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# SOME REPORTS ON THE STATE-OF-THE-ART IN AUTOMATION OF MODERN MERCHANT SHIPPING. VOLUME II. CONFERENCES AND VISITS

Donald H. Kern, et al

Purdue University

Prepared for:

Naval Ship Systems Command

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## VOLUME II – CONFERENCES AND VISITS

First Quarterly Report
May 16, 1973 – August 15, 1973
Contract No. N00024-73-C-5483
Naval Ship Systems Command

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 2425

REPORT NUMBER 55
Purdue Laboratory for Applied Industrial Control

**Prepared by**

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JUNE 18-29, 1973

# CHAPTER 9

# THE SIXTH IMEKO CONGRESS

DRESDEN, GERMANY

June 18-22, 1973

## BACKGROUND

IMEKO (The International Measurement Confederation, the initials are from the German language version of the name) is the recognized international technical and engineering organization in the fields of sensors, measurement theory, and measurement applications. It was formed in 1958 in Budapest, Hungary. It holds a regular triennial international Congress in the measurement field and numerous symposia and colloquia in the interim periods. As indicated above this particular Congress was the sixth of the IMEKO series.

Membership in IMEKO is ostensibly by countries with one engineering or physical society or academy in each country serving as the member organization for that country. The Instrument Society of America represents the United States in IMEKO. There are a total of 20 member countries with India just having been accepted as a member.

IMEKO recognizes four major languages in the presentation of its papers. These are English, Russian, German, and French. Papers may be written and/or presented in any of these languages depending upon the writers preference. Simultaneous translation is provided in the other languages during the presentation. However, publication is by photo-offset means and is thus in the language of origin. Publication of Congress papers takes place in a set of Preprints available at the Congress itself and a Proceeding published later by North Holland Publishing Company, Amsterdam, with the aid of the Hungarian Academy of Sciences.

## THE DRESDEN CONGRESS

The Dresden Congress of IMEKO presented a total of 175 submitted technical papers, 7 survey lectures, 2 technical addresses, and 11 round table discussions. These occurred in anywhere from one to seven simultaneous sessions over four and a half full days. Another half day was used for excursions to East German industrial companies and scientific research laboratories to view examples of their work in this area.

Of the above: 49 submitted technical papers, 2 survey lectures, and 2 round table discussions were directly applicable or topics very closely related to the ship automation field.

A list of these papers in presented in Table XIII subdivided according to general topic areas for those in the English language and likewise in Table XIV for those in the German language. It should be noted here that several of the important English language papers actually were prepared in Russia and other eastern countries but written in English for a wider appreciation of their contents. The same is true of many papers from western countries whose native language is not listed among the chosen four major languages.

## TABLE XIII

## IMPORTANT IMEKO CONGRESS PAPERS PRESENTED IN THE ENGLISH LANGUAGE

A. Theory of Measurement Systems (including reliability studies)

"Adaptive Methods for the Increase of Accuracy from Indirect Measurings"
Y.I. Perelman, O.A. Pelyakov, K.S. Ginsberg, USSR

"Networks and Error Accumulation"
L.-G. Rosengren, Sweden

"Synthesis of Measuring Networks with Given Vulnerability for the Acquisition of Measurement Data"
A. Koturewic, B.T. Dvazenovic, SFR of Yugoslavia

"Measuring Systems Optimization with Respect to Reliability Requirements"
J. Migdalski, J. Jazvinski, PR Poland

"Optical Design of a Hierarchy of Calibrations"
L.-G. Rosengren, Sweden

"The Role of Statistics in the Engineering of Measuring Systems"
P.K. Stein, USA

"Application of Multiple Regression Analysis in Measurement and Calibration"
K. Jizuka, M. Goto, Japan

"Unform Accuracy Specifictions for Measuring Instruments Used in Automttion"
H. Karsai. Hungarian PR

"Sampling Errors in Digital Measuring Methods"
A. Wojnar, PR Poland

B. Means and Methods for the Instrument-Computer Interface.

"Means and Methods for Measurement and Computer Interfacing"
T.J. Williams, USA, on behalf of IFIP

## TABLE XIII (cont.)

"Theory of Faults and Structure Optimum of Multi-Channel Change-Over Switches in Measurement Systems and Process Computers"
J. Semko, USSR

"Real-Time Digital Filtering in on-line Measurement Systems"
D.M. Velasevic, SFR Yugoslavia

"Acquisition of Measurement Data by Telemetry"
G. White, United Kingdom

### C. On-Line Measurement of Process Variables

"Sensors for On-Line Process Control"
W.E. Miller and W.G. Wright, USA, on behalf of IFAC

"A Transistorised Hot-Wire Anemometer"
I.K. Choudhury, R.K. Mukhopadhyay, India

"Flowmeter for Fluids and Gases"
G.A. Barill, Yu. G. Vasilenko, Yu. N. Dubnitshev, V.P. Koronkevitch, V.S. Sobolev, A.A. Stolpovski, E.N. Utkin, USSR

"Accuracy and Precision in Laser Doppler Flow Measurement"
J. Delcour, W.H. Havens, A.H. vanKrieken, J. Oldengarm, H.J. Raterink, The Netherlands

"Precision Cold-Junction Compensator for Twenty Thermocouples to Computer-Aided Process Control"
H. Haas, A. Hampel, Hungarian PR

"A Concept of a Computer-Based Information System for Power Generation Units in Thermal Power Plantes"
R. Cerny, CSSR

"A Measurement of Active and Reactive Power Variations: an Equipment Based on the Use of a Process Computer"
F. Ferraris, J. Gorini, Italy

"A Digital System for the Accurate Measurement of Phase Variations in Polyphase Networks"
R. DeMori, F. Ferraris, Italy

## TABLE XIII (cont.)

D. Measurement of Discontinuous Varibles

"Computer-Aided Analysis of Turbine Blade Vibration Test Data"
F.L.N.Nagy, S.R. Taylor, United Kingdom

E. Measuring Systems for the Detection and Control of Pollution

"Aerosol Pollution Measurement Using Turbulence Signal Techniques"
D.H. Harris, M.S. Beck, P.J. Hewitt, United Kingdom

"Remote Sensing of Oil Pollution by Optical Sensors"
S. Axelsson, Sweden

F. Testing Calibration, and Parameter Estimation of Process Sensors and Process Measuring Systems.

"Vibration-Interferometer for Mechanical Oscillation Scanner Calibration"
M. Navrátil, CSSR

"Mathematical Models in the Calibration of Measuring Equipment"
E. Layer, T. Sluszkiewicz, PR Poland

"Measurement of the Surface Temperature by a Zero Heat Flux Method"
Y. Morita, Japan

"Determination of the Performance of Pyrometric Measuring Instruments"
V.V. Kandyba, USSR

"The Evaluation of the Possibility of Increasing the Accuracy of Measuring High Pressure by Means of Manganin Transducers"
E. Czaputowicz, J.W. Szamotulski, PR Poland

## TABLE XIV

## IMPORTANT IMEKO CONGRESS PAPERS PRESENTED IN THE GERMAN LANGUAGE

A. Theory of Measurement Systems (including reliability studies)

"The Behaviour of Frequency Analogue Measuring Systems"
E.-G. Woschni, GDR

"Frequency-Analogue Converter FALCON in the PR 9321 Digital Strain Guage"
H.-D. Cargill, FRG

B. Means and Methods for the Instrument-Computer Interface

"Problems of Data Acquisition for the Automation of the Analysis of Radar Information with a Process Computer"
G. Richter, A. Beckert, GDR

"The Application of Hybrid and Digital Computers in the Field of Vibration Measurements"
K.D. Jahn, FRG

"Computer-Adapted Transducers with Frequency Output"
H.-R. Tränkler, FRG

"Standard Interface of the Electronic Measuring Technique with Regard to Computer Application"
G. Naumann, P. Kuntze, GDR

"A Programmable Electronic Equipment Set for Automated Collecting and Processing of Measuring Values with Application in Industry and Research"
P. Veith, FRG

"CAMAC - a Modular Instrumentation System for Computer-Aided Measurement and Control"
H. Klessmann, Berlin (West)

C. On-Line Measurement of Process Variables

"Possibilities of the Contactless Electrodynamic Flow Measurement"
H. Zecha, GDR

## TABLE XIV (cont.)

"Elimination of Errors in Ultrasonic Flow Metering"
Ch. Wartini, GDR

"Electronic Compensation of Viscosity Dependence of Turbine Flowmeters"
K. Molnár, Hungarian PR

"On Measuring Fluctuating Thermal and Temperature Fields"
L. Tomis, CSSR

"Principles of Fluidic Temperature Measuring Devices"
H.-J. Tafel, FRG

D. Measurements of Discontinuous Variables

"Comparison of a Spatial Filtering and a Correlation Method for Non-contact Speed Measurement"
R. Fritsche, F. Mesch, FRG

E. Measuring Systems for the Detection and Control of Pollution

"Measurement of Total Oil Content in Natural Waters"
M. Lohász, G. Eppeldauer, Hungarian PR

F. Testing, Calibration, aand Parameter Estimation of Process Sensors and Process Measuring Systems.

"Systems of Instruments for the Measurement and Analysis of Vibrations and Shocks"
D. Krieger, H.-J. Hardtke, GDR

"False Measuring Values in Electromechanical Vibration Pick-ups Due to Environmental and Coupling Influences"
G. Kleinmichel, GDR

"Identification of the Dynamic Behaviour of Thermometers"
D. Hofmann, GDR

"On the Influence of Dynamic Processes Upon the Determination of Accuracy Parameters of the Measuring Systems"
H.-J. von Martens, GDR

# THE STATE OF THE ART IN SENSOR DEVELOPMENT

As is mentioned several times in the discussion, reliable sensors are the major drawback to a wholehearted acceptance of computer control of ships by their crews. The survey paper by Miller and Wright, Paper A-4, "Sensors for On-Line Process Control," given at the IMEKO Congress is especially valuable in this regard with its review of the overall state of the sensor art as viewed from still another industry - the steel producing industry. Pertinent excerpts from this paper important for our project are reproduced below:

> "The objective of this paper is to summarize the situation which one will encounter when attempting to apply sensors, or to apply automatic control around sensor limitations, or non-availability. In order to acheive this objective with some degree of organization, it is proposed to divide sensors into three groups:
>
> GROUP 1 - Mature Development
>
> Group I comprises sensors which are commonly used throughout many industries, and which are considered to be in a mature state of development (Table I). Such devices will be characterized by relatively low costs, minor maintenance needs, and will give repeatable results at specified accuracies. Usually, these sensors are available from many different suppliers.

## TABLE I

### SENSORS - GROUP 1 - MATURE DEVELOPMENT

| Variable to be Measured | Sensor Type or Principle |
|---|---|
| Shaft Speed | Analog Tachometer,<br>Digital tachometer |
| Shaft Position | Various Analog devices,<br>Digital encoder |
| Force | Load Cells -<br>Strain Gage,<br>Magnetic Flux |
| Voltage | Potentiometer,<br>Transformer |
| Current | Shunt,<br>Current transformer,<br>Hall transducer |
| Power, KVAR | Hall transducer |
| Temperature | Thermocouple,<br>Pyrometer,<br>Resistance Temperature Detector |
| Pressure | Electronic Force Balance |
| Fluid Flow | Turbine |
| Fluid Level | Manometer with filtering and transmitter |

## GROUP II -Commercially Proven

Group II comprises sensors which provide measurements having an extra degree of difficulty (Table II). These devices will have been developed in recent years to meet the increasing needs of various industries. Sensors in this group are considered to be commercially proven, although due to their increased complexity, demands on maintenance will be higher.

## GROUP III - Experimental

Group III comprises sensors which may be considered in some way to be still experimental and needing further development effort (Table III).

In the context of this paper, all sensors are to be scanned by a digital computer. The output of the sensor, therefore, must be a voltage. In this regard then, the sensor may be regarded as a transducer which changes the actual variable into a voltage suitable for being read by the computer.

## State of the Art Summary

A complete state of the art summary is more than can be accomplished within the time and space limitations of this paper. However, a search of the literature reveals some interesting opinions, and to review a few of these will be valuable.

## Pressure, Flow, and Level

Rosenbrock and Young, in their 1966 IFAC survey paper "Real Time On-Line Digital Computers"(2), expressed the view that the chief measurement problems lay in the areas of flow and chemical composition. It seems that their statement is still true today.

## TABLE II

### SENSORS - GROUP 2 - COMMERCIALLY PROVEN

| Variable to be Measured | Sensor Type or Principle | Cost in $ 1000 | Application |
|---|---|---|---|
| Strip Thickness | X-Ray<br>Isotope<br>Contact | 30/50<br>15/25<br>3/ 5 | Rolling Mill |
| Slab Thickness | Thermal Scan | 12/18 | Rolling Mill |
| Strip Width | Thermal Scan<br>Optical | 40/60<br>40/60 | Rolling Mill |
| Plate Width & Length | Thermal Scan | 60/100 | Rolling Mill |
| Tension | Load Cell | 15/25 | Rolling Mill, Paper Machine |
| Plate Thickness and Crown | X-Ray<br>Isotope | 50/200 | Rolling Mill |
| Paper Thickness | Isotope<br>Electromagnetic | 10/30 | Paper Machine |
| Basis Weight | Isotope | 10/30 | Paper Machine |
| Moisture Content | Infra-Red | 12/20 | Paper Machine |
| Capacity | Optical | 10/30 | Paper Machine |
| Level, Density | Isotope | 5/10 | Distillation Column |
| Hot Steel Chemical Analysis | Vacuum Spectrometer<br>X-Ray Spectrometer | 15/20<br>15/20 | Basic Oxygen Furnace, Blast Furnace |
| Aggregate Analysis | X-Ray | 50/100 | Blast Furnace Cement Plant |
| % Oxygen | Paramagnetic | 5/10 | Cement Kiln |
| % Carbon Dioxide | Thermal Conductivity | 5/10 | Cement Kiln |

TABLE II con't.

| | | | |
|---|---|---|---|
| Slurry Density or Consistency | Radiation Absorption<br>Mechanical Torque | 5/10 | Mining, Cement Paper |
| Molten Metal Temperature | Expendable Thermocouple | $ 50 Each | Basic Oxygen Furnace |
| Temperature of body in relative motion | Slip Ring Thermocouple | 2/ 5 | Cement Kiln |
| Temperature | Two-Color Pyrometer | 5/10 | Steel, Cement |
| Noise | Microphone with selective electronics | 1/ 2 | Grinding Mill |

## TABLE III

## SENSORS - GROUP 3 - EXPERIMENTAL

| Variable to be Measured | Sensor Type or Principle | Cost in $ 1000 | Application |
|---|---|---|---|
| Strip Shape | Load Cells | 125/175 | Rolling Mill |
| Chip Moisture | Capacitance | 5/10 | Digester |
| Chemical Components<br>Vapor Pressure | Gas Chromatograph<br>Boiling Point Analyzer<br>Flash Point Analyzer | 5/10 | Distillation Column |
| Hot Steel Chemical Analysis | Neutron Activation | 20/50 | Basic Oxygen Furnace |
| Oxygen Activity & Carbon Content | Electro-Chemical | 2/ 4 | Basic Oxygen Furnace |
| Slurry Analyzer | X-Ray | 50/100 | Concentration Plant |
| Gas Analysis | Electro-Chemical | 5/10 | Basic Oxygen Furnace,<br>Blast Furnace |
| Gas Flow | Venturi Principle | 1/ 2 | Basic Oxygen Furnace<br>Blast Furnace |
| Coal Flow | Revolving vane plus pulse generator | 5/10 | Steam Boilers |
| Flue Gas Analysis | Catalytic Combustion<br>Paramagnetic | 5/10 | Steam Boilers |
| Carbon Dioxide Analysis | Catalytic Combustion | 5/10 | Sewage Plants |
| Rod and Bar Diameter | Thermal Scan | 10/20 | Rolling Mill |
| Turn Indicator for Plate | Thermal Scan | 20/30 | Rolling Mill |
| Linear Strip Speed | Laser | 25/35 | Rolling Mill |

This situation is not too surprising as far as chemical measurements are concerned, since such measurements are inherently difficult and complicated. But is the measurement of flow really so uncertain?

The Instrument Society of America Transducer **Compendium** 1969(3), stated that surprisingly few new types of flow transducers have been developed. The most widely used transducers were of types known and used for many years. Some new transduction principles were referred to. Among these are (1) magnetic resonance, (2) laser operated, (3) swirl meters.

It would appear today that these new instruments have not caused a revolution, and that in fact the situation in 1973 is still essentially the same as was described in 1966.

As expressed by ISA, there are three areas of flow measurement which present special problems. These are pulsating flow, two-phase flow, and slurry flow. Although pulsating flow theory exists, no entirely adequate meter has yet been developed. Two-phase flow occurs in many chemical applications where a fluid exists simultaneously as a gas and a liquid. Measuring total fluid rate is difficult.

The measurement of slurry flow is desireable in many different industries. In most cases, such measurements pose problems. Generally speaking, frequent maintenance is required to maintain the sensor reliability and accuracy at an adequate level.

When we turn to pressure and level measurements, we find that enough techniques exist to enable virtually any necessary degree of accuracy, reliability, and repeatability to be obtained. In this regard, it is interesting to list some of the devices or effects employed in the various level measuring devices. Among these are:

- Current Probes
- Nuclear Radiation
- Capacitance
- Sonar
- Ultrasonic

## Motion, Dimension, Force, and Torque

Sensors to measure these quantities are categorized as GROUP I of this paper. They are readily available from many suppliers, with probably 200 manufacturers located in the United States alone.

An interesting example of the use of a force sensor is encountered in the measurement of tension in either steel or paper.

## Temperature

Temperature sensors have been classified as either themometers or pyrometers. Originally, the term "pyrometer" was applied to instruments that measured temperatures above the range of the mercury thermometer. Today a different meaning is attached to the two terms. If the temperature-measuring device is inserted into or attached to the body or substance that is to be measured, the device is called a "thermometer". If the device is located some distance away from the temperature source, it is classified as a pyrometer. This concept practically limits the term "pyrometer" to radiation and optical devices.

"Thermometers" such as the thermocouples and resistance temperature detectors represent reliable measurement means in those cases where physical conditions permit their use. Where physical contact is not possible, we have to use some form of pyrometer. We may consider three types of sensors here. These are:

(1) Total Radiation Pyrometer
(2) Spectrally-Selective Pyrometer
(3) Two-Color Ratio Pyrometer

All of these have been used with satisfactory results in various applications.

## Humidity and Moisture

In the last three years a large number of advanced control systems have been applied to paper machines. These have employed sensors to measure such things as moisture content, capacity, weight, etc. In the United States, nearly 100 such systems have been installed. The sensors for these, therefore, have been included in GROUP II.

## Geometric Measurements

Sensors to measure geometric quantities, e.g., width, thickness, diameter may be said to have reached a very satisfactory degree of development. They can also be very expensive, perhaps more so than any other sensor.

# REVIEW OF CHEMICAL ANALYSIS TECHNIQUES

For many people, chemical measurements have an air of mystery which may almost seem to verge on black magic. With the thought that a concise review of the ways of making such measurements may be welcome, the following summary has been prepared.

## Classification of Measurement Methods

Chemical composition variables are measured by observing the basic interactions between matter and energy. Atomic theory of matter leads to the concept that theenergy states of electrons within a substance are characteristic of the composition of that substance. These energy states can be inferred by observing the consequences of interaction between the substance and an external source of energy. This external energy may be in any of the following basic forms:

(1). Electromagnetic Radiation
(2). Chemical affinity or reactivity
(3). Electric or magnetic fields
(4). Thermal or mechanical energy

## 1. Interaction with Electromagnetic Radiation

This method involves the measurement of the quantity and quality of electromagnetic radiation emitted, reflected, transmitted, or diffracted by the sample. Some techniques involved in this are:

X-Ray analysis
Ultraviolet Spectrophotometry
Infra-Red Spectrophotometry
Microwave Spectroscopy
Colorimetry
Polarimetry

## 2. Interaction with other Chemicals

The chemical affinity of certain compounds for each other often permits positive identification and analysis of chemical components by virtue of their interactive behavior. It should be noted that while these reactions are unique for each element or compound, they may be masked by the presence of more reactive substances. These techniques, therefore, should be applied only to systems of known composition limits. Measurements which may be taken are:

Consumption of sample or reactant
Measurement of reaction products
Thermal energy liberation
Equilibrium solution potentials

## 3. Reaction to Electric and Magnetic Fields

This method involves the measurement of the current, voltage, or flux changes produced in energized electric and magnetic circuits containing the sample. The instrumental techniques which are based upon reaction to electric and magnetic fields include the following:

Mass Spectroscopy
Electrolysis
Measurement of electrical properties
Measurement of magnetic properties

## 4. Interaction with Thermal or Mechanical Energy

Instrumental techniques which are based upon interaction with thermal or mechanical energy include the following:

| Effects of Thermal Energy | Effects of Mechanical Energy or Forces |
|---|---|
| Thermal Conductivity | Viscosity |
| Melting & Boiling points | Sound Velocity |
| Ice Point (Crystallization) | Density |
| Dew Point | |
| Vapor pressure | |
| Fractionnation | |
| Chromatography | |
| Thermal Expansion | |

A discussion of techniques falls short of providing the knowledge and insight necessary to design or specify a chemical analysis system or device. For specific problems, one should either consult a specialist, or refer to the literature and develop the necessary background himself(1,3)."

## REFERENCES

1. Considine, D.M., ed., "The Handbook of Applied Instrumentation," McGraw-Hill Book Company, Inc., New York, 1964.

2. Rosenbrock, H.H., and Young, A.J., "Real Time On-Line Digital Computers," 3rd Congress of IFAC Proceedings.

3. Harvey, G.A., ed., "ISA Transducer Compendium," Instrument Society of America, Pittsburgh, Pa., 1969.

# CHAPTER 10

# VISITS TO ORGANIZATIONS ACTIVE IN SHIP AUTOMATION ACTIVITIES

## INTRODUCTION

Report co-author T.J. Williams took advantage of the trip to Europe to attend the IMEKO Congress and the IFAC/IFIP Ship Operation Automation Symposium to visit several organizations manufacturing components for ship control use and/or engaging in research on advanced ship operation practices.

# GEC-ELLIOTT AUTOMATION LIMITED

GEC-Elliott Automation Limited was formed in 1969 by the merger of the General Electric Company (England - no relation to G.E. in the United States) and the Elliot Process Automation Company along with many small subsidiaries of both. At the time of the merger Elliott was one of two major process control computer manufacturers in the United Kingdom, the other being Ferranti. GEC also manufactured process control computers but like G.E. in the United States these were used mainly in control of steel mill systems and power stations manufactured by GEC.

The difficulties of the reorganization have consumed the best part of three years with the result that GEC-Elliott Automation Limited has lost the best part of that amount of time in its competition with comparable companies throughout the world. However, with the consolidated company they do have the capability of carrying out complete plant automation systems for any type of industry including shipping. They also have a new computer design, the Model 4080, which appears to be excellent for any of these tasks if not too expensive. Thus they promise to become a power in the automation field, probably including shop automation, in the relatively near future.

Visits were made to the offices of GEC Computers, Borehamwood, Hertfrdshire, where the following individuals were contacted:

Mr. S.L.H. Clarke, Group Technical Director

Mr. D. Harvey, Marine Systems Division,
GEC-Elliott Process Automation, New Parks,
Leicester.

Mr. Roger Charters, Group Leader,
4080 Computer Project, GEC Computers.

At this location Mr. Charters reviewed the 4080 Computer and a visit was made to the manufacturing floor where the first two examples of this machine were in successful operation and being used for program development work. It was learned that the first commerical models will appear in November 1973 and that production is sold out through February 1974 (16 machines).

This machine is comparable to the most modern and capable American 16 bit minicomputers and is in the price class of the larger and more expensive of these. This may be the most important drawback considering the fast price reduction still occurring in US machines of this class today.

Mr. Harvey described the capabilities and products of the Marine Systems Division. These are described in detail in the material in Appendix II-1 and will not be repeated here. In addition to these control systems the GEC Group of companies can supply all other components of the ship except the hull, ie, engines, radars, pumps, communication equipment, cargo machinery, etc. Unfortunately a major group of personnel built up by Elliotts for marine automation prior to the merger was lost during the long period of reorganization and must be redeveloped.

A visit was also made to the Hirst Research Laboratory of GEC at Hirst, Hertfordshire. Here the following individuals were contacted in addition to Mr. Clark who accompanied me:

Mr. Robert W. Sutton, Mgr. Automation Laboratory

Mr. John Blomberg, Project Leader, Ship Positioning, GEC Electrical Projects, Rugby.

Miss Sue Robertson, Programmer, Automation Laboratory

The ship positioning project involves the control of a drilling vessel equipped with fore and aft ducted propellers in the face of wind, current, and tidal forces. Such a vessel would be used for deep ocean drilling and positioning to within an accuracy of about 7 meters is required to prevent damage to the drill stem. The project is being carried out by Mr. Blomberg on the hybrid computer system of the Hirts Research Laboratories, Automation Laboratory with the help of Miss Robertson. Successful operation with a relatively simple ship mathematical model has been achieved. It should be noted that successful U.S. versions of such systems have been in active use for some time.

## DECCA RADAR LIMITED

Decca Radar is a major manufacturer of marine radar systems and engine room analog alarm monitoring and control systems. They are a very conservative company believing that ship owners demand a set of very high quality instruments and controls which do not push the state of the art. They manufacture a full set of 3 and 10 cm marine radars which are advertised as "anti collision" systems but which depend completely on manual operation. These sets are very widely sold. Their principle of operation is explained in Appendix II-2.

Decca manufactures a full range of analog alarm monitoring and control systems for engine rooms from the very simplest to the most complex EO/UMS system. These are:

ISIS 100 - Developed in 1973, the very simplest of systems where complete manning of the ship is envisioned.

ISIS 200 - Developed also in 1973, a completely conventioned analog system incorporating the latest in single separate loop techniques.

ISIS 300 - Developed in 1968, a very superior integrated system employing remote multiplexing and some digital techniques but not a recognized digital computer as such. Incorporated in many ED/UMS systems.

ISIS 400 - Decca is prepared to go to complete computer systems when demanded by their customers. They feel this may be several years away at present.

Present requirements of customers for the various systems is predicted by Decca as being as follows:

| | | |
|---|---|---|
| ISIS 100 | - | 19% |
| ISIS 200 | - | 70% |
| ISIS 300 | - | 10% |
| ISIS 400 | - | 1% |

A specification for the ISIS 300 systems is presented in Appendix II-3.

The following individuals were contacted at Decca Radar Limited:

Mr. C.L. Taylor, Marketing Director

Mr. J.H. Beattie, Marketing General Manager

Mr. R. Harris, Marine Automation Sales Manager (ISIS Systems)

Mr. H.L.A. Fry, Bridge, Navigation and Radar Product Manager

Decca personnel also discussed with this author their joint project with the Department of Trade and Industry of the British Government on future ship automation. This project entitled MANAV is sponsored 50% by Decca and 50% by the Department of Trade and Industry. Esso was an early participant but has since left the project.

This project assumes that the transocean problem will be easy to solve and is already being thoroughly studied by others. They are concentrating on what they call the "estuarial problem", ie., navigation in fairways of harbors, bays, and rivers, and the problem of stopping the vessel at a position close to the dock. They assume that final docking will be done by means of tugs, etc. They are also concentrating on the use of existing charts since they feel that translation of these to CRT signals is an almost insurmountable problem.

This project is a very long term one and an early solution is not contemplated.

## BRITISH SHIP RESEARCH ASSOCIATION

The British Ship Research Association is a private research group engaged in research related to the shipping industry - mainly concentrated in ship building automation activities. They are supported approximately one third each by ship builders, ship owners, and the Department of Trade and Industry of the British Government. Individuals contacted there were:

Dr. R. Hurst, Director of Research
Mr. Michael N. Parker, Head, Computer Division
Mr. John E. Chadbund, Head, Production Division
Mr. George R. Snaith, Head, Marine Systems Division
Mr. Edward Harding, Computation Engineer
Mr. James Morrison, Marine Engineer
Mr. John Fellows, Economist

Appendix II-4 presents a review of the work of BSRA and a set of organizational charts.

The most important project of BSRA in light of our present project is their study of "An Automated Ship Having a Minimum Crew". This project was funded for a seven month feasibility study by the Department of Trade and Industry. A report is due in mid Fall, 1973. It will probably call for a demonstration study on an actual ship. The proposal which resulted in the actual funding for this project is presented in Appendix II-5.

## NORCONTROL

Norcontrol is the major Norwegian company in the ship automation field and a world leader in the production of computerized, radar-based, anticollision systems. Personnel of this company were responsible for the successful conclusion of the M/S TAIMYR Project in 1969 which established radar based anti-collision systems as a viable ship automation component. At present they have approximately 50% of the world market on these systems. Appendix II-6 presents a review of their present product line in the ship automation field, including both digital computer based and conventional systems.

# APPENDIX II-1

## CAPABILITIES OF THE GEC-ELLIOTT AUTOMATION LIMITED IN THE SHIP CONTROL FIELD

# GEC-Elliott Process Automation Limited

Head Office
New Parks, Leicester, LE3 1UF
Telephone: 0533 871331 Telex: 34551
Cables: 'Assocelect' Leicester

GEC Elliott Process Automation Limited is capable of supplying through its marine systems division comprehensive systems and consultancy services covering the following:

- Control of main engine speed and direction of conventional diesel systems for the normal range of vessels, e.g., cargo liners, OBO carriers, refrigerated cargo ships, small coastal tankers, LNG and LPG carriers.
- Control of main engine speed and direction of steam turbine driven vessels such as the very large crude oil carriers and container vessels.
- Automatic control of main and auxiliary engine services whether diesel or steam.
- Automatic control of generating plant.
- Cargo space temperature and refrigeration machinery monitoring and control.
- Automatic watchkeeping.
- Supply of complete bridge and control room consoles, etc.

The growing trend towards standardisation in the shipping industry has resulted in cost stabilisation and greater ease of maintenance due to the employment of engine room staff on a day work basis in accordance with UMS classification. Additional advantages stem from increased automation; quite apart from the potential savings in manpower there is more consistent operation and continuous supervision of plant which can lead to longer machinery life and a significant decrease in costly shutdowns.

A logical development from equipment standardisation is the 'package approach' with a single manufacturer assuming responsibility for the design and supply of comprehensive systems.

The advantages of such a concept are two fold. For the shipbuilder, the reduction in time, paperwork and cost can be significant, while dealing with a single supplier for a wide range of equipment reduces complication and duplication of effort. For the shipowner, when the ship has gone into service, maintenance and repair problems can be greatly reduced.

To sum up, the advantages of the package deal are:

- The customer is relieved of design problems.
- Equipment and systems are more efficient.
- The spares situation is improved by standardisation of parts.
- Complications in after sales service, spares and maintenance are reduced because the customer deals with only one manufacturer.

The marine systems division of GEC Elliott Process Automation represents the consolidation of the marine automation activities of the GEC, English Electric, AEI and Elliott Group of companies. A tremendous range of company manufactured equipment is available including marine supervisory and control systems both electronic and pneumatic, diesel engines for marine propulsion

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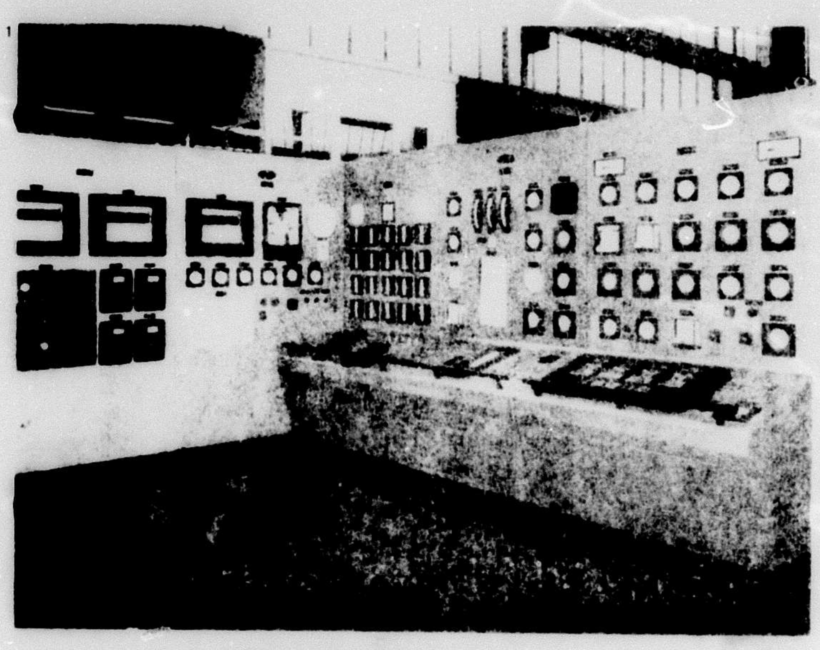

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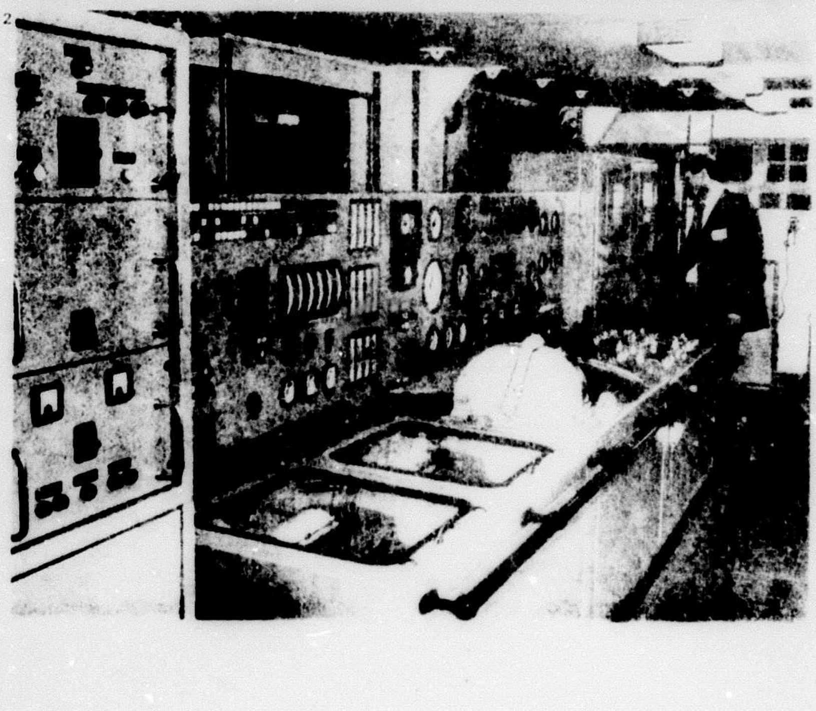

*1 The main cubicle and control desk for the engine room automation and control of supertankers. This panel shown on test in the GEC-Elliott Process Automation Limited factory is for a 284 500 dwt giant tanker being built by the Odense Steel Shipyard Ltd. for A. P. Moller Ltd.*

*2 The main and auxiliary machine control console of the 12 500 dwt Lloyd Braziliero MV 'Itaquice'. The GEC-Elliott Process Automation Limited computer based automatic watchkeeping equipment performs several distinct functions, including logging engine parameters, automatic trend recording, alarm recording, manoeuvre recording and indication of machinery malfunction.*

and auxiliary duties; motor control gear; motors; alternators; a.c. electrical equipment; diesel and turbo-electrics; turbines; communications and navigational aids; and complete marine automation systems. This wide manufacturing capability means that the 'integrated package' approach to contracts in in the shipping industry can be undertaken.

### Main Engine Control Systems

A low cost pneumatic system specifically designed for the marine industry offers high accuracy components with few or no moving parts. A wide choice of bridge systems is available to suit operational requirements. It is of modular concept and each item is completely piped, wired and tested prior to despatch.

In this GEC system the logic control section is pneumatic, a feature common to all transmission systems offered. They are available in different forms to suit varying operational requirements.

The company also offers alternative types of bridge control equipments including electronic systems and systems 'tailored' to suit particular engine and operating needs.

Each overall system, may readily be broken down into the following sub-sections, each one requiring careful consideration if the control system is to operate with maximum efficiency:

1 Signal transmission between bridge and engine control position.
2 Logic control system.
3 Individual propulsion plant requirements.

### Automatic Watchkeeping

Automatic watchkeeping systems offered are based upon compact stored programme computers. The use of computers provides a flexibility and sophistication which enables the system to be easily adapted to suit any marine application or to be expanded to provide greater automation.

The automatic watchkeeping system provides the following major advantages integrated into one compact system:

- Comprehensive alarm coverage.
- Time identified records of all abnormal conditions in the engine room and cargo spaces.
- Monitoring of main engines, auxiliaries and electricel systems without the need for large and complicated instrument panels.
- Printed records of manoeuvres.
- Computation facilities for importent parameters.
- Production of engine room log.
- Trend recording.
- Simple adjustment of alarm limits.
- Instantaneous digital display of any selected variable.

Information from the ship's plant is gathered by the watchkeeper system in two basic forms: analogue signals such as temperatures or pressures, and state signals from contact closures on machinery. Monitoring of analogue sources ensures that any rapid deterioration can be forestalled. When an analogue point exceeds its defined limits or a digital point is activated by a fault the alarm system will indicate the faulty point while a typewriter will print out all relevant data. The state of any point can also be indicated on demand.

The watchkeeping system is housed in a compact cubicle, while the operators control panel is located on the main console together with the output typewriters. The equipment is designed to operete under the extremes of environmental conditions encountered et sea and conforms to the specifications of the marine classification societies.

### Other Systems

In addition to computer-based automatic watchkeeping, the company also supplies conventional systems for remote and automatic control of machinery, comprehensive instrumentation and alarm systems.

GEC-Elliott Process Automation Limited can supply complete systems for any marine application, co-ordinating the manufacturing capabilities of some of the foremost names in the sphere of marine equipment.

All equipment is constructed to withstand the rigorous environmental conditions encountered at sea and is designed to meet the stringent requirements of marine classification societies.

*3 The GEC-Elliott Process Automation Limited MARCH 2112 computer-based automatic watchkeeper successfully completed tests to gain approval by Lloyds Register of Shipping, the American Bureau of Shipping and Bureau Veritas. One of the test programmes required for the approval of marine equipment includes 100 hours operation under dry heat conditions at up to 70 C, humidity and temperature cycling down to −10 C.*

*4 A 210,000 dwt tanker built by Odense Steel Shipyard Ltd. came into commercial service early in 1969. It is fitted with GEC-Elliott Process Automation Limited engine-room automation and control equipment.*

*5 The print out of all events is presented on one of the two typewriters in the watchkeeping system console of the M.V. 'Glen Avon' supplied by GEC-Elliott Process Automation Limited. Immediately above the typewriters are complete identification lists of the analogue and state points on the vessel. The system control panel is on the right.*

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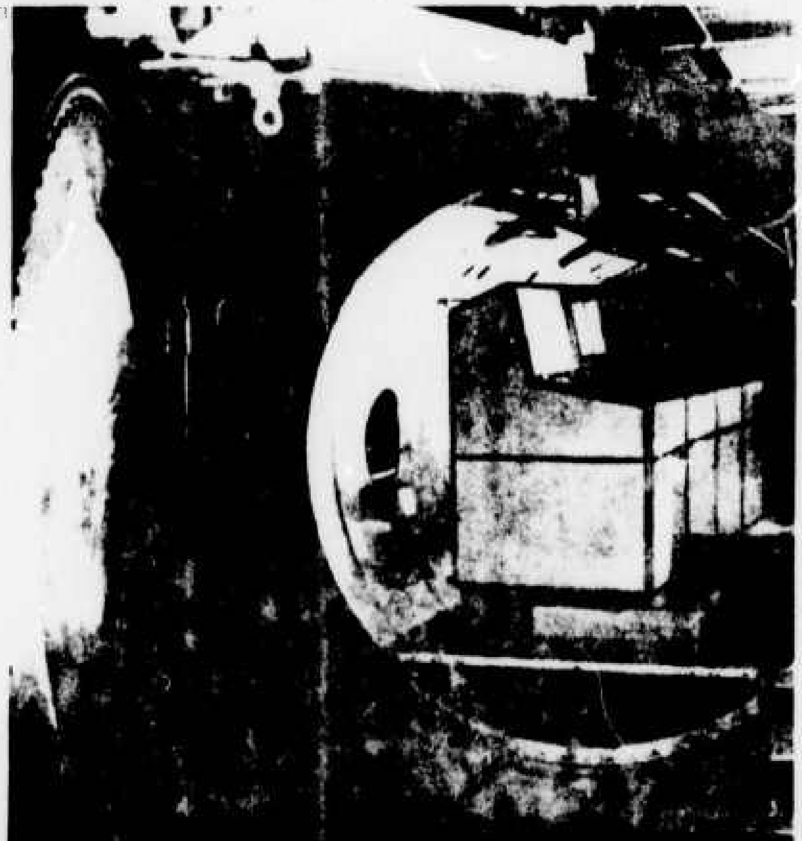

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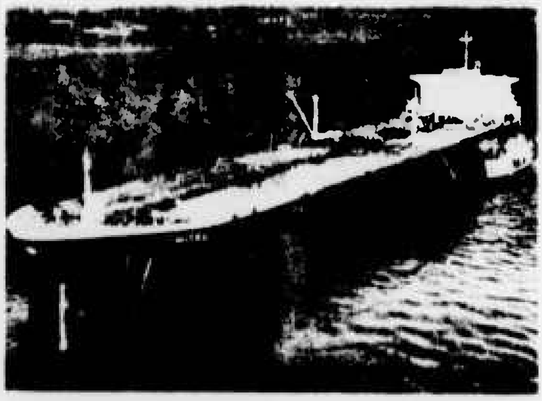

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# GEC-Elliott Electrical Projects Limited

Head Office
Boughton Road, Rugby, Warwickshire
Telephone: 0788 2144
Telex: 311335
Telegrams: 'Projelect' Rugby

GEC Elliott Electrical Projects Limited serves world industry by designing supplying and commissioning comprehensive electrical systems and associated control schemes tailored to meet the exacting requirements of many industries. The Marine Drives Group of The Electrical Projects Company offers to the marine industry the combined expertise of the former English Electric, AEI and GEC marine units, backed by the considerable research and production resources of the present GEC and the know how of GEC Elliott Automation in the field of computer technology.

The Marine Drives Group produces fully engineered 'project' systems for its customers, and also provides a very useful single contact and centre of responsibility for those contracts where integration of individual products is desirable. In particular, it is responsible for all forms of electric propulsion and special drive systems, including shaft-driven generators, pulse generators, winch schemes, dredging plants, floating cranes, oil drilling equipment, floating docks, high-voltage marine systems and all naval work. Its spares and service section provides the back-up required to maintain the equipment throughout its working life.

### Electric Propulsion

Scores of diesel electric, turbo electric and gas turbo electric ship propulsion systems have been supplied by the companies now within the GEC group, some dating from the early part of the present century. Some recent examples are the Antarctic supply vessel RRS 'Bransfield', which has a 5000 shp single-screw twin engine diesel electric propulsion system which can be remotely controlled from the mast head 'conning' position as well as from the navigating bridge.

Recently commissioned is the 3400 shp twin-screw suction dredger 'Sir Thomas Hiley' which is operated in Australia by the Brisbane Department of Harbours and Marine. This vessel is equipped with three diesel-generators connected in a constant current loop which supplies the two propulsion motors, two suction pumps jet pump and bow thruster.

The 'Willem Heckroodt' and 'Danie du Plessis' are two 2270 shp twin screw fire fighting tugs, each powered by three diesel generators which provide the electrical supply to the propulsion motors and fire pumps, utilising a modified Ward Leonard control system. An example of steam turbo-electric drive is the 20 500 shp twin-screw ferry 'Rangatira', built to operate between the north and south islands of New Zealand, where The Union Steam Ship Company have operated electrically propelled ferries since 1931.

The experience of the Marine Drives Group indicates that a case exists for the increasing use of gas-turbo-electric propulsion in the immediate future. This form of drive requires minimal maintenance, and a figure of 10 000 running hours between major overhauls can confidently be expected.

Electric propulsion is often utilised where extra flexibility of control is required, a typical example being the fisheries research vessel being supplied to the Department of Agriculture and Fisheries of Scotland. This is a 2000 shp single-screw diesel electric vessel in which the generator sets are mounted on a special raft equipped with flexible mountings which isolate vibration from the ship's hull.

### High Voltage Systems

The Marine Drives Group has pioneered the application of high voltage electrical supplies to marine work, and has considerable experience in this field. Examples include the two B.P. tankers 'British Admiral' and 'Argossy', the Cunard prestige liner 'Queen Elizabeth 2', and, more recently, two 18 900 tdw product carriers built by Cammell Laird at Birkenhead for the Esso Petroleum Company Limited. One of the main factors influencing the selection of a 3.3 kV system for these two vessels was the considerable saving in space and cost achieved by the use of vacuum contactors on the main switchboard. The generating equipment of each of these ships comprises two 2.4 MW, 3.3 kV brushless alternators which are shaft driven from the main propulsion gearbox, and two auxiliary diesel-driven 525 kW, 440 V generators. The 3.3 kV switchboard is equipped with air circuit breakers for control of the alternators and vacuum contactor-starters for the four 750 hp cargo pump motors and two 600 hp transverse thrust motors.

