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MAIN ELECTRICAL EQUIPMENT FOR PUMP DREDGER

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I. PREFACE

Dredgers...pump dredgers, dipper dredgers, grab dredgers, bucket dredgers, drug hopper dredgers and so on...play an important roll in improving harbours or canals and in reclaiming land. Among them pump dredgers are most widely used. The following article is concerned with the main electrical machines and apparatuses for them.

Motor operating pump dredgers whose main pumps were driven by motors supplied with the electrical source from the shore had chiefly been put into practice until a recent date. There were various difficulties for the purpose of complying with the formalities and laying a power cable wherever desired in a short period, which sometimes restricted dredging works, while from the economical view the extent of 2,000~7,000 PS pump power had been required. Most of new pump dredgers come to be equipped with diesel engines or turbines for dredging pumps. And at present it is the most generally adopted system that diesel or turbo generators are equipped to supply exclusively for the various use power and lighting.

Our Company in those days of the establishment imported the electric machines and apparatuses for main dredging pump from Siemens-Schuckert Werke, our technically cooperating company, and delivered them to the Musashimaru, a diesel electric pump dredger ordered by Toa Kowan Co. Since then we have manufactured many electric machines and apparatuses for dredging equipment.

This time our machines and apparatuses were set on the No. 2 Fuyomaru and the other five sister dredgers which are 4,000 PS gas turbine driven pump dredgers constructed by Nippon Kokan KK, and the Daishinmaru, a 2,000 PS diesel engine pump dredger ordered by Otani Heavy Industry Co. While those machines are operating with satisfactory results, we introduce the outline of them in the following publication for your reference.

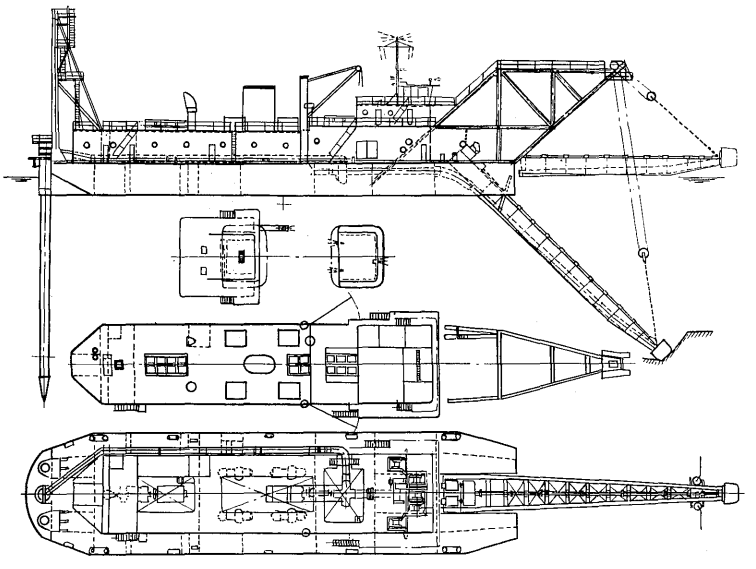

Fig. 1 General view of the pump dredger

II. OUTLINE OF MAIN MACHINES

It is wellknown as works of pump dredgers that dredging pumps suck sand and soil with water and carry them away in the distance of more than several hundred meters through draining pipe line. On the uppermost of *Fig. 1,* the ladder is shown slanting down to the right at the slope of about 45 degrees and what is like a cube at the top of the ladder is the cutter, and on the left hand the spud is drawn downward. Then we explain concisely the use of those machines.

1. Cutter

The cutter, fixed on the tip of the ladder and driven by cutter motors, digs sand and soil or breaks a rock, and let them suck effectively through the mouth of the main pump under the state that they are properly mixed with water.

2. Ladder Hoist

The ladder hoist is a machine which moves the

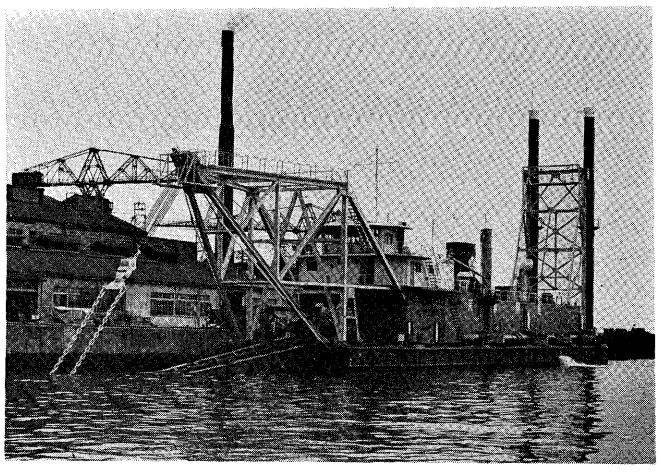

Fig. 2 The No. 2 Fuyomaru

ladder with a cutter on its tip, upward or downward to the convenient position for pump dredging. The position drawn with a dotted line on *Fig. 1* shows that the ladder is lifted by the hoist. And *Fig. 2* is the view of it sunk a little in the water.

