UDC 629. 122. 522

ELECTRICAL EQUIPMENT FOR AUTOMATED SHIP (MO-SHIP) WITH UNMANNED MACHINERY SPACE DELIVERED TO KAWASAKI HEAVY INDUSTRIES CO., LTD.

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I. INTRODUCTION

In recent years, ships have increased in size but at the same time the labor shortage has become more acute. Therefore, there has been a trend toward more improved automation in order to save on labor and make operation of the ship safer and more economical. Many new ships are now employing the "MO" system in which the engine room is unmanned at night.

In the "Recommendation for MO Ships" published by the Nippon Kaiji Kyokai (NK), it states that a higher level of equipment than found previously, especially in relation to monitoring and alarms and fire prevention, is required for safe operation of the ship when the engine room is unmanned for at least 24 hours". Automation of the main engine remote control and various types of protective devices continue to reach higher levels.

For this reason, it has become necessary for systematic technical treatment of the equipment in the ship as part of the "totalized system". Recently, Fuji Electric delivered electrical equipment designed on the basis of these new viewpoints to Kawasaki Heavy Industries Co., Ltd. for their new MO type ship, the Fukukawa Maru. This ship has already made several voyages and the equipment's high level performance has been verified. This equipment will be introduced here. *Fig. 1* shows an outer view of the Fukukawa Maru.

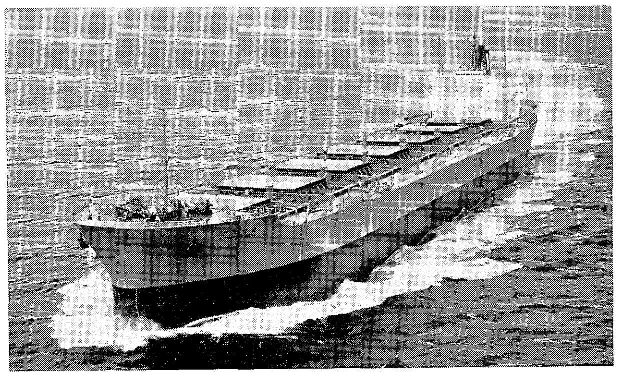

Fig. 1 M/S "Fukukawa Maru" equipped with unmanned machinery space 121,552 DWT (Bulkc carrier)

II. MAIN DIESEL ENGINE REMOTE CONTROL EQUIPMENT

1. Outline of Equipment

1) Construction and control

The main engine of this ship is a Kawasaki M.A.N. K9Z93/170E type diesel engine (MCR 24,750 ps × 115 rpm). *Fig. 2* is a block diagram of the control system for this engine.

The main engine remote control equipment is very important in the automation system of the MO ship since it maintains the ship safety by operation of the main engine from the bridge when the engine room is unmanned. This point was taken into consideration and technology concerning the highly successful systems developed jointly by Siemens and M.A.N. was introduced to meet the requirements.

(1) Manual operation

During manual operation, the mechanical hand wheel (type which can be turned in both directions) for operation of the M.A.N. KZ engine is used. All of the necessary control for starting, stopping, reversing and speed regulation is handled by this wheel. In other words, when the mechanical hand wheel is turned from the stop position to either the ahead side or the astern side, a region is passed through when only the starting air is injected into the main cylinder and then another region is passed through when both the starting air and the fuel oil are injected simultaneously as can be seen from *Fig. 2*. After starting is completed, injection of fuel oil can be increased by increasing the angle to which the hand wheel is rotated. The fuel oil control shaft is normally pulled in the fuel oil increase direction by a spring and during manual operation, the oval ring connected to the mechanical hand wheel determines the quantity of fuel injection. The air for control of the main air valve for starting and the cam shaft for forward/reverse conversion is controlled directly by the cam valves (355/1 and 355/2 or 355/3 and 355/4) which are linked to the movement of the mechanical hand wheel.

