, dealt with in a manner which enabled them to be tolerated, without impairing the reliability of the service.

For the record, the experience did not seem to do those concerned any harm, as, on retiring, most of them lived to a very ripe old age.

The next change of note was the conversion of the vessels in the 1950's to burn boiler oil as fuel instead of diesel oil. This caused a new crop of problems which again were duly solved.

In the final stages of the service, the wheel had almost turned the full circle when five out of the seven mail vessels were steamers, although somewhat different from the older ones. Now there was the high pressure turbine with water-tube boilers, with varying degrees of automatic equipment. The amount of other equipment also bore no relation to that of the older vessels. Instanced are 350 000 cubic feet of refrigerated cargo space, full air-conditioning of all accommodation spaces, etc.

The passing of the service is regrettable, as it was a good training ground for the marine engineer. The regularity of the sailings and the strict timetable demanded a discipline that those who experienced it never forgot.

Important though it was to the two main countries which it served, it was only a small part of the shipping scene and its demise is only one part of the tremendous change which has taken place over the last twenty years or so.

There will be further change in the future inspired by the rather doubtful future of supplies of oil. In times of change it is useful to look at history, as very often it can give a lead to the direction in which thought should be directed.

The service has mostly mirrored the changes which have occurred in ship propulsion systems in merchant vessels, apart from the final change to steam, which was against the general trend, because of ship size and the availability of diesel engines of the requisite size.

For the merchant ship of today, the diesel engine is favoured rather than the steam engine, because of its higher thermal efficiency. What, however, is going to happen in the future? Will the cycle of change revert to coal fired steam vessels, or will it revert even further to sailing vessels? Will nuclear power ever become sufficiently economical for merchant vessels, or will some other fuel come to the fore?

It may appear heretical for the President of this Institute to mention sailing ships, but as many members of the Institute will be working on machinery types for the future, it is perhaps well to emphasize that no method of propulsion should be discarded before it has been thoroughly investigated.

I have been connected with marine engineering for the last forty-five years and I have been fortunate in that this has been the period of greatest change in the history of marine propelling plant. It has provided continual interest and I am glad to think that the young marine engineer of today can look forward to many further exciting changes which will extend into the next century.

During this period any little success I have had in life would not have been possible without the help and encouragement of many colleagues ashore and afloat. The honour you have bestowed on me by electing me your President should also be shared by them. My sincere thanks are due to you and to them.

Paper read at the Institute on Tuesday, 11 January 1977.

# THE REDUCTION OF ELECTRICAL CABLING COSTS – INTRODUCING THE DATA HIGHWAY

**W. S. Brown***

INTRODUCTION

The ever increasing cost of labour in the shipbuilding industry has meant a rise in the capital and installation costs for ships electronic cabling. In the present economic climate they are bound to continue upward, and coupled with the increasing requirements of insurers and owners etc., to install more electronic equipment, the number of cables used in any vessel grows larger, thus increasing costs still further. The trend towards reduced crew, using the concept of the unmanned engine room and partially manned bridge, highlights the need for more control and monitoring systems with their resultant increase in cable requirements.

It is in these circumstances that interest is increasing in any system of transferring information from one location to another in the marine environment, which can show a reduction in the number of cables required. Some such systems have already been tried and evaluated, with varying degrees of success. Some are in regular service with merchant ships. In many cases the reduction in cable requirements has been made for a specific system, as the need arose. It is, however, noted that no system is yet in service, which combines the multitude of ships functions within the concept of reducing the overall cable requirements to the functional minimum. This is the concept of a Data Highway.

SELECTION OF TRANSMISSION PRINCIPLE

A systematic study has been carried out by the Department of Marine Design of the author's company in which the many forms of data transmission on a vessel were considered. These ranged from the use of radio and microwave transmission, hydraulics and pneumatics, to the use of fibre optics and higher utilisation of standard ships cable. Although some of these technologies showed advantages in specific areas, the many problems associated with initial and maintenance costs enabled the selection to be reduced to the use of fibre optics and existing ships cable. The fibre optic technology shows many advantages in an Intrinsically Safe (I.S.) environment. However, the vulnerability of the optic lead, the interface problems with existing machinery, and the accuracy required in joints (for repair and installation) means that expensive connectors and a high standard of finish are required to attain the necessary reliability. It would appear at present therefore, to have no advantage over a cabled system.

In a totally wired vessel the problem of routing the cables and the number of junction boxes required suggests that the answer to cable

* Hawker Siddeley Dynamics Engineering Ltd.

reduction is based upon making better use of the cables themselves.

Within this field there are many systems which can, and have been employed to make one pair of cables carry the maximum amount of information. The general term for this is multiplexing. A marked reduction in both cable and installation costs may be achieved, even taking into account the special problems of integrity and interference. The actual reduction depends upon the precise philosophy employed.

The B.S.R.A. report [1] 'Study of Ships Automation identifies the need for a comprehensive data transmission system if ship automation is further introduced into Merchant Ships. The majority of views contained in the report, relate to long term needs, requiring a large degree of system integration, but additionally short term automation suggestions are included. With regard to data transmission, the suggested solution provided by the report has the virtue of enabling it to be incorporated with the minimum of sub-system interaction. This approach has high potential, as if the transmission system is properly designed, it can be considered ideal for retrofit application.

Thus data transmission throughout a ship, using the minimum number of cables, may be considered as a data highway with the capability of transferring information in either one or two directions. The philosophy of the data highway is therefore established, requiring that information is converted at each access point, to a form suitable for transmission with the highway.

For this purpose, a digital pulse technique is used for transmitting the data. This is now well established and proven in many fields of industry. Dramatic cost reductions for digital system components have helped to accelerate the use of these techniques. For example, 10 years ago it was an economic proposition to use these techniques for distances covering a number of miles, a specific example being in the coal mining industry. As the cost of the electronics has reduced so the distances involved have come down proportionally, making the data highway now economically viable within the envelope of a ships length. Digital data transmission multiplexing techniques enable the number of interconnecting wires between subsystems to be reduced substantially. The cost of digital transmission is now lower than dedicated wiring carrying analogue signals. The problems associated with digital data transmission and its successful use is dependant upon several factors, such as required speed of transmission data rate environmental noise etc., however these are engineering problems that can be overcome by the correct choice of transmission mode, and detail design at the data highway interfaces. A correctly designed system should not depend upon a critical choice of cable, thus ensuring the maximum flexibility of application. The choice of cable only becomes important when such a highway is used on vessels governed by an Intrinsic Safety standard.

SELECTION OF A TRANSMISSION MODE

When considering the design of a system suitable for the marine environment the various techniques of multiplexing must be considered, and a choice made. The spectrum of multiplexing techniques is vast, ranging from modulated carrier wave systems, as used for line colour television, to simple pulse systems. In the marine environment carrier wave systems can be discarded as their use creates problems of interference with radio communication systems. Of the simpler techniques various forms of transmitting the digital pulse exist, i.e.;

Pulse Amplitude Modulation (P.A.M.);
Pulse Width Modulation (P.W.M.);
Pulse Repetition Frequency Modulation (P.R.F.M.);

and various combinations of these. Briefly looking at some of these in turn, their respective advantages and disadvantages may be noted.

a) Pulse Amplitude Modulation:- The principle of operation is based upon using different pulse heights to convey information. Pulse amplitude losses make this system susceptable to data corruption over long cable lengths, and the pulse height is further influenced by positive and negative transients being induced on the transmission cable. In its simplest form it becomes a pulse present/no pulse system. Its dependance upon known cable characteristics and its relatively slow response make it a poor choice on which to base a total ship data highway system. (See figure 1a).

b) Pulse Repetition Frequency Modulation:- The principle of operation is based upon the time spacing between pulses of fixed height and width to convey information (See Figure 1b).

c) Pulse Width Modulation:- The principle of operation is based upon the width of a pulse of fixed height to convey information. The spacing between the pulses may or may not be constant. (See Figure 1c).