*1 The control room of the Antarctic supply vessel R.R.S. 'Bransfield', showing (left) the main control console and (right) the main a.c. switchboard*

*2 An engineering rating in the steering flat of RFA 'Lyness' a Royal Navy supply ship. Other Royal Naval vessels equipped with GEC telephone systems include 'Ark Royal', County and Leander class frigates, nuclear submarines, and the Royal Yacht 'Britannia'*

*3 Dust covers removed from a 100-extension cabinet-type exchange installed on the 'Oriana'. Other well-known passenger liners fitted with GEC telephone systems include the 'Canberra', 'Northern Star', 'Southern Cross' and 'Iberia'*

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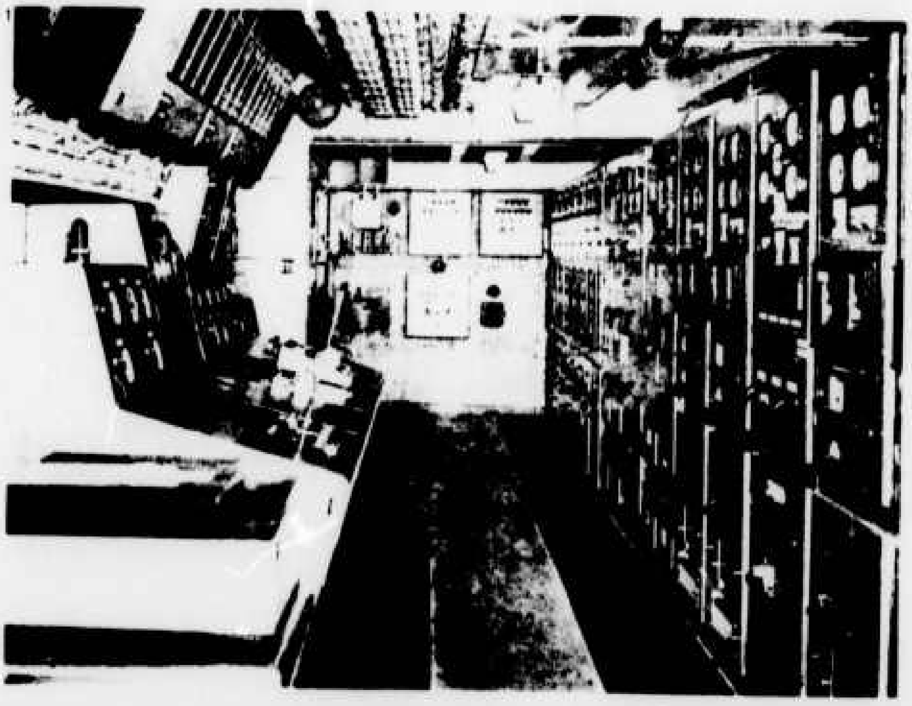

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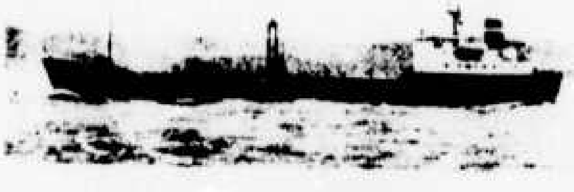

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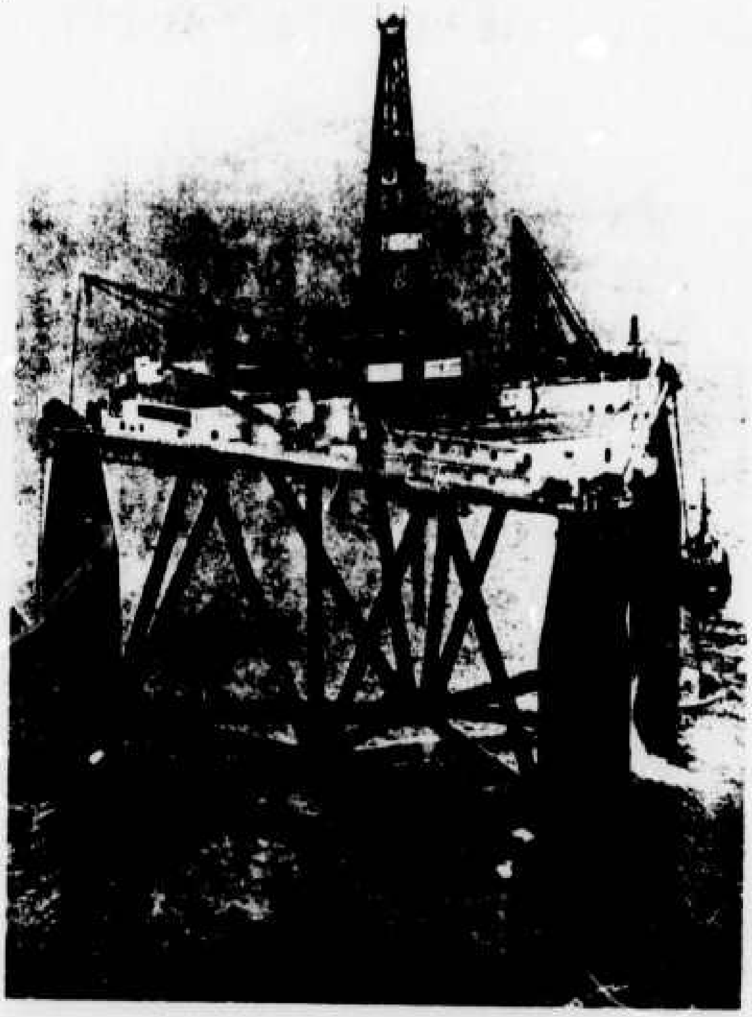

*4 The 7000 ton oil-tanker 'Port Tudy', which utilises thyristors to supply d.c. to the electric drives to the cargo pumps*

*5 The 2270 shp diesel-electric fire fighting tug 'Willem Heckroodt'*

*6 The 5000 shp diesel-electric Antarctic supply vessel R.R.S. 'Bransfield'*

*7 The B.P. drilling rig 'Sea Quest' is equipped with electrical generating plant drives and communications equipment supplied by the Electrical Projects Marine Drives Group*

### Off-Shore Platforms

The Marine Drives Group has accumulated considerable experience in electrical equipment for off-shore drilling. One equipment has been in continuous operation for nearly twenty years, and has given complete satisfaction. More recently, equipment was supplied for the B.P. Rig 'Sea Quest', which has been used extensively for drilling in the North Sea. Such equipments were formerly of the Ward Leonard type, often used in conjunction with amplidynes to provide special control characteristics, but the development of thyristor control has now reached a stage where these solid-state devices can be used with complete confidence for off-shore work.

### Thyristors

Since thyristors were first introduced in 1963, GEC has been in the forefront of the development and application of all types of drives on land and sea, and has supplied equipments to control drives up to 7000 hp. A recent example is the 7000 ton tanker 'Port Tudy' which utilises thyristors to supply d.c. to the electric drives to the cargo pumps. These have been in successful operation since early 1970, and a sister ship with similar equipment entered service late in 1971.

### Computers

The experience of GEC-Elliott Electrical Projects Limited in the application of digital computers to the on line control of major industrial installations is currently being utilised in the marine field, where considerable effort is being devoted to the development of automatic equipment for the dynamic positioning, or station-keeping, of vessels, by means of on-line computer control.

GEC is one of the world's foremost suppliers of electrical drive systems for all types of cranes; this expertise is particularly strong in the field of container cranes, and is linked with their marine experience in a comprehensive capability for equipping floating cranes.

### Telephones

For fifty years GEC has been installing telephone systems in every type of vessel—the experience of half a century that enables GEC-Elliott Electrical Projects to design communication systems for ships of any size or type. Standard cabinet-type automatic exchanges are available for 25, 50 or multiples of 100 extensions. Alternatively exchanges with unlimited capacity, automatic or manual, can be custom-built for the largest cruise liner.

Ships' exchanges can be connected to the public telephone service via the radio room, or by shore lines when in port. Other facilities include executive right-of-way which allows designated officers to break into established calls, fire alarm and emergency calling, and connexion to public address systems. In the event of a power failure the telephone systems can be arranged to operate from the ship's emergency power supply. A complete service is provided from the original system planning and design to installation and regular servicing.

# GEC-Elliott Process Instruments Limited

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Telephone: 01-692 1271 Telex: 22469
Telegrams: 'Elliotauto' London SE13

## Electronic Weight and Force Measurement

GEC Elliott electronic weighing equipment is widely used in both landbased industries and in marine applications. In addition to straightforward weighing, it is employed on ships particularly for measurement of propulsion thrust and cable tension.

The equipment employs electrical load cells, incorporating resistive strain gauge transducers which permit accuracies and repeatabilities of better than 0.1 per cent over ranges from a few pounds to thousands of tons. A flexible system of electronic instrumentation modules meets the most complex requirement, with remote transmission and indication, recording, control and computer interface facilities available if needed.

An important application that becomes increasingly significant as the sizes of vessels increase, particularly with tankers and bulk carriers, is propulsive force measurement. This provides valuable data to the marine engineer and architect, and is a useful tool in operating the vessel at its optimum point on the speed/fuel cost curve. Such systems have been installed on, among others, the 'Esso Northumbria', the largest vessel ever built in the United Kingdom, and her sister ship. Typically, between twelve and twenty load cells are mounted in a circular array at the thrust block of the propeller shaft and give, through their associated electronics, a continuous and direct measure of the propulsive force, measured at the point where that thrust is sustained. This direct measurement ensures the highest accuracy, compared with any inferential technique.

Another major application is on submarine cable laying ships, monitoring cable tension to prevent damage or fracture, whether in laying new cables or in lifting existing cables for inspection or repair. Since the first such system was installed aboard the cableship 'Mercury' in 1955, similar equipment has been supplied for many other vessels.

Again, measurement is direct, with a special rig mounted at the pay out station in the bows, but without interfering in any way with the cable laying operation.

Similar techniques are applied to other cable tension measurements—to prevent loss of scientific apparatus trailed from oceanological survey ships, to measure trawl line tension as a precaution against net breakage on fishing boats, to test or monitor tug tow line strain, and to ensure that mooring cables are not excessively loaded.

General marine applications of electronic weighing include cargo weigh *platforms*, and load cells built into winches and cranes for logging purposes and to ensure that safe loads are not exceeded. On dredgers and ballast vessels, belt weighers are used both to achieve safe distribution of the cargo and for delivery of known quantities of material.

A novel installation on the fringe of marine technology is a system built for weighing

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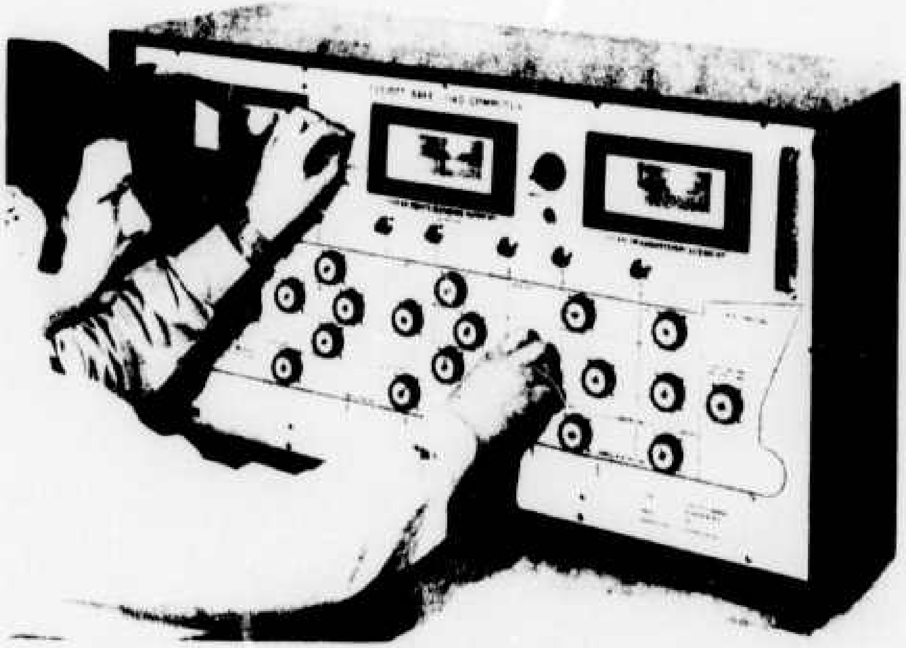

*1 The ship safe loading calculator provides fast and accurate calculations for cargo distribution*

*2 Presentation of how bending moments and shear forces vary along the hull*

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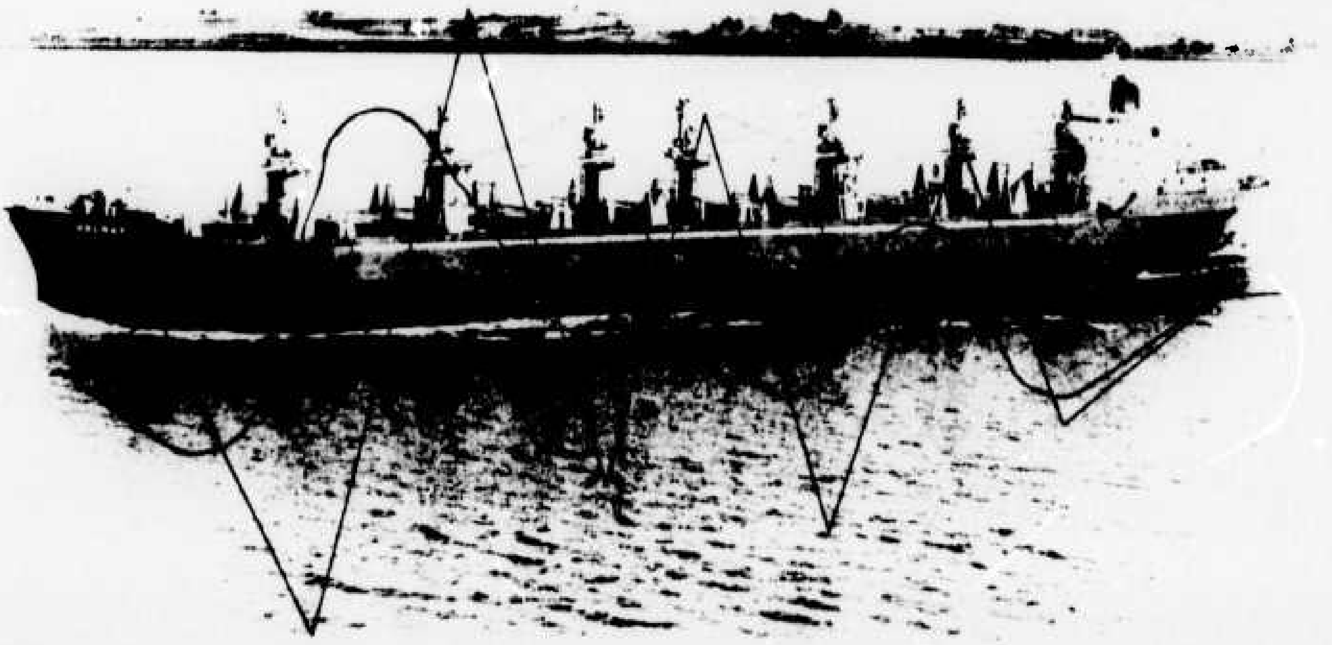

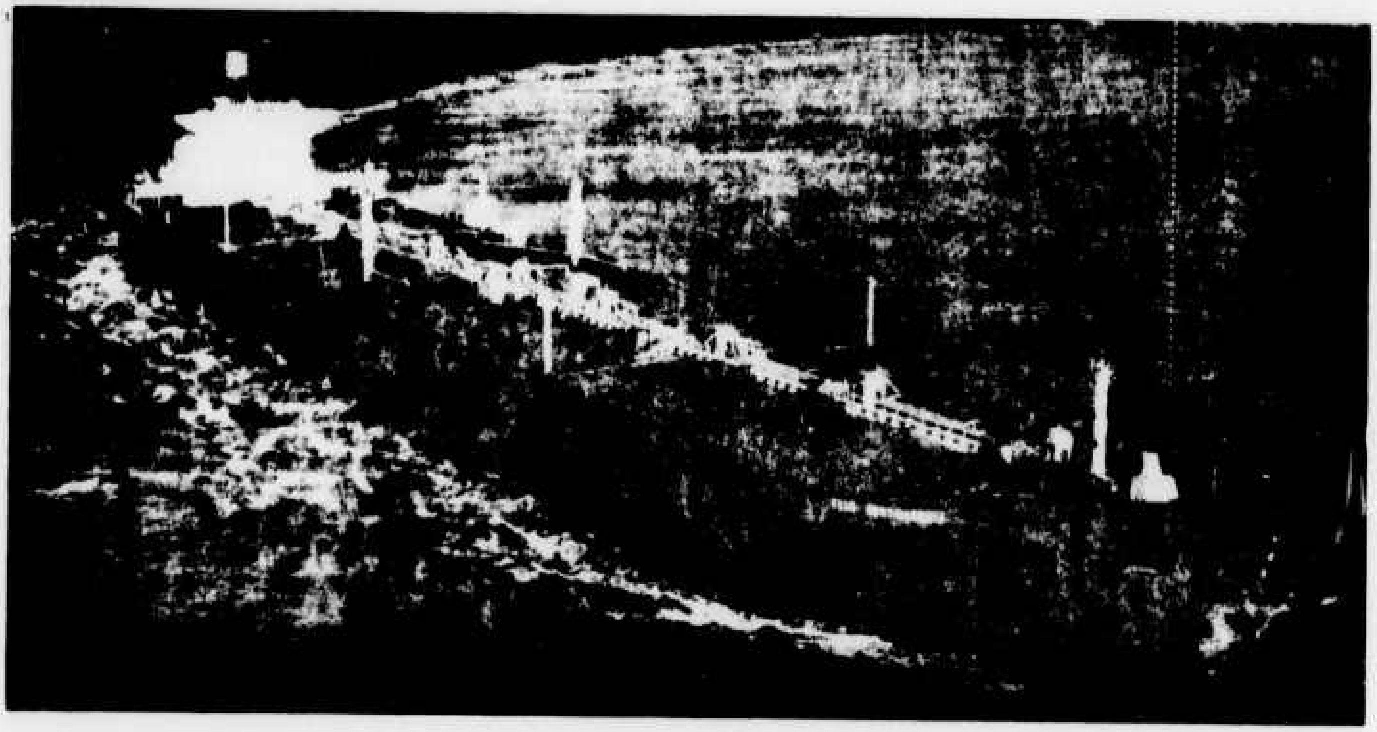

3 *'Esso Northumbria'*

*(Photo: Esso Petroleum Company Limited)*

hovercraft. By supporting the craft on load cells, the makers were able to determine precisely the centre of gravity and to test balance both statically and with lifting thrust.

## Ship Safe Load Calculator

The GEC-Elliott ship safe loading calculator provides a quick and accurate means of determining the optimum distribution of cargo within the various holds, to achieve correct trim and to minimize stress on the hull. It eliminates laborious manual calculation, which may seriously delay loading and hence extend the vessel's turn round time, and enables deck officers to check a proposed load distribution within two or three minutes.

Each calculator is built to specification for a particular ship and a diagram of the ship, including all cargo tanks or holds, is engraved on the front panel, with loading dials mounted in their appropriate positions. The operator simply dials in the proposed load for each hold and the unit automatically carries out the required calculations. Drum type indicators with long scales for easy and accurate reading, continuously display both trim and displacement. Multiposition switches then enable the operator to read out the resulting shear forces and bending moments at various points along the hull, the results being displayed on a third drum indicator.

BM and SF are automatically presented as a percentage of the maximum permissible value at the point selected. Red and green bands on the scale thus show immediately whether the condition is safe, without reference to tables. Since by definition the peak shear forces and peak bending moments cannot occur simultaneously at the same positions, the calculator provides readout points at carefully selected positions where the maximum forces are most likely to arise.

The calculator responds immediately to changes in input and the results are continuously updated. The operator can therefore see at a glance whether his redistribution of cargo is producing a better result, and so can quickly obtain the best loading pattern for safe and profitable operation.

The instrument has been approved by Lloyds and other major international classification societies, producing results accurate to within 2 per cent for shear force and 3 per cent for bending moment. Trim can be read within 25 mm and draught resolved to better than 1 per cent.

An important optional feature of the GEC-Elliott instrument, not available on other loading calculators, is particularly significant for owners of tankers and bulk carriers. This additional facility provides automatic calculation and compensation for the 'bulkhead effect' – the transfer of forces from the hull by internal structures that results from alternate hold loading patterns.

Other special features of the calculator include a 'harbour' switch that modifies SF and BM results for still water conditions, allowing greater flexibility in calculating the sequence of loading, or a 'ballast' mode that automatically incorporates the higher BM values allowed by Lloyds for bulk carriers in ballast. A 'store' facility enables a previous load condition to be instantly recalled for comparison purposes. Provision is also made for actual deflection, in millimetres (or inches if required), to be displayed on the BM indicator.

The instrument is strictly a calculator, which employs electronic analogue techniques to simulate the effects of various loading conditions. It therefore does not require connection to the ship's hull, but operates solely from a 110/230 V, 40-60 Hz supply.

The calculator incorporates a set of test loading conditions which enables the operator to check that every part of the instrument is in proper order, before making calculations. The test routine takes only a few minutes.

## General Marine Instruments

In addition to the safe loading calculator and the electronic weight and force measuring equipment described here, GEC-Elliott Process Instruments markets a wide variety of other marine instruments of both *general* commercial type, approved by Lloyds' Register of Shipping, and Admiralty Pattern. These include certain components also incorporated in the marine automation systems constructed by GEC-Elliott Process Automation.

Among these instruments are the Barton and Moore product ranges of pneumatic instrumentation, widely employed in, for example, control of flow, pressure, level and other parameters associated with engine and bridge systems on merchant ships. The Admiralty Pattern pneumatic instrumentation and control equipment, providing broadly similar functions but to more stringent specifications, includes valve positioners, multifunction calculating relays, controllers, pressure regulators, temperature and pressure transmitters, differential pressure instruments, motion transmitters, and accessories such as air filters for use with these units.

GEC-Elliott instrumentation is also much used in monitoring conditions in both normal cargo spaces and in refrigerated produce holds. Such equipment is commonly based on an indicating controller recorder, with platinum resistance thermometers. A very wide range of Dynamaster potentiometric instruments is available to meet virtually any such requirement, in accordance with Lloyds' requirements.

## Installation and Maintenance Services

As well as supply of instruments, the company operates two specialist divisions providing a comprehensive installation, maintenance and repair service for instrumentation and control equipment. These units undertake both regular and emergency contracts, and can supply trained staff or undertake the recruitment and training of personnel on behalf of the client. The services of these divisions are available to any ship builder or operator, and are not conditional on the purchase of hardware from the parent company.

# GEC-Elliott Industrial Controls Limited

Head Office
Kidsgrove, Stoke-on-Trent, ST7 1TW
Telephone: 07816 3511 Telex: 36293/4
Cables: "Enelectico" Stoke-on-Trent

This company combines the industrial control activities of GEC, English Electric and AEI. Electronic and electromechanical products for marine application range from main propulsion control equipments to small motor starters.

### Main Propulsion Controls

The company designs and manufactures control equipment for any form of marine electric drive including main propulsion, dredger drive and bow thrust. The photograph shows final tests being carried out at Rugby works on the engine room control desk and main propulsion control cubicle for the twin screw, 9000 ton, 20 500 shp seagoing turbo-electric ferry 'Rangatira'.

### L.T. and H.T. Multimotor Control Centres

The GEC-Elliott Mark V range of fully metric multi-motor control centres are modular in concept, and very compact in design. A special 'marine high' version is available with a maximum height of 1979 mm as opposed to the 'industrial high' of 2335 mm. Designed to class 3C of BS 4070/1966 and IEC 158-1, the Mark V centres can be supplied with a full range of starters and feeders. The busbar system is rated up to 3000 A, with a 31 MVA fault-rating. A recent order covered two Mark V centres for each of 24 fast cargo liners for Brazil's merchant fleet.

For applications requiring fully withdrawable starters, the Company manufactures also the Type MMC1000 motor control centre. Amongst ships recently fitted are the Shell Tankers 'Mactra' and 'Murex', and the seagoing ferry 'Rangatira'. The equipment is available for a 50 MVA fault level.

High tension applications are at present comparatively rare in the marine field, but indications are that this is becoming more acceptable because of economic advantages. The GEC-Elliott HMC400 3·3 kV vacuum contactor control centres are very compact; up to four 1300 hp starters occupy a cubicle measuring only 762 mm wide by 2286 mm high. The use of GEC-Elliott vacuum contactors ensures a very high degree of reliability and provides over 2 000 000 full load operations without contact maintenance. HMC400-W equipment has recently been supplied for the Esso tankers built by Cammell Laird.

### L.V. Motor Starters

A complete range of a.c. standard hand-operated and automatic motor starters in industrial enclosure is available from 1 hp up to the largest sizes required. The range includes a series of starters in special marine enclosure.

### Adjustable speed d.c. thyristor drives

The 'Emotrol' series of standard thyristor-controlled adjustable speed d.c. drives is available from 1/4 hp. to 600 hp. Fully modular construction is used to ensure maximum flexibility together with simplified servicing, and the equipments are offered with an exceptionally wide range of extra facilities—at an exceptionally low cost.

### Static Exciters and Automatic Voltage Regulators

The use of static AVR's and static exciter/AVR systems has been a feature of GEC and AEI development since the 1950's. There are over 400 merchant ships in service equipped with the company's static regulating systems. These include 'Queen Elizabeth 2', and many of the largest super tankers now at sea.

### Generator Automatic Load Control Systems

The standard GEC-Elliott automatic synchroniser, load sharing and master frequency control units are designed to cover many different applications ranging from maintaining a steady load on one diesel generator operating in parallel with shaft-driven generators, to fully automatic load demand control of multiple machines.

### Static Inverters

GEC-Elliott Industrial Controls manufacture three categories of inverters for marine applications:—

General purpose: For operating a.c. driven equipment from ships d.c. mains 110V or 220 V.

Standby: For protecting important plant against supply failure.

No-break: For provision of guaranteed power supply to essential instrumentation, on-board computers, and other sophisticated electronic and electrical equipment, with complete continuity in the event of power supply failure.

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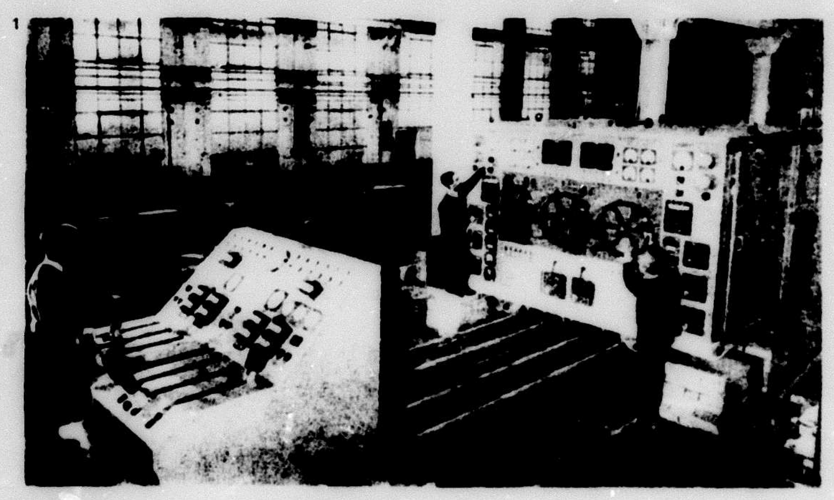

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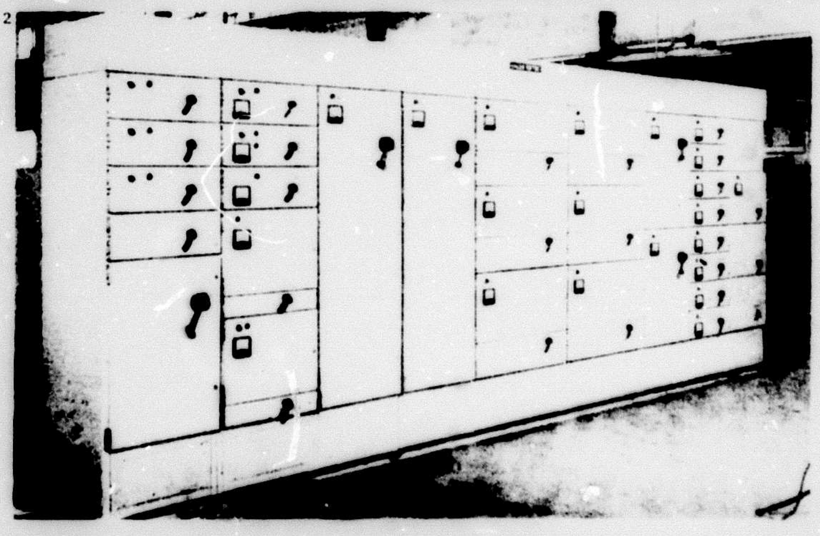


*1 Main propulsion control for the [illegible]0 500 shp T.E.V. 'Rangatira' on final test at Rugby works*

*2 Mark V multi-motor control centre designed specifically for marine applications*

## MARINE SYSTEMS DIVISION

## RANGE OF ELECTRONIC MONITORING & CONTROL EQUIPMENT

GEC-Elliott Process Automation Limited - Marine Systems Division are able to offer a comprehensive range of monitoring and control equipment from a straightforward alarm system through to sophisticated computer based control systems.

All the equipment is in "modular" form which means that extra facilities can be added by plugging in extra modules, unwanted facilities can be left out to reduce costs, and repairs can be quickly carried out. The design is solid state throughout with maximum use being made of integrated circuits, and printed circuits.

The range consists of the following:-

### 1. ALARM ANNUNCIATOR SYSTEM

This is a non-scanning system for monitoring conditions on the ships machinery. Inputs must be from contacts e.g. pressure and level switches. When an alarm condition is detected, visual and audible alarms are generated.

The system offers the following facilities:-

(1) Initiation from normally closed or normally open contacts.

(2) Detection of fleeting alarms.

(3) Delayed initiation of alarms - particularly useful for avoiding spurious alarms from level switches due to ship's movement.

(4) Generation and inhibition of group alarms.

(5) Print out of alarms on a "strip" printer.

(6) Calling system to relay alarms to the bridge and accommodation for UMS requirements.

Items (3) to (6) are optional and can be left out if not required.

### 2. LOGIC SEQUENCING SYSTEM

These systems are for such applications as generator control, pump control, burner management, in fact any process requiring logical decisions and sequencing.

The equipment used is the MARCH 4 Programmable Logic Controller (PLC) and the MARCH 4 range of Input/Output units.

The following facilities can be provided:-

(1) Logical decisions.

(2) Timing and sequencing.

(3) Counting.

(4) Comparison of values with fixed limit or variable setpoint values.

(5) Outputting of control signals.

3. COMPUTER BASED SYSTEMS

These cover the more sophisticated applications such as:-

(1) Data logging and manoeuvring recording.

(2) Efficiency calculations.

(3) Calculations of hull loading.

(4) Control functions such as boiler and generator control.

(5) Cargo handling.

(6) Planning of maintenance.

The equipment used in the GEC 2050 mini-computer together with the MARCH 4 range of Input/Output units. The 2050 computer is a real time machine designed for industrial and marine applications. The 'T' version is specially toughened for marine and other rough environments.

D.R. NEAL/KK
15.6.73.

# MARCH 4 Programmable Logic Controller

| | |
|---|---|
| **PLC processor** | **M40-81-00** |
| **PLC fixed store No.1** | **M40-80-00** |
| **PLC fixed store No.2** | **M40-80-01** |
| **PLC Test/Monitor** | **M40-82-00** |
| **PLC bin** | **M41-13-00** |

Associated Equipment (Input/Output Modules)

| | |
|---|---|
| Digital Input – 16 contacts | M40-24-00 |
| Digital Input – 16 electronic | M40-23-00 |
| Digital Output – 16 power (with read in) | M40-41-10 |
| Digital Output – 16 relay (with read in) | M40-40-20 |
| Sequence Timing Unit | M40-61-00 |
| Program Writing Unit (off line) | M40-00-10 |

The MARCH 4 Programmable Logic Controller (PLC) is a low cost assembly of standard modules which enables industrial processes and machines to be controlled and sequenced in a more convenient, flexible and economic way than is possible using hard wired relay or solid state logic networks.

The PLC program is held in a plug-in modular PROM store (Programmable Read Only Memory) and the program is written by the Process Control Engineer when specifying his control system. The instructions repertoire is chosen to enable simple logic, sequencing and timing, and also more sophisticated counting, comparison and industrial data handling type programs to be efficiently and simply programmed.

## PROGRAM INSTRUCTIONS

**Bit Instruction**

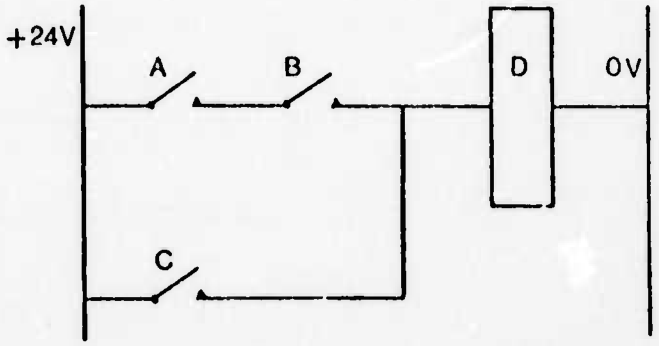
There are three types of instruction, the first type operate on individual bits of digital input/output (I/O), and a single bit B register within the PLC, for example:-

| | |
|---|---|
| BIN | Inputs a specified I/O bit into the B register. |
| BOUT | Outputs the contents of the B register to a specified I/O bit. |
| AND | Forms the logical AND of the specified I/O bit and the contents of the B register and places the result in the B register. |
| OR | Forms the logical OR of the specified I/O bit and the contents of the B register and places the result in the B register. |

A.1001-280

**Relay Example**

These, and other one bit instructions, may be used in logic networks such as the very simple example shown:-

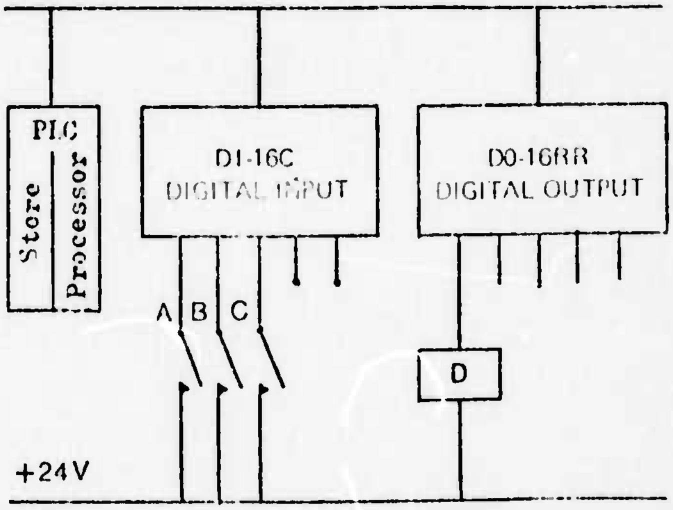


The relay D is operated if A and B close together OR if C closes. Assuming that the PLC's digital inputs come from the normally open contacts A, B and C and that a PLC digital output drives relay D, the required program is simply:-

```
BIN     A
AND     B
OR      C
BOUT    D
```

The connections to the PLC are shown below:-

MARCH 4 INTERFACE



Unlike a conventional relay network, the connections are independent of the logic required, this being determined by the program. Also, a single input contact may be used many times in the program, without the need for its physical replication.

## PLC OPERATING INSTRUCTIONS

The following are typical of the instructions available.

### Bit Instructions

| | |
|---|---|
| BIN | Input the specified Bit to the B register |
| CBIN | Input the **complement** of the specified Bit to the B register. |
| BOUT | Output the contents of the B register to the specified Bit. |
| AND | AND the specified Bit and contents of the B register and place result in B register. |
| CAND | AND the **complement** of the specified bit and the contents of the B register and place result in B register. |
| OR | OR the specified Bit and the contents of the B register and place result in B register. |
| COR | OR the **complement** of the specified bit and the contents of the B register and place result in B register. |
| BOUTO | Output a one to the specified Bit. |
| BOUTZ | Output a zero to the specified Bit. |
| BONE | Set the contents of the B register to one. |
| BZERO | Set the contents of the B register to zero. |

### Word Instructions

| | |
|---|---|
| WIN | Input the specified Word to the A register. |
| WOUT | Output the specified Word from the A register. |
| EQUAL | Set B register to One if specified input Word **equals** the contents of the A register. |
| MORE | Set B register to One if specified input Word is **more** than the contents of the A register. |
| LESS | Set B register to One if specified input Word is **less** than the contents of the A register. |
| COUNT | Count (i.e. add plus one) in the specified Word. The count is in Binery Coded Decimal (B.C.D.) and the result is also placed on the A register. |
| WOUTZ | Output a zero to the specified Word, and clear the A register. |
| CLA | Clear A register, i.e. set its contents to zero. |
| RESET | Reset all I/O units. Note S, I, A and B registers and variable store are **not** affected. |

### Jump Instructions

| | |
|---|---|
| JUMP | JUMP the sequence count to the specified value. |
| JONE | JUMP the sequence count to the specified value, if the contents of the B register equal one. |
| JZERO | JUMP the sequence count to the specified value, if the contents of the B register equal **zero**. |
| ENTER | ENTER a sub-routine, i.e. jump the sequence count to the specified value and preserve the old value. |
| EXIT | EXIT from a sub-routine, i.e. jump the sequence count to the value preserved (by the previous ENTER instruction) plus one. |
| PATCH | Jump the sequence count to the next multiple of octal 40 less one. |
| NON-OP | No operation – i.e. jump to next instruction in sequence. The address part of this instruction is not significant but is normally all zeros. |

Program Writing Unit

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a GEC Elliott Automation company

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### Word Instruction

The second type of instructions operate on 16 bit words of I/O and the contents of a 16 bit A register within the PLC, instructions to input or output a word, compare two words for equality, count in a word (representing a 16 bit BCD number) etc are included.

The PLC contains an internal 16 word (each of 16 bits) variable store which may be addressed with either bit or word instructions. It is used for storing the intermediate results of logical programs or temporarily for storing 16 bit data words.

### Jump Instruction

The third type of instruction enables the program sequence to be varied by causing the controller to jump to another point in the program, including jumping to a sub-routine.

## SPEED

The PLC will repeatedly perform programs at speeds which are typically between 1000 and 100 times per second (depending on the length of the program). Thus the typical response time to a change of state of an input contact is between 1mS and 10mS.

## STANDARD SUB ROUTINES

Sub routines are self contained programs of instructions which may be entered from more than one point in the main program. Standard sub-routines are available for many frequently used operations, such as timing, counting and sequencing.

## TEST/MONITOR UNIT

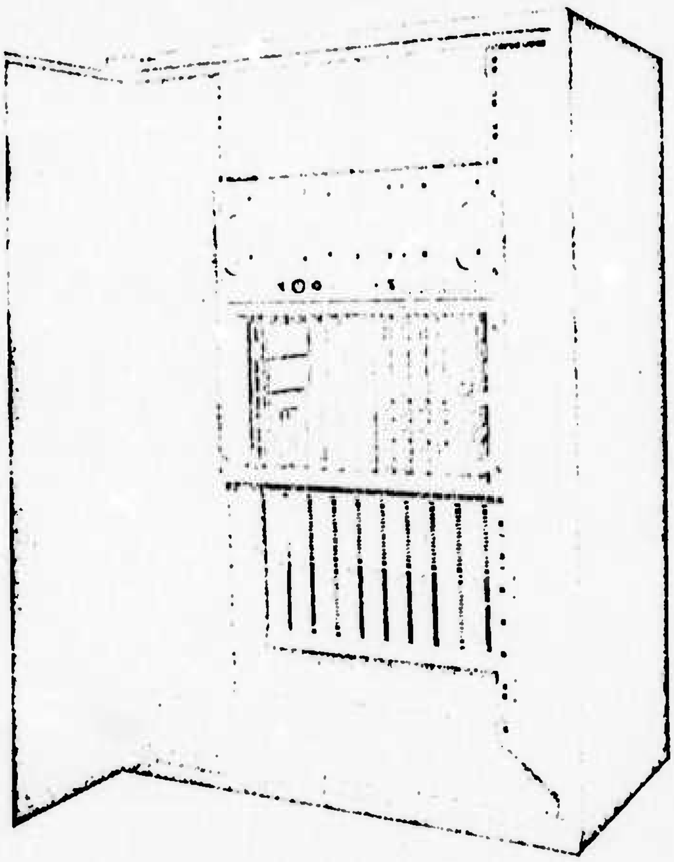
An optional Test/Monitor Unit is available which may be used to test the PLC's internal working or to monitor the states of any of the digital I/O signals.

## PROGRAM WRITING UNIT

An off line Program Writing Unit (PWU) is available for permanently writing the program into the fixed PROM store via an operator keyboard. Provision is made for modifying the program once written, should this be required.

## PHYSICAL CONSTRUCTION

The PLC consists of a Processor Card, one or optionally two Fixed Store Cards and an optional Test/Monitor Card, mounted in a standard MARCH 4 size 19" wide 10½" high bin. Provision is made for a Sequence Timing card and ten other MARCH 4 I/O cards in the same bin. This bin together with the necessary power units and an I/O terminal field is normally installed in a 30" x 42" x 18" wall mounting cubicle or can be mounted in any other suitable 19" rack assembly.



## SPECIFICATION

| | |
|---|---|
| Instruction Code: | 11 Bit Instructions<br>9 Word instructions<br>7 Jump instructions |
| Speed (approximate): | 10μS per bit or word instruction<br>2μS per jump instruction |
| Fixed Store: | |
| Type | PROM |
| Word size | 16 bits |
| Module size | 32 words |
| Maximum size (1 store card) | 512 words |
| Maximum size (2 store cards) | 1024 words |
| Variable Store: | |
| Type | RAM |
| Word size | 16 bits (also bit addressable) |
| Size | 16 words |
| Input/Output | |
| Word size | 16 bits (each bit is individually addressable). |
| Address field size | 47 ways (of 16 bit words).<br>Therefore the PLC can communicate with a total of 752 input + output points. |

# Classification societies approve GEC·Elliott computer·based watchkeeper system

A major breakthrough in marine automation has been achieved by GEC-Elliott Process Automation Ltd., of Kidsgrove, Staffs. The company's computer-based "automatic watchkeeper" system has now been type-approved by three major classification societies: Lloyd's Register of Shipping, the American Bureau of Shipping and Bureau Veritas. According to the manufacturers the GEC-Elliott system is unique in being approved by these three major societies.

More than 40 standard computer-based systems have been ordered from GEC-Elliott and the latest order brings the total value of these contracts to about £3m.

The latest order is especially interesting in that it has been placed by the Marine Engine Division of Doxford & Sunderland Ltd for use on the company's new engine test bed. We understand that the initial application will be mainly for control, performance calculations and data logging of the Doxford-Hawthorn Leslie Seahorse medium-speed engine (S & S R, July 10, 1970) the four-cylinder prototype of which is due on trials in the near future.

APPLICATIONS

The first vessel to be equipped with the GEC-Elliott Process Automation computer-based watchkeeping system was the Glen Avon (S & S R, October 3, 1969). This 800 dwt sludge carrier is operated by Bristol City and County Corporation with a completely unmanned engineroom. In service for the past two years in the confined waters of the river Avon and the Bristol Channel, the Glen Avon installation has proved the benefits of an advanced marine automation system and operated without any marine engineers on board, giving a 35% reduction in crew.

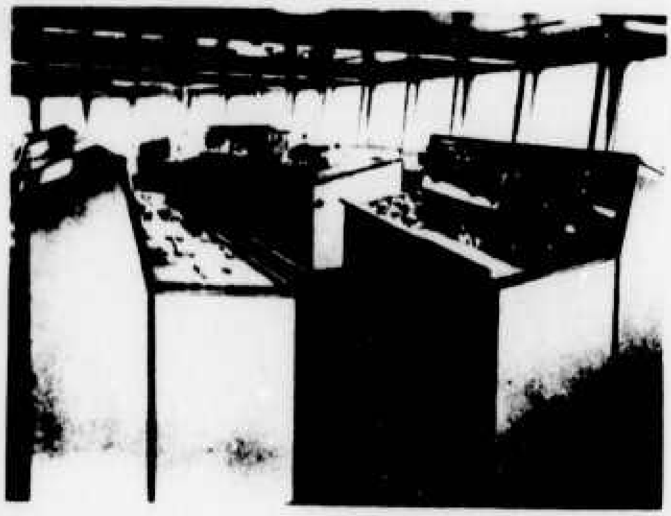


**Fig.1.** Bridge consoles on the pioneering Bristol Corporation vessel Glen Avon in which the GEC-Elliott computer-based automation system entirely replaces engineroom staff.

The ship and all its machinery is easily controlled from the bridge and all key parameters, ranging from all manoeuvres, the operation of main machinery to fire detection, are monitored and recorded automatically.

For the White Fish Authority, GEC-Elliott Process Automation is providing an advanced computer-based watchkeeper system for the St. Jasper, a modern stern freezer trawler designed from the outset for unmanned engineroom operation. Over 650 parameters are monitored via a MARCH 2112 computer, including 480 digital points and a number of other functions.

The potential value of automation aboard relatively small vessels, such as trawlers is proving particularly significant because the high rate of manoeuvring and stress of local operations, demands constant surveillance of engineroom operation. Automatic systems such as the GEC-Elliott computer-based automatic watchkeeper system releases valuable manpower for duties required to ensure continuity of fish catching, handling and freezing. The St. Jasper systems will also be used, in connection with inputs from ancillary equipment, for ship management functions, for example, deciding the optimum time to change fishing grounds by computing the rate of catch to the time/cost of reaching more productive fishing grounds.

OVERSEAS ORDERS

For 34 fast cargo vessels, 3 product carriers and one OBO vessel now building in three Brazilian and in two Continental shipyards, the standard GEC-Elliott MARCH 2112 automatic watchkeeper system is being installed. Although four types of main engines and other differences in the machinery are involved, this versatile system enables all operational facilities connected with controls, displays and the data logging, to be similar on each ship, providing the various Brazilian owners with complete flexibility in manning the ships and minimising training problems. Sixteen of the 25 ships to be built in Brazil are to Lloyd's Register rules, the remainder are to American Bureau of Shipping classification.

More than half of the present Brazilian contracts for computer-based equipment have been delivered to the shipyards and four have been successfully commissioned, the first having been in operation for more than nine months.

A class of 10 Polish-built vessels will also have the standard GEC-Elliott automatic watchkeeper. The first vessel, the Amaralina successfully completed her sea trials off Gdansk last December. Similarly, the first of three Yugoslav vessels to be equipped with the system is in service and has completed three months initial sea going duty to obtain Bureau Veritas certification.

## PROVEN RELIABILITY

Functional testing of the standard GEC-Elliott computer-based automatic watchkeeping system, in both console and cabinet versions to gain Lloyd's, American Bureau of Shipping and Bureau Veritas approval has been carried out at the British Aircraft Corporation environmental test facilities at Stevenage, Herts., England.