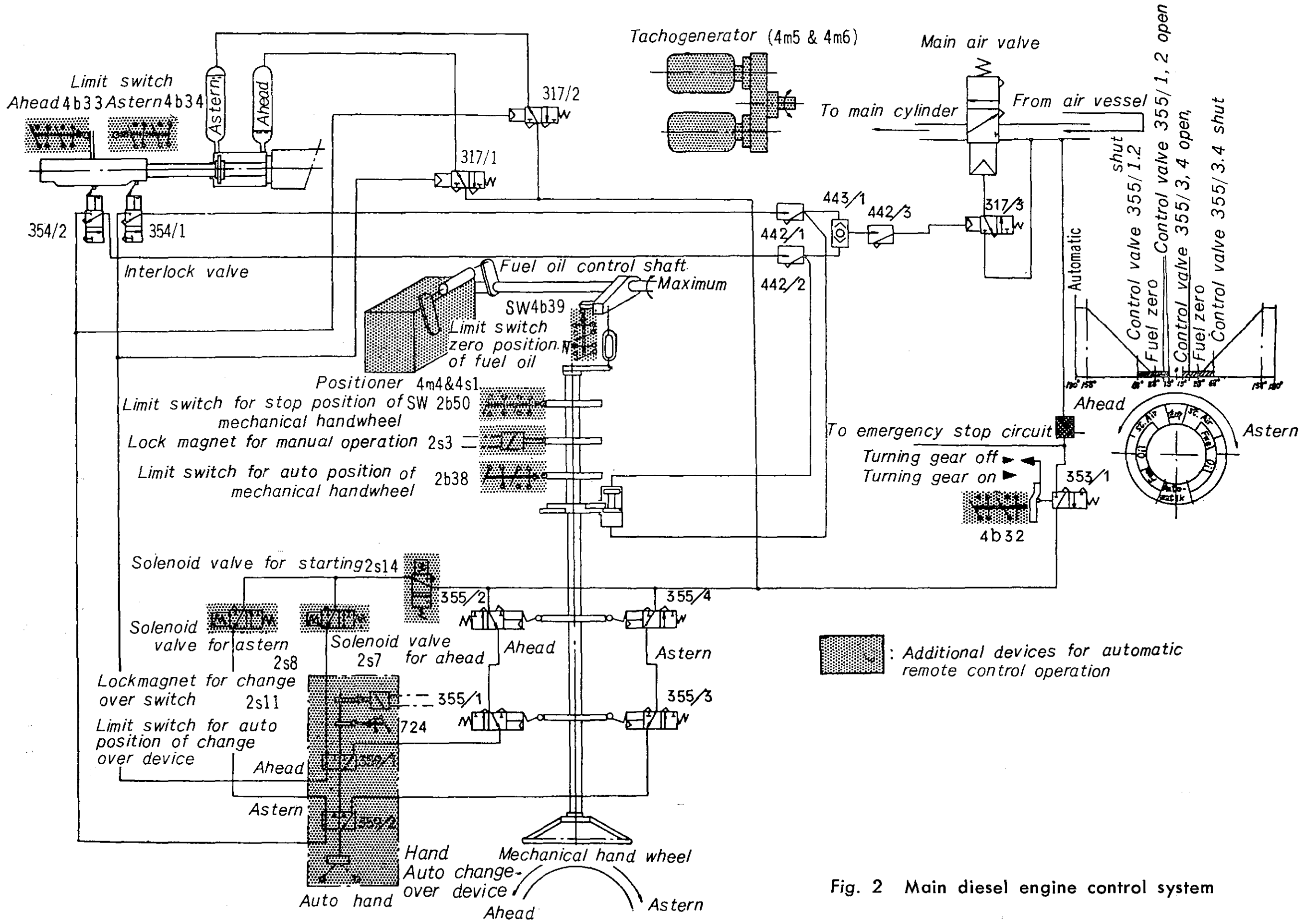

Fig. 2 Main diesel engine control system

(2) Automatic remote control operation

During automatic remote control operation, the solenoid valves and positioner are arranged in parallel with the air system and mechanical system as can be seen in *Fig. 2.* By operation of the hand/auto changeover device and turning the hand wheel to the automatic position, all of the operations described above for manual operation are performed by a completely automatic program on the basic of one-touch control with the engine telegraph operation lever.

In other words, solenoid valve circuits (2S7) and (2S8) are provided in parallel with the control air valve circuits (355/1 and 355/2 or 355/3 and 355/4) which are operated by the mechanical hand wheel described above. The control air valve circuits are changed over to the solenoid valve circuits by means of the three-way valves (359/1 and 359/2) located in the afore-mentioned hand/auto changeover device. Therefore, when the hand/auto changeover device is turned to the auto position, the control air system is controlled by the solenoid valves and operation of the hand wheel has no effect on this system.

During automatic operation, the fuel oil control shaft is controlled via the spring rod by means of the electro-hydraulic positioners (4m4 and 4s1) which are in turn controlled by the 0 to 10 mA output current of the Transidyn (transistor-type regulator). Therefore, during automatic operation, the mechanical hand wheel is turned from the stop position through 180° to the automatic position so that the fuel oil control shaft can be moved to the position for the maximum quantity of fuel oil.

2) Control circuit

In the automatic remote control equipment for this diesel engine, the transmission, handling and control of signals are all performed electrically except in the final actuator section. *Fig. 3* shows a block diagram of the control system.