3. Spud Winch

Generally, pump dredgers are equipped with two spuds. They act as the fulcrum cooperating with the swing winch, at the time of swinging. It is the spud winch that hoists up these spuds. *Fig. 1* shows that the lower end of the spuds is staked in the sand under water and the view of *Fig. 2* is that both spuds are shifted up from the water. Under the dredger's working, each spud is striken in mud by turns every half cycle of the swinging.

4. Swing Winch

In the lower of *Fig. 1,* two pulleies can be seen on each side of the ladder's end. Now, two anchors are thrown in the water in a distance of about 200 m from the both side of the ladder. Then, if the rope at the right side is wound by using the right pulley with the right spud staked in mud, the dredger will make turning to the right. And in this case, operating dredge pumps and the cutter at the same time, the dredger will dig out sand and soil or rocks to the right. Driving the same way it can be easily understood how to dredge the left side in water.

III. CONDITIONS OF MAIN ELECTRIC MACHINES FOR DREDGING

The electric machines for main supplementaries mentioned above have to be provided with the following conditions suitable for the uses.

1. Cutter Motor

1) Mechanically and electrically it should be sturdy.

Construction machines such as the power shovel or bulldozer in generally attackes against the hard ground or rock. So it is imaginable for us that the heavy fluctuation of load would be happend. And in the case of cutter, it is impossible to operate the cutter by watching by eyes just like in the case of construction machines on land because the cutter works digging the invisible ground under water. Whether, there were rocks or dangerous mine under water, the cutter goes on its appointed working.

As a matter of fact, an unfortunate accident were happened in 1958. When reclaiming land at Fukuoka harbour, the cutter of a dredger struck a mine that was laid in the last war and the dredger was destroyed to sink in the water. This means that we cannot recognize the state of ground under water until the cutter touch it.

As the cutter is fixed on the top of the cantilever type ladder when it is working, its transmitted vibration through the middle shaft and the ladder is very severe. However at present there is almost no authoritative data about this kind of vibration, so that we have practically measured the vibration of the main parts on several dredgers which were working in Yokohama harbour, Nagoya harbour and Sakai horbour securing the kind cooperation of Mizuno-Gumi KK. and Toa-Kowan Co.

2) It is required to be proof against Thrust of Rotary Mechanism.

The ladder is to be operated continuously with the slope of 30 to 45 degree. Therefore, we have to design it with great care so that it can be operated satisfactorily.

3) Special Cooling System has to be applied.

As it is set outdoors, sometimes it will be exposed to rain and wind, and sometimes it will be exposed to the spray seawater by storm. We must consider the cooling system against wet air and protect from damage caused by invaded seawater.

4) The Speed Detecting Device is Necessary for the Motor when Speed can be controlled freely.

Apparantly this depends upon the fact that we cannot watch the cutter speed in the water. But such a device is not needed when as the cutter motor we use squirrel cage type induction motor the speed of which is regarded as an constant speed.

2. Ladder Hoist Motor and Spud Winch Motor

There is no matter to be explained about these motors which are generally installed indoor. These have only to be fitted with magnetic brakes in order to be able to operate reversibly and stop the ladder or spud halfway.

3. Swing Winch Motor

This is also installed indoor and dredges up mud in cooperation with the cutter motor. But when the cutter motor has the characteristic of a constant

speed, we must control the winch motor speed very delicately for the purpose of carrying out the smooth dredging work.

IV. MAIN MACHINES FOR THE NO. 2 FUYOMARU AND OTHERS

The No. 2 Fuyomaru is a 4,000 PS gas turbine driven pump dredger built by Nippon Kokan KK. who concluded a technical contact with Elicott Co., the wellknown dredger builder in USA. Therefore it has a great meaning that we have ventured to adopt a direct current system motor for the cutter. Because of recent convention in our country and with fear of the vibration transmitted from the cutter, a direct current motor has never been adopted as a cutter motor. We here introduce about the main machines and apparatuses for one pump dredger manufactured by our Company.

1. Two Cutter Motors

1) Construction

Fig. 3 shows bird's eye view of two cutter motors installed on the ladder in parallel. They drive the cutter through the gear couplings.