The test programme included 100 hours operation under dry heat conditions at up to 70°C., vibration, humidity and temperature cycling down to -10°C. under the supervision of GEC-Elliott engineers and surveyors from the three classification societies. Other tests included operation at angles of tilt, in each plane, of up to 35°, and a series of voltage and cycle fluctuations in power supply.

The equipment completed all these tests satisfactorily and following the classification authorities surveyors making checks on systems test at Kidsgrove, works inspection prior to despatch, installation checks and finally sea-going trials, the GEC-Elliott MARCH 2112 system, as stated, gained Lloyd's Register type approval and type approval from the American Bureau of Shipping. These tests together with the satisfactory completion of the three months sea trials on the Irati have also gained the system Bureau Veritas certification.

## INCREASING OVERSEAS APPLICATIONS

Although it is generally conceded that the process control systems which are generally known as "marine automation" were first introduced on a significant scale in Japan, it is interesting to note that this British company has made a success of series marketing of what is by any standard, a remarkably sophisticated system. The melting pot into which the British electronics industry was thrown a few years ago appears to have performed a remarkable refining service albeit at some expense. It is encouraging to note that the original English Electric, AEI, GEC and Elliott Marine organisations have successfully merged and have, as a result, become stronger in the process.

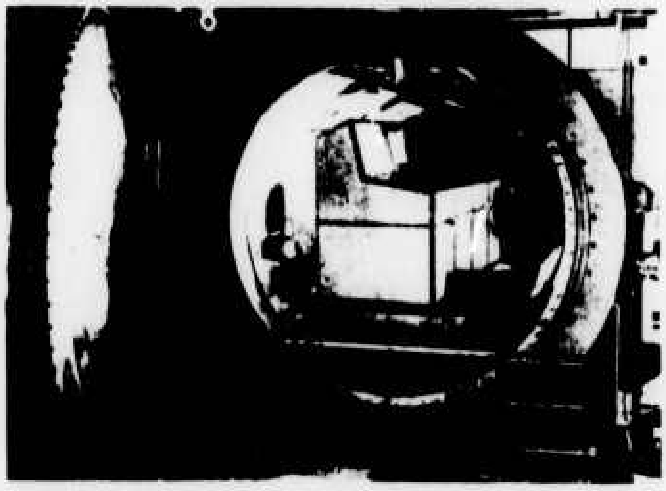


**Fig.2.** A convincing illustration of the extent to which tests are conducted on GEC-Elliott Process Automation equipment prior to classification society approval. The cabinet version of this equipment is shown here during the rigorous 100-h test in which dry heat conditions of up to 70°C and humidity and temperature cycling down to -10°C are conducted. The GEC-Elliott "marine watchkeeper" is stated to be the only equipment of its type to have successfully completed such tests.

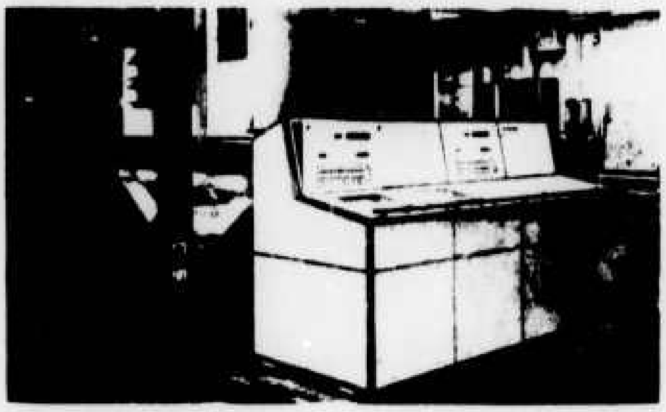


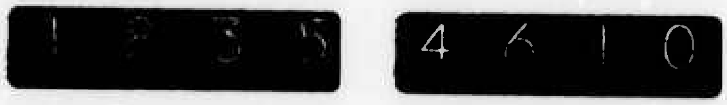
**Fig.3.** Another illustration during tests. This view shows another cabinet type unit, this time on the test rig for vibration testing of the British Aircraft Corporation's environmental test facilities at Stevenage.

# APPENDIX II-2

# METHOD OF OPERATION OF ANTICOLLISION SYSTEM WITH DECCA MARINE RADARS

# Anti-Collision display

- True Motion display with Relative Motion markers
- Off-centring on eight range scales with High Definition picture
- Nine range scales–¼ to 48 n.m. with optional 60 n.m. and statute mile conversion
- Digital bearing and range markers (50 yd to 60 n.m.)



**Three Anti-Collision radars with 16in. displays are available in the Decca solid-state series.**

| | | | | |
|---|---|---|---|---|
| AC1626A | 3cm wavelength | 25kW transceiver | 6ft. aerial | 16 in. diameter AC display ¼ to 48 n.m. range with off-centring. |
| AC1629A | 3cm wavelength | 25kW transceiver | 9ft. aerial | |
| AC-S1630A | 10cm wavelength | 30kW transceiver | 12ft. aerial | |

The first Decca Anti-Collision radar was introduced in 1968 and has been an outstanding success, making possible in a simple, practical way the rapid assessment of collision risk, and closest point of approach on True Motion.

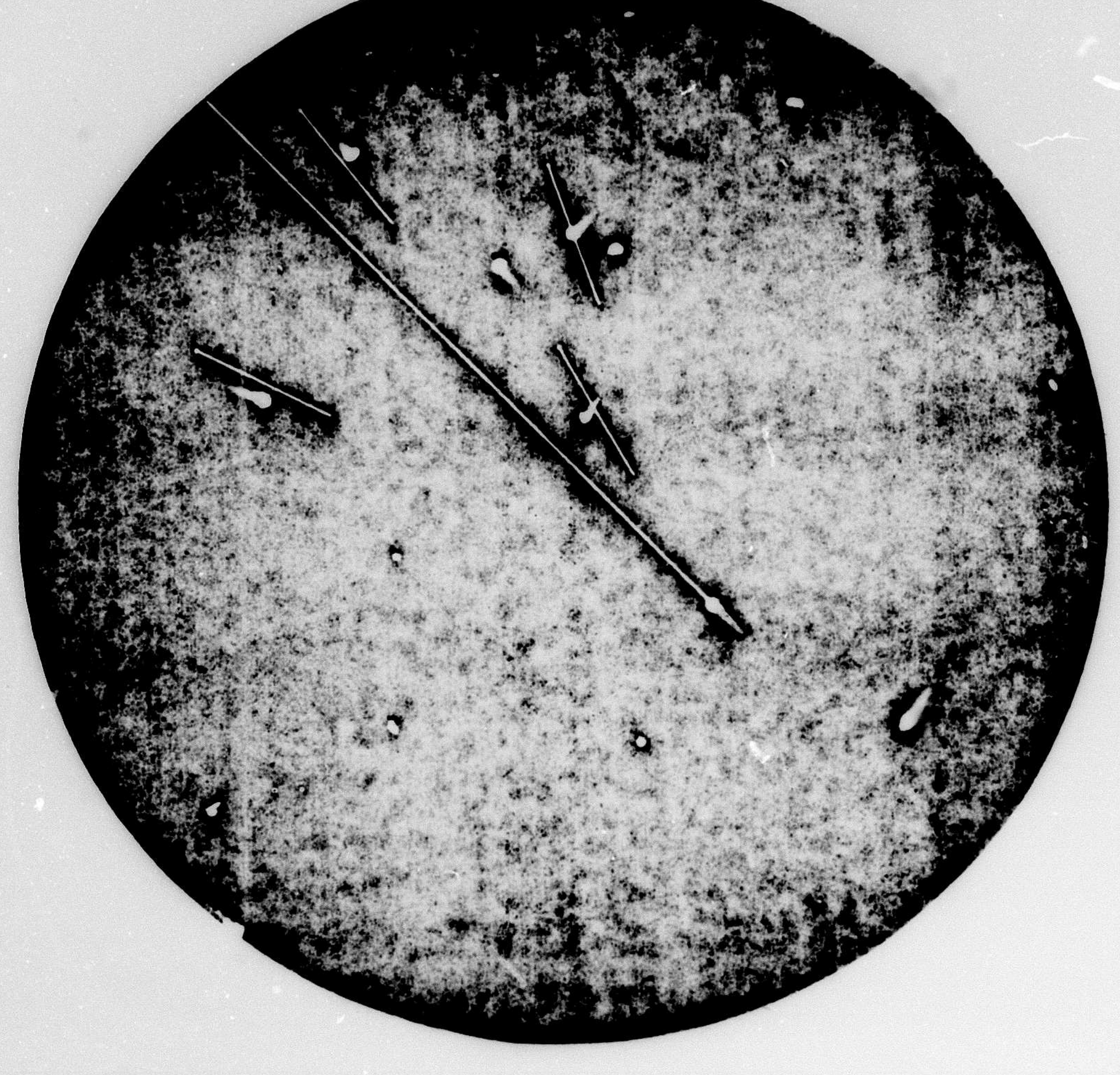
The well-tried principle remains unchanged in the new 16in. display solid-state version, but the unit is of totally new electronic design. Solid-state integrated circuits (micro-circuits) are extensively employed to improve reliability and provide compactness and stability, and the modular design of sub-units and assemblies facilitates maintenance and permits rapid repair by replacement. The display may be used for three different types of radar presentation—

**1—Anti-collison presentation.** This shows True and Relative Motion data simultaneously.

**2—True Motion presentation only.** The display will accept single gyro compass motor both for True Motion and azimuth stabilization from most types of commercial transmitting marine gyro and gyro-magnetic compasses, and automatic speed input from most types of commercial bottom and towed log. Standard True Motion speed range is from 2 to 36 knots.

**3—Relative Motion presentation with optional off-centring**
Basic operational features include provision of nine closely spaced range scales between ¼ n.m. and 48 n.m. (or optional 60 n.m. or all statute mile ranges) with fixed range rings at suitable intervals on all scales and distances displayed adjacent to the cathode ray tube. Digital read-out of measured range and bearing is an important feature of the display, adding greatly to ease of use and convenience for navigational purposes. Important ancillary units available are the performance monitor and Flat Plotter.

**The principle of the Decca Anti-Collision radar**
Markers can be placed on up to five echoes representing collision risks. The subsequent movements of the echoes relative to the markers will show clearly whether or not any of the echoes are in fact on a collision course. If the echo stays on the marker (which remains at a constant range and bearing from own ship) it is on a collision course; if it moves off, it is not. It is equally simple to determine whether it will cross ahead or pass astern, and to measure the CPA. Own ship and the echoes of other ships are displayed in True Motion. A full, detailed explanation is on pages 4 and 5.



## The Decca Anti-Collision system

- –Simple both to operate and interpret
- –Simultaneous TM and RM display
- –Accurate and immediate data tells you–
    - if a ship is on a collision course,
    - how a ship will pass you,
    - how the ships are meeting
- –Proved in service since 1968 as the most successful anti-collision radar.

In the above True Motion picture four markers are in use. They were positioned on the threatening echoes a few minutes ago.

By joining the bright spot at the outer end of the associated bearing marker to the present position of the echoes, you can see at a glance the relative track of each echo and hence its nearest approach, assuming no alterations of course or speed are made.

The bearing of the ship 25° on the starboard bow has remained constant and it is on a collision course. While the others are not on direct collision courses, the AC markers show clearly how they will pass and make the choice of evasive action from the large-scale True Motion picture as straightforward as possible. Furthermore, the True Motion gives earliest possible indication should another vessel also manoeuvre.

# The principle of the Decca AC system

The raw radar presentation of the Decca AC system is True Motion. In addition, up to five electronic markers 1 in. (25mm) long can be switched on to the cathode ray tube.

A bright spot at one end of the marker is positioned on an echo which may represent a collision risk. The marker line extends inwards towards own ship, remains at the same range and bearing from own ship and moves across the display with it.

Movement of own ship and other echoes on the screen is True Motion, showing the actual situation ; movement of echoes in relation to the bright spot on their markers is Relative Motion showing collision risk.

The five electronic markers are painted on the p.p.i. by an interscan technique so that the movement and brilliance of the markers are independent of the radar's mainscan.

Each marker can be superimposed and moved independently of the others. The marker controls are grouped together in a compact control unit mounted on the pedestal. Controls and indicators (illustrated opposite) comprise selector switches for each marker ; range,

## The five Relative Motion markers:

–show if ships are on a collision course

**1**

Radar presentation is True Motion. The ship represented here may be on a collision course.

**2**

Place a Relative Motion marker on the echo.

**3**

The echo moves down the marker towards you on a constant compass bearing and the ship is therefore on a collision course.

–tell how ships will pass you

**1**

If the echo moves away from the marker, a ship is not on a precise collision course.
If it moves off like this it will pass astern.

**2**

If it moves off like this, it will cross ahead.

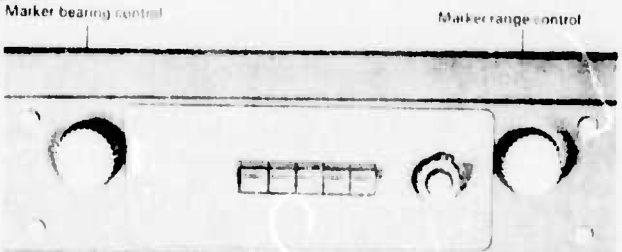
**3**

Join the bright tip of the marker to the echo, continue the line. Range rings or VRM will give you exact CPA (Closest Point of Approach) or the distance the other vessel will pass ahead of you.

bearing and brilliance controls; and a green window illuminated when 3, 6, or 12-mile radar ranges are in use—the ranges on which the markers can be operated.

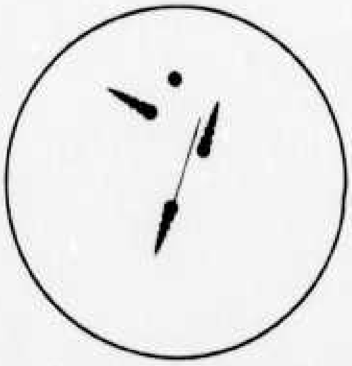
To introduce and position a marker, its marker key switch is pressed down, and the range and bearing controls used to align the marker with the selected echo. The marker switch is then centred and the marker will now remain pointing towards own ship and move across the p.p.i. with own ship on a constant range and bearing.

Individual markers may be repositioned at any time.



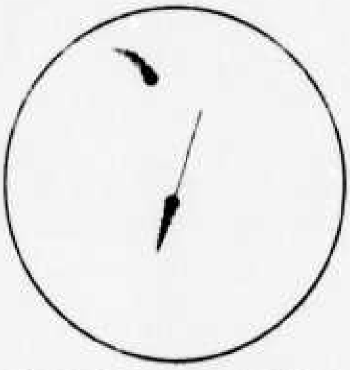
## The True Motion picture

—continuously monitors the overall situation



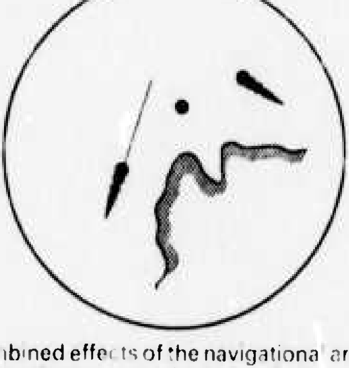
**1**

End on, crossing or stationary ships are readily identified.



**2**

Early warning is given of course alterations being made by other ships.



**3**

The combined effects of the navigational and traffic situations are clearly shown. Safe alterations by own ship can be readily planned.

## What you actually see on the radar

Approaching Dover with north-up display on the 6-mile range scale. The True Motion picture clearly shows the true course of all ships by the afterglow, and the buoys stationary around the Varne wrecks. In the top picture Relative Motion markers have been placed on three vessels which may constitute collision risks. After a short while the sequence shows they are coming clear, ahead of own ship.

# APPENDIX II-3

# SPECIFICATION OF THE ISIS 300 ENGINE ROOM AUTOMATION SYSTEM

## INDEX

## 2.0 DESIGN OBJECTIVES

The three principal design objectives which have been realised in the development of Decca ISIS-300 equipment are high reliability, ease of installation and serviceability. The equipment has been designed specifically for marine applications, and to operate continuously in the severe environmental conditions of the ship's engine room.

### 2.1 Reliability.

The most important function of the equipment is automatic supervision of ships' machinery and cargo. The achievement of very high reliability has therefore been the main design parameter. The equipment is completely solid-state in construction, and based on silicon logic throughout with maximum utilisation of integrated circuits. The data processing system is arranged so that possible faults in the digital sections cannot affect the alarm monitoring function. Signal scanning and amplification are decentralised to minimise the possibility of complete system failure. Automatic system integrity checks verify the operation of transducers and the central system at the completion of every scan.

### 2.2 Ease of Installation

Decentralisation of transducer signal scanning permits a reduction in transducer cabling of about 50 per cent in most ships, reduces the number of signal cables entering the control room to a maximum of six, and facilitates the use of a Central Processor occupying only eleven cubic feet of control room space. An alarm display for up to 240 channels needs only one simple cable connecting it to the Central Processor.

All plant cable termination arrangements are included in the Decca units, so that the shipbuilder does not have to provide junction boxes, terminal strips or other hidden extras. All inter-unit cables are supplied free issue by Decca, except the transducer cables. The mechanical design is based on simple bulkhead-mounting boxes, with panel-mounting alternatives where necessary, arranged so that only front access is required.

All units are conservatively rated for an ambient temperature of 65°C (150°F) so that an air-conditioned environment is not necessary.

### 2.3 Serviceability

The equipment is very simple to operate and yields its full benefits without the need for any specialised knowledge on the part of the operator. The controls and alarm setpoint adjustment facilities are simple and robust. Due to its solid-state design, there is no preventive maintenance to be considered except typewriter servicing when data logging is included.

The most important sections of the system are self-checking, and simple fault-finding routines are set out in the Instruction Manual. Even the most reliable electronic equipment is subject to failure at some time, and all ship-borne repairs are carried out by replacement of plug-in modules. ISIS-300 systems are built up from completely standard units, so that equipments can be supported by the Decca world service organisation.

## 3.0 DATA PROCESSING SYSTEM

This section of the specification describes the basic organisation of the system with respect to data processing operations. Every ISIS-300 system is divided broadly into four departments-primary measurements, signal selection, signal processing and control of the output units. (See Fig. 1).

### 3.1 Primary Measurements

The plant conditions to be checked or recorded are measured by transducers of various kinds. The term transducer applies to a range of devices which produce electrical signals proportional to measurements such as temperature, pressure etc. Most transducers develop a change in resistance corresponding to variations in the primary measurement, which can be evaluated by the signal processing system. A typical example is the resistance thermometer. Other transducers, such as tachogenerators and some ship speed logs, produce a voltage. In some cases the transducer output is not proportional to the measured value, and the signal processing department of the system must perform a linearising action on such signals.

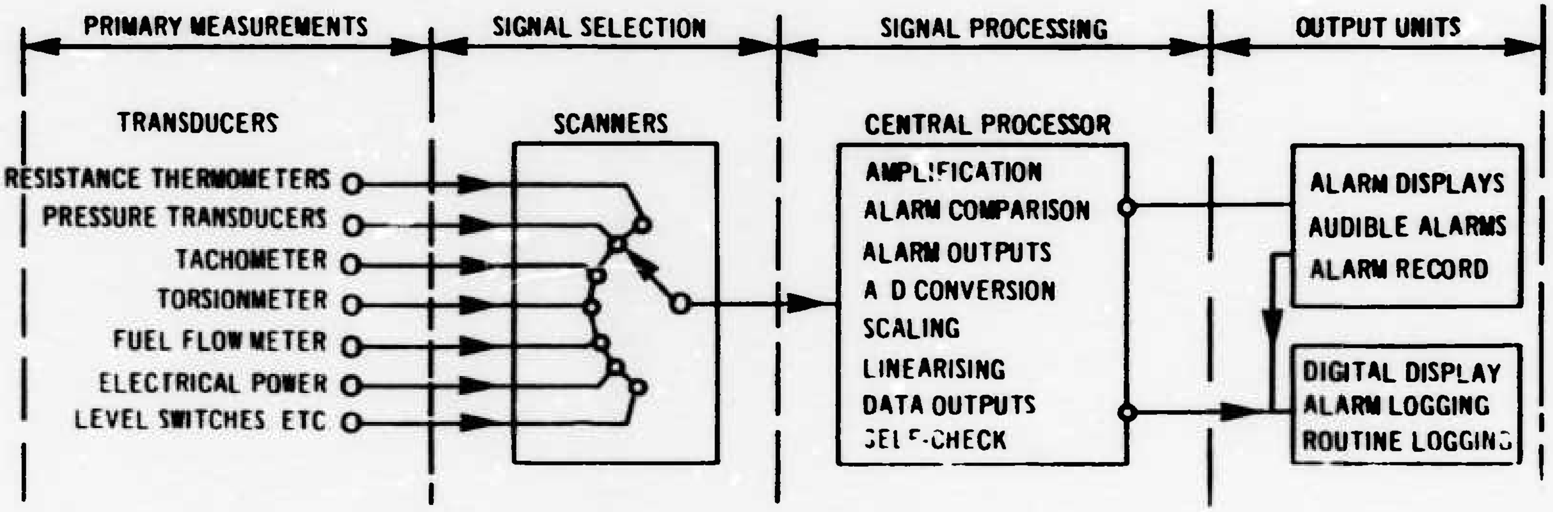
An analogue transducer gives an output which varies continuously with the magnitude of the measured condition. All analogue transducers provided with ISIS-300 systems are arranged to give an output in the range 0-100mV D.C. The term transducer is also applied to logical or switching devices which only give a change of output at one or more fixed points. The pressure switch is an example of a logic transducer.

Transducers supplied with ISIS-300 systems are all either made by Decca or approved by Decca after performance tests have been carried out under extreme environmental conditions. For further details see Section 5.0.

### 3.2 Signal Selection

The basic principle of the scanning system is that a number of transducer signal are evaluated sequentially by one high-quality signal processing system (the Central Processor). Transducer signals are selected singly for evaluation by means of solid-state switching networks, which are housed in groups of 20, 40 or 60 in Local Scanners. The transistor switches are operated by signals from a scan control unit which is regulated by an electronic clock. The scanning speed is 400 channels per second, and this gives the system a very short response time to alarm conditions. This feature is not only important for modern highly-rated machinery, but it also enables the logging system, if fitted, to tabulate a cascade of faults in the proper chronological order.

During the period of approx 2 milliseconds when a particular transducer signal is switched to the Central Processor, a code is also transmitted defining the type of parameter (e.g. temperature) its measurement range, the alarm limits to be observed and the engineering units to be used.



FOUR DEPARTMENTS OF BASIC SYSTEM Fig. 1

## 3.3 Signal Processing

Each transducer signal is passed through its own filter and capacitance transfer network, the function of which is to reject series and common mode noise (interference) thus refining the signal so that it is truly representative of the measured value. When the signal has been selected for evaluation it is amplified to raise the voltage level from 0-100mV to 0-5V.

The first evaluation process is comparison of the signal with high and low alarm reference levels. This takes first place in the process so that possible failures in other parts of the signal processing system will not affect the alarm monitoring facility. The state of each channel, normal or alarm, is fed into a core store memory during the course of each complete scan. At the completetion of a scan (every 0.6 seconds) the core store holds in memory the alarm status of up to 240 channels.

The Main Alarm Display contains a window for each alarm channel in the system. The core store is read every 0.6 seconds and the data is used to control the window illumination corresponding to those channels in an alarm state. At the same time the klaxon control unit is operated. The core store data is transmitted to the main alarm display in serial form on one simple cable, thus eliminating hundreds of cable connections, thereby improving reliability. The alarm monitoring function of the system is therefore completely independent of digital processes which are concerned with centralised read-out and data logging.

When a measured value is required at the digital display or on the printer, the transducer signal is referred to an analogue-to-digital converter (A.D.C.), which reproduces the transducer voltage signal in numerical form. In subsequent operations, quantities are processed in this digital form where magnitudes are expressed in binary digits (bits) instead of analogue voltages.

The digitised transducer signal is referred to a computing unit which multipliesthe signal by an appropriate constant so that its numerical value corresponds to engineering units such as lb/in$^2$. The computing unit contains multipliers for each of the transducer measurement ranges in the system's repertoire. For those transducers which produce non-linear signals, the computer applies a multiplier which varies with the magnitude of the transducer signal. Some transducers have offset characteristics, where their reading at say, 0 lb/in$^2$ is some value other than 0 volts. The computer may therefore be called upon to perform addition, multiplication, linearisation and combinations of all three, changing its routine as each transducer signal is referred to it.

## 3.4 Control of Output Units

Visual and audible alarm units are controlled in a similar manner to that employed in most simple alarm systems. New alarm conditions are announced by a klaxon and identified by a flashing window in the main alarm display, which bears the identity of the channel in alarm. When the alarm acknowledge button is pressed, the klaxon is silenced and the window remains continuously illuminated until the fault is cleared.

The digital display may be used to indicate the value of any channel, by setting three decode switches to the corresponding channel number. Alarm limit settings for each channel may also be shown on the digital display. Where a typewriter is not employed, a handwritten log may be taken by simply switching in the channels required and noting the data presented.

The typewriter can be employed to print a routine log of all or part of the data processed by the system. Printer controls consist of a log interval selector for, say, 2 and 4-hour intervals, and a demand-log push button used to initiate interim logs. Each log entry is time-identified, and means are provided to adjust system time to match ship's time.

Where printers are employed, their full value can be realised by incorporating alarm history printing. All alarm conditions, together with value and time, are recorded in red on occurance and again in black on clearance. Alarm data is recorded in the margin of the log sheet, so that only one printer is necessary to provide both routine and alarm logging.

In addition to the main alarm display, there is a group alarm display unit which can be used to give a summary of alarm information at a remote station, such as the bridge. This unit contains one window for each group of alarm parameters (e.g. port engine group) and responds to the alarm status of the entire group in the same way that main alarm display windows respond to individual alarm channels.

## 4.0 EQUIPMENT CONSTRUCTION

This section of the specification is concerned with the mechanical arrangement of the data processing system, and describes the basic construction of the main units and sub-assemblies.

### 4.1 Local Scanners (See Fig. 2)

Transducer signals are accepted into the system at Local Scanners, which are available in 20, 40 and 60-way sizes. This arrangement permits the selection of system capacity in 20-way increments, up to 240 channels, with minimum redundant capacity. Up to six Local Scanners may be used, and these may be selected in any combination of sizes.

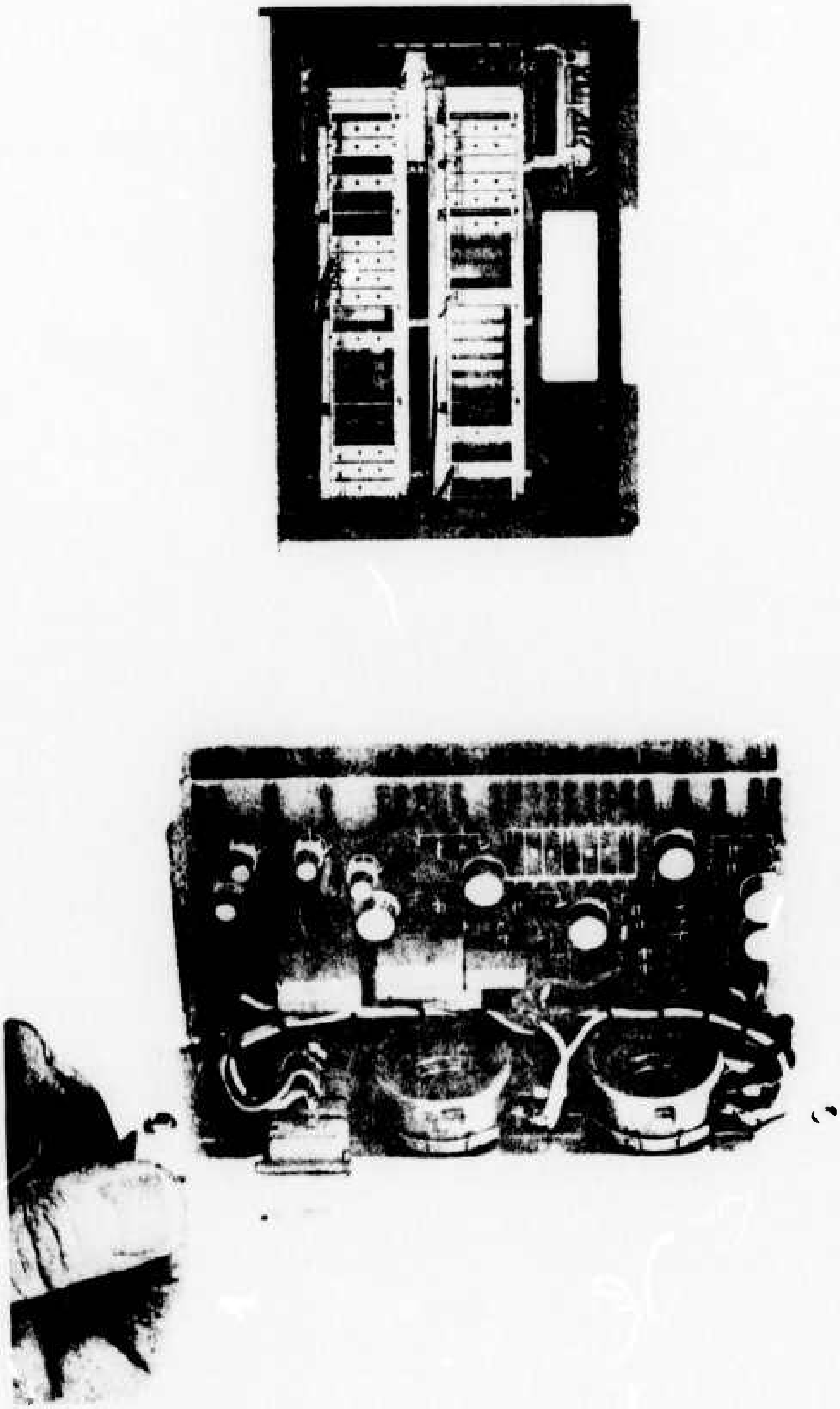
Local Scanners are designed to operate adjacent to machinery, and not within the protective environment of a control room. They should therefore be mounted wherever there are substantial numbers of transducers, thus providing the maximum benefit in terms of transducer cable reduction. In most ships this technique will provide a 50 per cent reduction in installed cable costs, compared to centralised scanning systems.

Local Scanners perform the following electronic functions:-

a) Transducer signal selection
b) Series and common mode noise rejection
c) Signal amplification
d) Transmission of signal to central processor
e) Transmission of high and low alarm references
f) Transmission of channel category code defining measurement range, units and alarm urgency status.

The 20-way Local Scanner is a bulkhead mounted unit containing a 20-way input acceptor frame, signal amplifier, scan control and power supply modules. The 40- and 60-way Local Scanners are basically similar but contain one or two extra input acceptor frames respectively, with one signal amplifier per frame. Each frame consists of a slotted mechanical structure and printed-circuit back wiring board with 20 edge-connectors corresponding with the slots in the structure.

Transducer cables are connected to Input Acceptor Modules, which plug into the printed circuit edge connectors and are secured to the structure by screws. There is one Input Acceptor Module associated with each transducer, and thus with each measurement channel in the system. Input Acceptor Modules incorporate a transistor switching circuit, filter and capacitance transfer noise-rejection circuits, potentiometers for setting of alarm limits, and a 7-bit diode pattern corresponding to the channel category code.



40-WAY LOCAL SCANNER, WITH INPUT ACCEPTOR MODULE Fig. 2

The electronic components are mounted on a printed circuit board, and protected by an aluminium chassis which also serves as an electrostatic screen. The chassis forms a mounting for the alarm limit potentiometers which are of robust design. The potentiometer spindles have screwdriver slots and collett lock nuts. When the nut is slackened, the spindle position may be adjusted. The corresponding alarm value is shown in engineering units on the digital display at the Central Processor control panel. Communication between Central Processor and local scanners is by telephone handsets, which plug into permanent sockets in the units.

Local Scanners are completely standard units, which are customised simply by the order in which Input Acceptor Modules are plugged into the frames. There are three basic types of Input Acceptor Module - logic (for switch inputs), analogue with alarm settings, and analogue without alarm settings. With these three basic modules, up to 24 different measurement ranges can be accepted.

Decentralisation of scanning has additional benefits with respect to system integrity. The system is arranged so that a possible failure of one Local Scanner will not affect the operation of others. It is also significant that the system does not rely on one central signal amplifier, there being one amplifier for each 20-way input acceptor frame.

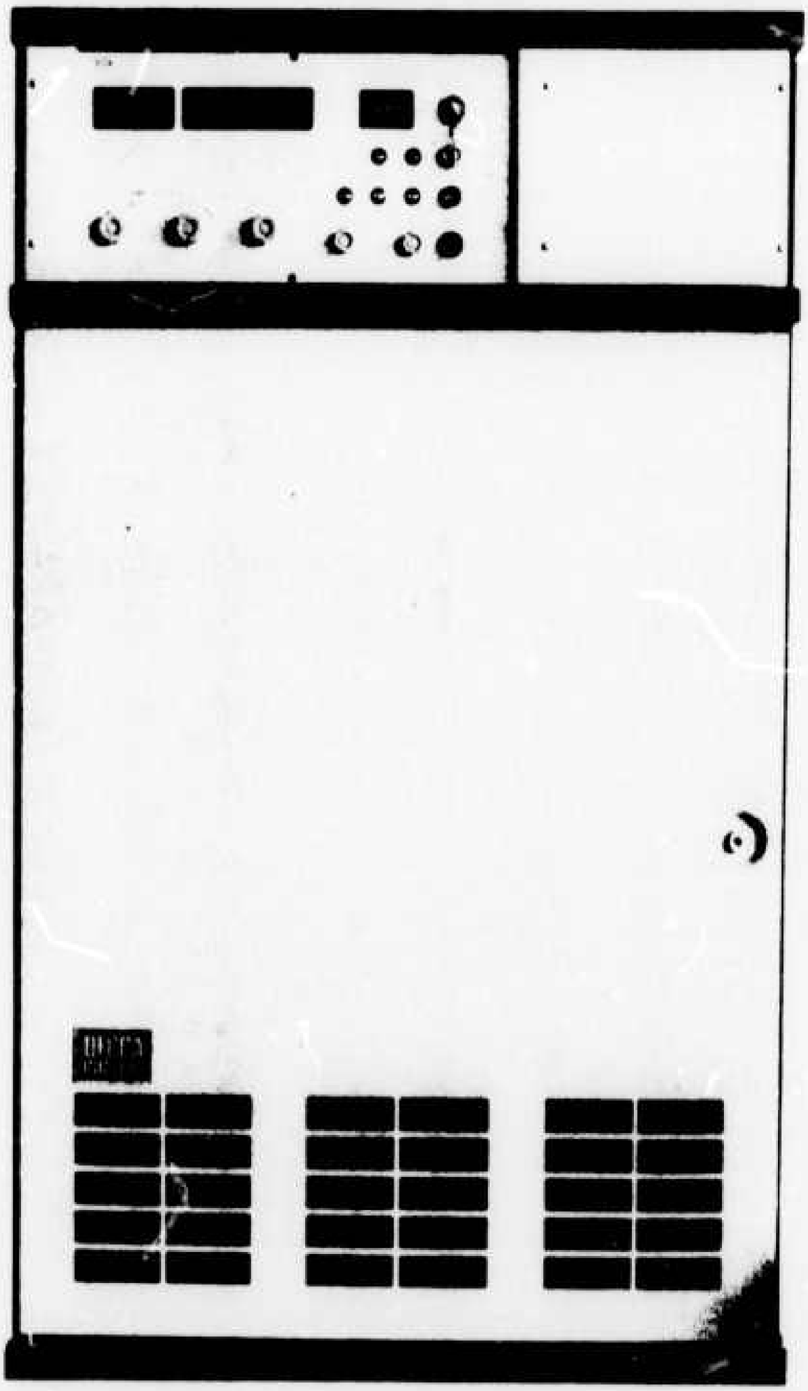
### 4.2 Central Processor (See Fig. 3)

The Central Processor cabinet is designed for bulkhead mounting, and requires access only from the front. All input and output cable terminations are located at a gland plate in the bottom of the cabinet.

The rear panel is the main structural member and forms a mounting for the two principal back-wiring printed circuit boards. Local Scanner cables are connected to terminal modules which plug into the lower back-wiring board. This board also receives up to six scanner sub-multiplexer modules (one per Local Scanner), peak store, alarm comparators, and sub-multiplexer amplifier modules.

These modules are all of similar construction, in which an aluminium chassis forms mechanical and electrostatic protection for a printed circuit board containing the electronic components. Each module is firmly secured by captive screws, and connects to the back-wiring board via edge connectors.

The upper back-wiring board receives the entire digital processing system. The method of construction used here is the cassette system, in which large printed circuit boards are coupled in pairs within very strong aluminium frames. When the cassettes are removed for servicing the printed circuit boards are still mechanically protected in all attitudes by the cassette frames.



CENTRAL PROCESSOR Fig. 3a

There are five cassettes, one of which is the power supply for the Central Processor. The other four are colour-coded for servicing purposes, and each contains two printed circuit boards. These are:-

| | |
|---|---|
| RED CASSETTE | Core store memory<br>Alarm display drive |
| BLUE CASSETTE | Scan pulse generator<br>Digital time and printer control logic |
| GREEN CASSETTE | Block address/integrity check logic<br>Digital computer |
| YELLOW CASSETTE | A.D.C. control and computer interface<br>Analogue/digital converter. |

In view of the very high density of integrated circuits in these cassettes a gentle flow of air is maintained by two small axial fans located below the cassettes and arranged to draw air through a filter in the cabinet door.

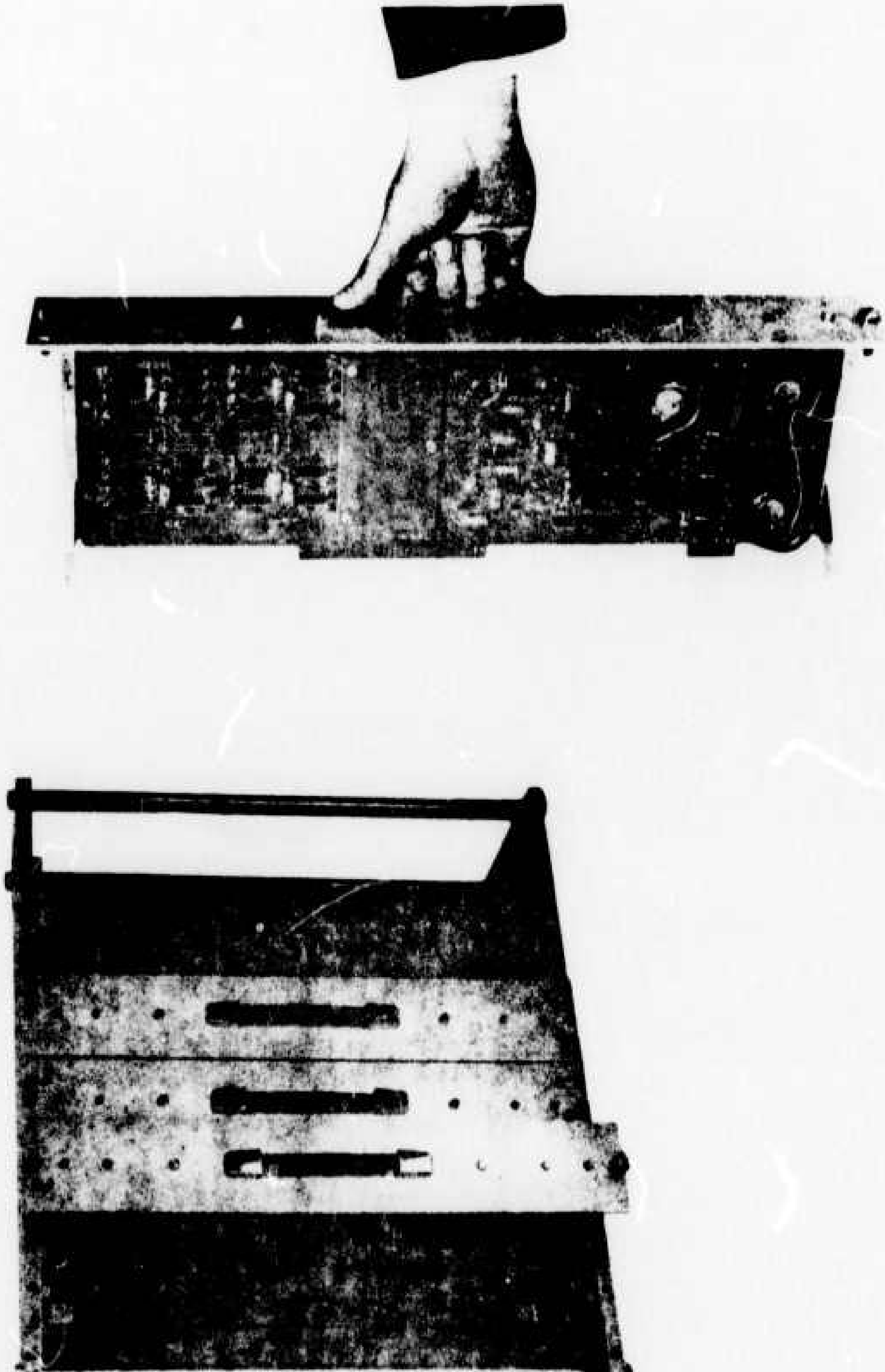
The upper and lower back-wiring boards are interconnected by a further printed circuit board. This method of construction eliminates nearly all conventional wiring.

The control panel occupies the upper part of the Central Processor and contains controls for the output facilities of the systems (See System Operation). This is a standard 19in. wide panel which can be withdrawn for servicing. On later models the control panel can be mounted separately in a console. Channel reference data, including channel number, description, measurement units and local scanner connection, is contained in a quick-reference file located behind a hinged flap at the right of the control panel.

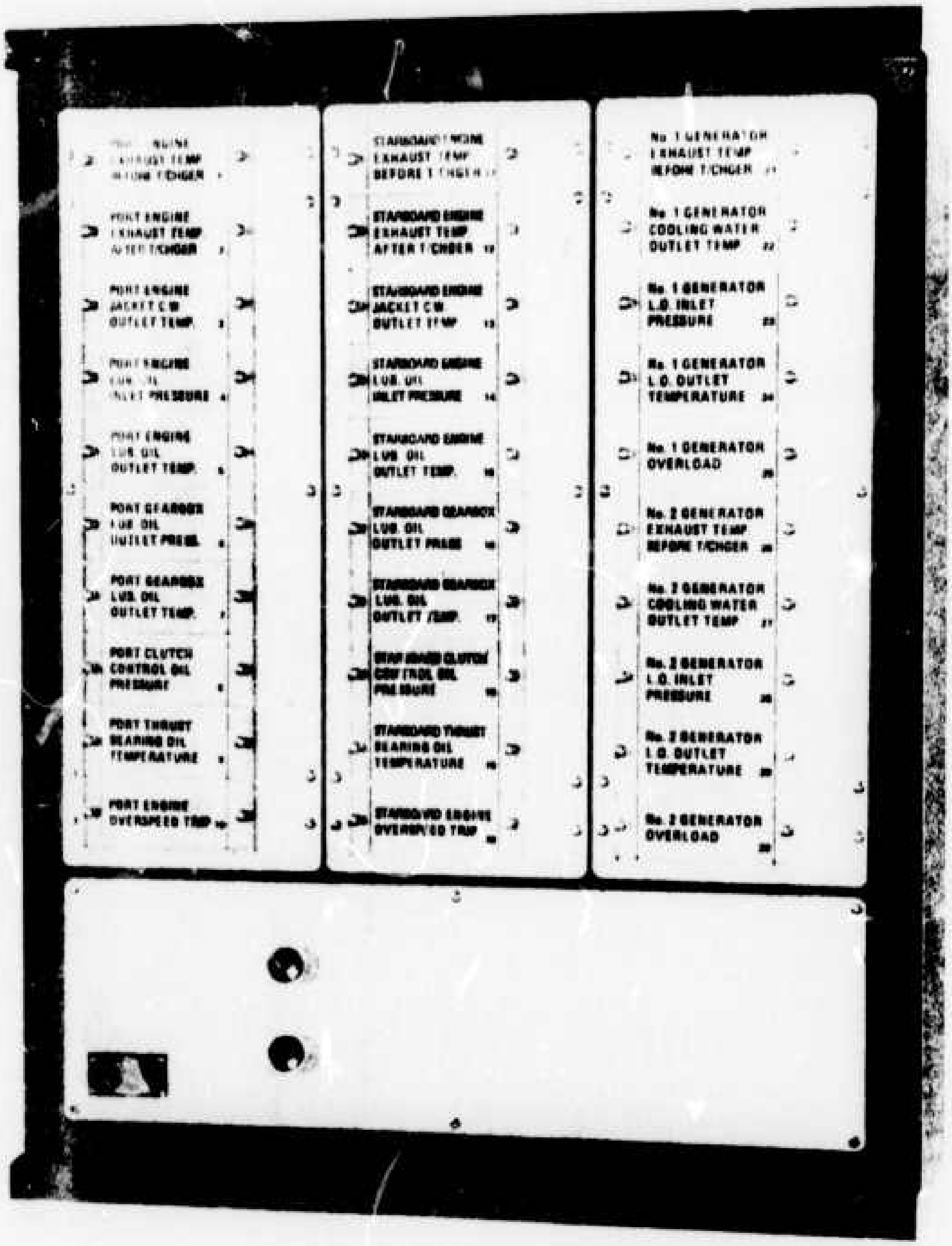
### 4.3 Main Alarm Display System (See Fig. 4)

The Main Alarm Display System is made up from any selection of 30,40, and 50-way units to suit the application. This arrangement permits the selection of alarm display capacity in 10-way increments, and provides for logical grouping of alarms in separate units . Main Alarm Display units are wired in series with a simple cable and any combination of 30, 40, and 50-way units may be selected, up to the system maximum of 240 ways.

The 30-way Main Alarm Display unit is available in panel mounting or bulkhead mounting form, and consists of three identical 10-way modules and a power supply. The 40 and 50-way units are basically similar, but contain one and two extra modules respectively. The front panel assembly for each module consists of a frame containing 10 windows, each window being a plastic film bearing the legend, sealed between two pieces of acrylic resin. This assembly can be removed complete, giving access to a printed circuit board containing all logic elements for the module and twin lamps for each window.