This remote control operation can be performed from either the bridge or the engine control room. The control loca-

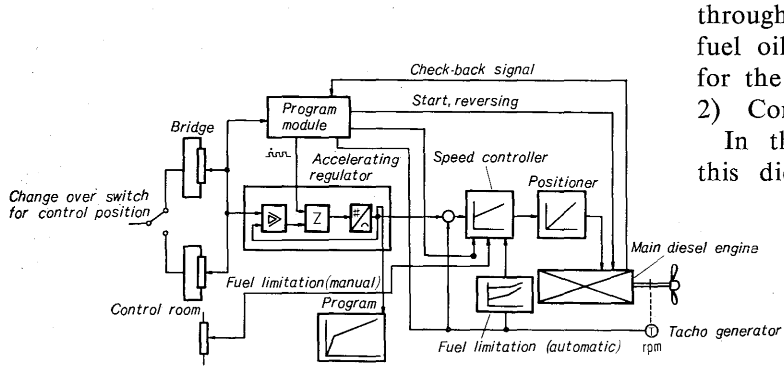

Fig. 3 Block diagram

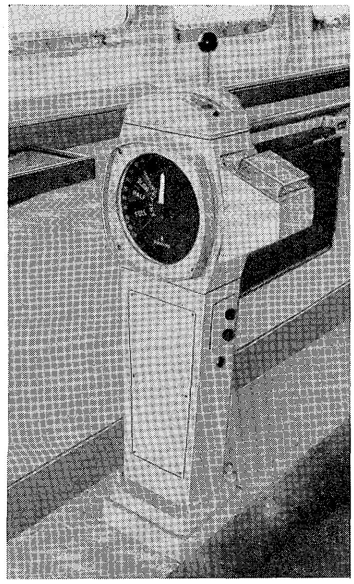

Fig. 4 Bridge control station equipped with enginetelegraph

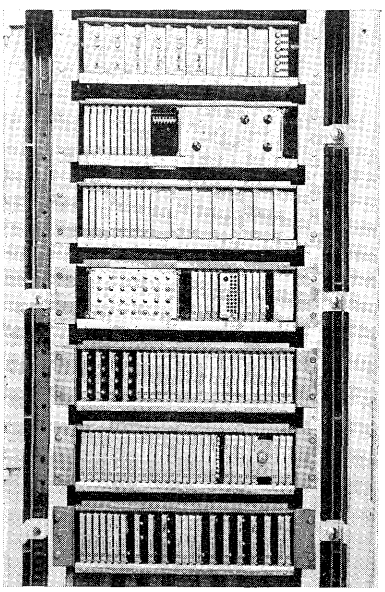

Fig. 5 Control cubicle for automatic remote control system block diagram

tion is selected by means of the location selection switch in the engine control room, and operation is performed by the engine telegraph which also serves as the operation lever. This engine telegraph has a scale divided into equal parts for rotational speed and in addition to the position transmitters for remote control, it is also equipped with a cam switch linked to the operation lever for control signals of the various operating conditions. *Fig. 4* shows the engine telegraph on the bridge.

The program section which includes the acceleration regulator employs silicon transistor-digital switching elements "F-MATIC N" so that almost no contacts need be used (refer to *Fig. 5*). In particular, as can be seen from *Fig. 3*, the acceleration regulator counts the pulse train until the regulator output agrees with the command value. This then undergoes digital/analog conversion and the desired characteristics are obtained as shown in the figure. Therefore, it is possible to obtain easily various acceleration characteristics which are more matched to the propeller torque and engine characteristics simply by changing the pulse frequency. It is also possible to obtain more stable and correct characterics than with the analog integrator type acceleration regulator which was often used previously.

In this equipment, the actual speed of the main engine is detected and controlled at a constant value, by the so-called electric governor system. However, there are two tachogenerators provided for speed detection because of their importance in the system. Any abnormalities are detected by a comparison monitoring of their two output values, and an alarm is given. The speed regulator is a transistor regulator (TRANSIDYN B) using silicon transistors and is in the form of a module assembled on a printed board in the same way as the previously described F-MATIC N elements. It exhibits excellent characteristics and stable operation.

2. Main Program

1) Starting

(1) If the fuel shaft is in the zero position due to the starting command, the solenoid valves shown in *Fig. 2* are excited and if the cam shaft position is in accordance with the command direction, the starting air is injected from the main air valve into the main cylinder.

(2) When the cam shaft is in a position opposite to that of the command, the cam shaft is moved by means of the control air system attached to the main engine but when there is no change within a short period, the solenoid valve is immediately cut off temporarily, one starting failure is counted and starting is tried again.

(3) When the cam shaft has stopped moving, the mechanical interlock is released, the main air valve is operated and the starting air is injected.

(4) If the firing speed is not attained within the fixed period after injection of the starting air, it is considered as a starting failure, the control air is temporarily interrupted and starting is tried again.

(5) When the starting failures exceed a total of three, the solenoid valves are interrupted and an alarm is given.

(6) When the engine telegraph has returned to the stop position, the starting failure counter is reset.

(7) When the firing speed is attained, the starting air is interrupted.

(8) The indicated amount of starting fuel during starting has no relation to the engine telegraph command amount and the most suitable amount which has been set previously can be provided.

(9) This starting speed command amonut is applied

to the speed regulator almost instantly by means of the 4 kHz rapid pulse. The sensitivity of the speed regulator is increased temporarily during the starting period so that there is a very high probability of successful firing.

(10) Eighty seconds after the correct cam shaft position is attained, an interlock circuit is formed so that the solenoid valves are not operated abnormally.