Although there is little to choose between these two principles, both having many successfull applications in industry, it is considered that for the marine environment the PWM technique offers a better solution in terms of hardware realisation. It offers a system of high integrity. It is therefore the opinion of the suthor's company that the preferred system for cable reduction in ships is to transfer information in a digital pulse code along a data highway upon which the code is carried by pulses of varying width. Each item, or bit of information is carried, in turn, by a pulse on the highway. Additional pulses are introduced into the sequence to provide checks and system control.

BASIC HIGHWAY SYSTEM

It is considered that the trend towards the implementation of a total ship concept of a data high - way will be a gradual process. As the opportunity arises monitoring systems will be replaced, then systems with monitoring and some control functions will be fitted. The application of a data highway in its basic form can be considered as a simple example.

The data highway consists of a central station, and a number of outstations which are connected by a four core cable. Each outstation is connected to the cable, but the electronics of the outstation do not interrupt the cores of the cable, they are junctioned to it. An outstation is a highway access point.

It may be seen from Figure 2 that an outstation may be connected at any point on the cable as long as it has a different identity to the other outstations on the cable. The identity, or address, is defined by a predetermined digital code. A digital code is made up of zeros and ones, such that number one is 0000, number 2 is 0001, number 3 is 0011, number 4 is 0010, number 5 is 0100 etc. to number sixteen which is 1111. Thus the address of outstation number six will be carried by four data pulses signifying zero, one,zero, one. (0101)

As the address content of the pulse pattern has been chosen at 4 pulses, the available combinations of these four pulses limit the number of outstations to 16.

The cores of the cable carry the following functions:-

Core 1 - Positive Voltage Supply
Core 2 - Up Line; Information from Outstation
Core 3 - Down Line; Information to Outstations
Core 4 - 0 volt Reference; Reutrn Power Supply

Thus the system may be regarded as a three line (Cores 2,3 & 4) communication system with additional power supply distribution.

The basic principle of operation is based upon the proven computer peripheral technique of address and reply. Each outstation is addressed in turn, 1 to N, and upon the outstation recognising its address, it provides a reply to the central station, where the return address is checked. Thus a pulse pattern is sent from the central station to a particular outstation on the Down Line, the pattern containing the address and information. A pulse pattern is sent from the outstation to the central station on the Up Line, the pattern containing the information and its confirmatory outstation address. The Up Line and Down Line are neither joined nor terminated at any point on the highway.

The pulse pattern comprises the address and information in serial form, which is output/input at both central and outstations in parallel digital code. Thus the data highway can accept and deliver any form of digital code in each direction.

The organisation of pulse information within the highway, is shown in Figure 3a for the Up line, and Figure 3b for the Down Line. These two figures show the timing pulses, data pulses, address pulses and parity check pulses in relation to each other.

For system integrity the following checks are made:-

a) The number of pulses in a pattern are counted.
b) The time pulse is checked for correct placing in the pattern.
c) The address is checked and confirmed.
d) A parity check is performed on the pulse pattern.

All these checks are carried out prior to transferring the data off the highway. Should the wrong answer appear as a result of the check, no data is transferred, and a further scan is awaited.

The parity check counts the information pulses as they are transmitted and counts them upon receipt. Thus one or more pulses added or lost will be detected.

Extension beyond 16 outstations is accomplished by the use of two or more similar highways. This approach has been adopted to achieve flexibility of application and reduce special to application costs in the transmission drive circuits of a highway.

Other considerations also influenced the choice of the capacity for the basic highway.

a) The attempt to limit the electronics controlling the functioning of the data highway to the component capacity of a double Eurocard standard of printed circuit board (160mm X 230mm) at each control and outstation. This constrained the system to a maximum number of information pulses at any outstation.
b) The attempt to limit the system to operation on existing standard cables. The volts drop of the cables being a major factor in achieving a system capable of meeting Intrinsic Safety (I.S.) requirements in respect of allowable power supply.
c) The attempt to achieve an economic hardware cost on the applications already in hand. The fact that all outstations are the same size (in terms of data content) is also a result of economic considerations, inferring reduced cost due to standardisation of production items.
d) The attempt to achieve a time scan (data rate) of half a second for the content of the total highway. The actual frequency of operation can be adjusted within wide limits to suit particular applications if necessary.

THE DATA HIGHWAY INTERFACE

The object of the data highway is to transmit signals from one location to another. In a highway system such as the one proposed here, the form of the signals that require transmission varies considerably. The conversion of signal form to the digital code required for the transmission, and the re -constitution of that form after transmission is the function of the system interface.

Each station has its own interface. Because of the varied nature of the data to be transmitted and received, the interfaces may be different at each station. In order to obtain a clearer picture of what is required, it is necessary to examine the range of functions likely to be encountered by the overall system.

The following functions are included:-

a) A.C. Voltage and Current
b) D.C. Voltage and Current
c) Frequency
d) Digital

With types a, b and c, conversion to and from the digital format will be required, while with type d, format changes will be necessary.

At any one station, usually one analogue to digital converter is required, signals for transmission being switched in turn, into the converter. Frequency to digital conversion can be simply obtained by counting frequency over a given period of time. However, low frequencies take longer to convert if high accuracies are required, and special techniques can overcome this problem. In general, a separate digital to analogue converter is required for each output function, data being routed to these, Figure 4 being a typical outstation.

The sequence control unit will vary in complexity depending upon the scope and function of the partic -ular interface unit. It can range from a simple logic circuit, through the use of memories to some form of microprocessor handling many other functions as well.

Thus in total the interface with the data highway may be considered as a number of data processing circuits whose complexity is dependant upon, and peculiar to, any given application.

INFLUENCE OF THE MARINE ENVIRONMENT

Invariably discussions on the topic of data highways reduce to the consideration of four items, Electrical Interference, Reliability, Vulnerability to Accidental Damage and System Integrity.

Electrical Interference

This may be sub-divided into two areas (a) Induced Interference i.e. from motors, starters, power cables etc., and (b) Radio Frequency Interference (R.F.I.) with and from ships radio communications.

a) Induced interference, in the form of positive and negative 'spikes' and transients, is avoided by the inclusion of a low pass filter at each input connection with the data cable, and by the basic method of transmission which in itself is highly resistant to corruption.

In general, these transients are extremely quick voltage changes, compared with the width of the data pulse, and should any still remain after the filtering, then the form the information decoding circuits are such as to disregard them. Additionally, when communicating control information, validity checks are normally incorporated. Data handling caters for three or more samples before action is taken.

b) Induced R.F.I. problems are avoided by the inclusion of R.F.I. filters on all lines (including power lines) into/out of the stations. These filters are enclosed in a separate screened compartment together with the input/output connections. In addition panels, sub-assemblies etc., are fully bonded together and to ships frame.
Radiated R.F.I. is reduced by the same filters to remove the high harmonics present in the transmitted signals thus avoiding interference with ships communications etc..

Reliability

This is defined as the probability of a device (system) performing its purpose adequately for the period of time intended under the operating conditions encountered. The data highway system can be considered to be on-line continuously and requiring no routine maintenance.

A highly automated merchant ship using all or part of the data highway concept is certain to be more complex than its conventional equivalent, and thus on a component count alone, and ignoring such factors as operator and maintainer induced failures, some increase in the overall component failure rate is to be expected. Whether or not this increased rate of component failure is reflected in a similar increase in system failure, and thus a reduction in ship operational availability, is a matter of engineering design. In this context the recent development of high integrity multiplexed systems for aircraft and industrial control is particularly relevant. In such systems, although component failure follows the conventional pattern, system duplication and fault tolerance is such that the incidence of overall system failure has to be measured in tens, or even hundreds of years.

A data highway system designed with intrinsically safe requirements included from the start, and having used the lessons from the other fields of electronics, can be offered with confidence specifically for the Merchant Marine Service. The reliability of the system for any function can be shown to be equivalent, or better in some applications, than fully cabled vessels.
Although a data highway may not be required to meet I.S. levels in a particular application, a system so designed offers a higher degree of confidence in a lesser environment.

Vulnerability to Accidental Damage

Further, the use of a single cable in some applications, means that it can be more easily protected against damage. This can take the form of an armoured sheath type, and/or the cable can be run in dedicated trunking. Additional consideration can be given during any application design to the aspect of providing a second cable, perhaps having a different route through the ship, which can be interchanged with the main cable in whole or part. This function of interchanging can be accommodated automatically.