CASSETTE FRAME AND RED CASSETTE Fig. 3b



MAIN ALARM DISPLAY, 30-WAY Fig. 4

Each alarm display unit is provided with two buttons coloured red and green. The red button is for acceptance of alarms and the green button tests all lamps in the display system. Where several display units are employed, the buttons are paralleled so that alarm aceptance and lamp tests may be made at any of the units.

When required, alarm display units may be provided with alarm inhibit switches, which permit an operator to switch off alarms associated with equipment not in service (e.g. standby generator). Inhibit switches are mounted adjacent to the alarm display windows, and are accompanied by a warning light which is activated when a channel is inhibited.

For unattended machinery installations, automatic inhibition of alarm groups can be provided.

### 4.4. Group Alarm Display (See Fig. 5).

The Group Alarm Display is basically one 10-way alarm display module with group alarm logic and a power supply, contained within a panel mounting or console mounting enclosure. The alarm windows may be supplied with amber legends on a black background for use on the bridge. Group Alarm Displays are provided with lamp test buttons, but not alarm acknowledge buttons. Local audible alarms can however be installed, together with inhibit switches and warning lights.

### 4.5 Typewriter Unit (See Fig. 6.)

The Typewriter Unit performs two separate functions, alarm event recording and routine logging. It produces routine logs as required on pre-printed paper, and records all alarm entries and exits in the margin of the same paper. The typewriter employed is the IBM Model 731 golfball-head machine, which has a line length of 102 characters. There are 12 characters per inch, and the print speed is 15 characters per second.

The Typewriter Unit comprises an alumimium base casting, two printed circuit modules containing printer drive and storage logic, a power supply and paper store. The pre-printed stationery is fan-folded in packs of 300. It is fed through the typewriter by a pin feed arrangement, and the printed log sheets emerge from a slot on the top of the enclosure.

The complete unit provides a dust-free environment for the typewriter and its ancillaries, and can be bolted to a desk surface. Data and power are supplied to the unit on separate cables via plug and socket connections at the rear of the unit.

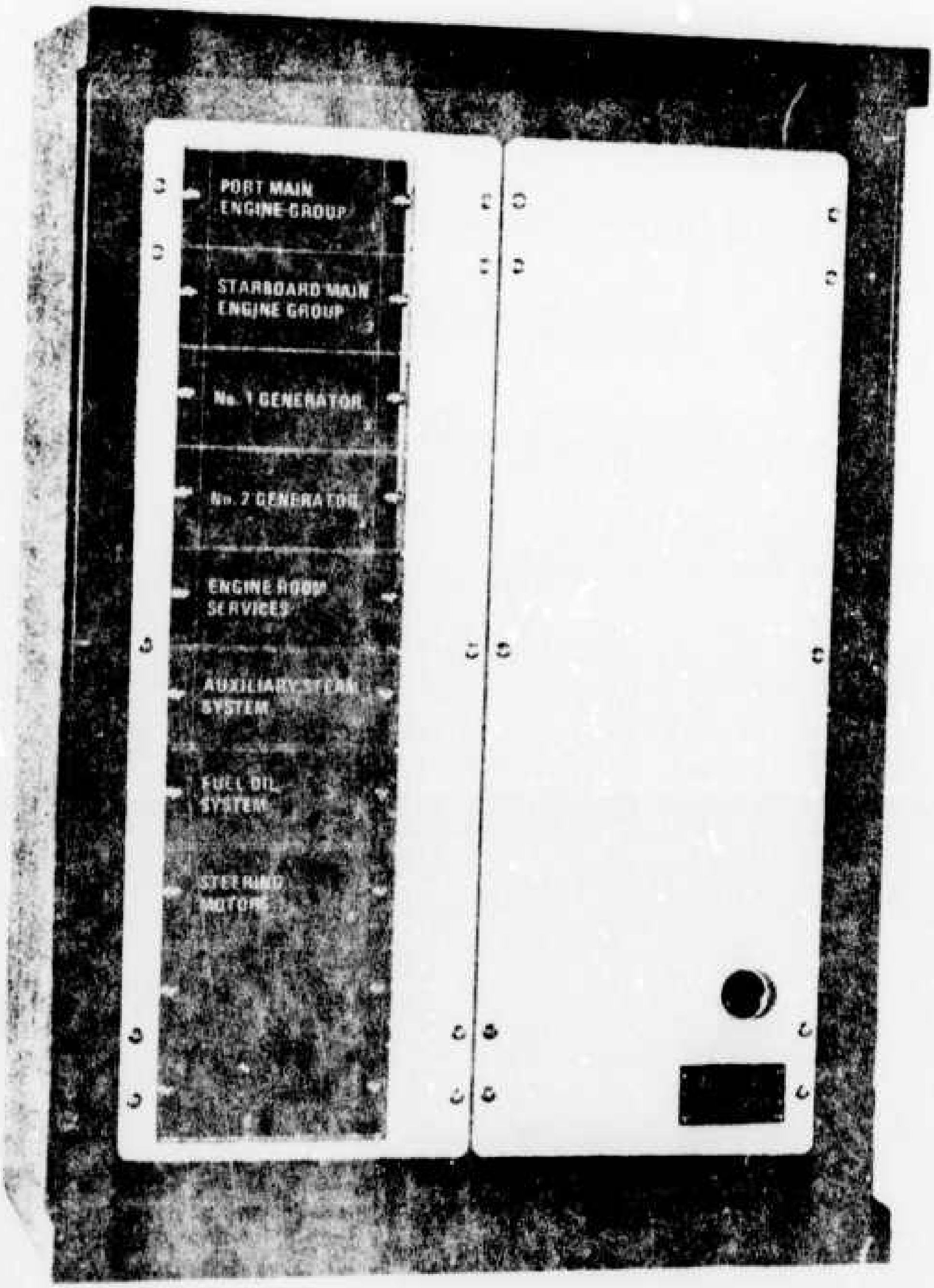
The physical layout of the log format is standardised to provide a maximum of 20 lines of data, each containing up to 12 channel values. This standard format is pre-printed for each system with all necessary information to define each entry position. The length of each line of data may be varied to provide a logical layout to suit the machinery or cargo installation. (See Fig. 7.)

At the completion of a routine log, the typewriter head returns to the margin position to record all alarm events which may occur up to the time of the next routine log. The number of alarm entries, and therefore paper consumption, is indeterminate so an automatic paper register is incorporated. The start of each complete format is identified by a black spot. When a new log is required paper is automatically advanced through the typewriter until a photo-electric cell senses the next black spot on the pre-printed stationery. This mechanism ensures that each routine log starts at the correct position on the log paper.

## 4.6 Dimensions

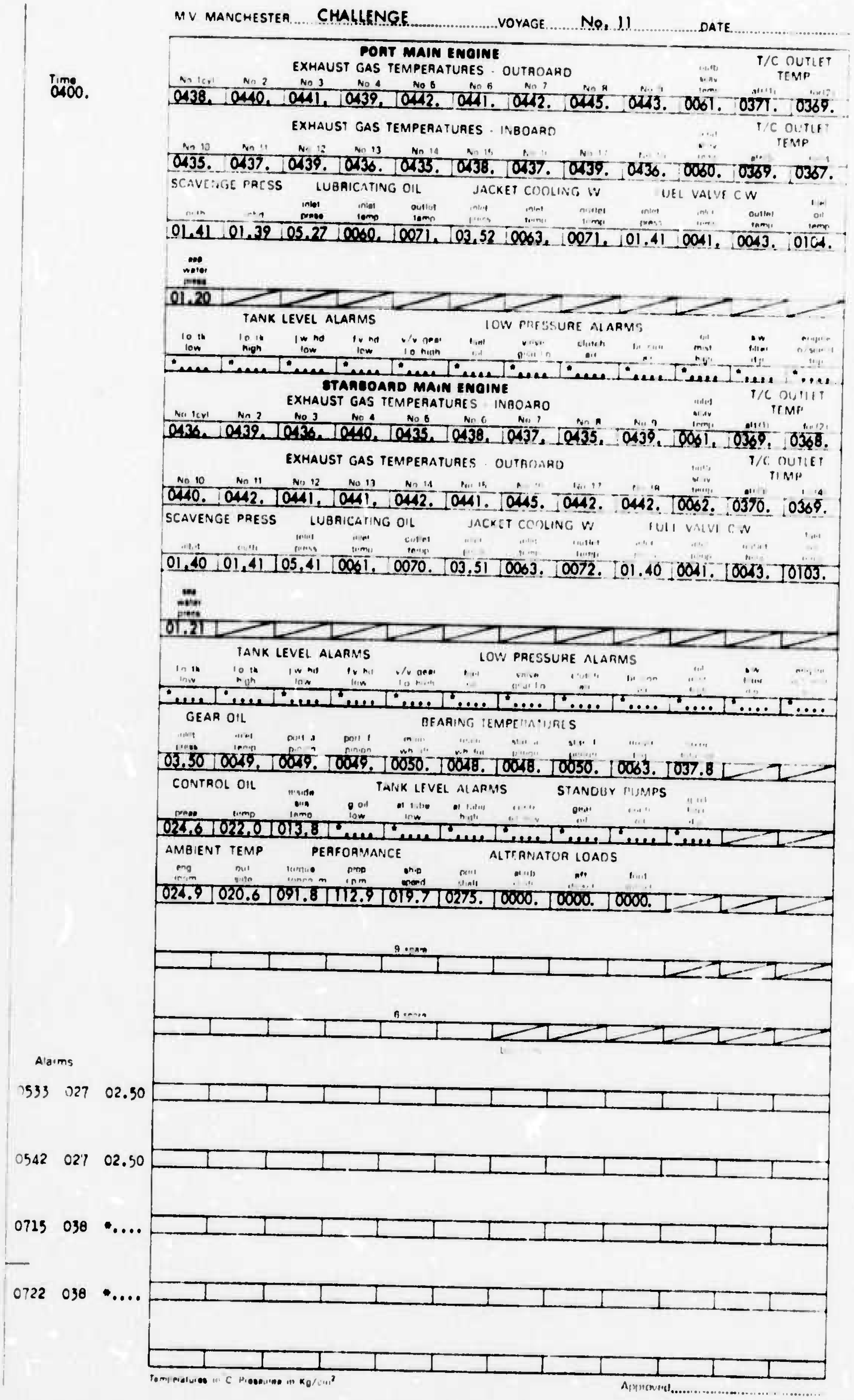
The approximate dimensions of the principal units of the ISIS 300 range are shown below.

| | Height | | Width | | Depth | |
|---|---|---|---|---|---|---|
| | Ins. | mm | Ins. | mm | Ins. | mm |
| Local Scanner 20-way | 43 | 1090 | 21 | 540 | 10 | 250 |
| Local Scanner 40-way | 43 | 1090 | 31.5 | 800 | 10 | 250 |
| Local Scanner 60-way | 43 | 1090 | 41.5 | 1050 | 10 | 250 |
| Central Processor | 52 | 1330 | 31 | 790 | 12 | 305 |
| Main Alarm Display 30-way | 25 | 630 | 19 | 490 | 7.5 | 190 |
| Main Alarm Display 40-way | 25 | 630 | 25 | 630 | 7.5 | 190 |
| Main Alarm Display 50-way | 25 | 630 | 30.5 | 780 | 7.5 | 190 |
| Group Alarm Display | 19 | 490 | 13.5 | 340 | 7.5 | 195 |
| Typewriter Unit | 13 | 330 | 20 | 510 | 26.5 | 675 |



GROUP ALARM DISPLAY Fig. 5

TYPEWRITER UNIT Fig. 6



M V MANCHESTER CHALLENGE VOYAGE No. 11 DATE

Time 0400.

**PORT MAIN ENGINE**

EXHAUST GAS TEMPERATURES - OUTBOARD — T/C OUTLET TEMP

| No 1cyl | No 2 | No 3 | No 4 | No 5 | No 6 | No 7 | No 8 | No 9 | outb scav temp | aft(1) | fwd(2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0438. | 0440. | 0441. | 0439. | 0442. | 0441. | 0442. | 0445. | 0443. | 0061. | 0371. | 0369. |

EXHAUST GAS TEMPERATURES - INBOARD — T/C OUTLET TEMP

| No 10 | No 11 | No 12 | No 13 | No 14 | No 15 | No 16 | No 17 | No 18 | inbd scav temp | aft | fwd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0435. | 0437. | 0439. | 0436. | 0435. | 0438. | 0437. | 0439. | 0436. | 0060. | 0369. | 0367. |

| SCAVENGE PRESS | | LUBRICATING OIL | | | JACKET COOLING W | | | FUEL VALVE C W | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| outb | inbd | inlet press | inlet temp | outlet temp | inlet press | inlet temp | outlet temp | inlet press | inlet temp | outlet temp | fuel oil temp |
| 01.41 | 01.39 | 05.27 | 0060. | 0071. | 03.52 | 0063. | 0071. | 01.41 | 0041. | 0043. | 0104. |

| sea water press | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01.20 | | | | | | | | | | | |

| TANK LEVEL ALARMS | | | | | LOW PRESSURE ALARMS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| lo tk low | lo tk high | j w hd low | f v hd low | v/v gear lo high | fuel oil | valve gear lo | clutch air | [illegible] | oil mist high | s w filter d/p | engine o/speed trip |
| *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... |

**STARBOARD MAIN ENGINE**

EXHAUST GAS TEMPERATURES - INBOARD — T/C OUTLET TEMP

| No 1cyl | No 2 | No 3 | No 4 | No 5 | No 6 | No 7 | No 8 | No 9 | inbd scav temp | aft(1) | fwd(2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0436. | 0439. | 0436. | 0440. | 0435. | 0438. | 0437. | 0435. | 0439. | 0061. | 0369. | 0368. |

EXHAUST GAS TEMPERATURES - OUTBOARD — T/C OUTLET TEMP

| No 10 | No 11 | No 12 | No 13 | No 14 | No 15 | No 16 | No 17 | No 18 | outb scav temp | aft | fwd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0440. | 0442. | 0441. | 0441. | 0442. | 0441. | 0445. | 0442. | 0442. | 0062. | 0370. | 0369. |

| SCAVENGE PRESS | | LUBRICATING OIL | | | JACKET COOLING W | | | FUEL VALVE C W | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| inbd | outb | inlet press | inlet temp | outlet temp | inlet press | inlet temp | outlet temp | inlet press | inlet temp | outlet temp | fuel oil temp |
| 01.40 | 01.41 | 05.41 | 0061. | 0070. | 03.51 | 0063. | 0072. | 01.40 | 0041. | 0043. | 0103. |

| sea water press | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01.21 | | | | | | | | | | | |

| TANK LEVEL ALARMS | | | | | LOW PRESSURE ALARMS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| lo tk low | lo tk high | j w hd low | f v hd low | v/v gear lo high | fuel oil | valve gear lo | clutch air | [illegible] | oil mist high | s w filter d/p | engine o/speed trip |
| *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... | *.... |

| GEAR OIL | | BEARING TEMPERATURES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| inlet press | inlet temp | port a pinion | port f pinion | main wh aft | main wh fwd | stbd a pinion | stbd f pinion | thrust brg | [illegible] | | |
| 03.50 | 0049. | 0049. | 0049. | 0050. | 0048. | 0048. | 0050. | 0063. | 037.8 | | |

| CONTROL OIL | | | TANK LEVEL ALARMS | | | | STANDBY PUMPS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| press | temp | inside air temp | g oil low | st tube low | st tube high | [illegible] | gear oil | [illegible] | [illegible] | | |
| 024.6 | 022.0 | 013.8 | *.... | *.... | *.... | *.... | *.... | *.... | *.... | | |

| AMBIENT TEMP | | PERFORMANCE | | | ALTERNATOR LOADS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| eng room | out side | torque tonne m | prop rpm | ship speed | port shaft | stbd [illegible] | aft diesel | fwd diesel | | | |
| 024.9 | 020.6 | 091.8 | 112.9 | 019.7 | 0275. | 0000. | 0000. | 0000. | | | |

9 spare

6 spare

Alarms

0533 027 02.50

0542 027 02.50

0715 038 *....

0722 038 *....

Temperatures in °C Pressures in Kg/cm²

Approved..............................

TYPICAL PRE-PRINTED LOG SHEET Fig. 7

## 5.0 TRANSDUCER DETAILS (See Figs. 8a & 8b)

Transducers for pressure and temperature measurements have been developed especially for use with the Decca ISIS-300 system. A wide range of other proprietary transducers is also supplied, these units having been tested and approved by Decca laboratories.

## 5.1 Temperature Range -50°C to +150°C / -58°F to +302°F

The majority of temperatures in this range are measured by means of the platinum resistance thermometer Type TE, which is designed for insertion in pipelines and tanks. The sensing element is a 100 ohm platinum wire resistance element wound on a glass former and encased in a stainless steel sheath, the element leads being brought to a ceramic terminal block. The complete insert is mounted in a fabricated stainless steel pocket with a watertight head and gland. The insert is secured in the pocket by spring-loaded screws, which absorb vibration. This construction permits the changing of an insert without the need to empty the pipeline or tank.

Standard insertion lengths are 2, 4, 6, and 9 inches, and threads may be ½ or ¾ BSP. Other lengths and thread types can be supplied to suit the application.

Ambient air temperatures are measured by the platinum resistance thermometer Type TDA. The sensing element is the same as that used for the Type TE, but is arranged to protrude from the bottom of a bulkhead-mounting box. A perforated stainless steel tube provides mechanical protection for the sensing element.

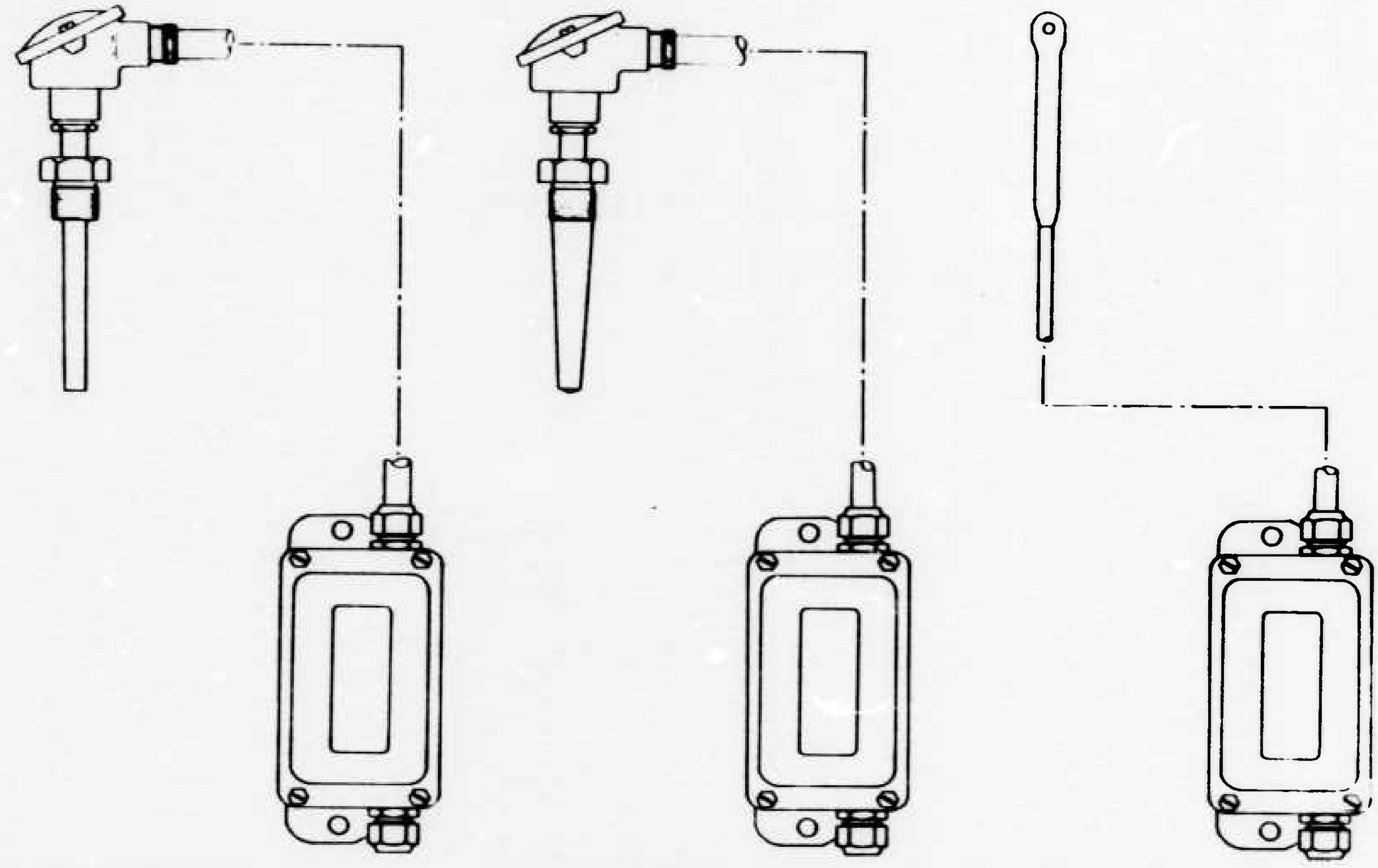
## 5.2 Temperature Range 0-700°C/32°F to 1292°F

The Type TF platinum resistance thermometer is designed for the measurement of diesel-engine exhaust gases and the higher steam temperatures. The insert assembly is similar to the Type TE insert except that the element is wound on a ceramic former. The pocket is machined from stainless steel bar stock to a tapered form, capable of withstanding the extremes of heat and shock which exist in diesel engine exhaust systems.

Standard insertion lengths are 3½, 4, 6, and 9 inches, and threads may be ½ or ¾ BSP. Other lengths and threads can be supplied to suit the application.

## 5.3 Temperature Range -30°C to +22°C/-22°F to 71.6°F

The thermometers in this range are designed for the measurement of temperatures in refrigerated cargo spaces, air ducts and domestic stores. Three types of thermometer are supplied, each of which employs the same sensing element. In order to achieve the very accurate temperature measurements necessary for refrigerated cargoes, a high-sensitivity, high-stability thermistor element is used. This is formed from a wafer of ceramic material which has a very high temperature coefficient of resistance, about 10 times that of a platinum resistance thermometer.



Resistance Thermometer
Types TC & TE

Resistance Thermometer
Type TF

Thermometer
Type TA

STANDARD TRANSDUCER ARRANGEMENTS Fig. 8a

The type TA thermometer is arranged as a suspension unit for cargo spaces, the element being contained in a vulcanised rubber sheath and provided with a suitable length of TRS cable.

The Type TBA thermometer is designed for bulkhead mounting and is similar in mechanical construction to Type TDA for ambient air temperature.

The Type TC thermometer is designed for air trunking to and from containers and other spaces. It is of similar form to Type TE. Standard insertion lengths are 4, 6, and 9 inches, and threads may be ½ or ¾ BSP. Other lengths and thread types can be supplied to suit the application.

## 5.4 Pressure Measurements 0-70 Kg/cm$^2$/0-1000 lb/in$^2$ *

Pressures are measured by means of semi-conductor strain gauges. The measuring element is a silicon semi-conductor bridge diffused on to a solid silicon diaphragm . The diaphragm is incorporated in a stainless steel pressure chamber, which receives the process fluid via a small orifice designed to prevent errors due to pulsation. The strain gauge capsule is contained in a watertight cast aluminum box together with encapsulated temperature compensation circuits and terminal strip. The transducer is mounted off-line, on a convenient bulkhead or stanchion. Process fluid is led to the transducer via 1/8 bore instrument piping and connected at the transducer by means of an Ermeto coupling. A cock is provided in the pressure line to isolate the transducer when necessary, and to test the alarm system for low pressure. When necessary an isolating chamber is also fitted before the transducer to maintain satisfactory operation with heavy fuel oils etc.

Standard Pressure ranges are as follows:-

| Metric - Kg/cm$^2$ | British - lb/in$^2$ |
|---|---|
| 0 - 1.76 | 0 - 25 |
| 0 - 7.03 | 0 - 100 |
| 0 - 14.07 | 0 - 200 |
| 0 - 35.14 | 0 - 500 |
| 0 - 70.3 | 0 - 1000 |

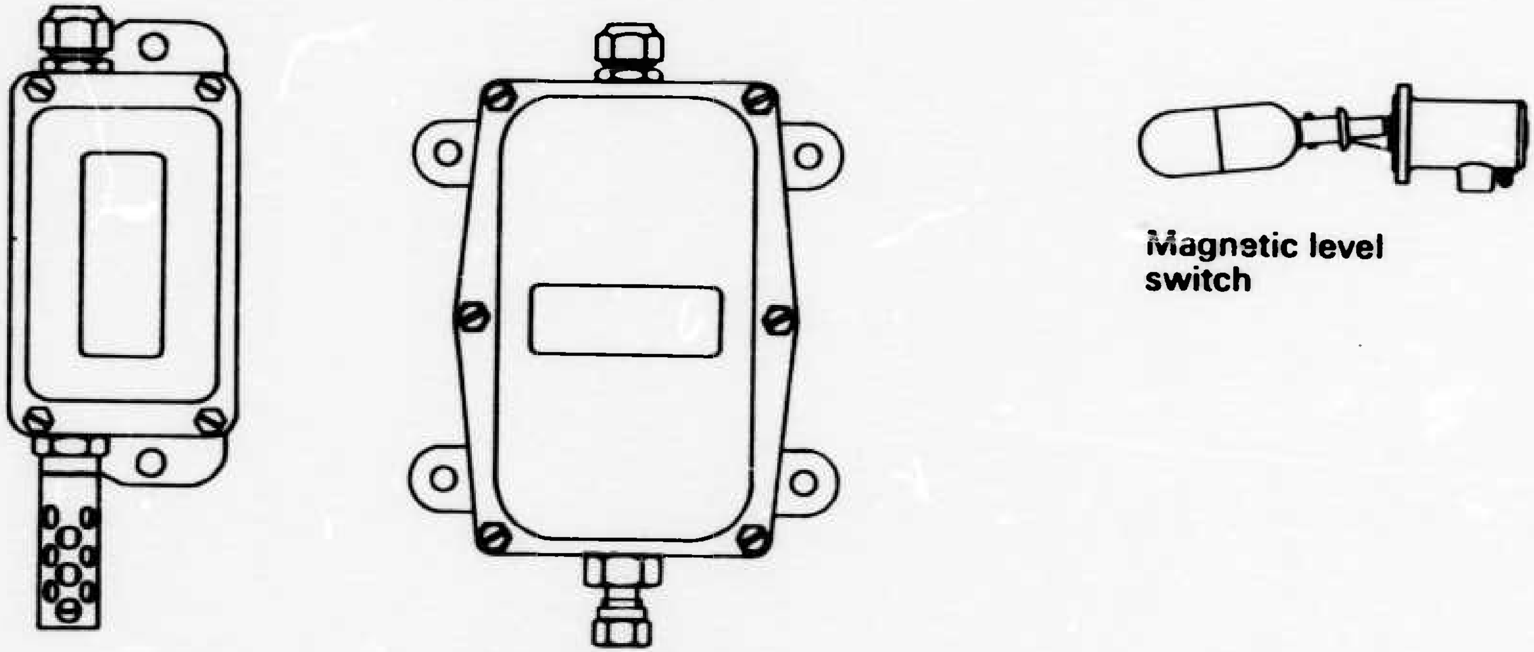
## 5.5 Other Measurements

Various other transducers are available for measuring differential pressures, flows, speeds of revolution, electrical quantities and chemical qualities such as $CO_2$, pH etc. These are carefully selected to suit each application and are extensively tested by Decca laboratories before being accepted for use with the ISIS-300 system.

### Logic (Switch Action) Transducers

All logic transducers offered with ISIS-300 systems have been carefully evaluated, and because the operation of switching devices cannot be automatically verified only the most reliable types are used. All have rare metal contacts arranged to open an alarm. The range includes pressure and level switches of well proven design.

* **Not applicable. A later type is included in this quotation.**



Thermometer
Types TBA & TDA

Strain gauge
pressure transducer

Magnetic level
switch

Fig 6. Basic range of Transducers

STANDARD TRANSDUCER ARRANGEMENTS Fig. 8b

## 6.0 SYSTEM PERFORMANCE

### 6.1 Accuracy

The accuracy of the system varies according to the transducer measurement range. The combined system plus transducer accuracies are:-

| | |
|---|---|
| Range - 30°C to +22°C | ±.1°C between -3°C and +3°C<br>±.25°C over full range |
| Range -50°C to +150°C | ±1°C over full range |
| Range 0°C to 700°C | ±2°C over full range for resistance thermometers<br>±8°C for thermocouples |
| Pressure ranges | ±2% of range static error. |

The accuracies for the range -30°C to +22°C are in accordance with BS3273 for measurement of refrigerated cargo temperatures.

### 6.2 Speed of Operation

The system operates on a fixed cycle and achieves the following speeds of operation:-

| | |
|---|---|
| Scan speed | 400 channels per second |
| Display update time | 0.6 seconds |
| Alarm response time | 0.6 seconds maximum |
| Print-out speed | One channel every 0.6 seconds |
| System self check | Every 0.6 seconds |
| Transducer check | Every 0.6 seconds |

### 6.3 Environmental Performance

The equipment has been designed to withstand the very severe environmental conditions which can be met in ships' engine rooms. The environmental test programme for ISIS-300 equipment is as follows:-

Temperature (Ambient)

-15°C to +65°C - Continuous operation

Humidity

12 hours at RH of 95% with free ambient air temperature of 40°C.

### Vibration

Operational tests in three planes at the following levels of vibration.

| | |
|---|---|
| 0 - 15 c/sec | .06in amplitude |
| 15 - 100 c/sec | 1g acceleration |
| 100 - 500 c/sec | .5g acceleration |

Vibration endurance test 10 hours at resonance.

### Shock

Operational tests in three planes - 10,000 cyles at 5g acceleration.

## 6.4 Power Supply Variations

The system is protected from transients and brief interruptions in the ship's power supply by a motor alternator which provides 1000c/sec power. The alarm lamps, Central Processor fans and typewriter motor operate from 50 or 60 cycles power which is supplied by an isolating transformer.

The equipment is designed to operate with power supply variations of voltage +10% -15% with simultaneous frequency variations of ±5c/sec.

## 6.5 Integrity Check Routines

The automatic integrity checks carried out at the completion of each scan are:-

1. All Local Scanners transmitting
2. All Input Acceptor modules operating
3. Alarm comparator accuracy within specification
4. Data system accuracy within specification
5. Central Processor transmitting to alarm displays

Transducers on alarm channels are automatically checked for open or short-ciruit faults. Power supplies are continuously monitored. The typewriter paper supply is also checked to prevent possible platten damge.

If a system fault occurs, the audible alarms are sounded continuously, as distinct from the intermittent tones for machinery alarm conditions. First line fault location is provided by five indicator lamps on the control panel. Two of these are red which are normally on, showing that both 50/60 and 1000c/sec power supplies are available. Three amber lamps marked A, B and C are illuminated in various combinations to show principal fault conditions, for which lamp codes are given in the instruction manual. Second line fault location is carried out by following simple test routines. In some of these routines the digital display facility shows numerical codes corresponding to fault conditions.

The test routines are designed to isolate faults to plug-in modules, so that the system can be restored to operation quickly by a marine engineer using simple tools.

## 6.6. Classification Societies

The regulations and recommendations of all Classifications Societies have been studied and taken into account in the design of the ISIS-300 system. Particular care has been taken to meet the requirements for component standards, environmental performance and system integrity. At present, alarm monitoring systems are approved by Classification Societies on the basis of technical details submitted and performance checks after installation.

## 7.0 NOISE REJECTION

The term noise refers to interference voltages which occur mainly due to the presence of magnetic and electric fields in the areas in which transducers and transducer cables are situated. These interference voltages may be many times larger than the the actual signal. The use of screened, twisted-pair cables provides the first line of defence against noise.

Noise is classified in two forms- Series Mode and Common Mode. An interference voltage between the two signal lines is called Series Mode noise, and voltage appearing simultaneously on both lines with respect to earth is referred to as Common Mode noise.

The true transducer signal is a DC voltage and therefore AC signal components can be identified as noise. A filter is used to reject input voltages of frequency greater than a few cycles per second. The most serious source of Series Mode noise is the ships mains frequency of 50-60c/sec. In this region the ISIS system will reject all but 1/40,000 part of the Series Mode interference voltages. The rejection of noise improves still further at higher frequencies.

Common Mode noise can often appear as a result of transducer measuring techniques. For example, a C.M. voltage of 2 or 3 volts DC frequently occurs on bridge circuits. This type of standing offset must also be dealt with, as well as the interference from mains and R.F. transmitters etc.

Common mode noise in the DC to medium frequency range is rejected by a patented capacitance transfer technique which enables the system to sample the true signal while common mode voltages are isolated. For higher frequency C.M. noise, a balanced filter provides very substantial attenuation. The combination of these techniques enable the ISIS system to reject all but one millionth part of the induced Common Mode voltages.

Noise rejection charactersistics are expressed in decibels, where $\text{dB} = 20 \times \log_{10}$ noise/signal ratio. Thus a noise rejection of 1,000,000/1 is expressed as $20 \times 6.0 = 120\text{dB}$. It is common when specifying noise performance to refer only to DC Common Mode noise, but for ships equipment it is essential to consider both Series and Common noise performance from DC to high frequencies.

ISIS-300 Noise Rejection performance is:-

| | | |
|---|---|---|
| Series Mode | - | 90dB at 50c/sec<br>123dB at 1000c/sec |
| Common Mode | | 120dB from DC to 10Mc/sec |

The noise rejection characteristics of the ISIS-300 system are therefore such that series and common mode interference has negligable affect on system performance.

## 8.0 OPERATION OF SYSTEM (See Fig. 9)

This section of the specification deals with the methods of obtaining information from the various output facilities, and the setting of alarm limits. These notes should be studied in conjunction with Fig. 9, which illustrates the control panel of the Central Processor.

### 8.1 Channel Reference Numbers

A complete list of channel reference numbers is contained on an index which is stored behind a hinged flap at the right of the control panel. Each entry shows the channel number, measurement description, engineering units employed and the local scanner frame position to which the transducer is connected.

### 8.2 Digital Display

The digital display consists of eight numerical indicator tubes mounted in line. It is controlled by three channel selector switches and two display mode switches, and is used to indicate channel value, alarm limits, time and test codes. These readings are obtained in the following manner:-

1. Channel Value. With display mode switches set to "Data" and "Normal", select channel number on channel selector switches. The selected channel number will be repeated on the first three tubes, and its value will be shown in engineering units on the other five tubes (4 digits and - sign when appropriate). Fig. 7 shows channel number 125 selected and its value as 38.6. This value will be updated every 0.6 seconds, so that trends can be readily observed.

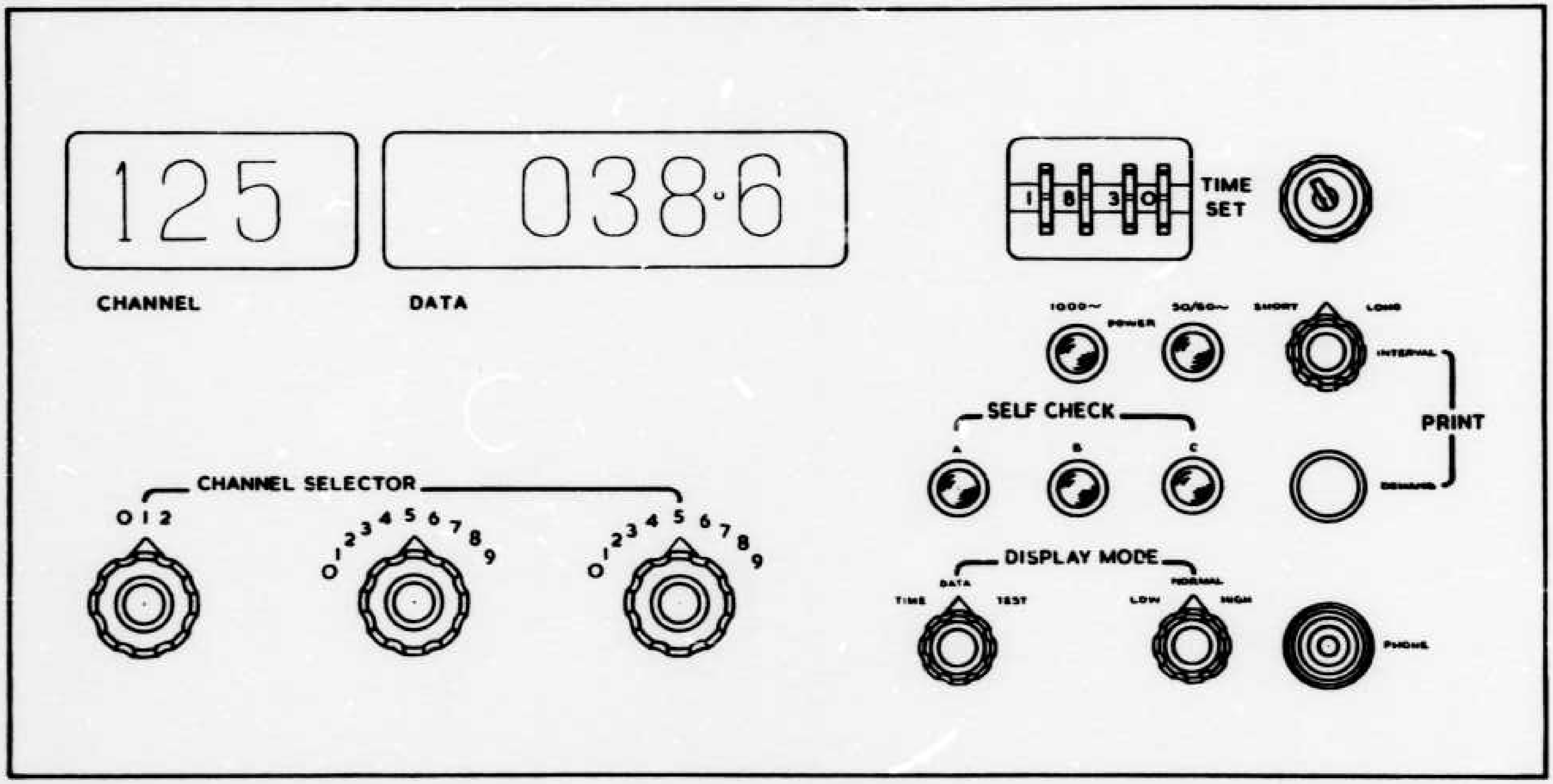
2. Alarm Limits. With display mode selectors set at "Data" and "Low" or "High" select channel number required. The first three tubes will repeat the channel number selected, and the other five tubes will indicate the high or low alarm setpoint. Thus the right hand display mode selector can be used to indicate, in rapid succession, a channel value and its high and low alarm settings.

3. Display Time. With the display mode selectors set at "Time" and "Normal" the last four tubes of the display will show system time, i.e. the time that would appear on a log sheet or alarm print-out.

4. Test Codes. With the display mode selectors set at "Test" and "Normal" the last four tubes will show numerical codes corresponding to conditions of operational status laid down in the instruction manual.

### 8.3 Printer Controls

The print interval selector is used to change the logging routine from frequent to infrequent operation. The actual intervals corresponding to these settings are to the users choice, from ½ hour to 24 hours.



CENTRAL PROCESSOR CONTROL PANEL Fig. 9

The print demand button is used when a log is required at any time between the routine log intervals.

## 8.4 Time Setting

When it is necessary to change system time, the new time required is set on four edge-scale switches (18.30) and the time set key is turned. This establishes the new time in the system, which may be verified on the digital display.

## 8.5 Setting of Alarm Limits

With the display mode selectors set to "Data" and "Low" or "High" select channel number required. At the corresponding Local Scanner frame position, turn the low or high potentiometer until the new alarm limit required is shown on the digital display. When necessary the telephone handsets can be used to establish communication between the Local Scanners and the Central Processor.

## 8.6 Acknowledging Alarms

Each Main Alarm Display Unit has a red button which, when pressed will acknowledge any alarm in the system. The flashing window then becomes steady and the audible alarms are silenced.

## 8.7 Testing Alarm Lamps

Each Alarm Display Unit has a green button which, when pressed will illuminate all alarm lamps in the system.

## 9.0 INSTALLATION

The installation of Decca ISIS 300 systems is carried out in liaison with shipyard personnel. The Decca Installation Service covers the following work.

### 9.1 Installation Design

This section of the work covers the establishment of transducer measurement ranges, siting and fixing arrangements, and advice on the siting of principal units and cable runs. It also includes liaison with other suppliers to ensure compatability of certain transducers of shipbuilders supply, attendance at shipyard progress meetings and determination of all system documentation (log sheets, alarm legends etc.)

### 9.2 Supply of Main Unit Cabling

All cabling for interconnecting ISIS 300 units, with the exception of those required to connect the transducers to the Local Scanners and the mains feeds to the power conversion equipment and Distribution Unit, are supplied by Decca as free issue to the shipyard.

### 9.3 Supervision of Installation

The mounting of transducers and principal units, and the running of all cables is usually carried out by the shipyard. Decca engineers will supervise this work and check out all wiring runs prior to connecting up.

### 9.4 Connecting Up Work

Decca engineers will make-off all main unit interconnections including the Local Scanner ends of the transducer cables. The connection of transducers, transducer interfaces and mains circuitry between the main power source and the ISIS Power Distribution Unit is to be carried out by shipyard labour.

### 9.5 Commissioning

Commissioning work includes the final checking of all connections, setting of alarm limits if required, and complete performance test of the system. The system will then be demonstrated to the shipyard accepting authority and Classification Society Surveyor. The commissioning work is additional to normal works commissioning, which is carried out prior to despatch. A Decca engineer will also be available for attendance at sea trials at an additional fixed daily rate.

## 10.0 INFORMATION AND SERVICE

The ISIS-300 supporting services are designed to ensure that the equipment will remain at a high level of performance throughout the life of the ship.

### 10.1 Instruction Manual

The most important section of the Instruction Manual lists a series of system check routines which are laid out so that a ship's engineer or electrical officer can trace faults to a plug-in module. Emphasis is on simple logic rather than electronic knowledge. System check routines start with a fault description and end with a module location, giving module replacement instructions.

The Instruction Manual also shows all interconnections between main units and identifies all transducer connections. Circuit and logic diagrams show modules and module functions only, in order to preserve a simple and easily understood guide to the system.

### 10.2 Training

The Decca Training School was established principally to train personnel from Decca subsidiary companies and overseas agencies in the servicing of marine electronic equipment. Although the ISIS-300 System is very simple in concept, basic training can be provided for seagoing personnel, when this is requested. The course covers the basic principles of data processing, fault finding routines and replacement of modules.

### 10.3 Servicing and Spares

The Decca marine servicing organisation comprises over 350 depots in major parts throughout the world. This organisation will be used to support ISIS-300 equipment in service. However, as reliability and serviceability have been the major design priorities, most faults can be easily rectified by ships' staff.

The extent of shipborne spares carried is generally agreed in liaison with the shipowner, bearing in mind the intended service of the ship.

## APPENDIX II-4

# THE WORK AND ORGANIZATION OF THE BRITISH SHIP RESEARCH ASSOCIATION

## SECTION 2

## ABOUT B.S.R.A.

B.S.R.A. was founded in 1944 as the central research organisation of the British shipbuilding industry, and for nearly 30 years has carried out a co-operative programme of research and development on all aspects of ship design, construction and operation. Today it also has the support of the British shipping industry. It is one of the largest ship research organisations in the world and enjoys great international prestige, so much so that it has acted as the model for several national ship research establishments subsequently formed in Europe and elsewhere. Through its close co-operation with the design offices of its Member Firms, it has an intimate knowledge of the ship design process and the requirements of a design department.

The activities of B.S.R.A. come under the following headings:-

### 2.1 Research in Support of Ship Design

Items of research in support of ships design include:-

Overall Ship Design
Development of Ship Design Procedures
Computer Aided Design
Ship Performance
Resistance and Propulsion
Steering and Manoeuvring
Ship Motions
Correlation of Tank Data with Trial Performance
Ship Structures
Structural Analysis
Loads and Stresses in Ships
Structural Steels and Other Materials
Ship Vibration - Especially Propeller Excited Vibration
Noise in Ships
Shipboard Engineering Systems
Evaluation of Advanced Machinery Systems
Automatic and Remote Control
Machinery Layouts

### 2.1.1 Ship Design and Computer Applications

Whilst B.S.R.A. is not a ship design organisation as such, it does nevertheless undertake a large amount of ship design in the course of its activities. In the late 1960's it developed the design for a British economy class 40,000/42,300 ton bulk carrier on behalf of a group of Member Firms. This design had a considerable influence on the designs for larger ships subsequently developed by individual firms. On another occasion preliminary designs for a series of stern trawlers were developed, and more recently designs for a range of Panamax bulk carriers have been developed in conjunction with a Member Firm. Detailed working drawings are being prepared for the midship holds of one of these ships in connection with an investigation into steelwork design office procedures.

In most of the items in support of design there is special emphasis on the use of computers, and the same also applies to the other sections of the reseach programme. The Association has a large computer installation based on an ICL 1903A computer and a Gerber computer controlled drawing machine. In addition to its own computer work, it runs a computer bureau service which is used by many non-Member as well as Member Firms. B.S.R.A. has developed an extensive series of computer programs covering routine ship design calculations. A complete list of the programs available is given in the Appendix.

B.S.R.A. has also been responsible for the development of the well-known BRITSHIPS system. BRITSHIPS is the acronym for the BRITish SHipbuilding Integrated Production System. It is an advanced system of computer programs concerned with design, production and planning and control in shipbuilding and is available to the Member Firms. The basic programs have been in full operational use by British shipbuilders for a number of years. Four large shipbuilding groups now use BRITSHIPS to generate the control tapes for their Numerically Controlled burning machines. The system has been developed on a modular basis which enables shipyards for which a full numerical control system would not be appropriate to obtain benefits in terms of improved accuracy and quality control through the use of computer based methods for lines fairing, shell development and the definition of the geometry of steelwork parts.

### 2.1.2 Ship Performance and Hydrodynamics

The Association has been responsible for an extensive programme of model experiment work to provide resistance and propulsion data for design purposes and to explore basic problems in ship hydrodynamics. The experiments have been commissioned at various establishments in the United Kingdom namely, the experiment tanks of the National Physical Laboratory at Feltham and Teddington, the Admiralty Experiment Works at Haslar and the Vickers Ship Model Experiment tank at St. Albans, but the work has been planned and controlled by B.S.R.A. with staff members participating on occasion in the conduct of the experiments and in the development of special instrumentation.