(11) When the main engine speed exceeds 60 rpm, the exciting circuit of the solenoid valve is interrupted by the relay.

(12) When the main engine speed exceeds 80 rpm on the forward side, the starting air intermediate valve is closed.

2) Speed increases

(1) When the main engine speed exceeds the firing speed, the speed command is converted to the starting speed command by means of the remote control position transmitter, being interlocked the engine-telegraph.

(2) When the engine telegraph moves to the maximum speed position, the afore-mentioned speed command becomes ineffective and a separately set maximum speed command can be given.

(3) When the speed command of engine-telegraph due to miss-setting is in the critical speed range, the lower limit speed of the critical speed range is automatically given out by the speed command circuit.

(4) The program speed command is increased in about 30 seconds by means of a 4 Hz comparatively rapid pulse up to the knuckle point (75 rpm) of the main engine speed. When the speed of 75 rpm is exceeded, the pulse is changed into one with a 0.05 Hz delay and the program speed command is increased at a gradual rate so that the maximum value is reached in 30 minutes on the forward side and 10 minutes on the reverse side.

(5) An alarm is given when the engine speed remains in the critical speed range longer than the specified time.

3) Deceleration and stopping

(1) When the engine telegraph returns to the low speed range deceleration occurs with the subtraction program by means of a 4 Hz pulse.

(2) When the engine telegraph is operating at "DEAD SLOW", below the maximum lower limit, a separate minimum speed circuit is provided to guarantee the minimum require amount of fuel and the stoppage of the engine is prevented.

(3) When the engine telegraph is operated in the stop position, a subtraction operation is carried out by a 4 KHz pulse and the fuel shaft is returned to the zero position within about one second.

4) Reverse

(1) When the engine telegraph is turned quickly to the reverse position, the fuel shaft which has no relation to the speed command at that time is returned to the zero position within one second.

(2) When the main engine speed falls below the speed at which reverse starting is normally possible due to the decrease in the ship's speed, the solenoid valve on the reverse side is excited. The cam shaft position is changed, the starting air is injected into the cylinder and the engine is rapidly braked.

(3) When the engine rotation exceeds the zero point and is on the reverse side, the main engine speed increases on the reverse side in accordance with the starting sequence of 2.1 and the speed increase sequence of 2.2).

(4) If the emergency operation push botton is pushed simultaneously when the engine telegraph is rapidly operated from the forward to the reverse side, the crash astern operation occurs. At this time, if a value of the reverse starting speed is selected which is larger than in the case of (2) above, the speed increase on the reverse side, covers the whole range simultaneously and the speed program is set by means of the 4 Hz fast pulse. In this case, the maximum speed command had no effect and the speed command according to the engine telegraph becomes effective. The manual fuel control circuit is cut out, the output value of the function generator used to set the main engine speed/torque limitation characteristics described later is changed and the torque limitation curve is set to a high value.

5) Fuel limiting and governor damping

(1) Manual fuel limiting

The maximum value of the output current of the speed controller is limited by operation of the potentiometer for fuel limiting on the engine control desk. This is effective when operating the ship in bad weather, etc.

(2) Automatic fuel limiting

In order to limit the fuel automatically in the engine low speed range, the fuel is limited in the

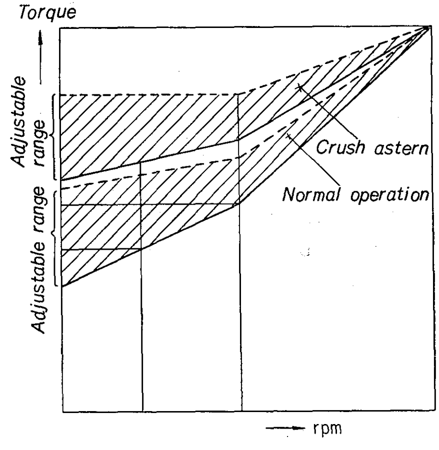

Fig. 6 Characteristics of fuel limiter

relation of the engine speed by means of an computing circuit with characteristics such as those shown in *Fig. 6*. In this way, good combustion during the engine acceleration process is guaranteed and smooth acceleration can be performed.

(3) Governor damping

In this equipment, the sensitivity of the electric governor is high in order to increase the follow-up characteristics of fuel control during programmed operation of the main diesel engine. However, when the program ends and the main engine is operating under normal conditions, this is automatically detected and the governor response speed becomes lower. This makes it possible to avoid any unnecessary hunting in the fuel control system and also to improve fuel comsumption.

6) Operation during main engine faults

In this equipment, a standard circuit is employed which carries out the following three types of operations in accordance with the seriousness of the fault signal (for example, contact signal for lubricating oil pressure drop, etc.) is received from the main engine.

(1) If a fault signal is received, the main engine is stopped immediately.
(2) If the fault signal continues for longer than a set time, the engine is stopped.
(3) If the fault signal continues for longer than a set time, the fuel is limited and the main engine speed is decreased to a set value.

However, above functions were not provided in this ship because of the opinion of the shipowner.