System Integrity

Considering first the data transmission of the data highway, it is upon the ability to provide uncorrupted data at the output end of the highway that the integrity is based. The transmission system must offer the maximum confidence to the user in this area. It is no good if data is sent to the wrong outstation due to corruption of the transmitting pulses which define the address. Thus the data must be validated, upon receipt, and this can be done in one or more ways. In the proposed system the number of pulses corresponding to the pulse sequence to/from any outstation are checked by a simple number count. This establishes whether transients and other pulse type interference has corrupted the information. If this check shows abnormality, the the data is not acted upon, a further scan being awaited. A further check is made on the timing signal information contained within the pulse sequence. Again, the data is not acted upon should this information not check out. In addition a check is performed on the data content and address content of the pulse pattern (parity check) to overcome any effects which may cause the pulse shapes to change

Further checks can be performed as part of the data processing if required. These inbuilt checks on the transmission itself provide the basis for a high factor of integrity.

In terms of system integrity the second consideration must be that of the data cable itself, where its susceptibility to damage (see above) and its physical characteristics must be considered. In a simple application of say, data monitoring only, the proposed system is not dependent upon a dedicated cable for the highway. Cores in existing cables may be used if available, thus at a refit, some systems not previously using a highway concept can be introduced if required, reducing in part the refit cost of cabling in these areas. In systems using a duplicate highway, the same solution still applies, subject to the two highway routes approximating to equal lengths.

Depending upon the application, the power carrying cores associated with the data highway may require duplication to avoid voltage drop. It is suggested that cores of $4mm^2$ cross-sectional area are used as standard, duplicating where necessary. In certain environments the use of screened cable, at least covering the data lines can be of advantage, though adequate provision exists within the proposed system so as not to warrant this expense.

## GENERAL APPLICATIONS

It is in the method of application of the data highway principle to specific vessels and functions where the advantages of cost reduction can best be seen. The highest benefit accrues where long high density cable runs are at present used, as for instance in container ships for monitoring of refrigerated containers, and in special product carriers where multichannel monitoring may be required.

Further applications also lend themselves to the data highway concept, viz; remote monitoring and control of engine room from bridge, remote control of deck lights/navigation lights, remote temperature control and minitoring of cargoes, operation of tank valves, pumps etc., data logging. In addition many domestic services can make use of the highway.

Within the sphere of specific intrinsic safety requirements the data highway lends itself to operation of tank valves and monitoring on both tankers and liquid gas carrying vessels.

It is in the latter two fields where interest lies, not only in the concept of a highway, but in obtain -ing certification to the appropriate I.S. level, for the total equipment forming a system. Thus a pump may be certificated in its own right, as may be a remote starter; a temperature senser may be certificated, as may a readout, but the difficulty appears when these items are put together to form a system. The question arises, who certificates the system and how?. The shipyard look after the certification of the individual parts of the system, but the owner is left with the problem of the certificate for the whole ship, a next to impossible task. Ideally the owner would like to see the contractor taking on the responsibility for obtaining certification for a whole system.

This problem can in part be solved by the use of a data highway system which in itself is fully certified to a suitable I.S. level. A highway of this form would require that specific interfaces with other contractors equipment would be in a form to meet I.S. standards, and could be so arranged. Ultimately the highway could be considered as standard bought-out, certificated item of equipment. In the long term all contractors would come together to obtain total system certification.

## CONTAINER MONITORING APPLICATION

An example of the data highway applied as a monitoring only system can best be shown by an application to container monitoring. This application is for the remote monitoring of state indicators on 96 Integral Refrigerated Containers carried as deck cargo. The requirements are:-

a) To indicate the state of three parameters namely:- Compressor Running; Defrost Cycle in operation; Temperature out of Limits. These indications are to be displayed separately for each container, in the wheelhouse.

b) A change of status of a parameter must be indicated within 30 seconds. Should any container indicate 'outside temperature limits' an audible alarm shall sound.

c) No local power is available in the container area. The system shall interface with an existing remote monitoring 4 pin socket on each container.

It is considered necessary to provide electrical isolation for each parameter of each container between the monitoring system and the container itself. This is to prevent a faulty container affecting either the other containers or the monitoring system in the event of the containers assuming differing potentials with respect to ships frame earth due to power supply lines breaking down. This isolation is accomplished by an optic coupling device. Additionally the monitoring system is protected against over voltage faults by an in-line resistor, enabling a container fault to exist for the duration of the voyage without damage to the monitoring system or the other containers.

The containers are stacked two high in groups of twelve across the deck hatches, and enables an outstation of the data highway to service 36 parameters. Thus the basic highway consists of eight outstations, each containing a transmission electronics board and an isolation electronics board. Up to 20 additional items of information can be handled at each outstation, such as a signal to say that the power cable to a container is physically connected. (e.g. A microswitch on the main power socket). This is not essential to every application. Since these signals from the container are on/off functions, the isolation board acts also as an interface board, providing signals compatible with the transmission board requirements.

The central station in the application also acts as a display unit built in modular form in which the transmission board is a module (See Figure 5). There are in addition 16 modules of display, two display modules corresponding to each outstation, and two additional modules. These are the power control module and alarm module.

The front panel of the power control module contains an on/off switch, power on indicator and fuse. The module function is to process and distribute the power supply requirement of the system, to the displays and to the outstations. The total outstation power requirements being a maximum of 12 volts, 1 ampere.

The front panel of the alarm module contains an audible warning device, lamp dimmer control and a Lamp Test/Fault Accept dual function switch. The module function is to process the logic functions for the alarm displays and provide common circuits for the test functions.

The front panel of the display module contains three indicators per container, with a switch. There are 6 containers per display module. The module function is to process the data from the transmission module and route it to the correct display. This module provides the man/system interface. If a container is not connected to the system, operation of the switch will suppress the display alarm indicators.

Should an application of this system require fewer than 96 containers to be displayed, only the number of display modules required are fitted. Blank modules are fitted in the remaining locations. Expansion is by direct replacement of a blank module with a display module.

Figure 6 shows the central station, depicting the modules fitted to form a mimic of the deck plan to facilitate location of the containers. It can be seen that both upper and lower levels of containers are indicated. The filters on the incoming supply lines and the data highway form part of the central station case assembly, and are fitted in a screened box adjacent to the input plugs. The power conversion from the mains supply to the system level is by two power packs located at the rear of the cabinet.

The outstations consist of waterproof deck boxes with cable gland entry, for each container, at the bottom. The data cable enters and leaves the deck box via glands at the side. Figure 7 depicts the outstation arrangement in which it can be seen that the electronic circuit boards are protected within a second box. This arrangement allows for container cable changes due to wear and tear, without exposing the electronics to salt laden atmosphere.

PRODUCT CARRIER APPLICATION

The application is for the control and monitoring of 98 cargo valves together with the monitoring of 42 analogue temperature channels on a product carrier. It is anticipated that the equipment will meet i a II B T 6 intrinsic safety standard 7. The operational requirements are that a maximum of eight valves must be operated simultaneously, whilst the position and temperature must be continuously displayed. The system comprises nine deck boxes and two pump room racks together with a central station/display panel.

Figure 8 tabulates the allocation of valve control, valve position and temperature indication channels within the deck boxes/racks, and identifies the corresponding outstations. Two outstations are contained in one deck box/rack in a number of locations to provide sufficient data access to the highway, as the maximum capability of one outstation is 56 bits of information. The UP line is operating at approximately two thirds of its maximum capacity whilst the DOWN line is operating at less than half its capacity.

The prime advantage in thus application is the cable reduction from some 400 cores for monitoring and 300 cores for control to three for the data highway and two for the powersupply. Here local power conversion takes place in a flame proof enclosure, using I.S. transformers etc., which is part of the deck box assembly. The power to operate the valves, run the highway and the interface circuits is derived from this locally generated supply. Thus the valve control cables reduce to two cores in a flameproof armoured cable connecting the outstations, and the highway reduces to 3 cores in a separate cable, DOWN line and reference line. This principle of obtaining local power for equipment operation has had 10 years proven application in the coal mines.