A major outcome of this work has been the development of a methodical series of merchant ship hull forms covering block coefficients from 0.55 to 0.85 which forms a basis for the design of merchant ship hull forms. These forms have been continuously refined over a long period and are known to give performances fully compatible with the best that can be obtained elsewhere in the world. They are much used by the Member Firms. Trawler forms have been similarly covered by a methodical series and other specialised merchant ship forms have been the subject of less extensive investigations.

More recently B.S.R.A. has concentrated on measuring the performance of actual ships, both during acceptance trials and in normal service and has collaborated with the British Government and other organisations in comparing ship performance with predictions based on model tests. B.S.R.A.'s Chief Naval Architect is Chairman of the Panel which supervises this collaborative work on ship model correlation. He also plays a prominent roll in the work of the International Towing Tank Conference.

### 2.1.3 Ship Structures and Vibration

B.S.R.A.'s work on ship structures is concerned both with actual stresses experienced in service, for which purpose special instrumentation is fitted to selected ships, and with the estimation of stress distributions at the design stage, for which stress analysis techniques are applied. For the analysis of large tanker structures, B.S.R.A. has worked with the Naval Construction Research Establishment to develop a suite of programs to allow convenient and efficient data preparation, checking, analysis by finite element methods and presentation of the results by automatic drawing machines. For smaller and more general ship structural analysis problems, B.S.R.A. has developed an alternative set of programs which are also based on the finite element method of stress analysis.

In addition to the above capabilities for the stressing of ship structures, B.S.R.A. has been very much concerned with the measurement of vibration on ships in service and with procedures to be used at the design stage to prevent, as far as possible, such vibration from occurring. Programs have been developed which use the large amount of actual ship data collected by B.S.R.A. as an empirical basis for the estimation of the vibration characteristics in the preliminary design stages, and programs based on the finite element method of analysis to determine the characteristics on either the main hull or local structural areas at later stages of design. In all this work on ship structures, B.S.R.A. maintains a close liaison with Lloyd's Register of Shipping and is represented by the Director of Research on the Co-ordinating Committee for Ships Structure Research in the United Kingdom which deals with the co-ordination of structural research undertaken by the Ministry of Defence (Navy), Lloyd's Register of Shipping, B.S.R.A. and the Universities. The Association also plays an active part in the work of the International Ship Structures Congress and is represented on Design Committee .C of the I.S.S.C. by the Deputy Head of the Naval Architecture Division.

### 2.1.4 Ship Systems and Engineering

In the engineering field the main effort is devoted to the study of shipboard engineering systems and automation. The emphasis in engineering systems work is in the updating of design methodology and design data, and a series of modular designs for various engine room auxiliary systems has also been developed with the aim of reducing design and production costs and fitting-out time on board ship. With regard to automation, guidance on practical design and installation matters has been embodied in a Code of Procedure, which is currently being updated, and effort is being devoted to the study of advanced automation systems, including computer-based systems. B.S.R.A. is also actively concerned with the production of standards for deck and engine room equipment in conjunction with the British Standards Institution.

Until the separation of the shipbuilding and marine enginebuilding industries in the United Kingdom in the late 1960's B.S.R.A. was actively concerned with the development and improvement of main propulsion machinery, both diesel and steam turbine. Although such matters no longer figure on the research programme, B.S.R.A. retains a close interest in the selection of the most suitable propulsion machinery for given types of merchant ship.

## 2.2 Research in Support of Ship Production

Research in support of Ship Production includes work in the following areas:-

- Numerical control machines
- Automatic and semi-automatic machines
- Mechanical handling
- Plant analysis and layout
- Welding processes
- Oxygen-cutting processes
- Pipe production
- Electrical installations
- Application of paint
- Materials of construction and outfitting
- Modular outfitting
- Internal transport in shipyards
- Evaluation of new techniques
- Dimensional quality control
- Environmental conditions in shipyards
- Group technology
- Value engineering
- Activity sampling and method study
- Management information systems
- Planning systems and network analysis
- Organisation and control systems
- Operational research

B.S.R.A. Production Division has been established for ten years. At first it was concerned mainly with steelwork and organisational methods, but now it covers all facets of ship production. Among the innovations which have been introduced may be mentioned:-

- N.C. frame bending machine
- Vertical electro-gas welding machine
- Friction welding machine for pipe flanges
- Permanent magnet lifting device
- Fluidised bed heater for plastic pipes
- Improved oxygen cutting nozzles

New processes include:-

- One-sided welding
- Heat line bending
- Gravity welding

New techniques:-

- Networking
- Simulation and L.P. Mathematical Modelling
- Coding and classification of materials
- Part-numbering systems
- Photogrammetry

The main effort in Production Research is directed at the higher cost areas in shipbuilding. For example, welding research aimed at the introduction of faster, automatic processes to ensure better quality control plays a large part. There is a close working arrangement with the Welding Institute which enables their work on welding processes to be translated into welding techniques or applications by B.S.R.A. for shipbuilders. Outfitting is a complex organisational problem involving many trades and materials and a special study was made resulting in a series of recommendations on networking techniques. More recently management control systems have been developed from a basic network.

The use of computers is becoming increasingly important and Production Division makes use of B.S.R.A. computing facilities for the preparation of N.C. control tapes, the solution of networking problems, simulation and photogrammetric calculations, evaluation of proprietary management packages, and as an aid to long-term planning by means of a mathematical model of a shipyard. This model has now been applied in four shipyards and further development of the technique is planned for this year.

## 2.3 Research in Support of Ship Operation

Much of the work mentioned above is directly or indirectly of assistance to shipowners, but in addition a separate programme of work exists particularly for the benefit of the shipping industry. This is organised in conjunction with the Chamber of Shipping of the United Kingdom, and the results are disseminated through B.S.R.A. to both shipowners and shipbuilders.

### 2.3.1 Fouling and Corrosion

A large part of the work for shipowners concerns corrosion, fouling and protection of ship hulls; most of it is carried out by a specialist Materials Section of B.S.R.A., staffed by metallurgists, chemists and paint technologists, but outside specialists, including universities, are brought in whenever this is appropriate.

This work covers:-

External Cathodic Protection
Protection of Ship Tanks
Wastage of Non-Ferrous Salt Water Systems
Cargo Pipeline Materials
Service Trials of Weatherdeck Coatings
Evaluation of Commercially Available Anti-Corrosive
    Paint Systems
Preparation for Maintenance Painting
Designing Against Corrosion Hazards
Bacterial Control of Fouling
Micro-Biological Deterioration
Effects of Underwater Scrubbing on Rates of Fouling
Health Hazards of Organo-Metallic Anti-fouling Materials
Prevention of Fouling in Seawater Systems in Ships
Underwater Maintenance of Ships
In Water Surveying

### 2.3.2 Other Shipowner Work

Experimental and theoretical studies are also being carried out under the Shipowner Programme in other areas. These include:-

Reviews and assessments of oil/water separation
Disposal of ship generated garbage
Noise control
Prevention, detection and fighting of ship fires
Ship berthing procedures using auxiliary manoeuvring devices
Trials to measure squat of large ships in shallow water
   with a view to utilization of maximum available draught.
Statistical studies of performance of ships' equipment and
   of damage to ships' hulls due to impact from seas.
Assessments of subdivision and stability.
Preparation of coding systems in connection with
   administration of repair and maintenance of ships.

The objectives of the above studies range from reduction in costs through improvements in revenue, safety and efficiency of operation to alleviation of pollution and its consequences. The actual nature of the studies vary, but in the main they are concerned with both technical and economic matters and a large amount of data is continually being compiled in both respects on all aspects of ship operation.

Results and experience gained from these studies are periodically gathered together in codes of recommended practice for the benefit of shipowners and shipbuilders.

### 2.4 Technical Information

The supply of technical information to Member Firms as well as its own staff is one of the major activities of B.S.R.A., and indeed, the Technical Information Division of B.S.R.A. is the most comprehensive source of information on marine technology anywhere in the world. Managers, designers and other employees of Member Firms greatly appreciate the value of having speedy access to information in a classified form which enables them to find exactly what they want with the minimum of effort or delay.

About 450 periodicals are received regularly, and in addition reports and papers are acquired from many technical societies and research institutions throughout the world. All this material is carefully scanned, and summaries or titles of the more important articles published in the Association's monthly Journal of Abstracts. From these summaries a reader can select articles of particular interest, and can then either inspect the originals if they are available locally, or obtain photo copies from B.S.R.A. Many of the articles are in foreign languages; translations of these into English can be prepared for a suitable fee.

Information contained in abstracted articles is indexed and arranged in such a way that bibliographies on any nominated subject can be speedily prepared. Many such bibliographies exist already and can be supplied on demand.

## 2.5 Consultancy and Repayment Work

In addition to the co-operative research programme which is restricted to Member Firms, B.S.R.A. also undertakes research, consultancy or any other form of assistance within its power on a repayment basis. This service is available to members and non-members alike, the only difference being that Members are given more favourable terms of payment. A considerable proportion of B.S.R.A.'s resources are devoted to this type of work, and all sections of the research staff participate. The majority of the projects are naturally of a marine nature, but clients from other industries are welcomed. For example, the methods used for obtaining statistical stress data in ships have also been applied to television masts, and protective measures against sea-water corrosion have been used in the cooling water systems of power stations sited on the sea-shore.

The Computer Bureau Service has already been mentioned. This also is open to non-members as well as members, but with preferential terms for the latter. Certain types of work involving the use of confidential computer programs are restricted to Member Firms only, unless special licensing terms are negotiated by non-members.

# APPENDIX

## COMPUTER PROGRAMMES AVAILABLE TO B.S.R.A. MEMBERS

### 1. B.S.R.A. Design Calculation Programs (Batch Processing)

| | | |
|---|---|---|
| BSRA/NA/W029<br>(Ships over 350 ft)<br>BSRA/NA/W036<br>(Ships under 350 ft) | | Hydrostatics |
| BSRA/NA/W030 | | Statical Stability |
| BSRA/NA/W034 | | Launching |
| BSRA/NA/W032 | | Tank Calibrations |
| BSRA/NA/L153 | | Watertight Subdivision |
| BSRA/NA/L104 | | Estimation of Effective Horse Power and Shaft Horse Power from B.S.R.A. Methodical Series Data. |
| BSRA/NA/W050 | | Propeller Calculations from Standard Series Data given Ship Speed EHP and RPM |
| BSRA/NA/W051 | | Propeller Calculations from Standard Series Data given Ship Speed, SHP and RPM. |
| BSRA/NA/W031 | | Grain Carrier Calculations |
| BSRA/NA/W033 | | Calculation of Longitudinal Strength Information |
| BSRA/NA/W038 | | Damaged Stability Calculations |
| BSRA/NA/W020 | | Dynamics of Launching |
| BSRA/NA/G004 | | Simplified Hydrostatics Program |
| BSRA/NA/L13 | | Propeller Performance when operating at other than the designed loading |
| BSRA/REM/60 | | Ship Hull Frequency amplitude estimations |
| BSRA/ME/W201 | B8 | Cost Revenue Sensitivity (CRS5) |
| BSRA/ME/W203 | B12 | Bulk Carrier Estimated Steelmass (BEST) |
| BSRA/ME/W206 | B22 | Bulk Cargo Generation Program (BCGP) |
| BSRA/NA/W170 | | Grain Stability |
| BSRA/NA/W158 | B9 | B.S.R.A. Methodical Series Powering Estimates |
| BSRA/NA/W160 | B14 | Evaluation of Transverse Shear Force, Lateral Bending Moment and Twisting Moment for Regular Oblique Waves |
| BSRA/NA/W205 | B23 | Fuel Tank Heating Coils |
| BSRA/ME/W204 | B24 | Cargo Tank Heating Coils |
| BSRA/NA/W211 | B29 | Drainage Stability Calculations (UNDAM) |

## 2. B.S.R.A. Remote Access Programs for Interactive Use

The following programs which are available on various remote access bureaux are the property of B.S.R.A. and are frequently being implemented on the 1903A at Wallsend:

| | |
|---|---|
| R11 | oFORMS (Ship Form Distortion and Analysis Program) |
| R12 | "CASCADE" Program Segments (Computer Aided Scantling Determination) Notice Numbers R18 to R24 and R57 to R63. Imperial Units |
| R13 | OBPS (Offset Bulb Plate Stiffener Selection) |
| R14 | IOAS (Inverted Ordinary Angle Stiffener Selection) |
| R15 | FBAR (Roller Flat Bar Stiffener Selection) |
| R16 | TBAR (Selects the dimensions of a Fabricated T-Bar, Flanged Plated or Flat Bar to satisfy a given section modulus) |
| R17 | oLOYD4 (Midship Section Scantlings of Two-Deck Freighter) |
| R18 | VOL (Volume of Bulk Carrier Hold) |
| R19 | BTMPL (Bottom Plating) |
| R20 | CGIR (Centre Girder) |
| R21 | INNBOT (Inner Bottom) |
| R22 | GAF (Girders and Floors) |
| R23 | oGAFAH (Girders and Floors, Specified Holds Empty) |
| R24 | BIBL (Bottom and Inner Bottom Longitudinals) |
| R30 | BENDS (Longitudinal Strength Program) |
| R32 | LONSH (Computes Launching Data) |
| R33 | STABC (Approximate Statical Stability Program) |
| R34 | LEVER (Program to Interrogate Cross Curves of Statical Stability) |
| R35 | FLOOD (Program to Compute Floodable Length Curves) |
| R36 | VOLUM (Program to Compute Volumes and Centres of Gravity of Holds and Tanks) |
| R37 | DSCAL (Scales offsets, waterlines and stations in any file with the same format of a DESIGN file or a PORTN file) |
| R38 | KPORT (Defines Ship over LBP in Simple Portion Format) |
| R39 | TANK (Calibrates any number of tanks, each tank being defined by a number of simple portions) |

| | |
|---|---|
| R40 | SERIES (Program to Extract B.S.R.A. Standard Series Forms) |
| R41 | SUPER (Cross Curves of Statical Stability Including Superstructures and Bossings) |
| R42 | TRIM (Margin Line Calculation) |
| R44 | oUNDAM (Damage Stability Calculations) |
| R45 | BALCO (Trimming Diagram Program) |
| R51 | BHPS1 (Powering Program TM 229) |
| R52 | BHPS2 (Powering Program) |
| R53 | BHPS3 (Powering Program) |
| R54 | VIBRN (Approximate Ship Hull Vibration Program) |
| R56 | DBHC (Double Bottom Heating Coils) |
| R57 | HOPPL (Hoppered Plate and Longitudinals) |
| R58 | SABAL (Shell and Bilge Plating and Associated Longitudinals) |
| R59 | SLIS (Shell Longitudinals, Inner Skin and Longitudinals) |
| R60 | UWSBAD (Upper Wing Tank Sloping Bulkhead and Diaphragm Plate) |
| R61 | DEK (Deck Plating and Longitudinals) |
| R62 | REQMOD (Required Midship Section Modulus) |
| R63 | MODCOR (Modulus Correction) |
| R64 | "CASCADE" Program Segments (Computer Aided Scantling Determination) Notice Number R65 to R82 Metric Units |
| R65 | VOLM (Volume of Bulk Carrier Holds) |
| R66 | BOTUM (Bottom Shell and Keel Plating) |
| R76 | CGIBM (Centre Girder and Inner Bottom Plating) |
| R68 | GAFM (Girders and Floors) |
| R69 | OGFAHM (Girders and Floors "Specified Holds may be Empty") |
| R70 | BIBLM (Bottom Shell Longitudinals and Inner Bottom Longitudinals) |
| R71 | HOPPM (Hoppered Plate and Associated Longitudinals) |
| R72 | BASSM (Bilge and Side Shell Plating and Associated Longitudinals) |
| R73 | SISKM (Shell Longitudinals, Inner Skin Plating and Longitudinals) |

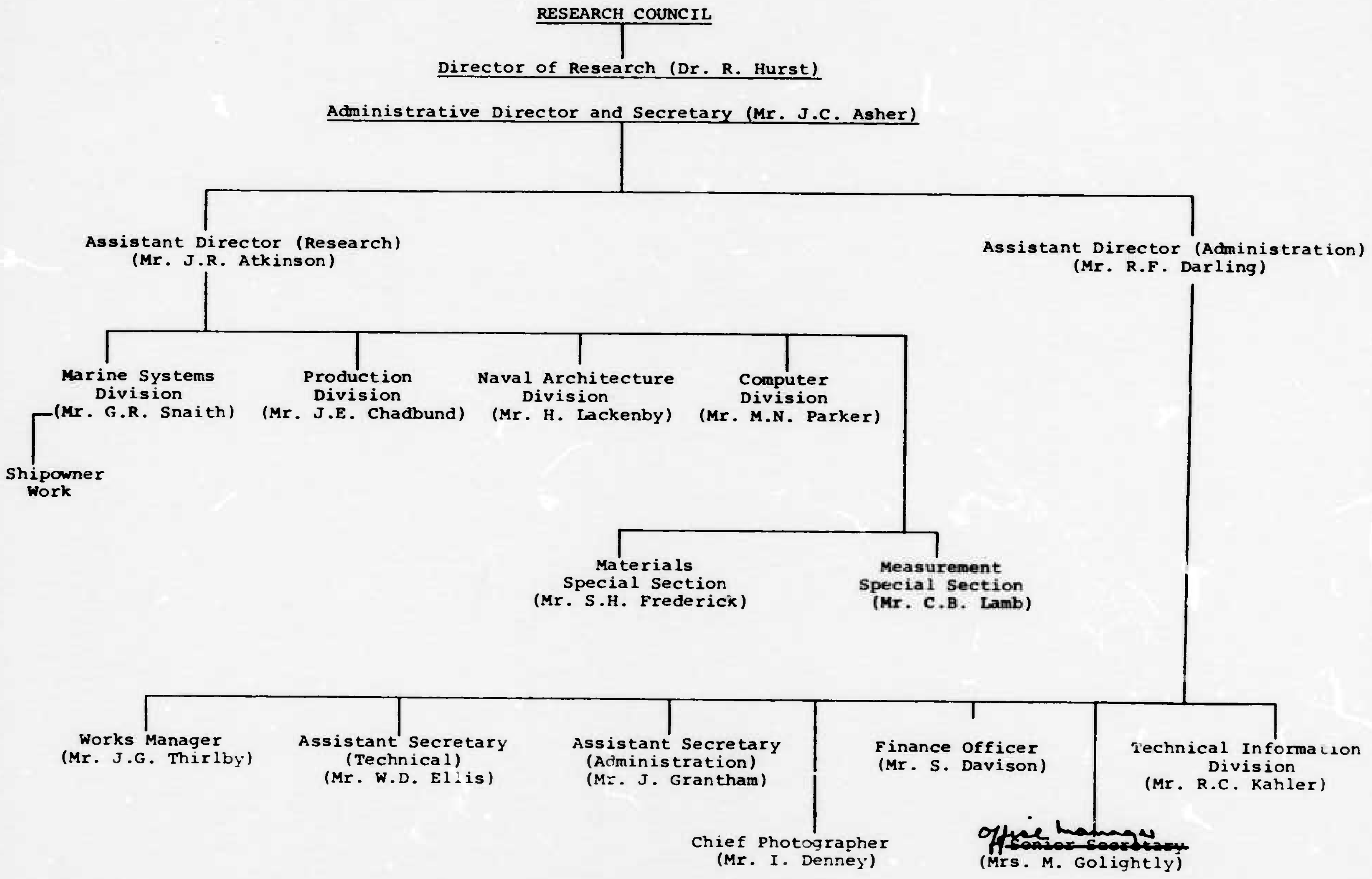
| | |
|---|---|
| R74 | SBADM (Sloping Bulkhead to Upper Wing Tanks, Diaphragm Plate and Associated Longitudinals) |
| R75 | DECKM (Deck Plating and Associated Stiffeners) |
| R76 | RSM (Rule Required Midship Section Modulus) |
| R77 | ASM (Actual Midship Section Moduli) |
| R78 | FRAM (Frames and Web Frames in the Holds) |
| R79 | HOTTM (Hopper Tank Transverse Material) |
| R80 | TOTTM (Top Tanks Transverse Material) |
| R83 | oFRATR (Midship Section Scantlings of Freighters of length greater than 9o metres) |
| R84 | oDRY9o (Midship Scantlings of Ship under 90 m) |
| R85 | BLKDES (Bulk Carrier Design, First Cycle) |
| R86 | JUMBO (Program to Compute Bonjean Curves and Hydrostatic Tables of Part of a Ship) |
| R88 | BSAD (Bending Moment Shearing Force and Deflection) |
| R89 | ESTGER (Post Processor ESSI to Gerber) |
| R90 | VIBSM (Ship Hull Frequency and Amplitude Estimations) |
| R91 | oPROPS (Lineshaft analysis) |
| R93 | BODY (Program to Produce ESSI Control tape for drawing a body plan) |
| R94 | TEKTR (Post Processor ESSI to Tektronix) |
| R95 | MICRO (Post Processor ESSI to Ferranti Microfilm Plotter) |
| R96 | SPOT (Steel Plate Ordering Technique) |
| R100 | MSPE (B.S.R.A. Methodical Series Powering Estimates) |
| R101 | ECEVAL (Economic Evaluation of Ship Design) |
| R102 | AXVIB (Axial Resonant Vibration in Ships Propeller Shafting) |
| R104 | TBARM (Selects metric dimensions of a Fabricated T-bar, Flanged Plate or Flat Bar to satisfy a given section modulus) |
| R115 | TOVIB (Torsional Resonant Vibration in Machinery Systems) |
| R117 | TKRDES (Tanks, Preliminary Design) |
| R203 | oCNSTO (Container Stowage) |
| R249 | BEST (Bulk carrier estimated steelmass, based on approximate scantlings to Lloyds. |

### 3. Britships Programs

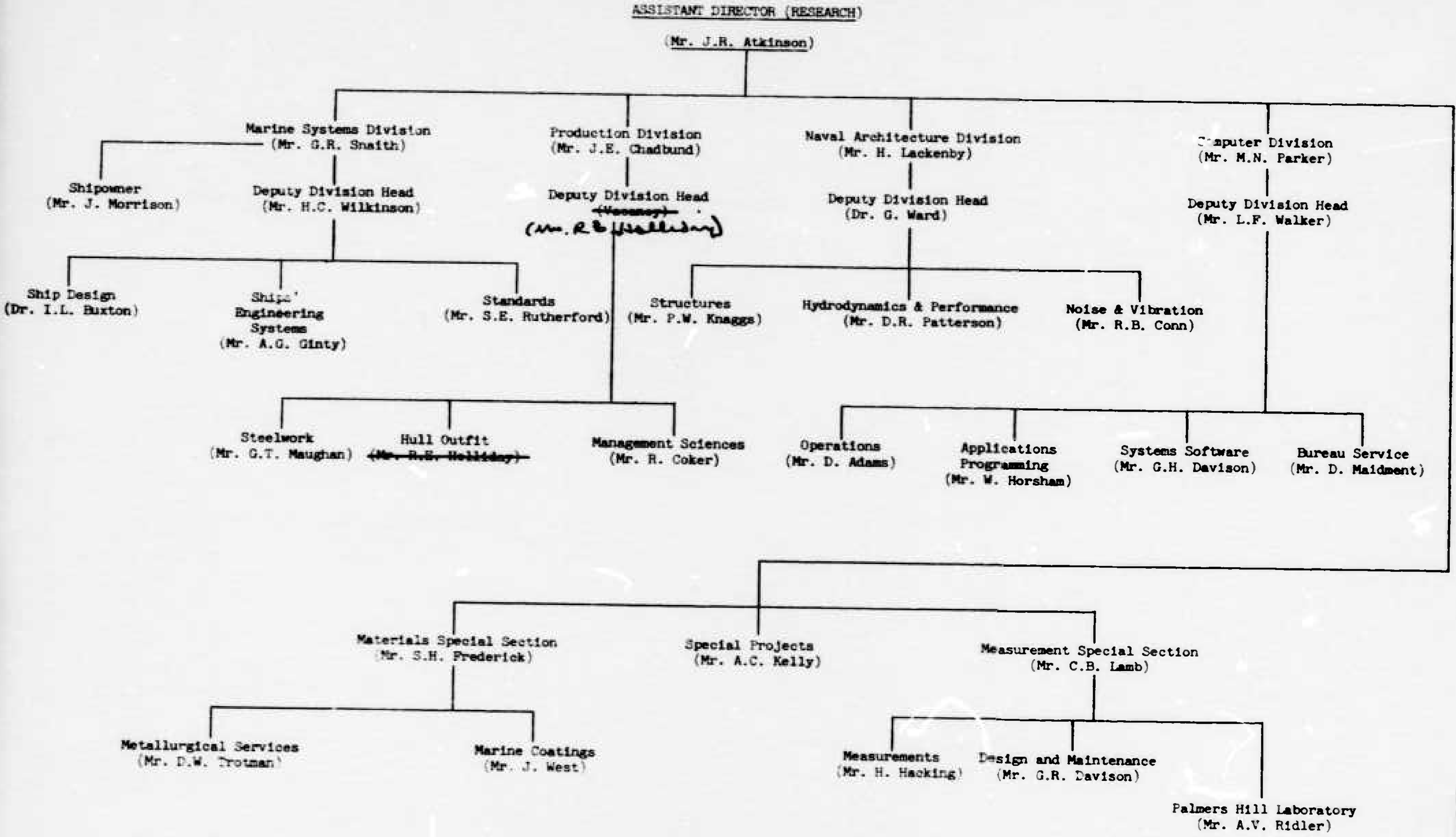
| | | |
|---|---|---|
| BSRA/NA/W085 | B7 | Draws body and waterline plans |
| BSRA/PR/W236-239 | B10 | Shipbuilding 2C,L |
| BSRA/PR/W230 | B13 | Minimum rectangle for developed shell plates. Ordering and cutting information |
| BSRA/PR/W231 | B16 | Shell Plate Post Processor for 3-axis Machine |
| BSRA/NA/W171 | B20 | Drawings of longitudinals and other surface lines |
| BRITFAIR | | |
| Shell Plate Development | | |
| BRITSHELL | B19 | Frame co-ordinates of longitudinals, shell seams and other lines on hull surface |

### 4. B.S.R.A. Programs for Management Information and Production Control

| | |
|---|---|
| BSRA/PR/W202 | Man Hour Curves |
| SPOT | Steel Plate Ordering Technique |
| SHOT | Sections (Heavy) Ordering Technique |
| SCOT | Steel Centralised Ordering Technique |

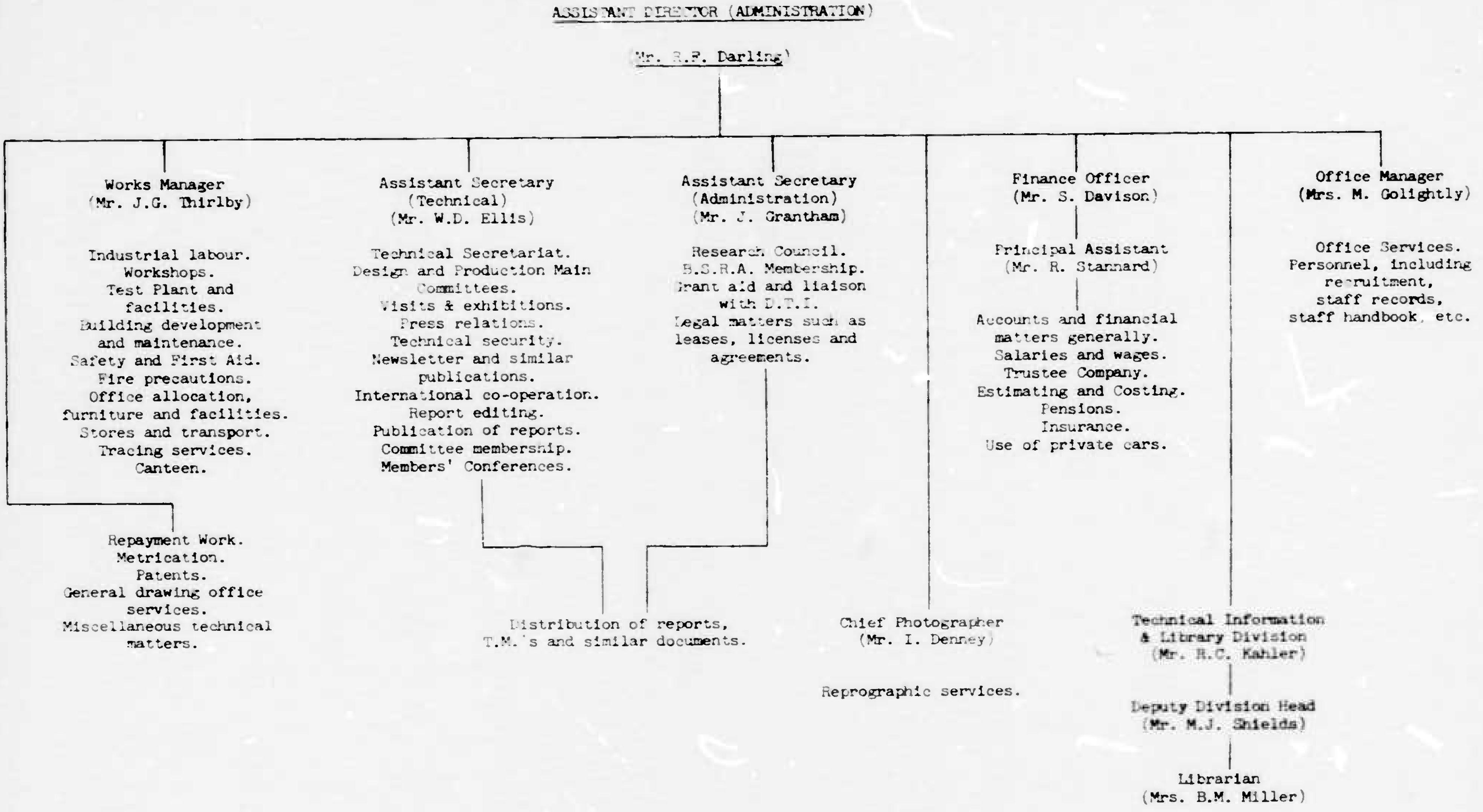


B.S.R.A. INTERNAL ORGANISATION



# B.S.R.A. INTERNAL ORGANISATION

## DETAILS OF RESEARCH SIDE



ASSISTANT DIRECTOR (ADMINISTRATION)

(Mr. R.F. Darling)

Works Manager
(Mr. J.G. Thirlby)

Industrial labour.
Workshops.
Test Plant and facilities.
Building development and maintenance.
Safety and First Aid.
Fire precautions.
Office allocation, furniture and facilities.
Stores and transport.
Tracing services.
Canteen.

Repayment Work.
Metrication.
Patents.
General drawing office services.
Miscellaneous technical matters.

Assistant Secretary
(Technical)
(Mr. W.D. Ellis)

Technical Secretariat.
Design and Production Main Committees.
Visits & exhibitions.
Press relations.
Technical security.
Newsletter and similar publications.
International co-operation.
Report editing.
Publication of reports.
Committee membership.
Members' Conferences.

Assistant Secretary
(Administration)
(Mr. J. Grantham)

Research Council.
B.S.R.A. Membership.
Grant aid and liaison with D.T.I.
Legal matters such as leases, licenses and agreements.

Distribution of reports, T.M.'s and similar documents.

Chief Photographer
(Mr. I. Denney)

Reprographic services.

Finance Officer
(Mr. S. Davison)

Principal Assistant
(Mr. R. Stannard)

Accounts and financial matters generally.
Salaries and wages.
Trustee Company.
Estimating and Costing.
Pensions.
Insurance.
Use of private cars.

Technical Information & Library Division
(Mr. R.C. Kahler)

Deputy Division Head
(Mr. M.J. Shields)

Librarian
(Mrs. B.M. Miller)

Office Manager
(Mrs. M. Golightly)

Office Services.
Personnel, including recruitment, staff records, staff handbook, etc.

# B.S.R.A. INTERNAL ORGANISATION

## DETAILS OF ADMINISTRATION SIDE

# APPENDIX II-5

## PROPOSED BSRA PROJECT STUDY FOR AN AUTOMATED SHIP HAVING A MINIMUM CREW

January, 1972.

THE BRITISH SHIP RESEARCH ASSOCIATION

443/MS(Rev. 1)

443/MS(Rev. 1)

MARINE SYSTEMS RESEARCH COMMITTEE

# PROPOSED PROJECT STUDY FOR AN AUTOMATED SHIP HAVING A MINIMUM CREW

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Research Project D17(Sy)

## CONTENTS

## SUMMARY

### The Project

The paper describes proposals for an automated ship project aimed at furthering the development and application of shipboard automation. It is contended that such a project should be defined in terms of its implications for reduced manning, since these provide the main economic incentive and affect the requirements for automation throughout the ship. The proposals are based on a 'minimum-crew' concept. This concept implies that there is a minimum size of crew below which it is not feasible to operate without going to a completely unmanned ship.

The proposed ship would operate with a periodically-unmanned bridge in open waters, and a periodically-unattended engine room except when bringing the machinery to the "standby" condition and when shutting down after "finished with engines". Consideration of the tasks to be performed, both in normal operation and under fault or emergency conditions suggests that an eight-man crew, dual-purpose trained, would be adequate.

The implications of operating with a crew of this size are discussed in relation to the automatic control facilities that would be needed in the three main areas of navigation and ship control, machinery operation, and cargo operations. Reference is also made to matters such as legal implications, classification, insurance and union acceptance.

To provide the control and associated functions needed for such a project will, it is considered, require the use of computers in some form and the ways in which the various computational requirements can be met are discussed.

It is considered that the proposed project is technically feasible, and economic calculations indicate that there would be likely to be a substantial economic incentive to the shipowner.

The factors affecting the choice of ship are discussed and a tentative choice is made of a combination carrier of about 100,000 dwt. Much of the outcome of the work would however be ship-type and size independent, and an alternative ship could be selected without greatly affecting the work content.

### Planning

The ultimate goal is taken to be the design, construction and proving in service of a minimum-crew ship as defined above. A phased programme of research and development is proposed, with a review of results and decision regarding future action at the end of each phase. Three phases are suggested, the research and development carried out in the first two phases enabling the ship and its equipment to be specified in progressively greater detail as the work proceeds, and enabling the content and cost of the remaining development work, and the cost of the ship, to be estimated more precisely:-

<u>Phase 1</u> - Analysis and outline design; detailed specification of requirements for control hardware and software.

<u>Phase 2</u> - Design/development work on control equipment, including computer hardware and software; more detailed design study.

<u>Phase 3</u> - Implementation by the design and construction of an actual ship, and proving at sea.

The possibility of integrating Phases 2 and 3 is discussed.

## Organisation, Control and Funding

The project would require technical contributions from the three major industries concerned, namely shipowning, suppliers of automation and computer equipment, and shipbuilding (including engineering equipment supply). Additional specialised knowledge could probably also be contributed by other organisations. Participation from a particular industry might be arranged through the appropriate industry organisations, or directly with one or more large companies within that industry. Discussion would be required to ascertain the degree of interest and willingness to participate.

The extent to which individual industries or companies would be willing to contribute (either financially or by active participation), and the possibility of governmental support being made available (as has been the case with similar projects abroad) would need to be ascertained. The machinery to be set up for organising and controlling the project would need to reflect the arrangements made for participation and funding.

# 1. INTRODUCTION

1. The application of automation to ships has made substantial progress during the last ten years, principally in respect of machinery installations, and a high proportion of ships now being delivered are suitable for periodically unattended operation of the engine room. The automation of bridge functions is at a much earlier stage, and is generally limited to the use of conventional auto-pilots, although progress is being made in the development of additional navigational and watch-keeping aids. With regard to cargo-handling operations, automation techniques are beginning to be applied in a relatively few ships.

2. Automation technology is still advancing rapidly, and experience in other industries suggests that further advances in the marine field will draw on the power and flexibility of computers to provide more comprehensive and sophisticated facilities for control and monitoring. Already a number of nationally-sponsored shipboard computer projects are being carried out abroad to demonstrate the feasibility of using this type of equipment at sea, and to explore applications and techniques (Ref. 1).

3. Research and development must now be concerned with preparations for this next stage of advance, and it is contended that the work should be co-ordinated by being focussed on a specific ship project, having aims which are realistic but sufficiently forward-looking to provide a worthwhile target. A previous study (Ref. 2) has indicated three probable stages of future automation development, defined in terms of their influence on manning requirements, which constitute the most significant and most clearly identifiable area of cost saving. These stages are:-

(a) Numbers of crew reduced as far as possible while still retaining continuous watch-keeping on the bridge, and separate deck and engineering staff.

(b) A change made to multi-purpose crew, and numbers reduced to the minimum considered feasible while still retaining a worthwhile crew function, eliminating the need for continuous watch-keeping ("minimum-crew ship"). The number of crew to be determined, but probably in the region of eight.

(c) The completely numanned ship.

4. It is considered that a programme of research and development aimed at forwarding the progress of marine automation would be most effective if it were focussed on a ship project aimed at Stage (b), the minimum-crew ship. It is anticipated that the spin-off from such a programme would automatically forward the development of Stage (a), enabling individual techniques and equipment which were developed to be adopted as they individually became economically viable. Also experience gained with Stage (b) ships at sea would provide an essential basis for progress towards the completely unmanned ship.

5. The purpose of this paper is to define such a project, to discuss the implications and the research and development work required, and to indicate possible means of implementation.

## 2. SCOPE AND PLANNING OF PROJECT

6. The project has as its ultimate goal the construction and proving in service of a minimum-crew ship, as defined above. It is recognised, however, that no commitments to build could be expected until sufficient research and development, co-ordinated with design investigation work, had been carried out to give reasonable assurance of technical and economic success. A phased development programme is therefore necessary, in which the outcome of each phase would be assessed before a decision was made to proceed to the next phase.

7. In this connection the report of a recent Governmental Committee on the management of development projects having high technical and cost content (Ref. 3) has recommended that development should be progressed in four stages: an initial feasibility study, followed by two stages of project definition, leading to the full development. In some instances the second stage of project definition may be omitted. Briefly, successive stages would incorporate increasing amounts of design and experimental work to give a progressively more precise technical definition and cost estimate of the product. Estimates of the remaining development work would also become progressively more detailed and precise. The end of each stage would constitute a decision point regarding further action.

8. It is considered that the work leading to the present paper corresponds approximately to a feasibility study as defined in Ref. 3, although since the nature and degree of participation likely to be forthcoming from other organisations is not known, it has not been possible to include estimates of the cost or duration of the development work. Some guidance as to the possible effects on ship economics is however given in Section 7.

9. It is proposed that the project should be considered as falling into three phases, outlined below. (These will correspond approximately to the remaining three stages of Ref. 3). A specific size and type of ship would be chosen to provide a focus for the work, as discussed in Section 3, although much of the work will be more widely applicable.

10. Phase 1. Analysis and Outline Design

(a) Investigation of functional requirements for all shipboard operations.

(b) Investigation of the automation techniques and equipment necessary to fulfil the requirements formulated in (a) with minimum-crew operation, including assessment of available equipment and techniques and specification of requirements for new equipment where needed.

(c) Investigation of the repercussions of minimum-crew operation on the design/selection of conventional equipment (e.g. propulsion machinery and auxiliary systems).

(d) Preliminary design investigations of the effects on ship and machinery layout.

(e) Study of other implications (legal, classification, union acceptance, etc.).

11. This phase is thus largely concerned with data collection and analysis, and systems design studies, and would result in a series of reports specifying requirements and detailing proposed solutions.

12. **Phase 2. Design/development**

(a) Development of such new equipment or techniques as are shown to be necessary from Phase 1, or the adaptation or further development of existing equipment or techniques.

(b) Proving at sea of equipment or techniques developed under (a) for individual shipboard functions (including software in the case of computer-based methods). This could be carried out on a piecemeal basis in existing ships or new construction.

(c) More detailed design study for minimum-crew ship, including costing.

13. Equipment or techniques developed in this phase for specific functions, if economically viable on their own, would become available for general use as spin-off from the project.

**Phase 3. Implementation**

14. This phase comprises the specification, design, construction and proving at sea of a minimum-crew ship. The ship would be built as a commercially-viable venture, apart from any exceptional costs for initial proving. Because of the changing market situation, the ship actually built could differ in some respects from that chosen to provide a focus for Phases 1 and 2, but it is anticipated that the results from these earlier phases could be applied with little adaptation to a variety of ships, as discussed in Section 3 below.

15. The possibility also exists of integrating Phases 2 and 3, that is, of proceeding direct from the initial analysis phase to the design and construction of the actual ship. This implies that the proving of new control hardware and software would be carried out on the one ship, and would probably necessitate fitting back-up equipment of conventional type. The ship would therefore differ in important respects from the minimum-crew ship as defined in this paper. A decision between the two alternatives brings in a number of factors which are discussed in more detail in Section 10. It is assumed in what follows that Phases 2 and 3 are carried out separately.

## 3. CHOICE OF SHIP

16. With the possibility of direct implementation in mind, it will be advantageous if the ship chosen as a basis for the project is of a type and size likely to be required in significant numbers. However, it is perhaps more important that the results themselves, in the form of equipment and techniques, should be widely applicable and in this connection it may be noted that:-

(a) As regard bridge activites (navigation and ship handling) the functional requirements are virtually independent of the type and size of ship, so that the choice of ship will not be significant in this respect.

(b) The machinery requirements will be largely dependent on the type of main propulsion machinery, and will be related only to a limited extent to the ship type and size.

(c) The cargo-handling requirements are obviously closely dependent on ship type, but even here certain parts of the system, e.g. those concerned with the loading plan, stress, trim, stability and ballasting, will be applicable to many ship types.

17. A further consideration in the selection of ship type is that since the greater part of the maintenance work will need to be carried out in port, because of the small number of crew, it will be necessary for the ship to be one which returns frequently to one or more ports at which suitable maintenance facilities can be provided. For the initial proving voyages it is strongly preferred that the ship should operate from a U.K. or at least a North European port.

18. There appears to be no one ship type and size which satisfies all criteria. Considerations of demand would suggest a dry bulk carrier, combination carrier, or tanker in one of the popular tonnage ranges. For building capacity in as many U.K. yards as possible, preference would be given to a tonnage of 100,000 dwt or less. A crude carrier or combination carrier would provide suitably comprehensive cargo-handling requirements (the somewhat more complex requirements of the products carrier are perhaps best not attempted in an initial project). From considerations of trading route a crude carrier or container ship would be most suitable. If there is a desire to minimise the magnitude of the risk in this first project (i.e. value of the ship and its cargo, risk of pollution) the emphasis would be on a smaller ship, and on a dry bulk carrier rather than a tanker. These factors are summarised in Table 1.

19. For the purposes of defining the project a somewhat arbitrary choice has been made of a combination carrier of about 100,000 dwt on the gounds that this size and type of ship would satisfy all the requirements quite well except those connected with trading route, although there are in fact ships of this type which do operate for long periods on a fixed trading route.

20. A final decision would need to take account of the views of any shipowner sponsorship for the project which might be forthcoming, and as pointed out earlier, it should be borne in mind that the outcome of Phases 1 and 2 of the project would be to a large extent applicable to ships of other types and size.

Table 1. Suitability of Various Ship Types

| Type of ship | Deadweight tons | Relative merits based on given criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Demand | Number of U.K. yards with capacity to build | Cargo-handling requirements | Low risk | Fixed trading route | Regular return to U.K. (or near) |
| Dry bulk carrier | 25,000 - 40,000 | Very good | Very good | Fair | Very good | Poor | Poor |
| | 60,000 - 80,000 | Very good | Very good | Fair | Very good | Poor | Poor |
| | 100,000 (say) | Good | Good | Fair | Good | Poor* | Poor |
| Combination carrier | 100,000 (say) | Good | Good | Good | Fair | Fair* | Poor |
| Crude carrier | 250,000 (say) | Very good | Fair | Very good | Poor | Good | Good |
| Container ship | | Poor | Good | Fair | Very good | Very good | Very good |

* a limited number of ships of these types do however operate on a regular trading route for long periods.