3. Manual/Automatic and Automatic/Manual Conversion

These conversions can be performed very easily according to the following sequence and in this way, the safety of the equipment is improved. It has been confirmed during operation at sea trial that this conversion is very easy during operation of the main engine and there are almost no changes in the speed due to the conversion.

1) Conversion from manual to automatic

(1) Change the manual/auto conversion lever to the automatic position

By this step, the positioner maintains the fuel control shaft in position.

(2) Turn the mechanical hand wheel to the automatic position

By this step, the above mentioned lever is locked mechanically in position.

2) Conversion from automatic to manual

(1) The mechanical hand wheel is returned from the automatic position to the position in which the handle rotation resistance increases suddenty (operating position in automatic control).
(2) Changing the manual/auto conversion lever to the manual position

By this step, the positioner forms hydraulic bypass circuit of the output cylinder and it becomes troque free.

4. Alarms and Indications

In the case of engine telegraph power source failure, control power source failure, tachogenerator faults and stoppages of the positioner motor, alarms and inications of the fault are given in the main engine remote control equipment in the main console as described in section III. These are displayed in the control cubicle shown in *Fig. 5*.

When there are three consecutive starting failures, indication and alarm is given independently on the main console. It is also indicated in the control cubicle.

When the main engine speed remains within the critical speed range for longer than the set period, an indication is given in the engine telegraph on the bridge, the engine control desk and the control cubicle.

Notification signals for the monitor of the starting and cam shaft moving times as described in 2.1, as well as the turning gear condition, the fuel shaft position and the course of the simulation test are indicated by lamps in the control cubicle.

On the bridge engine telegraph and engine control desk, there are panel unit for control and notification signals as well as command signals which consist of 12 illuminated push button switches.

5. Simulator Equipment

In this main diesel engine romote control equipment, the control cubicle shown in *Fig. 5* contains a simulator panel and indicator panel which are used

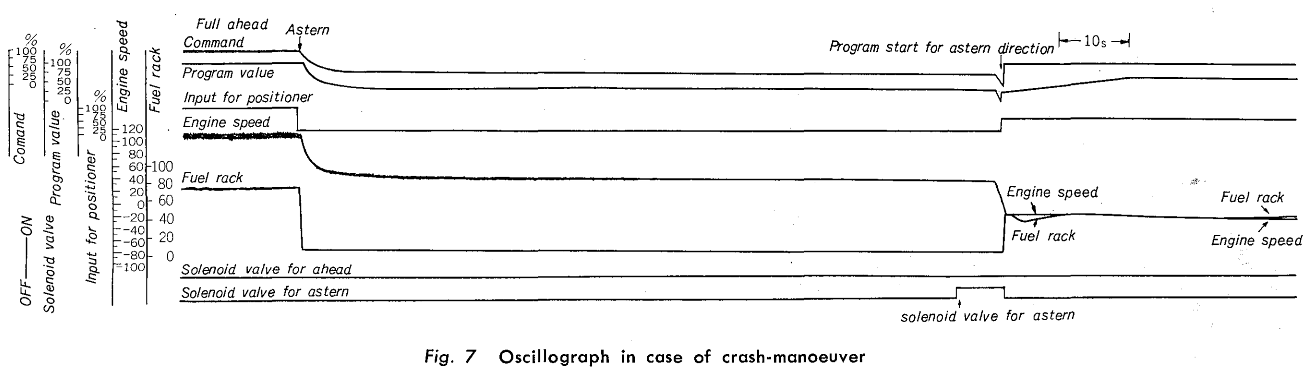

Fig. 7 **Oscillograph in case of crash-manoeuver**

to check the operating conditions of each part of the equipment during operation and stoppage of the main engine.

Recently there has been a tendency to use electronic control equipment widely in accordance with the higher level of automation in ships. This type of simulator equipment appears gradually to be becoming indispensible in order to facilitate checking by the ship's personnel.

6. Results of operation at Sea Trial

During operation at sea trial, the various regulation and setting parts were set in the most appropriate state matching the characteristics of the ship and the main engine. The functions and performance of the equipment were checked from all angles and all of the results were excellent. *Fig. 7* shows an oscillogram obtained at the time of crash astern operation.

III. MAIN CONSOLE

1. Outline

This main console consists of the following panels and box which are constructed of the devices required for measuring, indication, recording, instruction, and alarms of the main engine, turbine generator, diesel generator, the auxiliary engines and tanks, etc.

1) Main instrument panel
2) Temperature indicator panel
3) Centralized monitoring panel
4) Pressure gauge panel
5) Alarm logger panel
6) Master alarm box

Fig. 8 shows the main console (background) and the engine control desk (foreground) in the engine control room. In ships where the engine room is unmanned (MO ships), there is no personnel for operation and monitoring and since the main engine must be operated during this time, one of the most important things in remote control of the main engine from the bridge is that the equipment can indicate to the ship's personnel cases when abonormalities occur, especially in the devices in the engine room, in order to insure the safety of the equipment.