The interface circuits at the outstations contain analogue to digital converters for the monitoring of both valve position and tank temperature. Additionally some amplifiers are used to raise the signal level of the temperature sensors to that which can be processed by the interface board. Further, switching of the valve supplies for operation is carried out by solid state electronics rather than relays.

At the central station the display panel consists of a mimic with Light Emitting Diodes forming the valve position indicator, and analogue meter readouts which can be selected to monitor up to 12 temperature sensors in turn for comparative readings. The valve control is accomplished by three position rotary switches, one per valve. The necessary interface circuits contain digital to analogue converters, and are housed in an equipment rack behind the panel, as is the transmission board.

## FUTURE APPLICATIONS

Already minicomputers and microprocessors are fitted to ships for a variety of condition monitoring applications, and may have their information fed in manually, or by a multitude of analogue signal carrying cores[(2)]. It is in this area that the decision to fit computers, which in themselves may be expensive, is influenced by installation costs. The data highway can supply the cost reduction which may enable the owner to install the computer and retain his budget allocation.

The unmanned engine room concept is already in general use, and more and more engine room parameters are being displayed at the Bridge, requiring up to 250 channels of information to be supplied in separate cable cores. Here too, the application of the data highway in its simplest form can show the advantages of cabling reductions for both condition monitoring and remote control.

In the field of product carriers the above reductions can also be made together with the operation of equipment in 'Intrinsically Safe' areas. The container monitoring field has many applications for the data highway including monitoring of meat cargoes and providing a printed log to meet the U.S. Department of Agriculture requirements. Here the potential savings on a total container ship dealing almost totally with refrigerated containers can be seen.

## CONCLUSION

The concept of the data highway can reduce the electrical cable costs in ships, the actual reduction depending upon the specific application. In a number of applications studied to date, savings of approximately 60% would appear to be the norm, however, the inter-relationship of machinery states and alternative routings may influence this. It is the authors opinion that once a ship owner installs even a small data highway on a vessel, that he has made a major step to reducing his cable costs on other vessels.

## REFERENCES

1) B.S.R.A. "Study of Ship Automation" 1973 vol.1
2) FREDRIKSEN TONNING and OYSTEIN,1975 "Microprocessor application on Board Ships." IEEE Transactions on Industrial Electronics and Control Instrumentation vol. IEC1-22 No.3.

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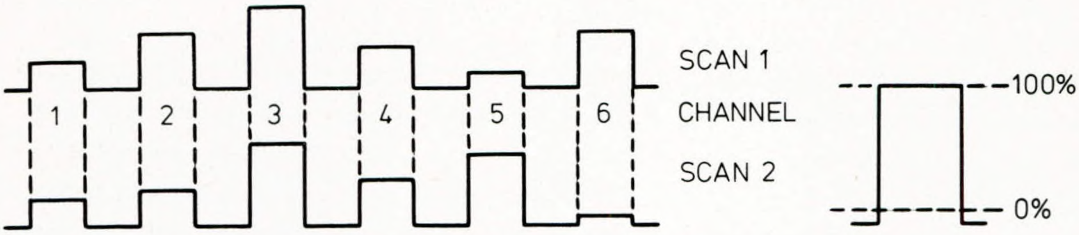