## 4. OPERATIONAL AND CREW REQUIREMENTS FOR PRESENT-DAY BASIS SHIP

21. It seems rational to specify the projected minimum crew ship in terms of the ship's function and how this function is to be fulfilled. The only basis there is for this at the moment is the equivalent manned ship which when carrying oil would have the following operational cycle, from discharge to discharge, starting from the completion of discharge, partially ballasted, and papers cleared. When carrying bulk solids the operational cycle would be similar apart from the cargo handling and tank cleaning operations.

| Deck | Propulsion |
|---|---|
| (1) Despatch parties to mooring stations (standby) and prepare bridge systems | (1) Prepare main engine and all necessary auxiliaries for start up (standby) |
| (2) Cast off and manoeuvre away from jetty | (2) Manoeuvre engines |
| (3) Manoeuvre ship through pilot waters, drop pilot. and proceed through congested shipping areas. Stow mooring cables and clear decks | (3) Manoeuvre engines |
| (4) Prepare and implement preliminary ballast arrangements | (4) Set main engines and auxiliaries to steady conditions |
| (5) Take instructions for ballast voyage. Plan voyage | (5) ditto and carry out machinery maintenance as required |
| (6) Implement voyage plan and proceed<br>Wash cargo tanks required for clean ballast (and other purposes), pass washings to slop tanks, separate and discharge water bottom. Take on clean ballast and discharge dirty ballast through separator and pass oil to slop tank<br>Carry out deck maintenance as required | (6) ditto |
| (7) Proceed with voyage navigating safely to rendevouz for orders. Report progress as required | (7) ditto |

| | Deck | | Propulsion |
|---|---|---|---|
| (8) | Receive orders | (8) | ditto |
| (9) | Plan final stages of voyage and implement safely and efficiently<br>Prepare loading plan.<br>Bunkers, provisions, etc.<br>Prepare berthing and mooring plan. | (9) | ditto |
| (10) | Pick up pilot and make approach to mooring.<br>Carry out or start deballasting | (10) | Manoeuvre engines |
| (11) | Despatch mooring parties to stations | (11) | ditto |
| (12) | Manoeuvre ship to bring alongside. Berth and secure | (12) | Manoeuvre engines till ship is secured and place on necessary state of quiet or standby |
| (13) | Acquaint shore personnel with loading requirements.<br>Complete deballasting.<br>Connect shore pipelines.<br>Load cargo, effecting all necessary checks and safeguards.<br>Adjust mooring to suit conditions.<br>Bunker and provision | (13) | Effect small repairs or maintenance |
| (14) | Check final state of ship.<br>Complete paper work.<br>Clear with authorities | (14) | Standby |
| (15) | Repeat (1) | (15) | Standby |
| (16) | Repeat (2) | (16) | Repeat (2) |
| (17) | Repeat (3) | (17) | Repeat (3) |
| (18) | Repeat (7) | (18) | Repeat (4) |
| (19) | Complete major portion of voyage and receive orders | (19) | Proceed steady |
| (20) | Repeat (9) but plan unloading in this case | (20) | Ditto |
| (21)<br>(22)<br>(23) | Repeat (10), (11) and (12) | (21)<br>(22)<br>(23) | Manoeuvre engines |

| Deck | Propulsion |
|---|---|
| (24) Acquaint shore personnel with unloading plan. Effect unloading and if necessary simultaneous ballasting according to predetermined plan. | (24) Operate cargo pumps or supply power to operate same |

22. Currently ships of the size being considered, and larger, are operating with crews of about 30 to 35 comprising possibly 10 or 13 officers and 20 to 25 crew. In addition to the Captain and Chief Engineer, a typical complement might be:-

Deck

First Officer
Second Officers (2)

Radio Officer

Bosun
Joiner
Seamen (6)

Catering

Chief Steward
Chief Cook
Assistant Cook
Stewards (2)
Galley Hand

Engineering

Second Engineer
Third Engineers (2)
Fourth Engineer
Electrical Engineering Officer

Engineering Hands (5)

23. Deployment of personnel during the operational cycle described above might be :-

| | Bridge | Deck | Engine Room |
|---|---|---|---|
| Mooring & Casting Off | Captain<br>Officer<br>Helmsman<br>Messenger<br>Radio Officer<br>Pilot | 2 Officers<br>10 to 12 Hands | 2 Officers<br>1 Hand |
| | 6 | 12 to 14 | 3 |
| On Voyage<br>Continuous<br>Full watches (excluding daywork) | 1 Officer<br>1 Helmsman (or Auto Pilot)<br>1 Lookout | | 1 Officer ) in<br>2 Hands ) manual E.R. |
| | 2 or 3 | | 3 on watch in manual E.R. |
| Intermittent<br>Bridge watch & daywork including tank cleaning & maintenance | 2 or 3 continuously plus Radio Officer | 1 Officer<br>7 or 8 Hands | 2 Officers ) UMS<br>5 Hands ) day workers |
| | 3 or 4 | 8 or 9 | 7 |
| Cargo Handling | - | First Officer<br>1 Other Officer<br>2 or 3 Hands | 1 Officer ) on<br>1 Hand ) watch |
| | | 4 or 5 | 2 plus<br>2 or 3 dayworkers |

24. Administrative work, overall supervision, forward planning and other ancillary tasks are carried out on a daily basis and at other necessary times by the Captain, Chief Engineer and First Officer.

25. Some of the work included in the listings above is directed towards the provision of heat, light and atmospheric conditioning for all concerned with the primary functions of ship operation, and the whole purpose for and effort of the catering staff (about 6) is concerned with the sustenance and welfare of the ship's operating crew.

## 5. IMPLICATIONS OF OPERATING WITH MINIMUM CREW : FUNCTIONAL REQUIREMENTS

26. The functions involved in the voyage cycle detailed in the preceding section will now be considered in terms of operation without continuous watches on the bridge or in the engine room, and with the number of crew reduced to the minimum considered necessary to cope with essential operating duties and to make adequate provision for emergencies. A first attempt is made to identify those functions which will require to be automated in order to permit operation in this way, to provide guidance in formulating the necessary programme of research and development.

27. It will be seen that the basic operational functions may be grouped as follows:-

Deck functions

1. Ship control in open sea
2. Ship control in congested waters
3. Ship control in pilot waters and mooring apprarches
4. Mooring and casting-off.

Engine-room functions

1. Full-away operation
2. Manoeuvring
3. Bringing from cold to harbour condition
4. Bringing from harbour condition to standby.

Cargo operation

1. Loading and deballasting
2. Unloading and ballasting
3. Tank cleaning.

### Deck Functions

28. (a) Ship control in open sea

For operation with the bridge unattended an automatic navigation and ship control system will be required which will maintain the ship on its intended route. For simplicity the route will probably be defined as a succession of straight lines on the map, and a voyage plan will need to be prepared fixing the end points of the individual legs of the route. It is considered that the most suitable type of control system is likely to be one which causes the ship to home on to the end point of the leg on which the ship is currently sailing. An essential feature will be an automatic position-fixing system, which will determine the position of the ship at frequent intervals. Position fixing may be by navigational satellite or a radio system such as Omega, Decca, etc., or a combination of these. The control system would need to incorporate automatic correction for drift due to wind and current, computed from s comparison of actual ship movement (from successive position fixes) with apparent ship movement (from ship's heading and speed through the water).

29. On reaching the end point of a particular leg, to within a pre-determined degree of accuracy, the ship would be caused to home on to the next junction. These course changes could be set-in on the equipment individually or the whole voyage programmed in from the beginning. Over-riding manual control will be possible at any time.

30. Detours to avoid bad weather, or for any other reason, could be arranged by manually setting-in the desired new route on the equipment. A refinement would be the use of weather-routeing computer programs (run either on a ship-board computer or a shore-based computer) which would determine from meteorological data the optimum course in terms of fuel consumption while avoiding regions in which the predicted sea state exceeded some given value. Such programs could be arranged to provide the route information in a form suitable for interfacing directly with the ship control system. The need for automatic speed reduction in bad weather, using signals from either ship motion or hull stress sensors, may need to be considered.

31. Also essential will be the provision of:-

(a) A collision avoidance system capable of identifying a potentially hazardous situation and of manoeuvring the ship, by controlling its speed and direction, so as to avoid the hazard. The homing system would be over-ridden temporarily for this purpose.

(b) An anti-stranding system capable of identifying an under-water obstacle and of stopping the ship, again over-riding the homing system for this purpose.

Fig 1 shows in block diagram form the various control systems and sub-systems referred to.

32. Bridge duties of ship's personnel during open-sea operation will be confined to routine equipment checks, periodic checking of ship's position and course, and either manually initiating required course changes or checking such changes as are made automatically. Personnel would be summoned by alarms in the event of a control system becoming inoperative, or of a potentially hazardous situation being identified by the collision-avoidance system or the anti-stranding system. ("Potentially hazardous" would need to be carefully defined in these connections to prevent unnecessary alarms.) Alarms may also be required to give warning of deviation (beyond some predetermined amount) from the desired route or course.

### (b) Ship control in congested waters

33. Basically the control system described above would be capable of operation in congested waters, but the number of potential hazards arising from the presence of other ships and adjacent coast lines would place greater demands on the collision-avoidance system. It would be a matter for judgement by the Captain, taking into account the degree of sophistication possessed by the collision-avoidance system, at what point manual control should be instituted. In these circumstances manual control of ship manoeuvres would no doubt be greatly assisted by the graphical display provided by the collision-avoidance system.

### (c) Ship control in pilot waters and mooring approaches

34. It is assumed that the ship would be under manual control in pilot waters and mooring approaches, assisted by tugs as necessary. The situation thus reverts to a conventional one. With regard to instrumentation, the graphical display from the collision-avoidance system referred to in (b) above would be required, but with the generally slow rates of movement this would tend to revert to a conventional radar display. A separate conventional radar may in any case be provided.

35. A need already exists for instrumentation to assist in the berthing of very large ships (Ref.4). In this connection radar-doppler and sonar-doppler equipments are becoming available which will give an accurate measurement of low approach speeds to a jetty, but possibly further development is required, together with the development of accurate short-range proximity indicators.

36. Two members of crew would probably be required on the bridge when the ship is under manual control in congested waters or close manoeuvring situations.

### (d) Mooring and casting-off

37. A recent comprehensive study of mooring methods (Ref.5) has shown that with modern power-worked systems and an optimum layout, the total number of men required for mooring, casting-off and associated activities can be reduced to six, probably divided into separate fore and aft working parties each comprising one skilled and two semi-skilled men. Even these requirements will however be difficult to meet from a total crew of about eight, at a time when the bridge will need to be manned, although it should be possible in an emergency. If mooring proves to be the only situation requiring a relatively large number of crew it will be uneconomic to increase crew numbers solely for this purpose, and it will be preferable to think in terms of using shore-based mooring parties, who will board the ship as it enters harbour. The shore-based men would work under the supervision of the ship's crew members who would be familiar with the ship's equipment.

### (e) Other deck functions

38. A radio operator might still be required, but since his work would be intermittent it would be possible for him to combine his function with that of electronic instrument technician, for which his training will render him suitable.

39. There will be little opportunity for undertaking cleaning and painting tasks at present carried out by ship's crew.

## Engine-room Functions

### (a) Full-away operation

40. In the full-away condition the engine room will normally be unattended except for periodic inspections. The propulsion machinery will be under the control of the ship control system, with facility for exercising manual control from the bridge. A number of ships are currently operating with periodically-unattended machinery spaces, and this experience provides a firm base line for progressing to the minimum-crew ship. Certain operations which are still carried out manually, e.g. pumping-up of service fuel tanks, and bilge pumping, will probably need to be automated, and this should present no serious problems. Automatic starting of stand-by auxiliaries, and auto-starting and synchronising of stand-by generators, are assumed, as is the employment of a comprehensive alarm and monitoring system.

41. The replacement of existing analogue controllers by on-line computer control may be advantageous, and could enable improved facilities such as variable-gain control and dynamic alarms to be provided as discussed in Section 9. Facilities for trend analysis will be required to give early warning of deterioration of machinery and equipment, so that preventive maintenance can be carried out in time to avoid failure in operation. The possibility of providing fault diagnosis computer programs will need to be examined.

42. The machinery installation will need to be designed for high reliability and safety, and special attention will need to be given to the early detection of fire and leakages. These matters are returned to later in section 9.

43. Staff duties when the machinery is full away will comprise periodic inspections to detect any abnormal condition, routine control equipment checks, minor adjustments and maintenance. The latter will probably be limited to servicing of instrumentation, and small tasks such as the re-packing of leaky glands.

### (b) Manoeuvring

44. The engine-room status when manoeuvring will be the same as when full away, and the main machinery will be under manual control from the bridge. The control equipment must be capable of controlling satisfactorily, without any manual adjustment over the whole range of conditions met with during manoeuvring.

### (c) Bringing from cold to harbour condition
### Bringing from harbour condition to stand-by

45. Starting-up the machinery plant from cold, and also bringing to the stand-by condition could, if necessary, be carried out automatically on manual initiation, either using conventional switching devices with time delays and interlocks or by computer control, but it is doubtful whether this degree of sophistication is worthwhile. With even a small ship's crew it should

be possible to arrange for the presence of two crew members in the engine room to carry out these operations manually, but a study of the work content will be needed to verify this.

46. During these two phases the satisfactory operation of all alarms and of automatic cut-in and safety devices (in so far as this is feasible) should be checked, unless similar checks have been made only a short time previously. It will be desirable for the engine-room to remain manned as the ship leaves harbour and for a further period of several hours to ensure that all equipment is functioning satisfactorily. This will be particularly important if any maintenance work has been carried out on equipment while the ship has been in harbour.

## Cargo Operations

47. The primary objective of this new ship type so far as cargo-handling is concerned is the same as that of present-day carriers operating on the same route but modified by the proviso that this objective has to be met with a greatly reduced crew.

48. For the purpose of defining the project a combination carrier of approximately 100,000 dwt has been tentatively chosen and in section 4 the operational and crew requirements for a conventional combination carrier operating as a wet bulk carrier were described. Although in the following description it is assumed that the cargo is liquid bulk, the onboard systems will be designed to handle other types of cargo.

49. A centralised cargo control system will be required and it is envisaged that all operations will be computer controlled, with one crew member monitoring conditions from the cargo control centre. The centralised cargo control system will coordinate cargo handling and engine-room machinery during cargo operations.

### (a) Loading and Deballasting

50. Deballasting will be carried out by the cargo control computer according to a voyage ballasting plan (prepared with the aid of a cargo planning suite of programs) formulated shortly after the ship left the discharge port, or a modified plan prepared on voyage. It is assumed that a mooring party will come aboard prior to berthing and that they and/or other terminal-based personnel will connect the shore pipelines. The ship's cargo pumps will not be used unless simultaneous deballasting and loading is carried out. Cargo oil will be pumped into the ship by shore pumps, and the cargo control computer will be mainly required for the sequence control of tank valves in accordance with a previously derived loading plan. Ship draught, trim and possibly stress will be monitored continuously by the ship monitoring system. Particular attention will be paid to topping up and other critical activities. Bunkering control will be carried out automatically after connection of the supply line.

### (b) Discharging and ballasting

51. Cargo discharge and ballast plans, if not already available in standard form, will be prepared as the ship approaches the discharge port. At the terminal the cargo control computer will automatically control the unloading sequence and ballasting, monitored by the ship monitoring system.

### (c) Tank cleaning

52 Cargo tanks to be used for clean ballast will be washed automatically, the washings passed to slop tanks, separated and clean water recirculated or discharged overboard. Inerting or other safety precautions will be effected as required. Dirty ballast will be discharged via an oily-water separator, and automatic closure of discharge valves will occur if oil is detected in the discharge. Subsequently the permanent ballast plan will be implemented automatically.

53 Fig. 2 is a block diagram showing the main sub-systems of the automatic cargo handling, ballasting and inerting systems onboard a minimum-crew ship. Items within the dotted lines constitute the centralised cargo control system which includes the cargo control computer (which would carry out on-line control of loading, discharging, ballasting and tank washing), and the ship and cargo monitoring systems. The cargo planning programs are shown outside the dotted area because they are essentially off-line programs which may be run either onboard or at the owners' office depending upon the size and type of the computer installation onboard the ship as discussed in more detail in Section 8.

## 6. IMPLICATIONS OF OPERATING WITH MINIMUM CREW: MANNING AND OTHER CONSIDERATIONS

### Manning

54. It is clear from the previous section that provided all equipment (both conventional equipment and control equipment) is functioning satisfactorily, the demands made on the crew for operational tasks are not great, and in themselves require only a small number of crew. In open-sea conditions, the crew are in fact being used solely to back up the automatic control equipment and hence to improve overall operational reliability. Apart from mooring, which it is possible will be dealt with by shore-based mooring parties, the greatest demands are made when the bridge must be continuously manned, that is in pilot waters and congested waters, but the periods during which this is required will be of short duration. It follows that the number and composition of the crew will be determined primarily by the need to provide for emergency repair and watch-keeping duties necessitated by some equipment failure

55. It must be emphasised that the high standard of equipment reliability aimed at (both by using equipment of high inherent reliability and by building-in redundancy as considered necessary) will, if achieved, make such occurrences rare. Also by aiming at ease of maintenance (fault-finding and repair) particularly of control equipment, periods of emergency watch-keeping will it is hoped be of short duration. Provision must nevertheless be made for coping with such situations should they arise.

56. The assumption is made that all officers will be dual-purpose trained, and qualified to stand watch on the bridge and in the engine room, although each will have special expertise and experience in a particular area. Owing to the small size of crew the amount of administrative work will be reduced compared with that for a conventional ship, and it is anticipated that the Captain and Chief Engineer will participate to a greater extent in the day-to-day operational work. It is also envisaged that any demarcation between duties carried out by officers and ratings will tend to become less rigid

57 The crew requirements may be summarised in general terms as follows.-

(a) ability to encompass the total expertise necessary to cover all technical and administrative aspects of ship operation

(b) capability for standing watches for limited periods of time as a substitute for individual control systems which may be temporarily out of action

(c) ability to effect such emergency maintenance as may be required without the imposition of undue physical or mental strain

(d) ability to be a mutually self-sustaining community

58. It will also be necessary that the general living standards and working conditions are not in any way inferior to those in a conventional ship.

59. With all these considerations in mind it is suggested that the crew should comprise a total of eight, made up as follows:-

Four officers, all dual-purpose trained, but each with special expertise and experience in one area, as follows:-

1. Administration and deck officer duties (Captain)
2. Deck officer duties
3. Engineer officer duties (plus some knowledge of control equipment)
4. Control and instrumentation (plus some knowledge of engineering)

One radio operator/electronic instrument technician

One general purpose rating, available for deck or engine-room duties

One cook )
Able to act as deck or engine-room hands
One steward ) if required.

60. In normal operation all crew members will be on duty during day work periods, and two crew members would be on call at other times to answer alarms. If, as is envisaged, alarms could necessitate those called out visiting either the bridge or the engine room, procedures would need to be evolved for answering subsequent alarms, but no difficulty is envisaged here.

61. In the event of an equipment failure necessitating continuous watch-keeping either on the bridge or in the engine room, single-man watches would be kept so far as possible. This would require the institution of some reporting system at night which might take the form of an automatic device giving an audible signal to the watch-keeper at predetermined intervals, say 15 minutes, to which the watch-keeper must reply by pressing a button within, say, one minute otherwise an alarm will sound summoning another member of the crew.

62. A more serious failure, say of the main ship control system, might necessitate two-men watches (helmsman and look-out). In this case the above crew composition would enable three officers and three ratings to be available for continuous watch-keeping, leaving the control engineer and instrument technician free to repair the equipment and answer alarm calls from the engine room. Meals during this period would be prepared by the off-duty watch-keepers.

63. The concepts of crew capability postulated here could give rise to problems of training. There is, however, some limited experience of dual-purpose training of ships' officers abroad, so that the concept is not new, and it would be anticipated that although the duties would be somewhat more demanding they would result in increased job interest and satisfaction.

## Arrangement of Control Centres

64. The assumption has been made implicitly in what has been said so far that a conventional bridge and a conventional engine control room would be provided. Although this could prove to be the best solution it will be necessary to explore other possibilities. In a ship of this type, operating with a very small crew, the concept of a single ship control centre may be more appropriate. The centre would contain the manual over-rides for ship and main engine control, and would be provided with instrumentation presenting the required information on ship and machinery state, together with necessary alarm/annunciator panels. The extent to which it would be advantageous to provide remote controls for other engine-room equipment would require study.

65. For convenience in assuming manual control of the ship such a control centre might need to be in the position of the conventional bridge in order to permit good visual observation of the surroundings. Rapid communication with the engine room by lift would be required. The layout of manual controls and instrumentation would also require careful consideration with the possibility in mind of one-man operation, as discussed previously.

66. The cargo control centre might require to be a separate entity, positioned either at deck level or as an adjunct to the engine room.

## Administrative Implications

67. The unconventional aspects of the type of ship proposed, particularly operation with unattended bridge and with a relatively small crew, may give rise to problems which are not purely technical. These problems would be concerned with compliance with legal requirements, classification, insurance, and acceptance by trades unions.

68. Legal requirements comprise the national requirements as laid down in the Merchant Shipping Acts and the Rules and Regulations made under those Acts, and also international aspects, which present a rather complicated picture. Both aspects will require study. It is anticipated that difficulty could arise in respect of:-

(a) Operation with a periodically unattended bridge
(b) Manning levels
(c) Manning qualifications

69. Discussions with the Department of Trade and Industry will be needed to ascertain whether any special dispensation will be needed to allow the ship to be operated in the proposed manner, and whether any additional safeguards will be required by them. D.T.I. will in any case need to be satisfied that the design of the ship and its equipment and the numbers and qualifications of the crew are adequate to ensure the overall safety of the ship and its crew. A discussion of the legal implications of automation is given in Ref. 6.

70 Classification society approval will also be required, and discussion with the selected society will be required at an early stage of the project to ascertain whether they would stipulate any special requirements regarding equipment A special supplement to class has already been assigned by most classification organisations to ships operating with machinery spaces unattended for specified periods, and presumably a similar arrangement would be sought for ships operating with an unattended bridge. Experience with nuclear ships has shown that classification societies are usually willing to make special provision for ships which incorporate technically unconventional equipment

71 Provided classification society approval is obtained, insurance cover will be forthcoming, but it is possible that insurance premiums will be increased at least during the initial period of operation, until satisfactory operation has been demonstrated in service

72 Operation of a minimum-crew ship along the lines envisaged will involve fairly radical changes in manning scales, working practices, and training and qualifications, all of which will be of concern to the relevant trades unions, namely the Merchant Navy and Airline Officers Association and the National Union of Seamen Discussions with the unions, presumably also bringing in the Shipping Federation, will be needed to ascertain whether the proposed changes will be acceptable, or whether special arrangements will need to be negotiated

## 7. ECONOMIC CONSIDERATIONS

73. It is not possible at this stage to make a realistic estimate of the cost of additional automation equipment required for the proposed ship, or of the effects on the costs of the conventional machinery and equipment. Some guidance can however be obtained by making estimates of the cost savings that would accrue from the reduction in crew and accommodation, modified by sundry other factors such as probable increased time out of service for scheduled maintenance and the possible increase in cost of insurance. Estimates can then be made of the maximum increase in first cost, due to the provision of additional automation and other equipment, which is acceptable for the project to be economically viable. The extent to which this permissible increase in first cost would also need to cover the cost of development work would depend on what other arrangements could be made for funding development, and whether the cost of development could be spread over several ships.

74. The method of calculation used is that described in Ref. 7, in which comparisons are made on the basis of nett present values using discounted cash flow techniques. A computer program incorporating the above method (Ref. 8) was used for the calculations.

75. The basis for the comparison was taken to be a 35 crew 100,000 tonne dw. crude oil carrier with a service speed of 15.5 knots on the Persian Gulf to Western Europe route. It was estimated that the payload of the ship would be 96,000 tonnes with a load factor of 50%, at a freight rate of £3.5 per ton escalating at 3% per annum over a ship's life of 20 years. Three different types of machinery have been considered, namely a slow speed diesel, a steam turbine, and an industrial gas turbine with simple regeneration in the form of air heating.

76. The following assumptions were made for the basis ship:-

| | |
|---|---|
| New building price | - £7.5 M |
| Owners' costs during building | - £100 K |
| Residual (disposal) value of ship | - £500 K |
| Structural steel weight | - 15,000 tonne |
| Steel costs | - £80 per tonne |
| Main machinery costs (all equal) | - £750 K |
| Labour costs | - £1.5 M |
| Building time | - 2.5 years |
| Length of round trip | - 24,000 miles |
| Number of days in service per annum | - 350 |
| Number of days in port per round trip | - 4 |
| Specific Fuel consumption:- | |
| Slow-speed diesel | - 0.35 lb/HP-hr on 1500 sec fuel at £9 per ton |
| Steam turbine | - 0.4 lb/HP-hr on bunker C at £8.5 per ton |
| Gas turbine | - 0.46 lb/HP-hr on<br>(a) distillate at £13 per ton<br>(b) 1500 sec. fuel at £9 per ton + 4% for fuel treatment |

(all escalating at 2% per annum)

Fuel used per day in port - 40 tonne

Crew costs - £110 K per annum escalating at 7%

Upkeep costs (maintenance, repairs and stores) - £90 K per annum escalating at 6%

Port costs per round trip - £6 K escalating at 5%

Other costs (insurance, administration, etc) - £150 K per annum escalating at 5%

Discount rate (rate of return on investment) - 8%

Corporation tax - 40%

Credit terms - 80% of shipyard price over 8 years at 7%

Profits are set against tax liability for depreciation purposes

These figures produce the net present values given in Column 2 of Table 2.

77. For the minimum-crew ship it is assumed that:-

(1) The number of crew is reduced from 35 to 8, and wage rates are increased by 30%, giving a net reduction in crew costs of 66%. (Wages represent only a proportion of total crew costs)

(2) The first cost of the ship is reduced by 3%, due to the reduction in accommodation.

(3) The building time is increased by 3%, to allow for the increased time required for fitting automation equipment. (This factor affects the timing of cash flows, but not their magnitude)

(4) Time out of service is increased by 27%, due to the increased time required for maintenance in port.

(5) Upkeep costs are increased by 10%, due to the cost of the increased maintenance work required in port.

(6) Port costs are increased by 2%, to allow for the cost of shore-based mooring parties.

(7) Insurance costs are increased by 10%.

78 These assumptions lead to the comparative figures given at Columns 3 to 5 of Table 2. It will be seen from Column 5 of the table that a sum of the order of £1 M would be available to cover the cost of the additional automation and other equipment required (including any additional installation costs), together with whatever proportion of development cost it was necessary to charge against the ship. It must be emphasised that it is not the total automation costs that are referred to, but the costs over and above the costs of present-day equipment. It would appear that, provided the stated assumptions are borne out, there is likely to be a substantial economic incentive to develop a ship of this type.

79. To show the sensitivity of the results to the various changes assumed in paragraph 77, Table 3 lists, for the ship fitted with slow-speed diesel machinery, the separate effect of each of the assumptions made. The effect of a change in any of these assumptions can be found by simple proportion. It will be seen that the results are dominated by the effect of the reduction in crew costs. The other favourable factor, namely the reduction in accommodation costs, is also directly related to the reduction in crew. The remaining factors, although significant, are much smaller in magnitude.

Table 2. Comparison of NPV of Automated and Basis Ship

| 1<br>Type of Machinery | 2<br>NPV of basis ship<br>(£) | 3<br>NPV for minimum crew (automated) ship<br>(£) | 4<br>Change in NPV for minimum crew ship<br>(£) | 5<br>Increase in first cost of minimum crew ship to give the same NPV as for basis ship<br>(£) |
|---|---|---|---|---|
| Slow-speed diesel | 1,898,000 | 2,542,000 | + 644,000 | 968,000 |
| Steam turbine | 1,779,000 | 2,425,000 | + 646,000 | 969,000 |
| Gas turbine (Distillate Fuel) | 463,000 | 1,155,000 | + 692,000 | 991,000 |
| Gas turbine (1500 sec. treated fuel) | 1,305,000 | 1,997,000 | + 692,000 | 991,000 |

## Table 3 Effect of individual factors on NPV of minimum-crew ship (Slow-speed diesel machinery)

| Variable | Change in NPV for 1% increase in variable | Change in variable | Change in NPV | Allowable increase in first cost for 1% increase in variable | Allowable increase in first cost |
|---|---|---|---|---|---|
| Crew costs | - £12,875 | - 66% | + £849,800 | - £19,370 | + £1,278,400 |
| First cost | - £49,800 | - 3% | + £149,400 | - £75,000 | + £ 225,000 |
| Building time | - £15,300 | + 3% | - £ 45,900 | - £23,000 | - £ 69,000 |
| Time out of service | - £ 4,570 | + 27% | - £123,400 | - £ 6,880 | - £ 185,800 |
| Upkeep costs | - £ 9,500 | + 10% | - £ 95,000 | - £14,300 | - £ 143,000 |
| Port costs | - £ 2,900 | + 2% | - £ 5,800 | - £ 4,400 | - £ 8,800 |
| Insurance cost | - £ 8,550 | + 10% | - £ 85,500 | - £12,900 | - £ 129,000 |
| | | Total | + £643,600 | Total | + £ 967,800 |

## 8. THE USE OF COMPUTERS

80. In discussing the possible ways of achieving the proposed objective and defining the systems and sub-systems required, mention has been made repeatedly of the use of computers. This is so basic an aspect of the project that it warrants separate consideration.

81. The progress made in the use of computers onboard merchant ships has been rapid (Ref. 1) and there is no reason to suppose that future developments will continue at any less a pace. However the majority of computer systems installed to date onboard merchant ships have been experimental in nature aimed at demonstrating the feasibility of using a computer at sea or at developing a particular product or range of products. It is contended that the general concept of using a computer onboard a merchant ship is proven (with the exception of certain peripherals) and that future shipboard computer systems can be designed without the necessity to demonstrate their feasibility by building a full scale experimental system onboard a 'guinea-pig' ship. This does not mean that individual items of equipment or sub-systems will require no development; considerable development of many of the navigational sub-systems will be required but it should be unnecessary to demonstrate the basic feasibility of using computers at sea.

82. It should perhaps be emphasised that the computer/computers visualised for use on-board a minimum-crew ship will differ significantly from the computers used ashore in computer bureaux. The computers which would be used belong to a family of machines designed and developed for the control of industrial processess or for military applications. As such they are smaller, faster, and generally more reliable than bureau computers because they are designed to meet more stringent environmental conditions. Computers of this type are referred to as process control computers, a name derived from the industries in which they were first used. The decreasing cost and physical size of these computers has enabled manufacturers of several current types of marine equipment which demand some kind of internal computation, to make use of small process control computers as part of their equipment. Typical examples of this can be seen in certain engine-room watch-keeping equipment, collision avoidance radars and satellite navigation systems. The philosophy of the minimum-crew ship extends the use of computers beyond their use as data processors within individual items of marine equipment to playing a vital role in the integration of certain shipboard activities which must be accomplished if the manning level defined in Section 6 is to be achieved.

83. An examination of the functional requirements of operating with a minimum crew (Section 5) indicates that some form of computational

facilities will be required for:-

- voyage planning
- weather routeing
- automatic position fixing
- course holding and drift correction
- collision avoidance
- shoal avoidance (anti-stranding)
- ship control (integration of powering and steering functions)
- on-line control of engine-room plant
- surveillance of engineering systems
- analysis of engineering data
- fault diagnosis
- maintenance planning
- and - administrative duties.

84. There are many ways in which these computational requirements can be met and computers are currently being used at sea in all of the areas listed above. Ref. 1 contains a table which summarises the shipboard activities which have been or are being carried out at sea by computers. However the shipboard computer systems used onboard the minimum-crew ship must differ from the experimental systems described in Ref. 1 because:-

- they must operate reliably in the absence of conventional back-up equipment
- there will not be computer development engineers in attendance onboard operational merchant ships
- and - with a minimum crew onboard the safety of the ship will be more readily compromised by a computer failure than on a conventionally manned vessel.

85. Therefore the computer systems onboard a minimum-crew ship must be designed from the beginning for:-

- maximum reliability
- high integrity (defined in this context as ability of a system to continue to function following failure or failures of one or more of its components)
- ease of maintenance.

86. There are broadly four different ways in which computer facilities can be provided for carrying out the various applications listed above:-

87 A. All computing carried out onboard by one computer

Although this would appear to be the simplest solution it has many disadvantages:-

- the reliability of the entire control system would depend upon the reliability of one computer. Almost any computer fault, however trivial, would cause a major system failure

- although process control computers are designed to operate in a time-sharing mode and to allocate their computing facilities according to the priority of the demands placed upon them, if too many functions are carried out on one computer it is possible to saturate the computer so that it becomes incapable of meeting these demands within acceptable time limits

- by process control standards this solution would require a very large computer with considerable back-up storage onboard, e.g. magnetic tapes, discs or drums. Most forms of back-up storage are as yet unproven at sea

- even if back-up stores were proved to be acceptable at sea certain programs would have to be permanently stored in the computer core-store resulting in an unacceptable amount of core-storage for a single computer.

88. B. <u>All computing carried out onboard by several computers</u>

The use of two or more computers operating in parallel with the ability to back each other up in the event of failure is an accepted, though somewhat expensive, technique adopted in air traffic control schemes. In addition to increasing the overall reliability of the computer system this technique reduces the possibility of saturation which could occur if a single computer was used. This is also an attractive proposition from the maintenance viewpoint because only one range of spares needs to be carried onboard.

A variation of this technique is the use of several computers of different types. For example high priority functions, essential to the safety of the ship would be allocated their own dedicated mini-computer, possibly with 'read only' storage resulting in better data storage security within the computer system. These individual mini-computers would be connected to one or more supervisory computers with conventional core-stores which in addition to coordinating the activities of the mini-computers would be used for low priority and off-line programs. In the event of a catastrophic failure of the supervisory computer the individual mini-computers would continue to operate independently, but some degree of manual coordination would then be necessary. This technique appears to have been selected by the Japanese for the nine-man crew ship which is currently being designed.

89. C. <u>Computing shared between shipboard and shore-based computers</u>

A third possibility is to minimise the amount of computing equipment onboard by carrying out as much of the data processing as possible ashore. This does not mean that on-line machinery control will be implemented remotely over a distance of several thousands of miles, but rather that all off-line programs, such as weather routeing, the preparation of loading and ballasting schedules, would be carried out ashore, probably at the owners' office and the results of the calculation transmitted to the ship. The communication facilities would need be no more reliable or available than those currently in use, but with improved communications more data processing would be done ashore. Obviously in this siutation there is a trade-off between the availability and reliability of the existing communication system and the size and complexity of the shipboard computer installation

90. In this configuration the shore computer would be a large multi-processing type installation with an appreciable amount of backing store, and the shipboard computer system comprises several dedicated mini-computers. The allocation of duties could be:-

| | Shipboard Computers | Shore Computers |
|---|---|---|
| Bridge | Position fixing.<br>Autopilot.<br>Collision avoidance.<br>Shoal avoidance. | Fleet scheduling.<br>Voyage planning.<br>Weather routeing.<br>Voyage supervision |
| Engineering | On-line machinery control.<br>Alarm surveillance and supervisory control.<br>Emergency shut down and protection.<br>First-line fault diagnostics.<br>Fire control.<br>Ballast control. | Maintenance scheduling<br>Machinery trend analysis<br>Back-up fault analyses |
| Deck | On-line cargo control<br>Tank washing control.<br>Ship stress monitoring.<br>Ship trim, draught, stability monitoring. | Loading/discharging/ ballasting plans |
| Miscellaneous | Communication processing. | Medical diagnosis. |

91. In this configuration the shipboard computers would be used in areas where:-

- they are essential to the immediate safety of the ship, e.g. collision avoidance and autopilot.
- the data processing requirements are incompatible with the use of a multi-purpose computer - e.g. on-line control and machinery protection.
- they are essential for contingency operation if the crew have to revert to manual operation - e.g. machinery alarm surveillance.

92. The calculations which might be carried out ashore:-

- require large data processing capacity and therefore if carried out onboard they would unduly complicate the shipboard computer installation
- the processed data is not required onboard the ship, e.g. routine maintenance scheduling
- the input data is more readily available ashore, e.g. meteorological information.

93. D. <u>All computing carried out on shore</u>

A fourth possibility is the removal of all data-processing functions from the ship and carrying them all out ashore. The ship in this case is regarded as a collection of sensers and actuators linked to a remote computer by a communication link. Even with the best communication facilities that are foreseeable at the present time this solution is considered to be impracticable, however it would be analysed in more detail during the project.

## 9. RESEARCH AND DEVELOPMENT WORK REQUIRED

94. In previous sections an indication has been given of the requirements that will arise for additional automation equipment in a ship which is to operate with the low level of manning proposed, and also of the other associated problems that will need to be studied before a ship of this type could be designed and put into service. An attempt is made in this section to outline in broad terms the research and development work that will be required, concentrating on Phase 1, since the outcome of this phase will determine in detail what is required to be done in the later phases to bring the project to fruition.

95. If a decision is made to proceed with the project, then depending on the precise terms of reference and arrangements made for participation by other organisations, this outline could be firmed up and expanded into a detailed work programme.

96. Reference is made to Fig. 3, which shows the various activities in block diagram form. It will be seen that the work can be grouped under the following headings:-

(a) Navigation and ship control
(b) Machinery installation
(c) Cargo operations
(d) Computers
(e) Other studies

### (a) Navigation and ship control

97. Phase 1 of the project will be concerned with analysing in depth the implications of navigating and conning a ship, in all areas of operation, with the low level of manning inherent in the minimum-crew ship concept.

98. Specific areas of study will include:-

- 'in depth' analysis of the operational requirements of the navigation and ship control systems onboard the selected ship type (although bridge activities are mainly ship independent), especially the operational requirements in congested water situations. Advantage would be taken of the design study currently being carried out by the Decca System Study and Management Division which is continuing work already undertaken by the Royal Radar Establishment under contract to the Esso Petroleum Company. In addition to the navigation and conning duties the operational requirements of the communication system will be analysed. In particular the duties of the radio operator will be defined. It is anticipated that the demands upon the communication system of a minimum crew will be greater than onboard a conventional ship and attention will be given to freeing the radio operator from routine duties to give him more time to fulfil his role of electronic engineer.

- the implications of meeting the operational requirements as defined by the above analysis with the proposed level of manning, particularly the implication of operating with a periodically unmanned bridge. Special attention will be given to:-
    - the nature of the position fixing system with regard to automatic operation, geographic availability, accuracy and compatibility with other shipboard systems.
    - the requirements of a true collision-avoidance radar device, capable not only of detecting potential collision situations, but also of determining and initiating avoidance action.
    - the requirements of an anti-stranding system capable of detecting underwater hazards at a range which will allow avoidance action to be taken.
    - the technical specification of a ship control system which will integrate the above systems with the ship's propulsion machinery, rudder and propeller.

and - analysis of the extent to which knowledge of the handling and steering characteristics of the ship will be required in connection with collision-avoidance and automatic ship control.

99. Considerable research and development work is currently underway in the United Kingdom by manufacturers of marine equipment sponsored in some cases by shipowners and/or Government bodies. The proprietary navigational equipment which will be available as a result of this research and development could, with additional development, be incorporated into the minimum-crew ship navigation and ship control systems.

100. During the analysis phase it will be necessary to define and to assess alternative ways of meeting the operational specification and the possibility of incorporating these new navigational aids into the minimum-crew ship navigation system. For example, each of the sub-systems described in Section 5 (Fig. 1) could no doubt be provided within the total time scale of the project by a collection of proprietary devices supplied by several manufacturers, they could be interfaced to a small process control computer (ship control system) to provide additional computing facilities required for use onboard a minimum-crew ship. Alternatively the ship control system could contain all the data processing capability required for position fixing, collision avoidance, anti-stranding, etc. Both alternatives have advantages and disadvantages which would be identified and assessed.

101. Phase 1 will also seek to identify areas which require significant research and/or development and to initiate and in some cases to complete back-up studies prior to the commencement of Phase 2.

102. It is anticipated that back-up studies will be necessary in:-

- ship handling and stability
- collision avoidance
- anti-stranding

and - the ergonomic design and nature of the control centre/centres onboard/ashore.

(b) Machinery installation

103. The development of the machinery installation for the minimum-crew ship will start from the base line provided by experience with existing ships operating with periodically-unattended engine rooms. It will be logical therefore to commence with a review of the instrumentation and control facilities fitted in such ships (which are closely related to classification society requirements) and of experience in service. The aim would be to identify areas where improvements in instrumentation and control facilities and in machinery design/selection/arrangement will be needed for successful operation with engine rooms periodically unattended over longer periods with minimal inspection and maintenance. Both turbine and diesel installations would need to be covered by this review.

104. An evaluation of alternative types of propulsion machinery will be required, leading to a recommendation of preferred type or types. In addition to the normal economic factors (first cost, running cost, weight, space occupied) special attention will need to be paid in the evaluation of reliability, maintenance requirements, and safety under conditions of unattended operation for long periods. The period for which the machinery must be capable of operating with no significant amount of maintenance must be defined. In view of the limited repair capability on board, consideration may need to be given to the possibility of providing twin screw, or twin engine/twin boiler, machinery to enable the ship to be propelled at reduced power in the event of breakdown of a major unit. Some increase in first cost to provide this capability, or to provide additional redundancy in the installation to obtain the necessary high reliability, may be acceptable so long as the overall economic benefits are not prejudiced.

105. Back-up studies will be required on the following topics to provide a basis for the design of the machinery installation and the specification of instrumentation and control equipment:-

(i) Reliability. In view of the importance of achieving high system reliability it is strongly recommended that use be made of the techniques of reliability analysis as an aid in the design of the machinery installation and its controls. These techniques are well established and enable quantitative estimates to be made of overall system reliability from data on the reliability of the individual system components. Valid service data on component reliability are not too plentiful at the present time, and the institution of a data collection scheme would be a long-term project. In the short term, however, much useful information could be derived from the service records which several shipowning companies have accumulated in connection with planned maintenance schemes, supplemented by data from naval sources and published papers. Although the information from these sources will not be fully comprehensive, it is anticipated that, when properly collated, it will be sufficient to provide a basis for system reliability studies, to the extent of giving valuable guidance on the degrees of redundancy necessary to achieve the desired level of system reliability.

(ii) Safety. Safety constitutes a study which is distinct from that of reliability, although the two overlap to some extent, particularly as regards the provision of standby equipment. Present-day requirements for unattended machinery installations include provision for automatic start-up of standby equipment, automatic power reduction or shut-down to avoid hazardous conditions, and the provision of a comprehensive alarm monitoring system. It will be necessary to examine these requirements to determine what, if any, additional features will be needed for minimum-crew operation, drawing on the results of the survey of experience with UMS installations referred to earlier. As previously mentioned, it will also be necessary to determine whether the main engines should be chosen so as to permit operation at reduced power in the event of failure of a major unit.

Present-day requirements place emphasis on means for the early detection of fire, but a greater degree of automation of fire-fighting equipment (possibly still manually initiated) may be required owing to the small number of crew carried. The possibility of arranging the machinery and piping so as to incorporate special safety features (for example, by the segregation and, so far as possible, containment of oil-fuel equipment and piping) may also repay study.

With regard to leakage and flooding, automatic bilge pumping, supplemented by periodic inspection of the engine room, should be sufficient to cope with minor leakage of water, but means for early detection and warning of a major leakage resulting from fracture of equipment or piping will be required, possibly with provision for remote closure of sea-water valves situated below the waterline. Special arrangements to contain oil leakages (with means for detection and warning) may prove to be desirable.

It will be advisable to carry out a formal safety assessment of the complete machinery arrangement as designed, to ensure that all credible failures can be dealt with without hazard to the ship or its crew.

(iii) Other operational aids. It is proposed that a study should be made of the feasibility of providing the facility of trend analysis, whereby changes in critical machinery parameters are monitored to give information on deterioration in performance well in advance of failures occurring, so that maintenance action can be taken at the next convenient opportunity. The parameters chosen will depend on the type of machinery fitted, and operational experience will be needed to confirm the significance of these parameters in relation to particular types of fault and to determine the levels at which maintenance is called for.

Automatic fault diagnosis by computer, based on an analysis of the alarm conditions which preceded and followed a failure or automatic shut down, would in principle appear to be a valuable aid to a small crew in coping with a machinery stoppage. The amount of analysis work required to develop the necessary computer programs (which would relate to a specific installation) may however be considerable, as may be the computer storage capacity required. The question of developing such programs within the scope of this project will therefore need to be considered in the light of possible benefits, effort required, and effects on equipment requirements.

(iv) On-line computer control. It is proposed that the possibility should be examined of using on-line computer control to replace some or all of the analogue controllers conventionally fitted to main and auxiliary plant. Computers can provide more sophisticated facilities such as variable-gain control, in which the controller gain is adjusted automatically to give optimum control at all operating conditions, and dynamic alarms, in which the alarm limits are altered according to operating conditions. It is also possible to provide greater integration of the various control systems in this way. It will be necessary to determine whether computer control will improve firstly the reliability of the control system, secondly the effectiveness of control and thirdly the economics.

106 The work so far described in this section will lead to the preliminary specification and design of the machinery installation and the associated instrumentation and control equipment. It is envisaged that as regards machinery and plant this will include a schedule of equipment together with diagrammatic arrangements of the principal piping systems and a small-scale machinery arrangement. Greater detail will be required where there is a departure from normal present-day practice. On the automation side control system diagrams will be required, together with schedules of instrumentation and control equipment, including computer equipment, and specifications for computer software. Preliminary ideas on control room arrangement, in the engine room and/or in a ship control centre, will be needed. Documentation will include reports on the back-up studies, and cost estimates prepared as part of an overall cost study.

107. This will complete Phase 1 of the work on the machinery installation. Phase 2 will comprise mainly software development and the proving at sea of computer hardware and programs for carrying out specific tasks, followed by the more detailed design study planned as the end point of this phase. Phase 3 will involve the detailed specification and design work necessary for the construction of the actual ship, followed by proving trials at sea.

### (c) Cargo operation

108. Because the cargo operation systems are more dependent upon the type of ship than the navigation and engineering systems, it will be necessary to specify the ship type early in the project. Having specified the ship type a detailed analysis of cargo operational procedures will be carried out to determine the requirements for the cargo operation systems. As described in Section 5, it is anticipated that to achieve the minimum-crew level of manning it will be necessary to use computers/computer for planning, implementing and supervising cargo operations. Although the exact nature of the computers' function in each of these areas will depend upon the selected ship type, for the combination carrier used as an example throughout this report, the work programme would include:-

- analysis of the requirements for a suite of programs capable of evaluating a loading plan from a series of loading instructions taking into account:-
    - type of cargo
    - ship stability, draught and trim requirements
    - ship stress

  resulting in the specifications of computer programs and the definition of the size and type of computer required for their implementation

- investigations relating to the on-line control of cargo handling. This is most applicable for wet bulk cargo although other types of cargo would be considered. Items considered would include:-
    - centralisation of control and monitoring of cargo machinery
    - the integration of the cargo machinery and the main engineering systems
    - intrinsically safe transducers for remote measurement of tank contents and atmospheres
    - the possibility of telemetric control
    - facilities to be provided for human supervision and/or intervention

  These investigations would aim not only at finding solutions to problems but at identifying specific areas requiring back-up studies.

- analysis and specification of a ship monitoring system which will monitor ship draught, trim, stability, and stress not only during on-line cargo handling but also on passage.

109. It is anticipated that the cargo operation systems with the possible exception of collision avoidance, will require most software development therefore it is important that the data processing requirements are clearly defined in sufficient time for them to be included in the specification of the minimum-crew ship computer system described in the following section (9d).

110. During the analysis phase it will also be necessary to assess proprietary cargo handling systems to determine their compatability with the minimum-crew ship concept.

### (d) Computer Systems

111. During this phase of the project various options should be identified and investigated relating to the type of computer hardware which will be available and the configuration in which it could be used. The relative merits of a single shipboard computer, several shipboard computers and combinations of shipboard and shore-based computers will be investigated. Of particular importance will be a survey of the communication facilities which would be available during both the proving stage of the project and during the operational life of minimum-crew ships, and the size of shore-based computer requirements. The results of this part of the project will be:-

- the identification of the hardware options
- the formulation of criteria by which these options can be assessed
- preliminary design recommendations for the configuration of the minimum-crew ship computer systems.

112 Final recommendations cannot be made until the specific hardware and software requirements of the engineering, deck and navigation systems have been defined. However, knowledge of the exact requirements (e.g. total storage required) will not preclude defining the general computer and control philosophy at a comparatively early stage of the project.