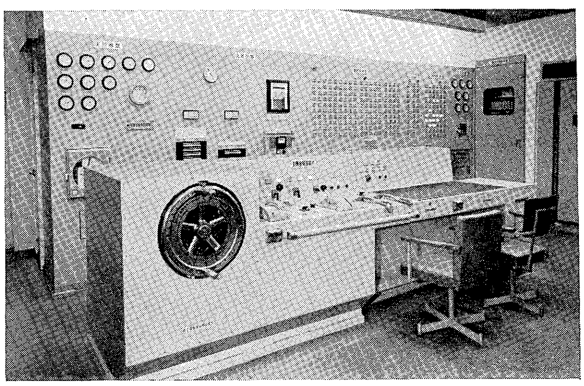

Fig. 8 Engine control desk and main console

The main console for this ship was planned with these points in mind. In the following sections, the temperature indicator panel, the centralized monitoring panel, the alarm logger panel and the master alarm box which are special features of this MO ship are described.

2. Temperature Indicator Panel

This panel has various functions including temperature indication concerned with the lubricating oil and cooling water sections of the main engine. These functions include setting of the alarm values for these sections, temperature indication of the exhaust gas part of the supercharger for the generator diesel, steam temperature indication prior to the main check valve for the generator turbine, alarm output in accordance with temperature deviations and recording of the exhaust gas temperatures of the main engine sections, industrial liquid conducting metering, detection of vibrations in the generator turbine, and protection against short circuits and switching of the auxiliary power supplies. The following three functions are characteristics of the Fuji Electric devices included in this panel.

1) Temperature indicator and alarm setter

This temperature indicator does not employ the normal cross coil type indicator but rather a self balancing type indicator (Fuji Electric brand name: Servozet). This indicator is highly accurate and is ideal for use on ships where there are a many vibrations because of its excellent vibration withstand resistance. The measuring points can be switched to a maximum of 50 points by means of push button conversion switches and this can be indicated.

The alarm setter employs the "Minizet" (Fuji Electric brand name) and it is located in the back surface of the equipment. The Minizet is completely electronic and has the following features for use on ships.

(1) It is compact and the space occupied is small.
(2) Since it is used in combination with the aforementioned Servozet, temperature indication and alarm is given at a single temperature detection terminal.
(3) It is simple to change the alarm setting value and the scale is clear and easy to read.
(4) The alarm output is easy to evaluate for any case even though there are several arrangements, because in addition to contact signal output, there is also lamp indication.

2) Temperature deviation alarm

In the Nippon Kaiji Kyokai Recommendations for MO Ships, it is stated that it is desirable that alarms be given in accordance with deviations in the temperature of the exhaust gas of each cylinder of main engine. Therefore, in this ship, Fuji Electric TELEPERM techniques are employed so that the reliability is high and operation is stable. In other words, arithmetical means of the exhaust gas outlet temper-

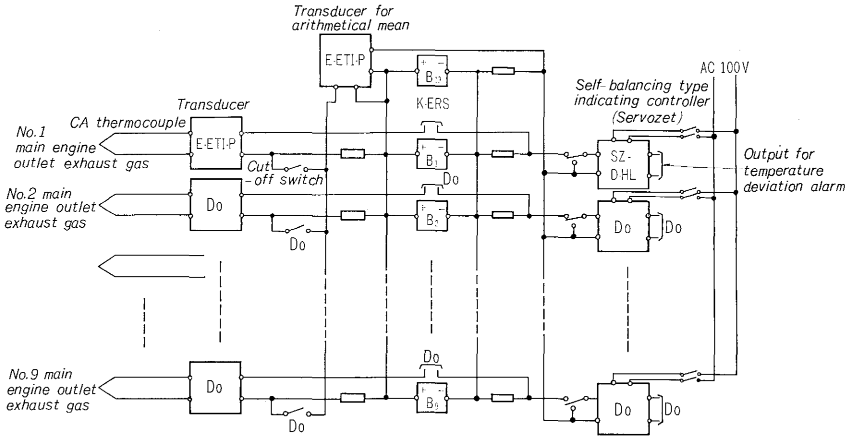

Fig. 9 Temperature deviation alarm cicuit for main engine exhaust gas

atures for each cylinder of the main diesel engine are taken by the circuit shown in *Fig. 9*. These mean temperatures and the exhaust gas temperature for each cylinder are compared and if the deviations are greater than a value set beforehand, an alarm is given. Even in the case where the main engine uses one or two fewer cylinders for some reason, the mean values of the exhaust gas outlet temperatures for the cylinders in operation only are calculated only by converting the switches for these cylinders and the correct deviation alarm is given. The set value of the temperature deviation alarm in this equipment can be changed simply by turning the setting dial and the temperature deviations for each cylinder are indicated. This leads to very convenient handling. This alarm device employs Fuji Electric TELEPERM units such as the E-ETI-P transducer, and the Servozet SZ-D-HL self-balancing type indicating controller. This temperature deviation alarm is also used for monitoring the exhaust gas outlet temperatures of the various superchargers for the main engine.