FIG 1 (a) - PULSE AMPLITUDE MODULATION

DIFFERENT SIGNAL LEVELS FOR EACH CHANNEL ARE GIVEN BY CHANGE IN PULSE HEIGHT

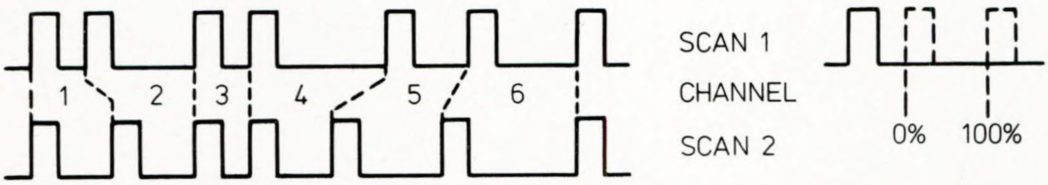


FIG 1 (b) - PULSE FREQUENCY REPETITION MODULATION

DIFFERENT SIGNAL LEVELS FOR EACH CHANNEL ARE GIVEN BY CHANGE IN SPACE LENGTH BETWEEN EACH PULSE

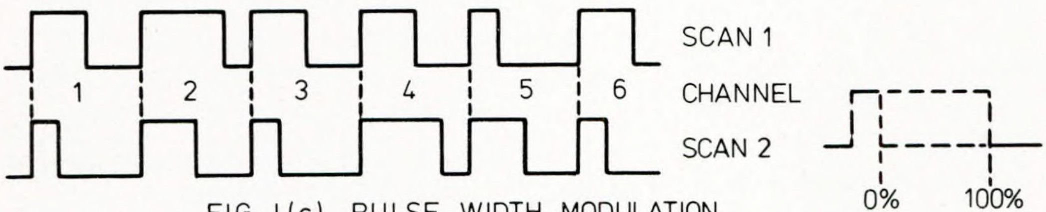


FIG I(c) PULSE WIDTH MODULATION

DIFFERENT SIGNAL LEVELS FOR EACH CHANNEL ARE GIVEN BY CHANGE IN PULSE WIDTH

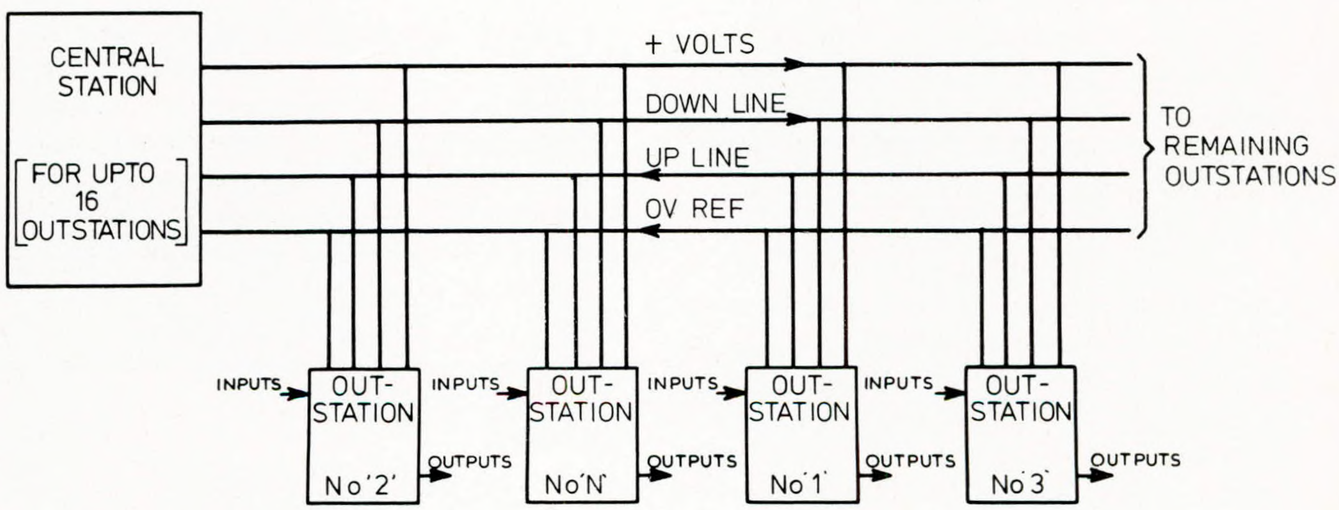


FIG 2 - TYPICAL DATA HIGHWAY

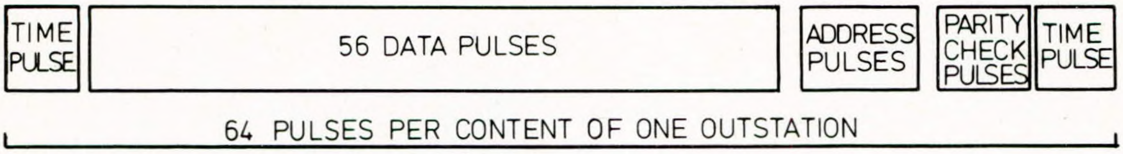


FIG 3(a) UP LINE PULSE PATTERN

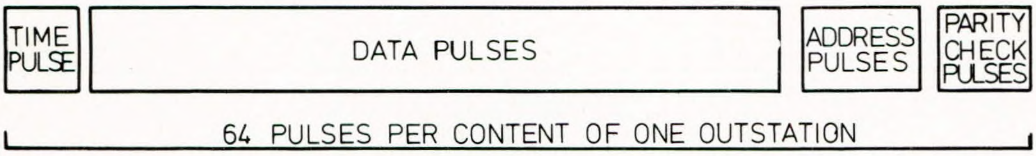


FIG 3 (b) DOWN LINE PULSE PATTERN

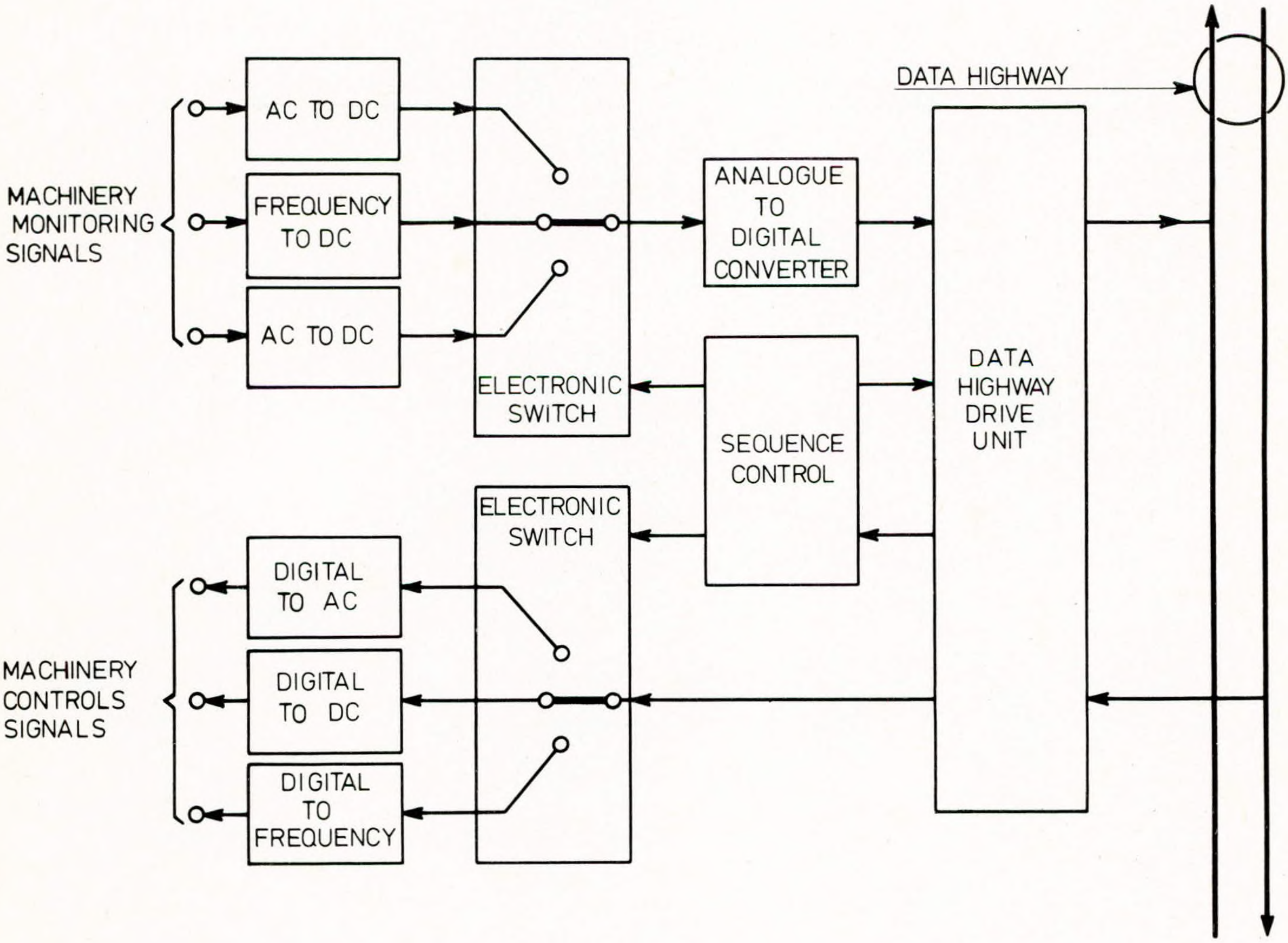


FIG 4 - TYPICAL MACHINERY INTERFACE

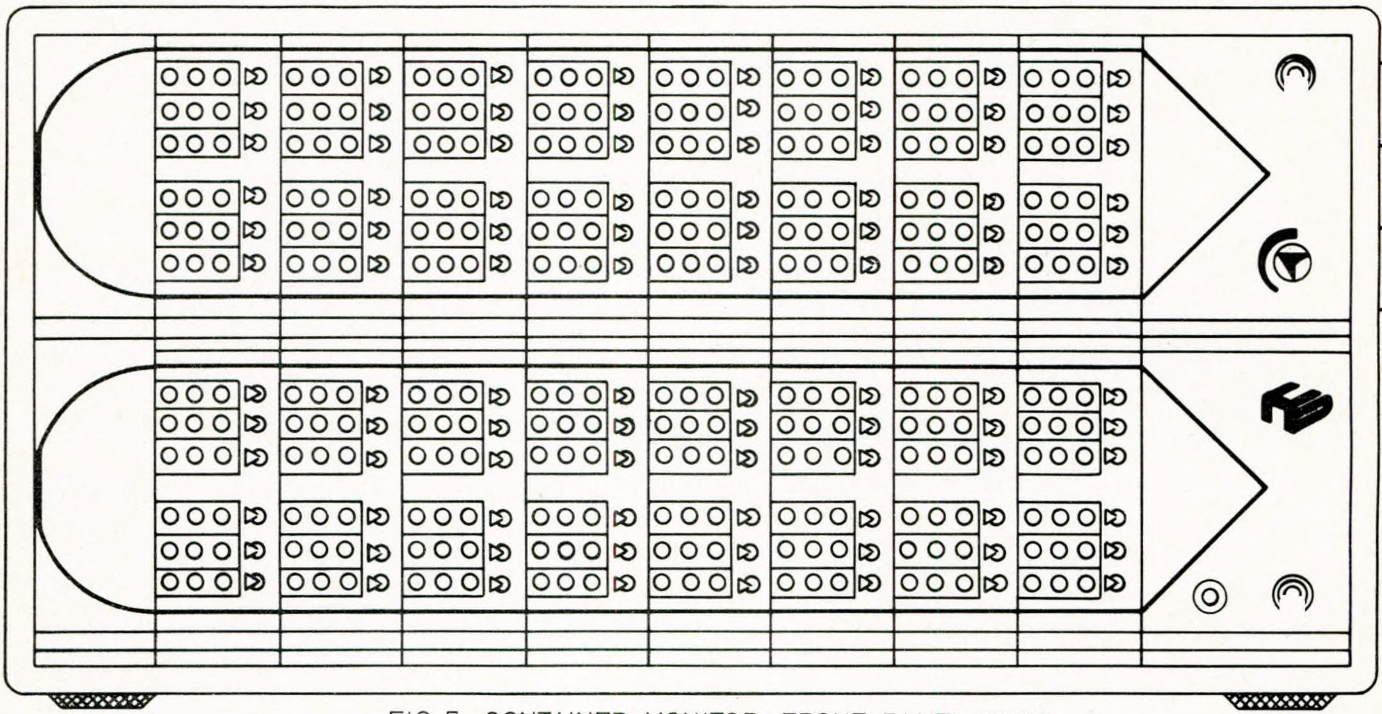

FIG 5- CONTAINER MONITOR FRONT PANEL MIMIC

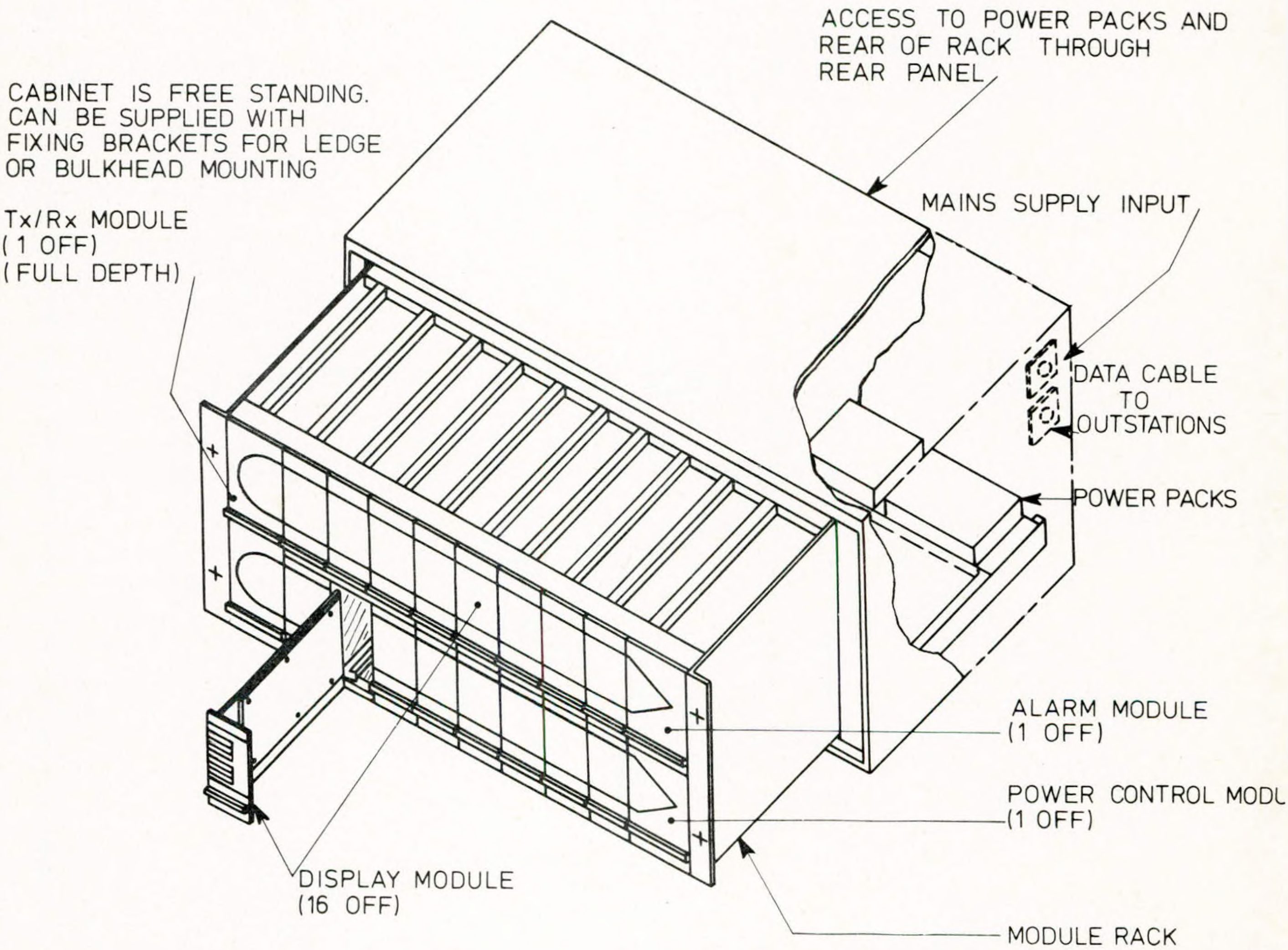


FIG 6- CENTRAL DISPLAY UNIT CONSTRUCTION

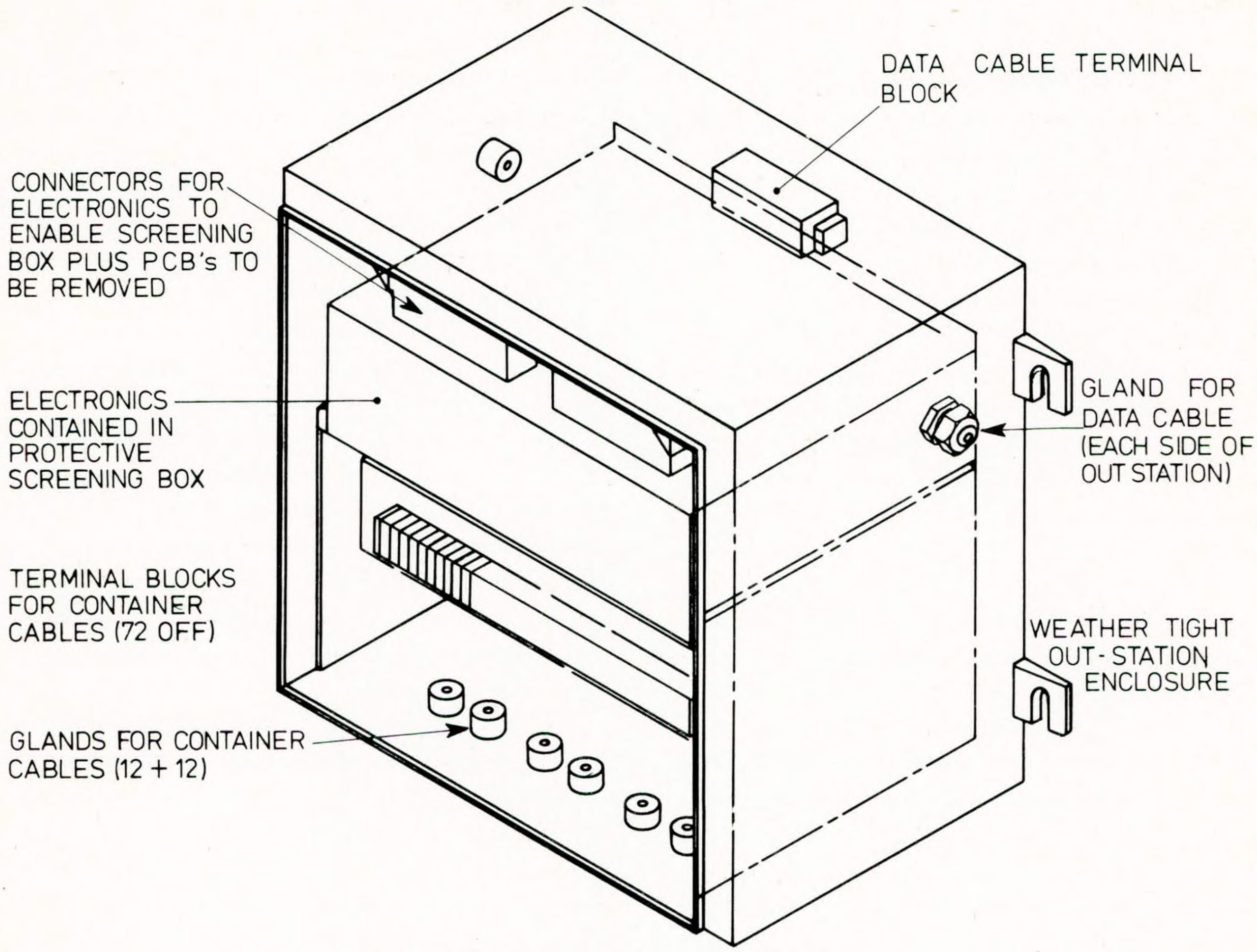


FIG 7 OUT STATION FOR 12 CONTAINERS

| DECK BOX RACK No | OUTSTATIONS No | No OF TEMP CHAN's | No OF VALVES CONTROLLED | No OF VALVES POSITION MONITERED | UP LINE DATA PULSES | DOWN LINE DATA PULSES |
|---|---|---|---|---|---|---|
| 1 | 0 | 3 | 8 | 8 | 53 | 32 |
| 2 | 1 | 3 | 8 | 8 | 53 | 32 |
| | 2 | 7 | 0 | 0 | 49 | 0 |
| 3 | 3 | 3 | 8 | 8 | 53 | 32 |
| 4 | 4 | 3 | 8 | 8 | 53 | 32 |
| | 5 | 8 | 0 | 0 | 56 | 0 |
| 5 | 6 | 3 | 8 | 8 | 53 | 32 |
| 6 | 7 | 3 | 8 | 8 | 53 | 32 |
| | 8 | 7 | 0 | 0 | 49 | 0 |
| 7 | 9 | 2 | 10 | 10 | 54 | 40 |
| 8 | 10 | 0 | 4 | 4 | 16 | 16 |
| 9 | 11 | 0 | 4 | 4 | 16 | 16 |
| 10 | 12 | 0 | 8 | 8 | 32 | 32 |
| | 13 | 0 | 8 | 8 | 32 | 32 |
| 11 | 14 | 0 | 8 | 8 | 32 | 32 |
| | 15 | 0 | 8 | 8 | 32 | 32 |
| NOT REQD | 16 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | | 42 | 98 | 98 | 686 | 392 |

FIG 8 -DECK BOX/OUTSTATION ALLOCATIONS

DISCUSSION

MR. E.J. HARDING said that, in his paper, Mr. Brown had referred to a study carried out by B.S.R.A., in 1973, which identified that Data Highways of the type discussed this evening were prerequisites of future shipboard automation systems. As a member of the team which carried out that investigation, he pointed out that the conclusion was that rapid changes in electronic technology, particularly the emergence of digital techniques, made multiplexing a potential feature of future systems. It appeared at that time that it was only a matter of a few years before a large number of multiplexed systems would be available.

Events since then had substantiated their conclusions and the author's paper was but one manifestation of this trend towards a new generation of automation hardware. However, experience with earlier equipment, particularly in the mid 1960's, was not without incident and urged caution in the adoption of new techniques into merchant marine, especially due to the severe environmental problems and the fact that repair and maintenance were more difficult than in land-based industry.

The author's company had, so he had claimed, carried out a systematic study of a wide range of techniques for data transmission on board ships and had come out with specific solutions; for example, pulse width modulation, a serial loop highway, parity checking for error detection. However, other companies carrying our similar investigations had come to different conclusions and a wide range of techniques were being proposed. How was the shipbuilder or shipowner to choose between them ? Furthermore, the highway itself was but one component of future automation systems which if predicted technological developments were realised, would incorporate other novel devices, such as micro-processors, analogue to digital converters, visual display units, etc. The adoption of this digital technology would not be without pitfalls. Mr. Brown had alluded to some in his paper, not least of which was the electromagnetic compatibility of this new equipment and the possible contamination of digital data by shipboard radio and radar equipment, both of which would increase in radiated output power within the next decade.