113. During Phase 1 users of shipboard computer equipment, equipment manufacturers, and statutory bodies will be consulted to:-

- collect data relating to the performance of computer/electronic equipment at sea. Among those consulted would be the White Fish Authority, the National Environmental Research Council, M.O.D.(N.), and certain ship-operators. It should be emphasised that B.S.R.A. itself has considerable experience in this field through participation in the 'Queen Elizabeth 2' shipboard computer project and the development of electronic equipment currently used for data collection at sea

- determine the availability and suitability of proprietary shipboard computer equipment, and process control computers

- ascertain the views of statutory bodies such as Classification Societies in particular to identify prior to Phase 2 equipment and/or techniques which would be unacceptable onboard an operational merchant ship.

114. Phase 1 will also include the identification and initiating of back-up studies which will be required to provide information for the later work of Phase 1 or during Phase 2. For example it will be necessary to investigate the installation, commissioning and operation (including maintenance) of computers onboard merchant ships, especially aspects such as:-

- provision of electrical power to shipboard electronic equipment
- environmental protection of equipment (temperature, humidity, vibration, corrosion)
- earthing arrangements and protection of electronic equipment from damage due to electrical transients
- suppression of electrical interference from electrical machinery, radio communication equipment, radar equipment, etc.
- servicability of equipment
- fault analysis and repair techniques
- spares holding philosophy

(e) Other Studies

115. It will be essential to the success of the project that any problems which may arise in connection with compliance with legal requirements, classification, insurance and acceptance by trade unions, should be identified at as early a stage as possible and given detailed consideration. Investigations of these matters will be required as discussed under the heading 'Administrative Implications' in Section 6. Continuing consultation with D.T.I. and the selected classification society will probably be required during the course of the project study.

## 10. CONCLUSIONS AND RECOMMENDATIONS FOR IMPLEMENTATION

### The Project

116. Proposals have been described for an automated ship project based on the concept of minimum-crew operation. This concept implies that there is some minimum level of manning below which it is not feasible to operate without going to a completely unmanned ship. (A crew smaller than this would not, it is thought, be able to provide adequate manual back-up and would be unlikely to form a viable social unit for extended voyages).

117. It is envisaged that the proposed ship would operate with a periodically-unmanned bridge in open waters, and a periodically-unattended engine room at all times, except when bringing the machinery to the 'standby' condition and when shutting down after 'finished with engines.' Consideration of the tasks to be performed, both in normal operation and under fault or emergency conditions, suggests that an eight-man crew, dual-purpose trained, would be adequate.

118. The implications of operating with a crew of this size have been discussed in relation to the automatic control facilities that would be needed in the three main areas of navigation and ship control, machinery operation and cargo handling. Reference is also made to matters such as legal requirements, classification, insurance and union acceptance.

119. It is considered that the proposed project is technically feasible and economic calculations indicate that there would be likely to be a substantial economic inventive to the shipowner.

120. The factors affecting the choice of ship have been discussed and a tentative choice has been made of a combination carrier of about 100,000 d.w.t. Much of the outcome of the work would, however, be ship type and size independent, and an alternative ship could be selected without greatly affecting the content of the development work required.

### Planning

121. A phased programme of development is considered to be necessary, and three phases are envisaged as follows:-

Phase 1. Analysis and preliminary design, leading to the outline specification of the ship and its machinery, and the detailed specification of requirements for control hardware and software.

Phase 2. Design/development work on control equipment and software, and proving of individual applications on (possibly existing) ships; more detailed design study.

Phase 3. Implementation, by the design and construction of an actual ship, and proving at sea.

122. At the end of each phase a decision to proceed would be dependent on the outcome of that phase, and on the acceptability of the more detailed and precise estimates then possible for the work content and cost of the remainder of the development work, and for the cost of the ship.

123. An alternative plan would be to integrate Phases 2 and 3, which would imply that the proving of individual items of control equipment and of associated software would need to be carried out on the project ship. This would necessitate providing conventional back-up equipment for certain of the control systems, and greatly extending the proving period of the ship. During this period manual operation of the bridge would be required, so that the number of crew, and the accommodation requirements, would probably be little less than for a conventional ship. The capital cost of the ship, and the operating costs during the proving period, would therefore be at least comparable with those for a conventional ship. On the other hand, it could be anticipated that the ultimate objective would be reached sooner than if Phases 2 and 3 were carried out separately, and operating costs would be reduced once minimum-crew operation could be effected.

## Organisation and Control of the Project

124. A project of the type proposed would need to be organised on co-operative lines so as to draw on technical knowledge and experience from the three major industries concerned, namely shipowning, the manufacturers of automation and computer equipment, and shipbuilding, including the associated engineering equipment suppliers. Shipowners would be concerned with on-board operational requirements and organisation; equipment manufacturers with the performance and capabilities of their products and their possible adaptation and further development to satisfy the operational requirements, and shipbuilders (possibly through B.S.R.A.) with the characteristics of the systems being controlled (including the ship itself) and also the detailed integration of engineering and control equipment with the total ship design. Additionally specialised knowledge could be contributed in specific areas by classification societies and regulatory authorities, Governmental research establishments, and possibly also universities and polytechnics

125. The detailed organisation and control of the project would be to some extent dependent on the method of funding, as discussed below, and on the degree of interest and cooperation forthcoming from the various sources Participation from a particular industry might be arranged though the appropriate industry organisation (e.g. Control and Automation Manufacturers' Association, Chamber of Shipping) or alternatively directly with one or more large companies within the industry.

126. The machinery set up for overall control would need to provide for representation of the various participating and/or sponsoring organisations.

## Sponsorship

127. The extent to which a company or organisation can be expected to be a contributor (either financially or by active participation) to such a project will depend basically on the potential benefits to the company or industry

concerned. Equipment suppliers would clearly benefit from the opening up of a new market for existing products, or from the ability to market new or advanced types of equipment. Shipowners and shipbuilders would benefit from being in a position respectively to operate and to market ships which exploit technical advances giving more economic operation.

128. Sponsorship could therefore reasonably be sought from the equipment manufacturing and shipowning industries, and given a measure of such support, a shipbuilding industry contribution could also be made.

129. Further, in view of the probable benefits to the relevant sectors of British industry, including the increase in export potential that would result from the successful implementation of the automated ship project, and bearing in mind that somewhat comparable projects in other countries have received a considerable measure of financial backing from the governments of those countries, it is considered that the project should seek support from U.K. governmental sources.

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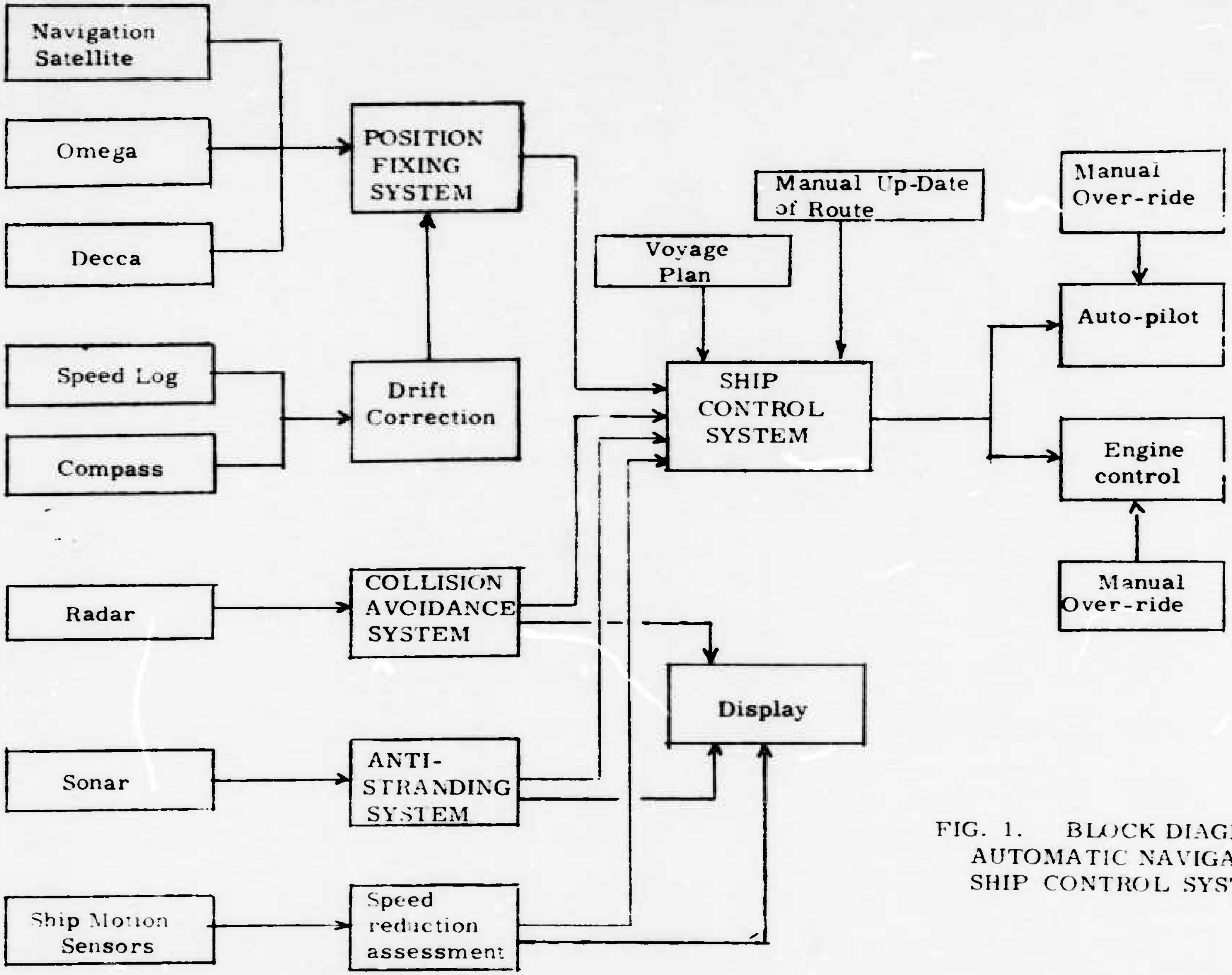

FIG. 1. BLOCK DIAGRAM OF AUTOMATIC NAVIGATION AND SHIP CONTROL SYSTEM

RESEARCH ITEM S8

DRG. N° 92/S.71

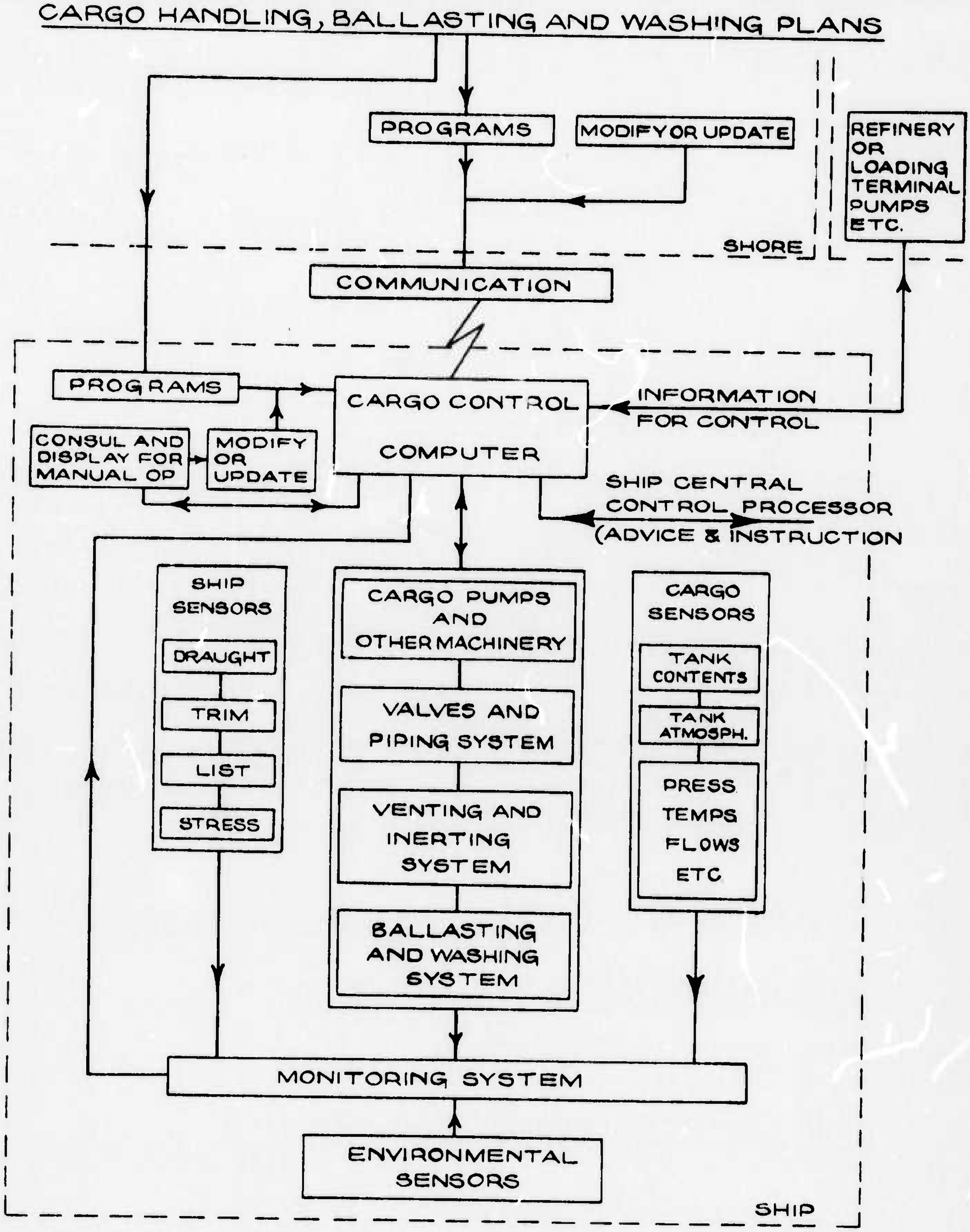

FIG. 2 BLOCK DIAGRAM FOR CARGO HANDLING BALLASTING AND TANK WASHING SYSTEMS

DRG. N° 92/S.71

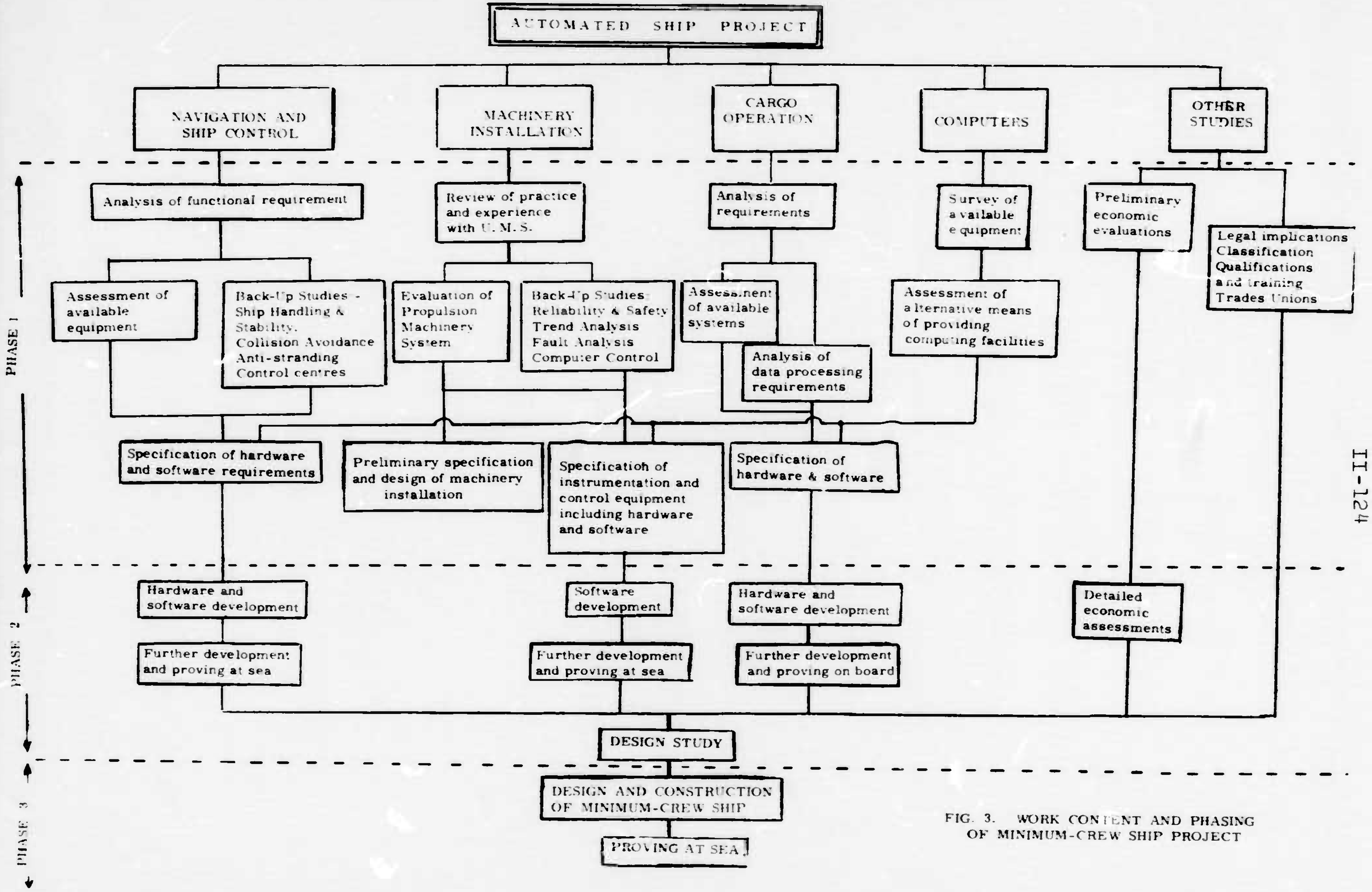

FIG. 3. WORK CONTENT AND PHASING OF MINIMUM-CREW SHIP PROJECT

# APPENDIX II-6

# COMPUTERIZED AND CONVENTIONAL SHIP AUTOMATION PRODUCTS OF NORCONTROL

Contents:

## Computerized Ship Automation

## "Conventional" ship automation

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# DATABRIDGE

DataBridge Integrated Navigation.

The steadily increasing demands made upon to day's navigators due to larger, faster and more expensive ships are creating a need for better navigational aids.

DataBridge is such an aid giving improved safety and reduced operational costs.

The system consists of the following subsystems:

| | | |
|---|---|---|
| a) | DataRadar | an anticollision system. |
| b) | DataPilot | a sophisticated automatic pilot. |
| c) | DataSailing I | a navigation system based upon signals from log, gyro and celestial observations. |
| d) | DataSailing II | an automatic navigation system based upon information from electronic navigation receivers, including Doppler Sonar systems. |
| e) | DataLoad | an advanced load calculator for tankers. |

Why integrated navigation?

The integrated navigationsystem based upon the utilization of computer is the technology's greatest triumph against collisions and pollution-disasters at sea.

- Integrated navigation gives 100% utilization of the various navigational aids.
- All navigational functions are gathered in one console.
- Safety combined with economical savings.

Increased safety is a major factor when considering DataBridge (DataRadar for anticollision and DataSailing/DataPilot for anti-grounding). The investments in DataBridge is considered to be a low "insurance permium" for the increased safety.

DataBridge involves a direct basis for pay back, as also reported from actual installations:

| | Typical figures of improvement: |
|---|---|
| - More accurate navigation and improved routing through DataSailing and DataPilot, integrated with Satellite Navigation | 0,5-1,0% |
| - Increased speed due to an improved autopilot optimizing course deviation/ rudder movements | 0,5-1,0% |

## DataRadar - Anticollision System.

The utilization of anticollision systems seems today to be a necessity to reduce the risks for collision in heavy trafficated waters. The philosophy behind the DataRadar is that all the necessary information as regards the traffic situation should be presented on one screen.

On the DataRadar the navigator can see a normal radar picture together with the presentation of course/speed vectors etc.

Operational features:

- Automatic tracking of 15 targets.
- Presentation of the normal radar picture and target vectors indicating targets position, speed and course.
- Continous updating of course and speed changes.
- Automatic acoustical and visual warning of collision danger for targets predicted to come inside CPA-Limit.
- Automatic and manual simulation of collision avoidance manoeuvre.

- Range of display: 6, 12 and 24 nautical miles.
- Up to 12 different display modes of true motion, true picture and relative motion - all in North up or Head up modes.
- Heading marker for own ship.
- Manual range/bearing marker for any echo or fixed point.
- Automatic fault chcking program for computer and system operation.
- Numerical display for own ship and target. Information: true speed, true course, range and true bearing of tracked targets, CPA to tracked targets, time to CPA and suggested collision avoidance course.

Interface to external equipment:

- Ship's normal radars.
- Ship's log.
- Ship's gyro compass.

Reports from captains:

- Clear picture and vector presentation makes it possible to navigate safe in heavy traffic without unnecessary reduction of speed.
- Captain knows other ships' movements. Time saving is possible.
- Use of the anticollision system evidently reduces the stress on the navigators and improve the safe navigation to a considerable extent.

DataSailing - Computerized Navigation DataPilot - Computerized autopilot.

DataSailing is the navigational part of the DataBridge system. The design philosophy is based on the fact that:

- About 47% of all wrecking of ships are due to grounding.

  It is evedently important to know the ship's exact position and to keep the correct course.

- Through today's means it is possible to improve navigational accuracy and thus reduce sailing distance.

DataSailing incorporates these features. However, the full benefit of DataSailing is not reached until automatic steering of DataSailing course is provided through the DataPilot system.

DataPilot is therefore based upon the design philosophy that:

- Automatic steering shall be based on great circle or loxodromic course which is continuously updated for drift. (Through the DataSailing system.)
- By using computer technique one obtains a higher course accuracy with less rudder movement and thereby a higher average speed.

## DataSailing I.

The DataSailing I system is based upon interface to ship's log and gyro compass together with manual input of up to 10 future turn points on the ship's sailing route.

- Automatic dead reckoning based on signals from gyro/log.
- Calculations of Great Circle / Loxodromic course between present position and next preset turn point.
- Manual input of set and drift corrections.
- Continuous updating of correct Great Circle Course.
- Calculation of estimated time of arrival (ETA).
- Calculation of time and distance between turn points both for Loxodromic and Great Circle Sailing.
- DataSailing Course given as a command to the DataPilot system.
- Warning when approaching turn point for change course.

## DataSailing II.

The DataSailing II system has the same features as mentioned under DataSailing I, but includes also the navigational benefits from:

- Automatic position fixing through:

| | |
|---|---|
| Satellite Navigation | a complete system delivery based upon automatic input of satellite signals to the DataBridge computer. Programming is to made for the Magnavox, ITT and TOSHIBA satellite receivers. |
| Decca Navigator | interfaced to DataBridge computer. |
| Omega Navigation | Omega receiver interfaced with DataBridge computer. · The Omega chain is expected to be world wide in 1974/75. |

Automatic position fixing based upon the above systems forms the basis for following:

- Automatic correction of Dead Reckoning position.
- Automatic set- and drift-calculations.
- Automatic course compensation for set and drift.

DataPilot.

The DataPilot system is an improved autopilot based on modern control theory and the use of a digital computer.

The DataPilot computer system gives the best possible course accuracy and increases the ship's overall speed.

Operational features:

- DataSailing course: automatic steering of loxodromic or great circle course as calculated by the DataSailing system.
- Manual course: steering according to a fixed course, manually set.
- Rudder control: direct control of rudder angle.
- Fixed turning rate for change of course.
- Manual change of tuning parameters (tuning to ship's steering characteristics.)
- Self checking program for detection of system or computer failure.

Benefits from DataPilot compared with conventional autopilots:

- Less course deviation.
- Less rudder angle
- Change of course with fixed turning rate, giving a smooth turning without overshoot.
- Integration of DataSailing and DataPilot gives automatic navigation at close by 100% correct course.

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# DATALOAD

## DataLoad - Computerized Load Calculation.

DataLoad is a computerized load calculator delivered as a program to be operated on a NORCONTROL datasystem e.g. DataBridge.

DataLoad calculates very accurately the stresses on the hull, the deflection, the draught and the stability.

DataLoad is designed with a view to operational requirements of modern supertankers and specialized liquid cargo and dry cargo ships. One of its major advantages is the accurate calculation of draught midship, fore and aft, making it possible to load more oil without exceeding draught and stress limits.

DataLoad CC (Crude Carrier) was developed in co-operation with A/S Computas, a subsidiary of Det norske Veritas.

## Specifications of DataLoad:

### Stress calculation.

A load distribution suggested by the operator forms the basis for calculation of the resulting shear forces and bending moments. These are accurate enough to be compared with the actual maximum stresses permitted by the classification society, giving the fullest possible use of the range of permissible stresses.

### Trim.

Initially the trim and draughts are calculated as they follow from the loading condition. Then the bending moment and shear force deflection curve is corrected for the temperature differences between deck and keel, and the resulting draughts given. This enabling loading of the ship to its full potential.

### Output information

Working from the tonnage and specific gravities at actual temperatures and 60° F, DataLoad calculates and prints out:

> Gross and net US Barrels and cubic feet (or $m^3$), tonnage, percentage full and specific gravity for each tank.

The relevant printout may be filed directly, which is convenient for on-board book-keeping.

## Loading check.

DataLoad provides a means for quick and easy checking of the load situation after loading, as the sounded ullage value for each cargo or ballast tank may be given instead of the tonnage.

## Stability calculation.

The ship's KG is calculated and compared to IMCO's recommendations, or alternatively the GM is calculated. In addition, the draught forward is tested against the minimum requirement to avoid slamming and the submerged part of the propeller is calculated.

## Communication with DataLoad.

Input to DataLoad is arranged so that the computer asks for the required information, to ensure that the input procedure is followed correctly. A standard teletype, which may be placed anywhere in the ship, is used for the communication.

## Hardware configuration.

The required hardware configuration is:

- NORD-1/NORD-4 computer with at least 5.5K memory available.
- Teletype teleprinter.
- Paper tape reader.

The system may be operated on a standard DataBridge system while the DataRadar sub-system is not operating.

The system may also be delivered with a separate computer.

## All-core DataLoad.

As an option the system may be delivered in a "core only" version, where the whole program is stored in the computer at one time. A computer with 16K memory is then needed. This may be achieved e.g. in a DataBridge system with DataRadar, DataSailing II and DataPilot. It should be noted that this operation mode is not standard and will include extra cost.

## Delivery to new ships.

NORCONTROL deliveres DataLoad complete with calculations and approved by Classification Society for the maiden voyage. However, the feature ullage/sounding input and output cannot be delivered until the final ullage tables are ready from the yard.

# DATA TANK

## DataTank - Computerized Monitor Loading and Unloading.

Taking into consideration the cost of off-hire for hull repairs, or the dangers for oil pollution, the needs for systems that ensure safe loading/unloading of oil is obvious. NORCONTROL has therefore developed the cargo monitoring system DataTank, that will increase safety of cargo handling operations and reduce the risk of hull damage.

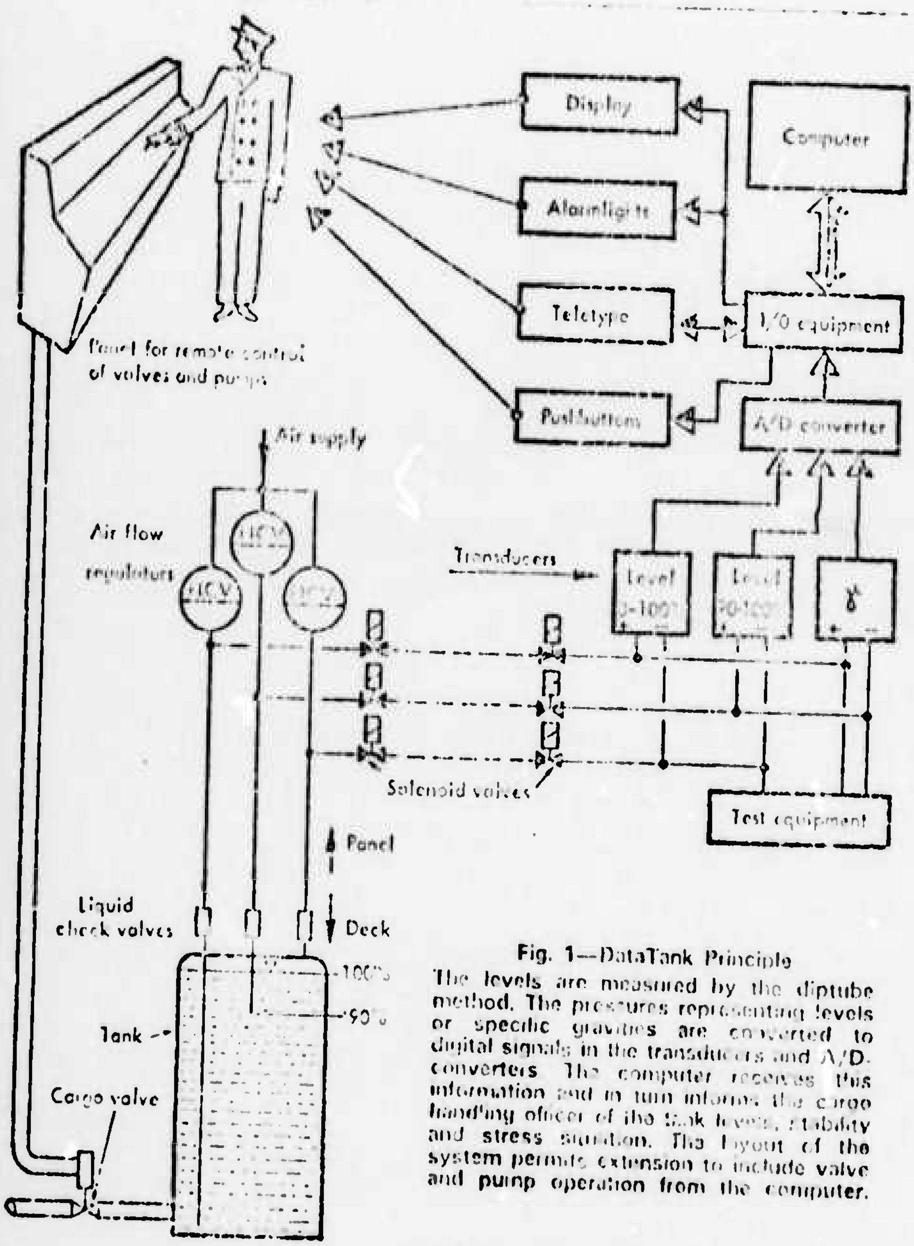


Fig. 1—DataTank Principle

The levels are measured by the diptube method. The pressures representing levels or specific gravities are converted to digital signals in the transducers and A/D-converters. The computer receives this information and in turn informs the cargo handling officer of the tank levels, stability and stress situation. The layout of the system permits extension to include valve and pump operation from the computer.

DataTank I (DT-I) offers on-line monitoring of any cargo handling operation onboard ships involving liquid, covering either handling of liquid only or liquid cargoes in combination with ore or bulk cargoes.

DataTank I measures draughts and tank contents continuously in order to calculate and check hull stresses, stability, draughts, cargo weight and total displacement.

The aim is to ensure safe operation of the ship, thereby excluding damage to the hull and loss of time due to insufficient loading instructions or neglect on behalf of the operator.

DT-I is composed of the following sub-systems:

DataLevel—Computer controlled level measuring.

DataLoad—A complete stability and stress analysis computer program.

The basic features offered by DataLevel are:

1) level measuring of cargo, slop, ballast, and fuel oil tanks;
2) draught measuring at four points; aft, forward, midship port and starboard;
3) high, low, and separate overflow level alarm;
4) digital and analog presentation of all tank levels;
5) streamlined operator communication;
6) measuring accuracy:
   0–100 per cent of the tank:
   1% of full level
   90–100 per cent of the tank:
   10% of full level
   0– 10 per cent of the tank
   1% of full level
7) measuring of liquid density

The features offered by DataLoad are :

- i) accurate assessment of shear forces and bending moments;
- ii) calculation of metacentric height;
- iii) alarm on development towards dangerous stress or stability situations;
- iv) continuous updating of calculated parameters.

The basic version of DataTank I offers monitoring alone, but its design provides for easy extension to versions offering process control. The system configuration is shown in principle in Fig. 1.

## Specification

### *DataLevel level measuring*

Norcontrol's wide experience with conventional level measuring systems formed the basis for the development of DataLevel. The system is designed specifically for use with the DT-I system, taking full advantage of the inherent simplicity and reliability of the dip tube method, which is further strengthened by the extensive self-checking procedures.

The purpose of DataLevel is to feed the computer continuously with information on level in the tanks, density of the cargo and actual draught at four points. This information is used by DataLoad for calculation of hull stresses etc.

The measuring principle used by DataLevel is the dip tube (or bubbler) method. A tube is immersed vertically in the liquid to a point where the lower opening almost touches the bottom of the tank. (Fig. 2)

Air is fed into the upper opening of the tube, and the pressure is high enough for air to escape from the tube at the lower end. The pressure in the tube is then equal to the sum of the static pressure in the liquid at the lower opening and the gas pressure above the liquid.

The static pressure in the liquid depends on the level and the density. This means that when the density is measured with necessary accuracy, and then, the air pressure in the tube, the liquid level may be calculated.

DataLevel always compensates for the gas pressure above the liquid.

The basic principle used for draught measuring is the same as that for the level measuring. However, in the case of ballast and fuel tanks the density is not measured, and so manually inserted values are used.

### *DT—DataLoad*

DataLoad takes the measured levels from DataLevel, calculates the actual volume, taking into account the measured trim, and the total cargo. This replaces the manual input of data to DataLoad off-line.

Making use of fixed data for the ship, DataLoad calculates the metacentric height (GM), shear forces, bending moments, deflexions and draughts along the hull. Calculated and measured draughts are compared; the GM is compared to the limiting value; the shear forces and bending moments are checked against the classification society limits.

The appropriate alarm will be sounded if the outcome of any of these checks is out of limits.

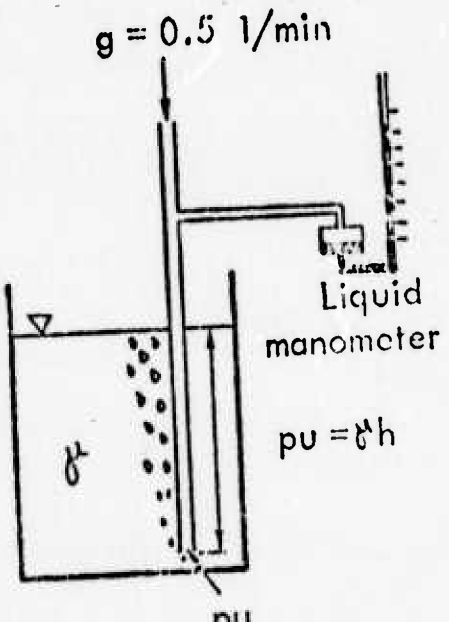


Fig. 2

### *Operator's panel*

DT-I is equipped with a communication console designed for easy read-out and operation. (Fig. 3)

There are two alpha-numerical displays, each of eight 32-character lines. One is used for continuous display of tank levels and densities. The other is used for general information, i.e. total cargo and displacement; draughts, trim and list, alarm messages; and operator communication.

DT-I may be supplied with an analog level indicator for each tank, to give a general impression of the load situation. These are mounted on a mimic diagram, normally above the valve operation panel, and are updated continuously while the measuring proceeds.

Below the digital displays is a push-button mimic diagram. This is used to specify tanks for digital display, fast sampling, limit alteration and density input and also to flash a lamp representing the tank being measured at the moment.

The remaining push-buttons give the operator access to the "Communication Functions", Alarm Acknowledge and System on/off. There is also a numerical keyboard.

The intention has been to make the interaction between the operator and the system simple and straightforward. Each communication function is clearly defined, and the entering and operating procedure for each function is consistent with one basic pattern.

### *Alarms*

Fig. 4 shows the DT-I alarm limits. The overflow alarm system is fully independent of the DT system.

Alarms are presented on the digital display, on the teletypewriter and on the alarm lamps situated next to the analogue displays. There are alarm lamps for high and low levels and overflow.

Altogether, DT-I gives the following alarms on measurements :

- ○ Instrument limits
- ○ Fixed level limits, full and empty
- ○ Movable level limits, upper and lower
- ○ Level rate limits, highest technically possible filling or emptying rate

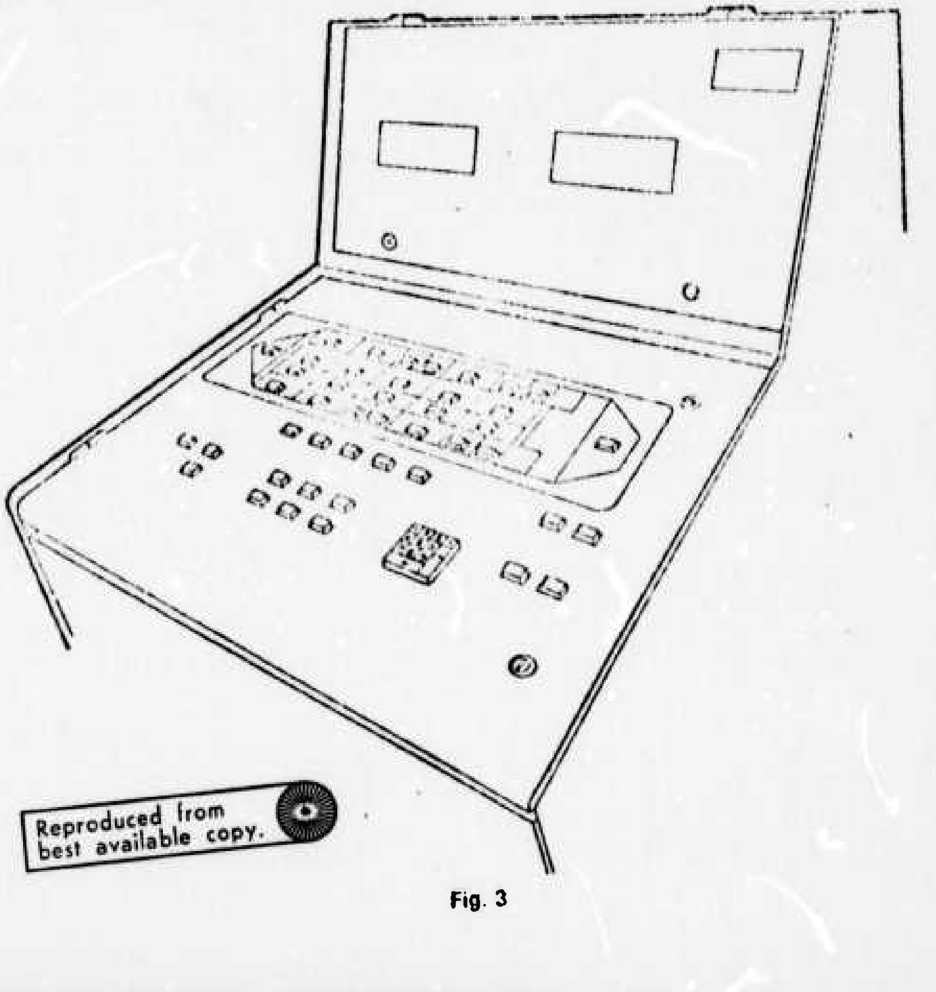


Fig. 3

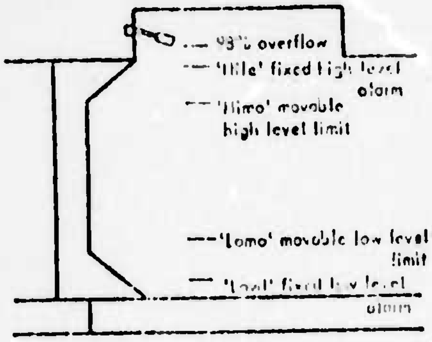


Fig. 4

*Print-out*

On request DT-1 prints out the following information:

- Tank contents:
  - weight
  - volume
  - level
  - % full
- Measured density
- Total displacement and cargo
- GM
- Trim, list, draughts
- Shear forces
- Bending moments

In addition, all alarms and operator actions with a bearing on the monitoring of the process are logged automatically.

*Level measuring plant*

Fig. 5 shows the pneumatic circuits of a DataLevel level measuring plant in principle. There are three measuring tubes for each cargo tank, two for each slop tank, one for each ballast tank and finally one for each draught measuring point. One tube goes to the bottom of the cargo tank, the second goes down to approximately 90 per cent of full level in the tank. The third is a gas pressure compensating tube at the top of the tank, as the gas pressure above the cargo is normally different from the atmospheric pressure outside the tank. A compensating tube like this is also used in the slop tanks.

The flow indication control valves continuously supply bubble air to the measuring tubes, one for each tube.

This means that with a small pressure drop in each tube from the panel to the measuring point, the pressure drops will balance in the case of a cargo tank, while for a ballast tank they are constant and without significance.

The pressure or differential pressure signals representing levels in the tanks are converted to analog electrical signals in the pressure transducers. These signals are in turn converted to digital signals and fed into the computer.

The pressure signals from the measuring tubes are connected to the high and low pressure sides of the differential pressure transmitters by two or three-way solenoid valves. The computer operates the appropriate valves according to the tank measuring sequence.

The DataLevel software uses the information from the transmitters to issue digital and analog level display and high and low level alarms.

The liquid manometer shown in Fig. 2 has two functions. It is used in connexion with DT as a very accurate pressure indicator for testing and calibration of pressure transmitters. The well is then connected in parallel with the high pressure side of the transmitter to be tested, and a pressure is applied by turning the handle of a pressure control valve on the front of the DataLevel panel. It can also be used for manual measuring of level in case of computer break-down.

*Centralized manual level measuring*

A manual back-up level measuring system is necessary in case of break-down of the computer or the computer interface equipment. The manual level measuring system delivered as standard with the DT system consists of three columns on a liquid manometer, one for port, one for centre and one for starboard tanks. Each column measures the full level in the tank, and for the cargo tanks compensation is made for gas pressure.

The tanks to be measured are selected by pressing tank selector push-buttons on the DataLevel panel. Mode selector push-buttons are also found on this panel, and it is possible either to measure the tank in question or manually clean the measuring tubes going to it. The mode push-buttons are also used when testing the pressure transducers, which normally feed the computer with information about the levels, against the liquid columns on the manometer.

The manual level measuring plant is also used for a detailed examination of a measuring tube which the computer, via the normal continuous testing procedure, has reported to the operator to be malfunctioning.

The power supply and all other parts of the manual level measuring system are independent of the computer and interface equipment.

*Self-checking features*

It is very important that a system as complex as this can tell whether its results are reliable or not. Self-checking procedures have therefore been made a major feature of the system, starting with the dip-tube in the tank and continuing right through till the result is displayed for the operator and printed on the teletypewriter.

Each dip-tube is tested in turn by a method developed at Norcontrol. Leaks or obstructions restricting the air flow are reported by the alarm system.

Magnetic valve solenoids and cables are checked for short-circuit or broken connexions, and the transmitters and analog to digital converters are tested each time a measurement is made.

The entire electronic interface system is tested regularly, and the "Panel Test" involves all push-button contacts and lamps, alpha-numerical displays, keyboard and tank level indicators.

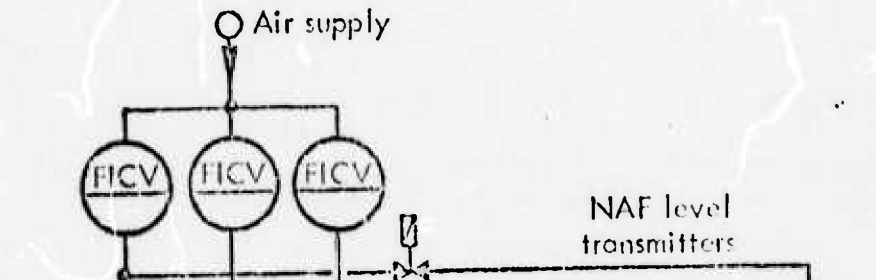


Fig. 5

*System configuration*
DT-I can be delivered with a separate computer or share one with DataBridge. The latter alternative limits the operator to using no more than one system at a time. The disadvantage with this arrangement is that, when for example washing tanks at sea, one has to choose between DataBridge and DataTank, while they are both needed.

DataTank is therefore recommended as a self-contained system with its own computer.

The equipment in the system is shown in principle in Fig. 6. The computer and interface electronics are placed inside the communication console. The level measuring system is built into a similar console or a separate panel.

DT-I assumes that central operation of valves and pumps is available from a position close to the DT-I communication console.

*Operational and economic advantages*
The purpose of a cargo monitoring system is improvement of both safety and economy. In technical terms, this means providing reliable and accurate level measuring along with accurate load calculations. A combination of both is necessary to provide monitoring of hull stresses to reduce hull damage. At the same time the system must be simple to use, reducing the stress on the operator, thus improving safety.

DT-I fulfils all these aims and represents a big step forward from conventional level measuring systems.

*Reliability*
Faults may occur in both bubble tube and float gauge systems, bubble tubes being usually the more reliable. The typical faults of the bubble tubes are leaks and obstructions, which in DT-I will be detected automatically by the tube test program. The three-tube arrangement also permits checking of the measurements where the same level (on 50 per cent–100 per cent) is measured independently by two tubes.

*Read-out*
For read-out of levels etc. there are two main requirements:

i) accuracy and resolution;
ii) clearly set out presentation.

In DT-I this has been achieved with an accurate digital read-out and a set of analog displays, one for each tank. These may be located in any way convenient for the cargo operation.