3) Recorders

The main engine cylinder exhaust gas temperatures and the main engine supercharger inlet exhaust gas temperatures are recorded by a 12-point self-balancing recorder (K-ERS-121 P/D). This type of recorder has been used widely on ships and has operated stably.

3. Centralized Monitoring Panel

1) Kinds of fault signals

When faults arise in the main or auxiliary engines or the systems of the MO ship, it is essential that the ship's personnel be notified accurately of the type of fault. The centralized monitoring panel is very important in this respect. Therefore, there are many more alarm points than in former panels and these points have been classified as follows so as to facilitate locating the faulty device and understanding the kind of fault.

(1) Classification according to equipments

a. Main engine and auxiliary devices (including generator)

b. Auxiliary boiler

c. Liquid levels of various tanks

d. Operating conditions of electric motors

(2) Classification according to importance of alarm

a. Emergency treatment required (Emergency)

b. Emergency treatment not required (Non-Emergency)

c. Necessary to reduce speed of main engine (Main Engine Speed Reduction)

d. Trip of important device (main engine, auxiliary boiler, generator, etc.)

In accordance with the above classifications, alarms and indications of the faults listed under (2) are given in the master alarm panel described later and alarms and indications of both kinds (1) and (2) are given in the centralized monitoring panel in the engine control room.

2) Alarm and indication systems

The fault signals of the various devices are all provided by contact points which are normally closed but open during a fault. This is a highly reliable alarm system since it is possible to detect misoperation of the alarm circuits due to vibrations, etc, loose screws in the detector terminals, etc. or disconnected wires in the circuits.

3) Indication of trip causes for the generator power supply

In MO ships, it essential to avoid total stoppages, so-called " black-outs " as much as possible. For this purpose, the various measures described in section IV have been provided. However, if the generator power source should be tripped due to some fault, it is essential to indicate the main cause of the tripping immediately so that the fault can be remedied. There are four main resons for tripping in the turbine generator ; decrease of the condenser vacuum, overspeed, drop in lubricating oil pressure and abnormal vibrations. In the case of the diesel generator, there are three main causes : overspeed, drop in lubricating oil pressure and cooling water temperature rise (insufficient cooling water or cooling water presure drop).

Of these various causes, only the original cause of tripping is indicated and the output of many unnecessary alarms is not indicated by sequence. Since it is necessary to indicate other alarms related to the generator during black out in addition to indication of the tripping cause of the generator power source, there is automatic conversion to a battery power supply at this time.

4) Alarm unit

The various alarm functions metioned above are in the form of modules constructed on printed circuit boards using small relays. Space required for attachment is minimized and handling is more convenient.

4. Alarm Logger Panel

This panel contains one alarm logger and under normal conditions it scans signals from the centralized monitoring panel and the main switchboard. When a fault signal enters the logger, the time of the fault, number, quantity being measured and alarm contents are automatically recorded by the printer. The alarm logger specifications are as follows:

1) No. of input points: 150 points
2) Input signals: normally-open contact signal, no voltage
3) Scanning rate: 5 ms/point
4) Digital printer: 20 columns (time: 9, channel no.: 3, system sign: 2, measured quantity: 2, alarm contents: 4)
5) Printing speed: 350 ms/point
6) Power source: AC 100 V 60 Hz

5. Master alarm box

If a fault arises in the main engine, auxiliary equipment, etc. when the engine room is unmanned, this fact must be notified to the chief engineer who is in charge of the engine room and the bridge which is manned at all times. However, separate indications in the chief engineer's room and on the bridge for all alarm signal whenever there is a fault represents problems in terms of the space and cost. Therefore, in this ship, these alarm points are classified in groups according to their importance and when a fault occurs in one of these groups, it is indicated in the master alarm box. Master alarm boxes are located in the engine control room, on the bridge and in the room of the chief engineer.

IV. POWER SOURCE EQUIPMENT

1. Main Generators Operation Modes

The main generators in this ship are one 875 kVA (1,800 rpm) turbine generator and two 750 kVA (720 rpm) diesel generators. Brushless systems are used in all cases to save on maintenance. *Fig. 10* shows an outer view of the diesel generotor. The operation modes of these three generators are as

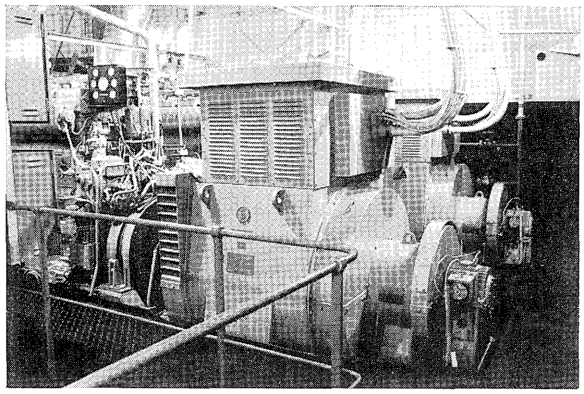

Fig. 10 Brushless type diesel-generator 750 kVA (10 P) 440 V 60Hz

follows:

(1) During normal operation at sea: One turbine generator
(2) Same as above (with ballast pump operating): parallel operation of one turbine generator and one diesel generator
(3) When leaving or entering port: parallel operation of two diesel generators
(4) When loading or unloading: parallel operation of two diesel generators or parallel operation of one turbine generator and one diesel generator

The ship power is supplied by the only one turbine generator driven by recovery of the main engine exhaust heat in the case of normal operation at sea for a long period and the ship's fuel costs are kept as low as possible. This system is tending to become the standard power generation system in large diesel ships.

In the case of automated ships, especially the MO type, continuous operation of the ships power source must be maintained and the quality of the power (constant voltage and frequency) must not change. When there are several operation modes of the generators as described above, it is desirable that the equipment be automated in order to prevent misoperation. Therefore, a generator control panel is provided in the main switch board and a large de-

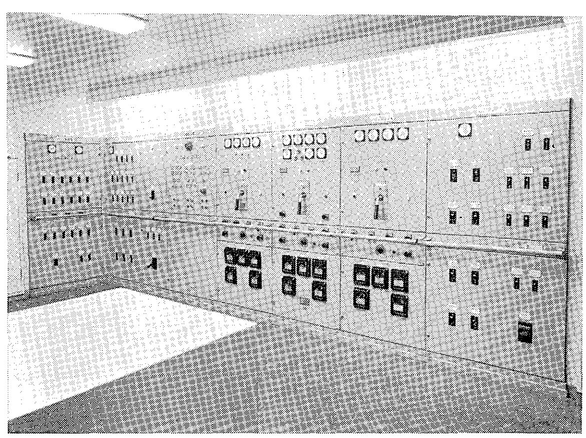

Fig. 11 Main switchboard

gree of power source automation is achieved by the use of an automatic paralleling device and a sequential start selecting system.

2. Main Switchboard and Power Source Automation Equipment

An outer view of the main switchboard is shown in *Fig 11*. This board is of the standing drip-proof dead-front type. From the right in the photograph are the No. 1 440 V power feeder panel, the No. 1 turbine generator panel, the No. 2 diesel generator panel, the No. 3 diesel generator panel, the generator control panel, the No. 2 440 V power feeder panel, the No. 3 power feeder panel and the 100 V power feeder panel. The main functions of these panels are as follows:

(1) Remote and automatic starting of diesel generators
(2) Priority starting selection and ballast pump control
(3) Automatic speed matching, automatic synchronizing and automatic load sharing
(4) Manual speed matching, manual synchronizing and manual load sharing
(5) Voltage regulation and initial excitation of generator
(6) Preference load cut-off system
(7) Generator protection in respect to overvoltages, overcurrents, etc.
(8) Measuring and indication of voltage, current, frequency and phase angle differences
(9) Operation and alarm indication
(10) Power supply to 440 V and 100 V loads in the ship and overcurrent protection

Of these functions, (1) and (3) are always employed in MO ships. They are attached in the generator control panel and are the main units in this ship for automation of the power sources. F-MATIC N elements are used in these units and they are completely contactless. There is complete interchangeability of parts with other automation units in the main engine remote control equipment, etc. and maintenance labor is saved and reliability is improved. These units have all been described before[1] and such descriptions will be omitted here.

V. MOTORS AND GROUP STARTERS

This equipment contains a total of 62 motors including one 300 kW upright type motor for the ballast pump. All of these motors are 400 V 60 Hz 3-phase squirrel cage type induction motors and motors with E class insulation which have already been used successfully in many ships.

Five motors over 100 kW and two over 50 kW are with compensating starters. All other motors are used for direct starting. As MO ships become popular, the trend is to use more and more group starting systems, and in this ship three group starters have been used for 18 auxiliary motors.

In MO ships, low voltage release system (LVR) is adopted for the most important auxiliary machine which makes possible automatic restarting after electric power have been recovered.

However, in this case, it is necessary to have priority starting of the auxiliary groups taking into consideration the capacities of the motors and generators and the importance of the auxiliary units so that the air breakers are not tripped by rush currents during restarting. Considerable attention has been paid to this point in this ship.

VI. CONCULUSION

In spite of their short history, MO ships have become exceedingly popular. In the future, there will be even higher level automation in ships and new possibilities in the development and expansion of automated and electrical equipment will be in demand.

The automation and electrical equipment delivered to the Fukukawa Maru was planned considering the abovementioned trends and complete success was achieved. For Fuji Electric, this was the initial step and the company is continuing to gain favorable results. In accordance with its strong research and development system, Fuji Electric is in a position to meet all trends in this field.

References:

(1) Niwa, Banba, Watanabe: Automatic Marine generating Plant Fuji Electric Review VOL, 17 No. 4 1971