For the above reasons many people felt that it was desirable to approach future ship automation in as comprehensive a way as possible and to focus more attention upon the operational requirements of the ship itself, and to define these in terms of new technology rather than vice versa. For this reason B.S.R.A. was currently involved in a programme of work aimed at ensuring the smooth introduction of digital electronic equipment into the next generation of automated ships, on behalf of the United Kingdom shipbuilding industry, in which the emphasis was on a total systems approach to the ship, the men who served on board and the equipment which would enable the vessel to fulfil her operational role.

In this context and with respect to digital transmission, B.S.R.A. would like to see a co-operative programme of work aimed at achieving a measure of standardisation, at least at interface level. Ideally this should also explore the economics of cable multiplexing in a wider range of applications than those mentioned in this paper. The work should be aimed at producing a code of procedure covering the use and installation of multiplexed systems on board merchant ships. It was desirable that the work culminated in a practical demonstration of multiplexing at sea for, without such a demonstration, it would be difficult to persuade owners and builders to accept what at first sight was a fundamental deviation from existing practice. Such a project would be both timely and welcome by most of the organisations involved.

Now a few specific questions: firstly economics in a paper with the title "The Reduction of Electrical Cabling Costs in Ships" it was surprising that definite figures were not given for potential savings. Had Mr. Brown any figures for either of the two applications described in his paper. In say the products carrier: how much cable would be saved; how much would the additional electronics cost, including the flameproof deckboxes; were any figures available for installation costs ?

Secondly, a few technical points. What techniques had been used in assessing the reliability of the proposed system ? For the examples given were figures available for MTBF and MTTR ? If a failure occurred in a deckbox, how could it be repaired without violating I.S. requirements if the ship was carrying a hazardous cargo ? Finally, a comment on electro-magnet interference: in the paper, Mr. Brown had implied that the cable used was unscreened. Mr. Harding understood that his company had had considerable experience in the use of equipment of this type in coal-mining applications when, almost by definition, the interference environment was benign compared with several locations on board a merchant ship. Furthermore, B.S.R.A.'s experience with shipboard instrumentation highlighted that contamination at radio frequencies would be a serious problem. Was the author convinced that the methods proposed in the text would be adequate to alleviate this type of problem and had any tests been carried out to verify their effectiveness in the marine environment.