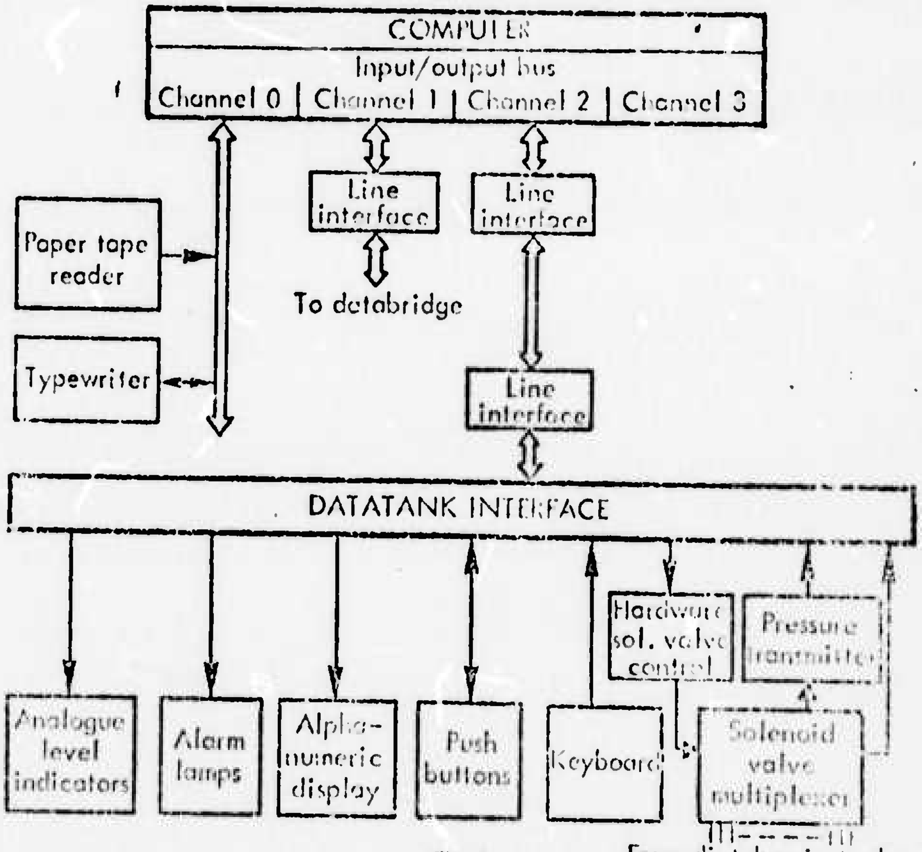


Fig. 6

*Mechanical strength*
A big advantage of bubble tube systems is the strength of the equipment on deck and in the tanks.

Bundles of three tubes of 10 mm x 1 mm are often used on deck, and these bundles are very easily installed and protected against mechanical damage. The tubing inside tanks is normally Yorcalbro or equivalent, and if installed and clamped according to the normal high standard for shipborne installations, then no problem should arise from this part of the equipment.

*Monitoring of hull stresses, bending moments and stability*
The classification society specifies how the ship is built according to these specifications. But it is the user's responsibility to operate the ship in accordance with the same assumptions.

No reliable statistics show how hull damage is related to operation, but much damage is no doubt due to high stresses during loading-unloading, tank washing etc.

Even though load calculators have been common for a number of years, and the yards equip their ships with rules for loading/unloading, load calculators only give the validity of the final load condition, or a set of load conditions. During loading/unloading and even more during tank-washing, many things can happen that change the pre-determined plans. DataTank I warns of a dangerous situation, so that the operator may change his procedure, and thereby reduce the risk of damage. Also, DataTank I prints all alarms. If a dangerous situation occurs, it will be logged.

This log may be of help in the planning of docking, charter/owner relations, etc.

So far, the economy of DT-I cannot readily be described in figures, as relevant statistics do not exist. However, one day off-hire to a VLCC amounts to $20 000–$40 000. Docking for repair will often be time-consuming. The saving of a few days of repair time will make DT-I a profitable investment.

# DATA CHIEF

## DataChief

Computerized engine room automation and maintenance prediction.

Computerized automation and monitoring systems are expected to be introduced at a large scale in the years to come. Not merely for purposes such as navigation, load calculations, etc., but also for engine room control.

The DataChief system consists of a family of sub-systems for engine room automation and maintenance prediction as follows:

- A condition monitoring system designed to monitor the condition of certain engine room components, like turbochargers, coolers, cylinders etc., as well as to predict the future date of the components maintenance by the DataTrend sub-system.
- Monitoring, alarm handling, auto start/stop of pumps and compressors and logging by the DataSafe sub-system.
- Complete electric power generating plant automation by the DataPower sub-system.
- Main engine remote control system, AUTOCHIEF II may be integrated with the DataChief. the AUTOCHIEF II is a "self-contained" system with tie-in to DataSafe, and in the future to DataTrend.

Each of these sub-systems may be separated from the others giving flexibility to fit the customers' specifications.

## DataTrend

The maintenance prediction system DataTrend has attracted considerable attention among shipping people. By means of DataTrend it is possible to supervise the propulsion machinery and to predict when and where maintenance is needed. The DataTrend system increases safety against break down, reduces maintenance costs and fuel consumption.

The following items will normally be monitored by the DataTrend system:

- Thermal loading of cylinder liners, pistons, exhaust valves and covers.
- Cylinder combustion
- Fuel oil system
- Turbochargers (turbine and compressor)

- Components in the scavenging air system
- Exhaust boiler
- Coolers (lub.oil, air, fresh water)
- F.w. evaporators. (optional)
- Auxiliary boilers (optional)
- Ship's hull (fouling)

Besides predicting overhaul and monitoring thermal loading, DataTrend keeps an eye on combustion and fuel injection, piston ring function and cylinder wear. The problems related to these items have traditionally been hard to come by, but with DataTrend a very useful tool is introduced. A few of the valuable possibilities:

- Faulty fuel injection nozzles may be detected, along with other fuel system failures.
- Combustion control, detecting abnormal timings and pressures.
- Piston ring functioning: Rings locked in grooves, broken rings and ring blow-by.
- Metal temperatures at various points in the combustion chamber (some measured, some calculated).
- A combination of the above mentioned features may give early warning of cylinder wear, even before it has started by detecting the causes thereof.

DataSafe

The watchkeeping and monitoring system, DataSafe, complies with all the class requirements for periodically unmanned engine room. The system has visual and accoustical alarms, alarm-logging of time and date, and includes a separate program for automatic checking of engine room state at time of change-over from manned to unmanned engine room. It also takes care of automatic start and stop of compressors and pumps in response to the state of the process.

DataSafe is based upon the UMS/EO-class requirements, but on several items goes far beyond these rules. Major features:

- Total process monitoring with a number of automatic safety actions, and alarm presentation with logically correct alarm blocking and dynamic limits.

- Delayed start of major power consumers until sufficient power available (eventually start of stand-by generator).
- Automatic restart of pumps after black-out.
- Purifier automation,
- Compressor automation.
- Exhaust boiler automation.
- Automatic filling-up of tanks.
- Complete engine room logging.

For a typical installation, the number of alarm points totals about 300. To deal with all the information received, a sophisticated alarm system is designed, where the alarms and messages are instantly presented on a display unit and an automatic logger.

All alarm and action limits are stored in the computer's programs, making it very convenient for the operator to make ajustments.

## DataPower.

DataPower is a system for monitoring and control of the ship's electric power supply. The system continuously supervises the power consumption, executes starts, synchronisation, connection to the main bus and automatic load distribution through a stand-by generator in cases of predicted overload and can be adapted to diesel- as well as turbo generators.

Major features are:

- Minimizing the risks for black-out, by always keeping a certain minimum extra power available. However, it is continously checked whether this surplus is too high, so that a generator eventually may be stopped.
- Automatic start of stand-by auxiliary engines, automatic synchronizing, connection and load sharing.
- Automatic disconnection and stop.
- Logging of all actions.
- Alarms if failures detected.

## AUTOCHIEF II

A main engine bridge control system delivered as an integrated part of the DataChief system.

## Basic DataChief hardware configuration.

All inputs from the process are conducted through the interface into the computer. Here the various programs take over, and after a large number of comparisons and calculations, the results are presented as output to the process or to communication devices, or they may be stored in the computer's memory.

The computer is placed in a Control Desk located in the Engine Control Room, thereby being close to the process.

The various remote controls and communication and alarm devices, along with the process interfacing equipment, are all located in the Control Desk.

In DataChief, analogue sensors are used exclusively in the process. Besides that information for multiple functions may be obtained by the same sensor, several possible sensor failures may be detected by the computer. In addtion, the input signals are easily filtered to reduce for instance false alarms.

Further, the self checking features will increase system reliability and safety.

## HISTORICAL REVIEW

The DataChief system has its roots back in 1969, when the world's first computerized merchant ship, the M/S "TAIMYR", went into service. After a very successful trial periode, it was decided to go "Full ahead" with the development of the DataChief system.

Especially the DataTrend subsystem has been expanded, in close cooperation with the Ship Research Institute of Norway (SFI) and the Norwegian Institute of Technology - Institute of Marine Engineering, both institutions highly regarded for their expertice in this field.

A test version of DataTrend was installed by these institutions onboard an OBO-carrier in November 1970. After only half a year in service, the system had come up with remarkable results as to predicting such noted trouble-makers as cylinder wear and thermal load.

## The first commercial DataChief system installed onboard M/T "THORSHOLM"

Recently the installation of the first commercial DataChief system has been successfully completed. The installation took place onboard Thor Dahl's 279.000 t.dw. tanker "THORSHOLM" which was built at the Mitsui yard in Japan. The installation includes DataSafe, DataPower, DataTrend and AUTOCHIEF II and was put into service in February 1973.

At present NORCONTROL has received orders for another three systems to be installed during 197[illegible] onboard the sister ship of "THORSHOLM", a 279.000 t.dw tanker, together with an A.P. Møller containership of 26.000 t.dw. to be built at the IHI yard in Japan, and finally in a semi-containership of 14.300 t.dw. belonging to the Malmros shipowners in Sweden for construction at the Wärtsila yard in Åbo.

These installations are representing a break through as regards automation of engine rooms. Computer systems of this nature pave the way for solutions of a number of so far unsolved problems resulting in considerable operational savings.

# AUTOCHIEF

Electronic system for remote control of main engine from the bridge.

AutoChief II is designed to control the propulsion machinery onboard ships with fixed propeller and is preprogrammed for the following makes of diesel engines:

Burmeister & Wain
Gøtaverken
Man
Sulzer.

The design is flexible and the system may be adapted to nearly any type of diesel engine.

AutoChief II may either be supplied as an independent system or as part of a complete engine room automation package. AutoChief is then included in our

a) Complete system deliveries for unmanned machinery space EO/UMS- classification.

or

b) DataChief complete computer based system for engine room automation (EO/UMS Class). AutoChief II is part of the computer system with RPM controlled by thermal loading.

AutoChief II represents a new generation equipment based on the system developed by NORCONTROL in the mid-sixties. Today more than 70 systems are in operation.

## Faster and better manoeuvring from the bridge/wing.

AutoChief II is an electronic/pneumatic system, in which the extensive use of integrated circuits has resulted in a reliability and simplicity of design not obtainable by the use of other types of switching elements. The system gives faster and better manoeuvring from the bridge. AutoChief II may be supplied with a special unit, allowing remote control of the main engine from the wings of the bridge (option).

## Periodically unmanned engine room.

AutoChief II meets the requirements for periodically unmanned engine room and comprises among other items emergency telegraph, electronic RPM-controller, and detector. A specially sophisticated starting program results in a minimum consumption of starting air, reduced thermal loading of the engine and less wear of the compressors. AutoChief also contains a fully automatic program which protects the engine against overload at cold start or during manoeuvring. AutoChief II is not only a

Bridge control system

but also an

Engine protection system.

Reduced cost and increased reliability.

The simple and compact system design gives in addition to low price and reduced installation costs

- high reliability
- easy maintenance and operation
- increased possibility for service by ship's own officers.

AutoChief II bridge control system may be used on several types of diesel engines, simplifying the need for training and reducing maintenance costs. Frequent changes of crew and officers also increase the importance of having a system with simple and selfexplainatory operator panels.

Installation onboard newbuildings
and already commissioned ships.

NORCONTROL can deliver the system installed and commissioned, inclusive training of the operating personnel. The installation onboard ships in service may be carried out whilst en route without off-hire or delay of the ship.

Specifications:

AutoChief II is mainly an electronic system where moving parts have been avoided as far as possible. The actuation of the motor is done by means of magnetic valves and pneumatic cylinders.

Bridge control system.

1. Programmed for slow speed and medium speed marine diesel engines with fixed propeller.

2. Control handle scale directly graded in RPM.

3. Built in PI-controller for control of engine speed. The controller also limits fuel oil supply as a function of wanted RPM and scavenging air pressure. The electronic controller may be disconnected if mechanical or hydraulic governor is preferred.

4. Electronic remote control of the main engine from the bridge or the control desk in the engine room. Three automatic start attempts, rated as easy, normal and heavy start.

5. Independent telegraph system for emergency use, located in manoeuvre console on bridge, locally on engine and engine room console.

6. Electronic RPM-detector on propeller shaft.

7. RPM-indicator in bridge and engine room consoles.

8. Electricity supply from 220 volts mains via rectifiers and battery. Power consumption during normal operation approx 50 watts.

9. Manoeuvre from the wings of the bridge (option).

The system comprises complete plug-in bridge and engine room panels. Electronic logic unit is located in the engine room panel. Complete simulation and test of the system possible from the engine room panel.

Engine protection system.

1. Shut down: 6 independent shut down channels.

2. Slow down: 5 independent slow down channels.

3. Input channel for limitation of RPM.

4. Nonlinear acceleration limiter gives fast manoeuvre with reduced acceleration at high RPM.

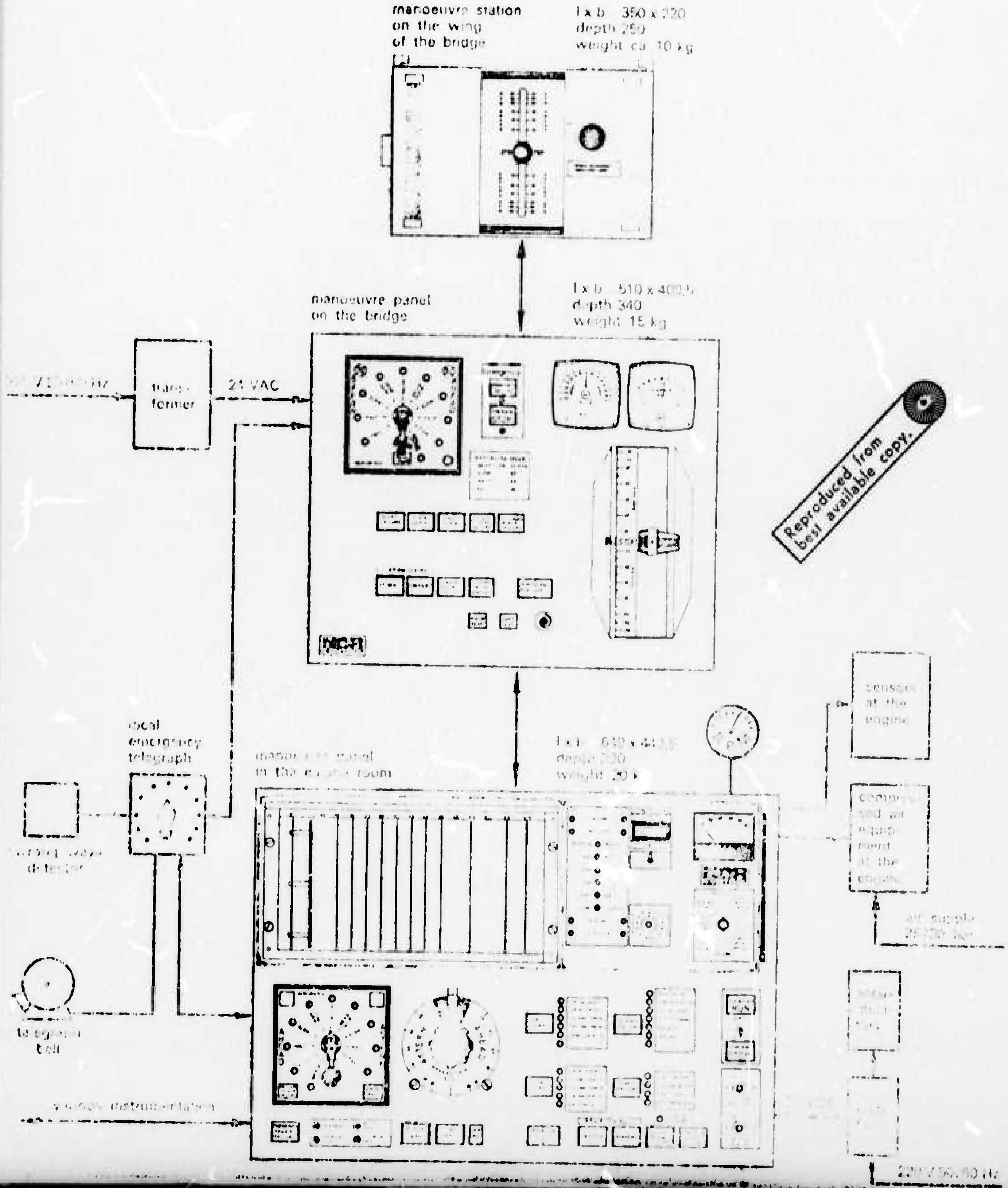
5. Fully automatic thermal running up program at start of cold engine or during manoeuvre.

6. "Slow turning".

7. Control of camshaft brake at change of direction of rotation (B&W).

8. "Slow reversing" (option for B&W super large bore engines).

**A schematic survey of a complete AUTOCHIEF II installation including manoeuvre station on the wing of the bridge.**



# EO/UMS - SYSTEM

## EO/UMS - Unattended machinery space

Automation and instrumentation for unattended machinery space.

In 1966 Det norske Veritas for the first time published the classification called EO, and also published recommendations for same. This classification EO are given for all ships built according to these rules and recommendations.

In 1969 the norwegian rules for manning ships in our merchant fleet were altered in such a way that ships having classification EO/UMS were allowed to sail with reduced machinery attendants.

These are both norwegian shipautomation highlights, but as one of the leading countries in shipping we may say that these highlights are common shipsautomation history.

Up to March 1972 400 EO/UMS installations were done, and about 50% of all newbuildings built to classification of Det norske Veritas had the EO classification.

One might think that the main reason for installing automation was to reduce machinery crew. This might be the main reason in the first few installations, but today this is not the case. Reductions in machinery crew is not necessary to justify the cost of EO/UMS instrumentation. The reason for this is that with an unattended machinery space the machinery crew on watch can do maintenance and repair word. They have regular working hours with no nightwatch and no watch duties in harbour.

This results in more effective repair - and maintenance work at sea and in harbour giving less off-hire and repair cost in shipyards. More and more shipping firms are giving these reasons for their convertion of ships into EO/UMS classification.

It has frequently been discussed how automation inflects upon the safety of the ship. Even if there still are some who are sceptic, it seems today to be a common opinion that automation increases the safety of the ships.

NORCONTROL has worked in this field since 1965 and has till today installed about 70 complete systems for unattended machinery space and another 70 systems covering less extensive systems.

NORCONTROL take care of complete system deliveries to:

- Newbuildings

- Ships allready in service
  installation during normal operation of the ship without off-hire.

## Extent of system delivery.

We take care of complete system delivery according to rules of the classification societies (EO, UMS class etc.)

- Alarmsystem
- Main engine remote and monitoring system
- Automatic stop/start auxhilliary engines
- Boiler automation
- Separator automation
- Engine room fire alarm system
- Remote control of sea water valves
- Temp. regulating valves
- Pump and air compr. automation
- Shielding H.P. fuel oil pipes. - Main and aux. engines
- Automatic lubrication of rockerarms exhaust valves
- Automatic regulating exhaustgas deverter valve
- Feedwater regulating
- Telephone system
- Calling system
- Power supply system
- Power supply air system included air dryer
- Further as required by the customer.

## System Specification.

Based on the general engine room specifications, NORCONTROL take responsibility for preparing the specifications according to classification rules.

- For ships allready in service our engineers will go onboard to asess additional automation required by the class. On this basis we present a fixed price quotation for the key job.

- For Newbuildings we are glad to cooperate with shipyard and shipowner allready at the negotiations and thus to present our proposal for a detailed stage of specification.

Drawings and system documentation.

As part of our system supply we deliver complete system manuals covering:

- Installation
- Operation
- Fault finding and maintenance.

Installation.

For ships in service our engineers and fitters will take care of installation at sea during normal operation o f the ship. No off hire for the ship is needed.

For yard installation NORCONTROL will take care of commissioning and strart up of the system and if wanted also:

- Supervision of installation
- Complete installation
- Consultancy in the field of ship automation.

Classification by Classification Societies.

After receipt of order NORCONTROL will arrange for approval of drawings, etc. by the Classification Society.

In case NORCONTROL take care of installation, NORCONTROL will also arrange for the classification of the complete system after commissioning.

Training Courses.

NORCONTROL have established a TRAINING SCHOOL with regular courses of 3-5 days, covering:

- Training in automation principles
- Training in operation
- Training in fault finding and maintenance.

Equipment has been installed in our Training Center in order to provide a very practical oriented training. Included in the training course are also 3 extensive compendiums, which is also being used at some Marine Schools.

# SECTION III

# THE IFAC/IFIP SHIP OPERATION AUTOMATION SYMPOSIUM

OSLO, NORWAY

July 2-5, 1973

Chapter 12 of this Section has been prepared by Mr. J. V. Leonard of Specialized Systems, Inc., Mystic, Connecticut. Chapter 13 was prepared by Professor D. T. Phillips of Purdue University, West Lafayette, Indiana.

# CHAPTER 11

# BRIDGE SYSTEMS AND GENERAL VIEWS

## INTRODUCTION

The IFAC/IFIP Symposium on Ship Operation Automation was organized by the Norwegian National Member Organizations of IFAC (The International Federation of Automatic Control) and IFIP (The International Federation for Information Processing) in Oslo, Norway, on July 2-5, 1973. The Symposium Sessions were held in the Lecture Halls of the School of Mathematics of the University of Oslo at Blindern, the northern suburb of Oslo. Nonresident attendees were housed in the student dormitories of the University which are operated at tourist hotels during the summer months.

This particular Symposium was one of three presentations organized by IFAC and IFIP to cover the whole of the shipping automation field. The other meetings involved were the *Ship and Shipyard Automation Symposium*, held as part of the Fifth World Congress of IFAC in Paris, France, on June 12, 1972 and the *IFIP/IFAC JSNA Conference on Computer Applications in the Automation of Shipyard Operation and Ship Design* to be held in Tokyo, Japan, on August 28-30, 1973. JSNA is the symbol for the Society of Naval Architects of Japan.

The Oslo Symposium was surprisingly well attended since it included 550 attendees from 30 countries. They heard a total of 62 papers presented in 17 paper sessions organized in three parallel groups along with four survey papers and nine round table sessions where paper authors answered questions of the audience. The material presented was very well received with considerable discussion both in the sessions and in the halls outside after the sessions.

## SOME GENERAL VIEWS

Those paper titles related to bridge systems are listed in Table XV. They were concerned mainly with the following topics.

1. Radar based anti collision systems
2. Electronic aids to navigation, satellites versus hyperbolic systems
3. Bridge layouts to take advantage of electronic and computer based aids available while drastically reducing crew size.
4. Possibilities of computer aided or computer based piloting in restricted areas including automated docking.
5. Dynamics of ship steering and related mathematical models.

It should be noted that two capabilities were tacitly assumed by most authors. These were that a digital computer used for any bridge function should be carrying out dead reckoning navigation of the vessel along a great circle track, and that if the engine room were properly equipped it should also be implementing bridge control of engine functions such as start-up, shut down, and speed changes.

There were no papers on sonar based anti grounding systems although this was well recognized in questions and answers and associated conversations as a vital need for the field.

In the electronic aids to navigation area there was general recognition of the value and assuracy of the TRANSIT

## TABLE XV, cont.

Session 5 - Navigation - Anticollision

"An Integrated System for Navigation and Anticollision for Ships", by E. Gjeruldsen and F. Fjellheim, Noratom-Norcontrol A/S, Oslo, Norway.

"Ship's Integrated Navigation Systems", by J.B. Carr, Sperry Marine, Bracknell, England.

"Integrated Navigation System with OMEGA as Primary Source of Position Information", by P. Bergstad, Norsk Aktieselskap Philips, Oslo, Norway.

"Automation of Collisions Avoidance at Sea - with Special Reference to the International Regulations for Preventing Collisions at Sea", by A.G. Cobrbet, Dept. of Maritime Studies, UWIST, Cardiff, England.

Session 8 - Anticollision - Steering of Ships

"On the Automatic Determination of an Optimal Anticollision Strategy", by M. Piattelli and A. Tiano, Consiglio Nazionale delle Ricerche, Laboratorio per l'Automazione Navale, Genoa, Italy.

"Automatic Path Guidance", by W.H.P. Canner, Chepston, Monmouthshire, England.

"Progetto Esquilino: An Experiment About an Optimal Gyro-Pilot", by P. Dagnino, D. Leccisi, M. Piattelli and A. Tiano, Consiglio Nazionale delle Ricerche, Laboratorio per l'Automazione Navale, Genoa, Italy.

TABLE XV, cont.

Session 9 - Steering of Ships

"Automation of Ship Steering Control on a Desired Track", by A. Yakushenkov, Merchant Marine Central Research Institute, Leningrad, USSR.

"Modern Control Theory Applied to Ship Steering", by H.F. Millers, Saab-Scania, Sweden.

"Adaptive Autopilots for Ships", by J. van Amerongen, and A. J. Udink ten Cate, Delft University of Tehcnology, Delft, Netherlands.

"The Design of a New Automatic Pilot for the Commercial Ship", by D.L. Brook, S.G. Brown Ltd., England.

Session 12 - Special Topics

"Ergonomic Studies Affecting Ship Control and Bridge Design", by R.E.F. Lewis, D.A. Attwood, D. Beevis and A.V. Churchill, Defence and Civil Institute of Environmental Medicine, Downsview, Ontario, Canada.

"About a Plan of Navigation Recorder", by Torao Mozai, Tokyo University of Mercantile Marine, Tokyo, Japan.

"Characterization and Identification of the Motions of Ships in Confused Seas", by C. Bozzo, Groupe D'Etudes "Signaux et Systems", Centre Universitair de Toulon,France.

"On the Control of a Submerged Vessel Using the Sideslip Angle Estimated by an Observer", By Y. Ogawara, Mitsubishi Heavy Industries, Ltd., Kobe, Japan.

satellite system of the U.S. Navy, but equally strong views concerning the present high prices of computer-based systems to take advantage of their ability. There was considerable discussion, although no concerted opinion, of the value of the present periodic fixes available from the TRANSIT system versus the continuous positioning which might be available in the future from a set of synchronous satellites. Some felt the TRANSIT was perfectly adequate considering the relatively low speed of ships and the availability of ship computer-based dead reckoning systems. Others appreciated the continuous positioning of the synchronous satellite system but questioned the wisdom of relying on shore-based computational aids to obtain these fixes.

The very great accuracy of the DECCA navigational system was recognized, but its short range was deplored. On the other hand, the relatively poor accuracy of the OMEGA system was a source of considerable concern to many attendees, even though it can potentially give worldwide coverage when fully available about 1975-76.

The bridge consolidation papers presented concentrated on the possibility of one man operation of the vessel with the Captain or watch officer actually steering the ship and controlling its speed himself rather than relaying his desires through several other individuals as at present. The papers presented reported nearly universal acceptance of these concepts whenever tried out in practice. It appears certain that they preview a radical change in ship operational practices within the near future.

The possibility of computer-based automated steering of the vessel in restricted waters or in approaching the dock is very intimately tied to the solution of two related problems: The first of these is the problem of making the computer aware of the local topography, the existence of obstructions, the actual dimensions of the safe fairway, and keeping up to date on any of these items which may have recently been moved. Since a vessel can theoretically call at any port in the world capable of handling it, this problem is an enormous one. The second problem involves an acceptable solution of the problem of detection of underwater obstructions and the prevention of grounding and/or ramming of these objects by the vessel. Solution of both of these promises to require considerable research and development prior to their solution.

## ADDITIONAL INFORMATION OBTAINED

The material of Table XVI was obtained in conversations with various individuals during the Symposium. It indicates substantial sales of the various makes of radar-based anti-collision systems around the world. This list does not include sales of any Japanese manufactured systems which might have occurred. Also included is the current best information on computer-based engine room systems which actually carry out a substantial control function.

## TABLE XVI

## CURRENT INFORMATION CONCERNING SALES OF COMPUTER BASED ANTICOLLISION SYSTEMS AND COMPUTER BASED ENGINE ROOM CONTROL SYSTEMS

| Manufacturer | Installations | Further Sales |
|---|---|---|
| **ANTICOLLISION** | | |
| NORCONTROL | 25 | 25 |
| Digiplot Division of IOTRON, Inc. | 29 | 16 |
| Sperry Marine | 4 | 12 |
| F and M Systems | - | 4 |
| AEI | - | 2 |
| AMS Division of MDS | - | 1 |
| **ENGINE ROOM SYSTEMS** | | |
| Kockums | 4 | 2 |
| NORCONTROL | 1 | 1 |
| MDS | - | 1 |

# CHAPTER 12

## ENGINE ROOM AUTOMATION STUDIES

The majority of the papers on engine room systems were research and development oriented as opposed to reports of actual results of appreciable real-time at-sea experience with specific installations. Those paper titles related to engine room automation studies are listed in Table XVII. One paper, "Direct Digital Control of A Diesel Engine," did report actual results with a specific installation, but the computer was an add-on that had to be located at a considerable distance from both the bridge and the engine room, and the author referred to the effort as an "experiment." He also noted that the problem of main engine automatic control has produced interesting solutions, but, "...Unfortunately, much rarer are the realizations of on-line computer control..." This lack of a reasonable number of papers detailing actual successful experience with main machinery automation was surprising in view of the first hand exposure to the highly automated machinery of the SEA SERPENT just prior to this symposium.

If the emphasis on research and development was a deliberate attempt to focus on what's new in main machinery automation, one can only conclude that not very much is new. Certainly, no dramatic new engineering approaches to either

## TABLE XVII

## PAPER TITLES RELATED TO ENGINE ROOM AUTOMATION STUDIES

Session 14 - General Systems Design

"Optimal Management Policies for Ship's Engine Systems", by P. Dagnino, G. Soncin and A. Tiano, Consiglio Nazionale delle Ricerche, Laboratorio per l'Automazione Navale, Genoa, Italy.

"New Developments in Engineroom Automation", by P.B. Fischer, S.T. Lyngsø, Denmark

"General Hardware and Software for Engine Room Monitoring and Control Systems", by S. Espestøyl and O.M. Sivertsen, Noratom-Norcontrol A/S, Horten, Norway.

Session 16 - Diesel Engines Control Systems

"Computerized Systems in Diesel Engine Rooms. Installation, Testing and Operation", by A. Andreassen and S.K. Johnsen, Noratom-Norcontrol A/S, Horten, Norway.

"Direct Digital Control of a Diesel Engine , by P.P. Puliafito and F. Tosi, Dept. of Electrical Engineering, University of Genoa, Italy.

"Direct Digital Control of Diesel Engine Fuel Injection", by A. Hansen, The Ship Research Institute of Norway, Trondheim, Norway.

Session 17 - Condition Monitoring of Diesel Engines

"Datatrend, A Computerized System for Engine Condition Monitoring and Predictive Maintenance of Large Bore Diesel Engines",

## TABLE XVII, cont.

H. Sandtorv, G. Fiskaa, The Ship Research Institute of Norway, M. Rasmussen, The Technical University of Norway, Trondheim, Norway.

"Cyldet, ASEA's System for Monitoring the Combustion Pressure in Diesel Engines", by A. Madesaeter and N. Hammarstrand, ASEA, Marine Automation Department., Vasteras, Sweden.

Session 19 - Steam-turbine Automation Systems

"A Digital Computer Based Engine Room Automation System for Turbine Driven Ships", by K. Lind, The Ship Research Institute of Norway, Trondheim, Norway.

"The L.N.G. Carrier - Automation Systems", by A.A. Ardley, Foxboro - Yoxall Ltd., Redhill, Surrey, England.

"An Integrated Control System for Boiler, Burner and Turbine on Ships", by F. Hasselbacher and M. Werner, Siemens Aktiengesellschaft, Erlangen, Germany.

Session 20 - Steam-turbine Condition Monitoring and Control Systems

"Electronic Driven Bridge Controls for Propulsion Systems" by J.J. Dor, Potomac, USA.

"The Design of a Discrete Multivariable Control System for a 35,000 hp Capacity Ship Boiler", by A. Tyssø, The Technical University of Norway, SINTEF, J. Chr. Brembo and K. Lind, The Ship Research Institute of Norway, Trondheim, Norway.

TABLE XVII, cont.

Session 22 - Special topics

"Experience with Advanced Instrumentation on Large Bore Engines", by O. Steen, Norsk Aktieselskap Phipips, Oslo, Norway.

"Engine Testing by Minicomputer", by E. Jonsson, Saab-Scania, Gothenburg, Sweden.

"Machinery Alarm Systems for Ships Operated with Unattended Machinery Spaces", Ir. W. de Jong, Lloyd's Register of Shipping, Rotterdam, Netherlands.

"Resistance Thermometers and Thermocouple Assemblies for Ship Automation", by F. Schwarz and J. Scholz, Degussa, Geschaftsbereich Technische Metallerzeugnisse, Hanau am Main, Germany.

systems or hardware were described. Despite some redundancy inherent in 20 papers by authors from 8 countries, there were no major differences in philosophy in the areas of overlap. This almost universal agreement on basic requirements and approaches to machinery automation probably represents an underlining of the absolute necessity for thoroughly proven system design and components to achieve the very high order of reliability essential to the satisfactory automation of a ship's machinery plant.

There was considerable emphasis on the maintenance management which is prerequisite to fully automated operation. There is a great deal of payoff in such maintenance procedures, even if the actual control of the machinery at sea is not automatic.

Of the 20 papers presented, two described total systems for main machinery automation. The first paper in Session 19, "A Digital Computer-Based Engine Room Automation System for Turbine Driven Ships," dealt with a digital computer-based system for automation of steam turbine machinery. "Computerized Systems in Diesel Engine Rooms - Installation, Testing and Operation,"the first paper in Session 16, was a general description of the Norcontrol computerized systems for diesel engine rooms. The latter paper brought into clear focus the basic functions that must be accomplished to fully automate the main machinery of a ship. The integration of the Data Chief system for engine room automation and maintenance prediction and the Auto Chief II main engine room remote control system provides for total engine room automation of a diesel powered ship. The Data Chief system is made up of three principal subsystems: Data Trend to monitor and log the condition of key components and predict maintenance requirements; Data Safe to monitor, handle alarms and provide automatic start/stop of auxiliary equipment; and Data Power to completely automate the electric generating plant.

Several papers dealt with remote operation and automatic operation of both steam and diesel machinery, with one paper addressing the benefits of automated computer control of normally "fixed" items of diesel engine design (exhaust valve operation, cylinder lubrication and cooling, and fuel injection). Several papers addressed maintenance monitoring and prediction, several were directed to specific subsystems, and a number dealt with individual equipment or hardware.

One paper dealt quite broadly with liquid natural gas carriers, covering far more than the automation of the main machinery. Such carriers have a major interface between the cargo and the steam plant due to the use of cargo "boil-off" as ship's fuel. The author stressed the important point that a fully automated ship should be a design entity with the total ship controlled through a management computer instead of a series of unrelated control systems for bridge, engine room and cargo.

These papers are reproduced in the symposium proceedings for detailed reference.

# CHAPTER 13

# CARGO HANDLING SYSTEMS, RELIABILITY STUDIES, AND SYSTEMS DESIGN STUDIES

The following comments are relevant to the following Ship Operation Conference sessions:

Session 23 - Cargo Handling on Tankers (4 papers)
Session 25 - Computer Automation (3 papers)
Session 26 - Software Reliability (4 papers)
Session 28 - Reliability, Fault Finding (3 papers)
Session 29 - Systems Design (3 papers)

Rather than deal with each paper individually, each session will be analyzed, and relevant points made about the topic being considered in that particular session; detailed analysis can be recovered from the conference proceedings. The papers presented in each session are listed in Table XVIII.

## TABLE XVIII

## PAPER TITLES RELATED TO CARGO HANDLING SYSTEMS, RELIABILITY STUDIES, AND SYSTEM DESIGN STUDIES

Session 23 - Cargo Handling on Tankers

"Computerized Cargo Handling on Large Tankers", by L. Sten, Kockums Shipyard, Malmo, Sweden.

"What Are the Benefits of Computerized Load Calculation", by R.T. Karlsen, Norsk Aktieselskap Philips, Oslo, Norway.

"Computerized Monitoring of Liquid Cargo Loading/Unloading", by K. Ellingsen, A. Holmberg and P. Stromme, Noratom-Norcontrol A/S, Horten, Norway.

"Some Experiences in Cargo Oil and Water Ballast Handling by Ship-Board Computer", by R. Tamura, Y. Okano and M. Fujita, Kawasaki Heavy Industries, Kobe, Japan.

Session 25 - Computer Automation

"Computerized Super-Automation System of the TOTTORI MARU, Turbine Driven Tanker", by H. Saito and S. Okano, Mitsubishi Heavy Industries Ltd., Nagasaki Shipyard and Engine Works, Nagasaki, Japan.

"Computerized Automation of the Containership LLOYG-IANA", by G. Sitzia and G. Sartirana, "Italia-Llioyd Triestino", Genoa, Italy.

## TABLE XVIII, cont.

"Computer-Based Ship Automation for a Polish Cargo Ship", by S. Zielinski and W.J. Martin, The Ship Research Institute, Gdansk, Poland.

### Session 26 - Software - Reliability

"The Cost Concept Related to Software Tasks in Evaluating Shipborne Computer Systems", by C. Boe, G. Dahll and T. Heimly, Det norske Veritas, Oslo, Norway.

"Experience With an Advanced Software System as an Operator's Aid in a Ship Computer System", by H. Røkeberg, Norsk Akieselskap Philips, Oslo, Norway.

"Reliability in Onboard Computer Systems. Equipment Selection and System Diagnostics", by K.H. Drager, Det norske Veritas, Oslo, Norway, and M.H. Haugerud, A/S Computas, Oslo, Norway.

"Reliability Considerations for the Control Equipment of an Unmanned Ship", by J. Oldenburg, ATEW, Flen, Sweden.

### Session 28 - Reliability - ault inding

"Elements of Reliability Engineering Applied to Ship Automation", by C. Bøe and T. Heimly, Det norske Veritas, Oslo, Norway.

"Trouble Shooting with B.I.T.E. on Marine Control Systems", by C.H. Collingwood and M. MacPherson, Hawker Siddeley Dynamics Engineering Ltd., Hatfield, Herts., England.

TABLE XVIII, cont.

"Trouble Shooting on Electronic Automation Systems on Ships", by W. Langhans, Siemens Aktiengesellschaft, Erlandgen, Germany.

Session 29 - Systems Design

"Electronic System for Intrinsically Safe Instrumentation and Monitoring", by H.C. Oppegaard, A/S NEBB, Oslo, Norway.

"High Voltage, the Answer to Increasing Power Demand on Board Ships and Oilplatforms", by T.E. Thorsteinsen, Amund Clausen A/S, Porsgrunn, Norway.

"Electronic Control of Marine Gas Turbine Engines", by J.M. Binns and M.J. Joby, Lucas Aerospace Ltd., Birmingham, England.

Introductory Keynote Lecture - "The Status of Ship Operation Automation Today," Theodore J. Williams, Purdue University, Lafayette, Indiana, USA.

Survey Lecture Number 1 - "Operational and Organizational Problems Regarding Centralized Control of a Highly Automated Ship," P. Bjurstrøm, The Swedish Shipowners' Association, Stockholm, Sweden.

Survey Lecture Number 2 - "Socio-technical Analysis of Ship Organizations", B. Nylehn, Technical University of Norway, Trendheim, Norway.

## CARGO HANDLING ON TANKERS

| Ship Involved | Country | Computer Used | Paper |
|---|---|---|---|
| SEA SOVEREIGN (210,000 tons) | Sweden | Control Data 1700, 28K | 23-1 |
| M/T BERGE FISTER | Norway | NORD I, 256K | 23-2 |
| M.S. OHTSWKAWA MARU (150,000 tons) | Japan | IBM | 23-4 |

In observing the speakers during the session on cargo handling, three key words repeatedly came up:

1. Reliability
2. Simplicity
3. Standardization

The general feeling was that the three areas were relatively untouched in systems analysis. Standardization of computer systems was often mentioned as a main source of trouble on part to part repairs. In the actual system design, simplicity was considered a necessity for functional operation. Although every speaker expressed concern for reliability, no real systems reliability studies were reported. (The Japanese indicated that almost 100% redundancy was built into their systems!)

The four main reasons for automation appeared to be:

1. Safety
2. Time savings

3. Reduced personnel
4. Less damage

There were two major trouble areas expressed by the majority of the authors involved:

1. Level controller defaults
2. Detection of sensor failures

Critical reliability components were:

1. Level gauges
2. Pressure gauges

The most comprehensive system was reported by the Japanese (23-4). Their system was used for:

1. Ballast control
2. Ballast calculations
3. Astronomical (geographical) calculations
4. Omega navigation
5. Ship motion/ship routing calculations
6. Medical diagnosis

## COMPUTER AUTOMATION

| Ship Involved | Country | Computer Used | Paper |
|---|---|---|---|
| TOTTORI MARU (237,000 tons) | Japan | MEICOM 350-55 (16 K core, 32 K drums) | 24-1 |
| LLOYDIANA (Container ship) | Italy | IBM 5/7, 1130 | 24-2 |
| Ship Research Institute | Poland | Polish Mini-computers K-202 | 24-3 |

The papers dealing with computerized automation were highly descriptive in nature and not much information was gathered from these "standard talks." It is worth noting that the Polish paper gave details of a Polish K-202 minicomputer system. In general, the opinions were that almost total computer control was on its way. Centralized versus decentralized systems were discussed but no definite conclusions reached. The only system actually operating in this series of papers was reported by the Japanese (TOTTORI MARU, 24-1). Software design was considered to be the most critical problem area. Automation would include:

1. Navigation systems
2. Cargo handling
3. Turbine plant control
4. Weather analysis systems
5. Medical diagnosis
6. Statistical analysis
7. Cargo monitoring

## SOFTWARE RELIABILITY

Software reliability is a relatively new and interesting concept closely connected with debugging, fault-finding, software malfunctions, and preventative maintenance. The basic idea is that "reliability type" curves can be constructed for the above system characters.

There were three papers presented, each disjoint in their treatment of this topic.

The first paper dealt with cost analysis of a computerized automation system. Cost estimates were arrived at as a function of computer system reliability and availability. Utility measures were used to "smooth" those measures. Very elementary cost functions were derived from system costs based on expected values. Total costs were arrived at based on individual various "system states," and then summing system component costs. No actual results were given, only simple models.

The second paper dealt with the actual shipboard experience of an officer of board the M/T BERGE FISTER. This presentation was one of the most interesting since the talk was the feelings of a person who had actually worked with an on-board computer for an extended length of time (16 months). The general thrust was that due to software implementation, routine operation had not been achieved. An interesting fact was that the operators did not know any programming languages, but still learned to accept the computer control. Operators detected trouble mainly on irregular patterns of light and sound on the terminal board! (Error messages were, of course, available for major malfunctions.) An interesting fact was that average hang-ups could not be resolved by the operators, but a systems expert was judged to be expendable in general. A further conclusion was that it is better to limit the knowledge of the operators so that the system is totally accepted. This creates a greater need for start-over routines, diagnostic systems, and fail-safe operations. (These conclusions are the author's opinions.)

The third paper dealt with reliability of computer systems, with regard to equipment selection and system diagnostics. The title is misleading since the only real reference to reliability was in relationship to hardware/software availability and not a "system reliability" analysis. The author's paper simply described a dual hardware system connected via two data channels for shipboard operation. One was for real-time operations (Process Control) and the other for diagnostic and predictive maintenance tasks. The bulk of the paper simply explains the hardware configurations, software systems, and computer diagnostic systems implemented on ship. The primary conclusion was that job-sharing by two hardware configurations result in a savings in software overhead.

## RELIABILITY - FAULT FINDING

The three papers in this session dealt with three separate topics:

1. Reliability analysis of automated systems on-board ships
2. Preventative maintenance via Built In Test Equipment (BITE)
3. Trouble shooting for an on-board computer installation.

The first paper was a terse technical presentation describing a software package called STAVAN (Det Norske Veritas, Oslo) developed to obtain system reliabilities. This program is based upon a Markov-chain approach to system reliability. The package seems to be unrealistic since it assumes that all components operate at constant failure rates, and all equipment fails indpendently.

The second paper dealt with a system called BITE, developed by Marine and Engine Controls. This system was designed to seek out and find items which have failed or are nearing failure modes. The entire system is geared to availability. The system itself, control/display panels, stimulus and measurement devices, control units and program storage are briefly discussed.

The third paper simply discusses some of the aspects of trouble shooting on board ships. Easy location and rapid replacement of parts were stressed. System trouble spots were identified as early failures, failures due to overvoltage, and wear-out failure. According to the authors, less than 10% of failures in electronic systems was observed, with most of these being external switch failures due to (a) mechanical damage, and (b) oil/dirt. A final conclusion was that integrated circuit systems greatly facilitate trouble shooting.

## SYSTEM DESIGN

These papers are, as a group, fairly technical and offer little in the way of useful discussion. The three papers are briefly summarized as follows:

1. The first paper dealt with the limited topic of intrinsically safe instrumentation and monitoring. The discussion was limited to liquified natural gas carriers and liquified petroleum gas carriers.

2. The second paper offers an interesting solution to the high demands on power supplies for on-board installations: High Voltage Systems. System design concepts, operating configurations, and distribution characteristics are discussed by the author.

3. The third paper presents a reliable way to guide on-ship operations for an Olympus 201 engine using electronic control. Test results (laboratory) are presented indicating the applicability to present and future marine gas turbine engines.

## CONCLUDING REMARKS AND CONCLUSIONS

During the duration of the Conference, the authors were primarily concerned with the state of (a) reliability analysis, and (b) cargo handling relevant to automated ships. The general conclusions reached are as follows:

### Cargo Handling

Computerized cargo handling is now feasible and operational (in varying degrees) to automated ships. The Japanese appear to have the most experience and superior systems, with the Norwegians close behind. There appear to be no formidable problems except in diagnosis of certain system failures.

### Reliability

There appears to be no real systems analysis procedure available for reliability analysis. Even worse, no hard data appears available at this time. An interesting fact is that everyone talked reliability, but no one had analyzed system reliability adequately. It is evident that much effort has been poured into hardware development and design, but little into long-run operational analysis. Further, the Europeans are interested mainly in safety and ease of control, disregarding the economic consequences of computerized operation. Reliability appears to be maintained by excessive redundancy and preventative maintenance procedures.