As mentioned above, since the great vibration and shock of the cutter are transmitted to these motors, we paid attention to the commutation and other problems peculiar to the direct current machine. As for commutator segment, great care was taken in selecting the quality of material and figure. Besides in order that every segment and every mica sheet which forming commutator might not protrude beyond the commutator circle, we seasoned enough and manufactured mechanically fast. After that we under-cut the mica about 1 mm. Brush holder is the tandem type one which has two brushes side by side in the revolving direction. We designed its construction peculiar to our Company that the brushes might touch the comutator in uniform pressure when brushes were weared. As it has one brush in one brush holder usually but this time two brushes, and brushes becomes so small size and the mechanical inertia is reduced. So that brushes hardly chatter even if vibrations are so severe, and the action of the commutation does not become wrong.

On the other hand armature windings and equalizing windings have class B-insulation which mainly uses glass fiber, and mica as the material of the insulation. For the conductor insulation we adopted the system of fixing sheet roll mica by heating peculiar to our Company which has the characteristics of the vibration-and shock-proof. In its system, so called " roll mica " are wound several times around the conductor. Then it is heated and fastened by the special rotating heater, around the conductor and after that they are cooled and pressed by special tool, suitable for the armature slot figure. The outer construction of the motor is made by the rigidly welded steel sheet. Yoke can be divided into two parts up and down at the level of the motor shaft that we can effectively examine and repair the motor in an emergency. By the way as there is no protuberance in this upper half part, we can put it on the floor without the injury of field windings. Besides a elaborate lock of the mecanically jointed parts protects the motor against the constant vibration and shock of ladder. We made use of a cylindrical roller bearing for the driving side and made use of a compound angular contact type radial ball bearing for the brush side, and ball bearing can suffer the upward or downward thrust of the rotor. As it will be mentioned later, for the speed control of motors we adopted the Ward Leonard control system in which we can smoothly control cutter motors speed from zero to 900 rpm.

Then we cannot cool the motor by fans fit on motor shaft as the constant speed motor adopted,

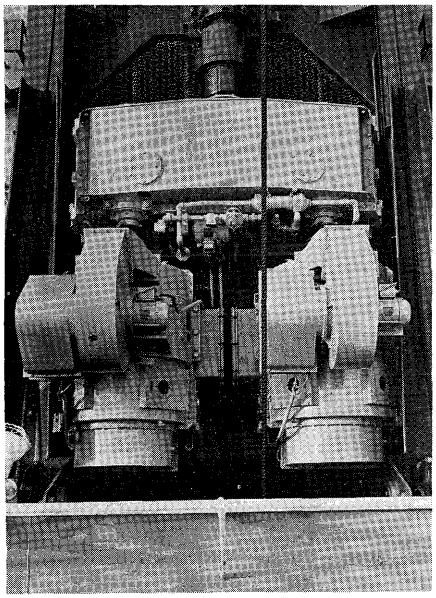

Fig. 3 Bird's eye view of two cutter motors on the No. 2 Fuyomaru

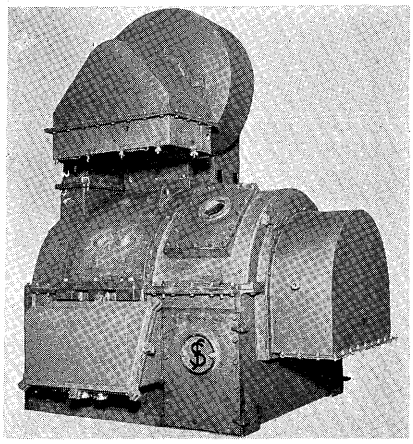

Fig. 4 Cutter motor

so we equipped a independent small-size motor driven cooling fan at the top of the cutter motor. A labyrinth system air filter is fit on the inlet of the cooling air and the cutter motors are protected against the effects of rain, snow and sea-water spray. The cooling air is lead into the anti-brush side space, it flows over the armature, field, commutator and brushes, cooling them and flow out through the air outlet. Thus the commutator and brushes are kept in good condition against the moisture condensation and the coil is protected against the adherence of the dust of the weared brush with moisture. However, since the outer air is inhaled into the motor we cannot avoid inhaling watery moisture into the motor and its condensing. So a drain cock is set at the lower side of the motor in order to draw off the condensed water at regular intervals.

The motor is fixed with the space heater in it, and the heater interlocked with the mains witch to prevent the deterioration of the insulated resistance at stand still. The motor is equipped with watertight doors at the inlet and outlet of the cooling air when the sea is so stormed, and cannot do the dredging work.