MR. J.E. COOLING asked the author whether he had devised any relatively simple methods to compare the costs of a multiplexed system with one which was conventionally wired.

The author had said that, "a correctly designed system should not depend on a critical choice of cable". How lax could one afford to be in cable specifications ? Mr. Cooling also asked how the choice of cable type affected the data error rate when electrical interference was present.

Were figures available for the system error probability rate, when subjected to specified types of electrical noise, i.e. Gaussian ? Had the author actually subjected the system to electrical interference tests ?

What was the effect in the author's system if: either data line was shorted to the other data line, or to the power supply lines ?; the power supply lines developed a fault ?

Could a fault in a single outstation cause the complete system to malfunction ? He asked the author what was the maximum data rate at which he normally transmitted. At what voltage were the data transmitted ?

How many code protection binary digits (bits) were added to the digital message ? He inquired as to whether any additional safeguard, other than code protection, were incorporated when a control selection was carried out.

What protection was provided against noise on the analogue and digital inputs to the outstations ? Was there electrical isolation between the inputs/outputs of the system and the data highway itself ?

How many bits were used in an analogue to digital conversion ? Did the 56 data pulses represent the complete amount of data which could be handled by any one outstation ? How many analogue quantities could be handled by each outstation ?

From the presentation of the paper itself, Mr. Cooling's conclusions were that this was a system which had been developed for use in coal mines, was now being adapted for marine use. It had not been redesigned, or modified, to cope with the different needs of ship's systems.

The basic data highway system, including power supply lines, was highly vulnerable to cable faults, and a single short circuit could take a whole section of outstations out of action. The same would appear to be true of faults in individual outstations. Duplication of the data highway did not avoid these problems with the system as it stood.

The use of ordinary ship's cables for the data highway would be satisfactory only at low data rates. If the transmission rate had to be significantly increased, then pulse distortion problems would become a major concern.

His company's work had been directed towards the naval marine, where costs were considerably higher than in the commercial marine. Their experience suggested that digital multiplexing techniques were not likely to be cheaper than conventional wiring methods.

MR. P. DIEDERICH said that multiplex was often adopted, not only to reduce costs, but also to improve a system's integrity and to allow for future extensions. If a large number of channels was involved, some of the cost reduction could be re-invested in order to improve the reliability of communications. He noted that Mr. Brown had not opted for a duplicate system, but instead had used all his available resources in creating a single system of high integrity. He did stress the insensitivity of his equipment to electromagnetic interference; he did not, however, make any mention of the extra electromagnetic radiation hazard created from his necessarily high frequency signals resulting from multiplexing signals which, by themselves, were carriers of low frequency information. With this in mind a fibre optics approach had undoubted advantages.

Mr. Diederich's motivation for putting this approach forward was the increase of interference with which very low level navigation signals had to contend in the VLF and LF bands. An optical signal transfer would be immune to electromagnetic interference and would not radiate interference. Accidental shorting of signal cables to mains was completely avoided. Fibre optics were intrinsically safe and explosion-proof throughout the system's run. An optical channel possessed an enormous band width which permitted the multiplexing of a practically unlimited number of signal channels.

MR. F.E. HUTCHINS, B.Sc., F.I.Mar.E., said that the techniques of multiplexing, or data highways, were applicable only to a signal or control circuits. The potential savings applied to no more than 45 per cent of a typical warship cables - the balance being power circuits, although it was possible to apply power control signals through power cables.

Careful thought needed to be given to setting-to-work processes and of the need to isolate circuits during such routines which were often put in hand before the total ship cabling was completely installed or connected.

There was justification for using data highways on a system basis rather than on a total ship basis.

Using data highways, it was generally necessary to add a power operating device at a control terminal, to convert the signal as transmitted into a usable form to operate on, say, a hydraulic valve, or the like. This could well mean extra power leads as well as the signal lines at the terminals, tending to offset cable reductions and to increase costs.

There was no doubt that data highways and associated techniques had potential advantages in complex ship electrical systems - but the application and form of control needed careful consideration to avoid introducing undesirable complexity at extra cost with little, if any, advantage.

MR. J.A. ROGERS said that, in the presentation of the paper, most of the emphasis had been focused on the reduction in cabling costs by use of the Data Highway principle.

This could be misleading, for one should view the overall cost of the "system" and not just one part of it in order to obtain a realistic total figure.

The following approximate costs were typical for the Products Carrier mentioned in the paper:

Conventional Intrinsically Safe
Electro-Hydraulic Control System

| | |
|---|---|
| Cost of cable | £ 8,500 |
| Cost of cable installation | £11,500 |
| Total | £20,000 |

Consider now:

Using the Data Highway Principle

| | |
|---|---|
| Estimated cost of cable, including installation | £ 5,000 |

If these two figures, £20,000 and £5,000, were compared, the first conclusion was that costs were reduced to a quarter of the original, however, to the £5,000 must now be added the additional cost of the Data Highway hardware, which must be below £15,000 to show an overall cost saving

MR. D. ST. J. SEIGNE, M.I.Mar.E., said that he would like clarification concerning the system for the product carrier, with particular reference to the arrangement of the hardware on deck. It would seem that, if the cargo control valves were to be operated electrically, then the operating portions would need to be flameproof. Presumably the power taken to each deckbox by the highway would also be above the intrinsically safe limits and so would have to be utilised in a flameproof enclosure. How much then, of the necessary equipment can be intrinsically safe. Could each deckbox be served by one intrinsically safe transformer or barrier, or would a multiplicity be required ?

Referring to the container proposal, could the author enlarge on the statement: ".......... the containers assuming differing potentials with respect to ship's frame earth due to power supply lines breaking down .........." What order of magnitude was envisaged for this potential ? A figure of 440 volts was mentioned by an earlier speaker.

Could the author also confirm if the proposed systems meet or would meet the requirements of BS 1597, "Specification for radio interference on marine installations" ?

He could hardly let the opportunity pass without remarking on the phrase ".........., partially manned bridge .........." in the introduction to the paper. He had consulted a nautical surveyor colleague of his for a definition, but he was too upset to pass any comment!

CORRESPONDENCE

MR. B.F. CRAWLEY wrote that other benfits, which were not necessarily cost savings, could be envisaged in warship procurement, due to the very long timescales involved in the design and build of such complex vessels (10-15 years). Inter-compartment cable planning must be carried out reasonably early in this period and, therefore, tended to put a hold on the development of electronic systems prematurely to the date of design freeze dictated by equipment installation. This situation could be helped by the use of general purpose data highways between compartments, leaving the specialised cabling to be restricted to within particular compartments. These cable details could then be specified at the same time as the equipment was detailed, nearer to the useful operational life of the ship.

The benefits of reduced size of equipment (and weight), claimed by Mr. Anderson, as a result of the reduction in cable glanding and terminations appeared to be particularly attractive in the nuclear submarine context. However, on closer study, it would seem that these benefits only affected the interconnections of the main cable runs. At both the source and receiving end of each cable, the original number of terminations would be required to connect the existing equipment into the data highway. It was presumed, therefore, that introduction of the data highway would need to be accompanied by other system re-design to realise the full benefits.

He endorsed Mr. Hutchins' views that some form of circuit duplication, preferably of an automatic standby nature, would be necessary for many warship applications and, also, that the Navy would wish to see some successful application of the equipment in the merchant fleet, or similar environment, before dedicating themselves to it.

Mr. J.D. MCIVER said that the paper clearly outlined the principles and possible application of a data Highway to specific ship's systems.

The reduction in the capital cost of cable and its installation cost, together with the cost of supporting services, e.g. cableways, glandings, etc., required to be offset against the cost of the electronic equipment, and its specific requirements, e.g. mounting, servicing spares and test equipment, etc. Could the author indicate where he believed the "break even" point occurred, by relating it to the containership example quoted in the paper ?

One of the factors which could influence the total costing was related to the type of transducer, or other devices, required to operate into the "electronic data highway". Did these input devices require special contact ratings, or other electrical features, to make them suitable for operation into the data highway ?

One possible application could be to main-engine monitoring and control and, in this regard, the equipment could be responsible for main engine shut-down. Could the author indicate the order of reliability that he would anticipate from the data highway equipment and would it be advisable to duplicate equipments ?

In view of the alleged reduction in quality of ships staff, what type of maintenance or servicing was required ?

AUTHOR's REPLY

Mr. Brown first replied to Mr. J.E. Cooling. The system proposed was not identical to that used in coal mines, rather a derivative employing additional safeguards suitable for the marine environment. In the applications noted, the system was considerably cheaper than that used in the mining industry. Some points raised by Mr. Cooling have been very beneficial in indicating the form of further testing.

He could not agree with the conclusions arrived at by the above gentleman. The system had been specifically designed for marine use, incorporating lessons learned in the mining and other industries Further, no pretence had been made at providing a higher data transmission rate, as the intended applications for a low cost system did not require it. Correctly installed, the system would meet BS 1597 with standard ships cabling. Consideration of the points raised on cable faults had been made, and the system was now less vulnerable to these than was indicated at the presentation.

To Mr. D. St. J. Seigne he would confirm that the equipment would meet BS 1597 when correctly installed. The use of screened cable in an above deck application would be necessary, whilst below decks this was not essential. Further testing was envisaged to prove these points in the near future.

The comments on fibre optics were noted, and they could well be used with the existing system for inter-connection of outstations, however power would still have to be distributed by conventional copper cable.

He completely agreed with the comments of Mr. F.E. Hutchins on the possible savings in warships being some 45 per cent only. Whilst a dedicated data highway per ship system was a specific approach to cable saving, the author would suggest that the economic viability was increased with more than one system on a highway.

Mr. J.A. Rogers and Mr. J.D. McIver had both referred to the actual costing involved, especially in terms of an overall system, and its support from a maintenance viewpoint. These aspects depended upon the complexity of the total system, and what amount of self diagnosis was inbuilt in the system design. The break-even point between conventional systems and a data highway system was related to the number of points monitored or controlled. In the application Mr. Rogers had in mind, the break point was not achieved; in other applications it had been. In the container ship example described in the paper, the breakpoint had been assessed at 48 containers on a total system basis.

The comments of Mr. B.F. Crawley reflected the position at the present time, and, hopefully, equipment would be defined within the shipbuilding industry in the future with a view to providing a standard interface for data highway connection.

Mr. E.J. Harding's point about the variety of multiplexing systems being proposed for the marine environment was well made. This system was aimed at the general purpose highway concept rather than that required for a fully automated vessel which would be extremely expensive at today's costs. In both respects the author's company would be co-operating with B.S.R.A. in the field of data highway evaluation, and there was possibility of using the container equipment, mentioned in the paper, for subjective testing by B.S.R.A.

In respect of isolating the I.S. requirements when repairing a possible failure in a deck box, the author would stress that the very meaning of Intrinsically Safe Circuits was such that no hazard would be present.

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