As mentioned above, this motor provides a wide speed range, but the operator is able to observe the meter speed in the driving room, the indication of which is transmitted from the tachometer dynamo installed in the motor's air outlet cover.

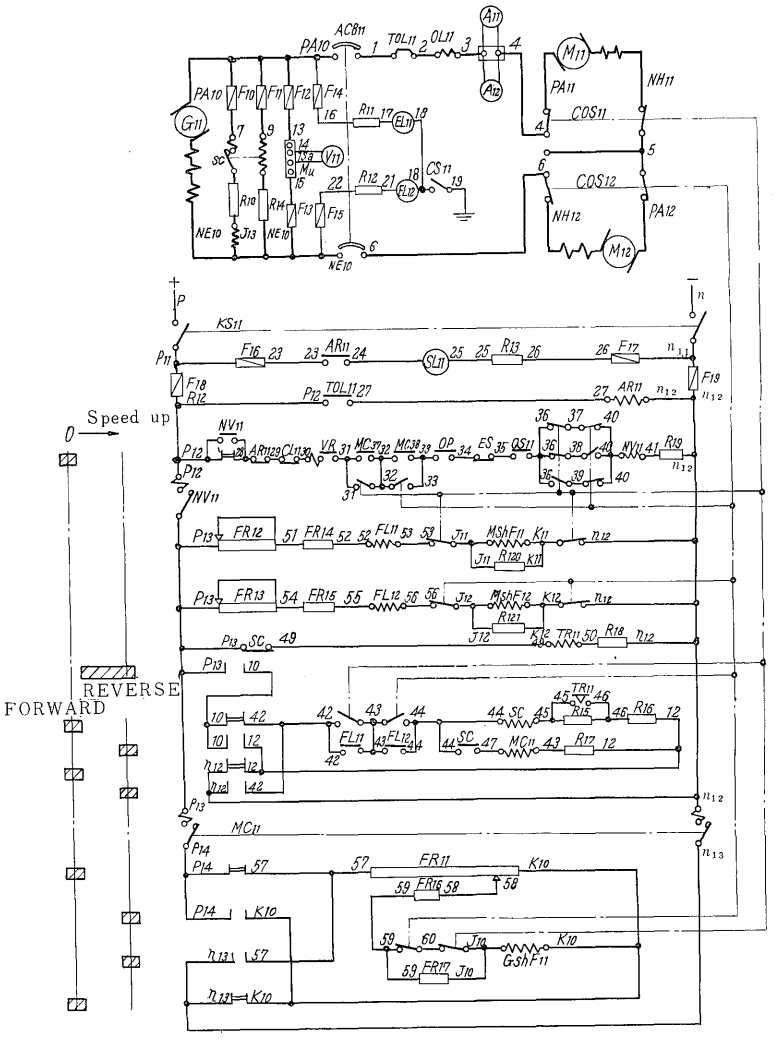

Fig. 5 Simplified connection diagram for cutter motors

2) Specification

As mentioned above, one set of the cutter has two motors. The specification is as follows :—

Outdoor use forced ventilated separately excited direct current motor,

VGM 324/28–16, 220 kw, 240 V, 1,000 A,
0～600 rpm constant torque control,
600～900 rpm constant output control,
150% load 15 minutes, 200% load 1 minute,
6 poles, B-class insulation,

Accessaries for each motor :—

One-motor driven cooling fan,
aVN 35+ORC 382–4,
0.9 m^3/sec, 80 mm/Aq, 1,750 rpm,
2 kW, 440 V, 60 c/s

3) Method of Control

Fig. 5 shows simplified connection diagram of governing circuit for cutter motors. As shown in the figure (*Fig. 3*) two cutter motors are connected in series with the main circuit of the generator.

The feature of the circuit is as follows :—

(1) When faults happen at one of two cutter motors and when the load is light, the other motor can drive the cutter by operating the change over switch (*COS*). Then a series resistance (*FR 17*) is connected with the circuit of generator's field coil (*GSh F*) and at this time the induced voltage of the generator becomes half.

(2) When we start the motor, it is necessary that oil pump has had enough oil pressure for supplying the bearing metal for intermediate shaft between the cutter and the cutter motors with oil (contact *OP*), a necessary voltage has supplied for the controlling bus bar (contact *VR*), doors for the inlet and outlet of the air has been opened and the motor driven cooling fan for the cutter motor has been started (contact *MC*), and the door of the controlling box has closed.

Under this condition if an operator operates the main handle, the operator can directly control the field regulator under the operating room.

When the handle of the master controller is operated from zero to 1 of its dial, the

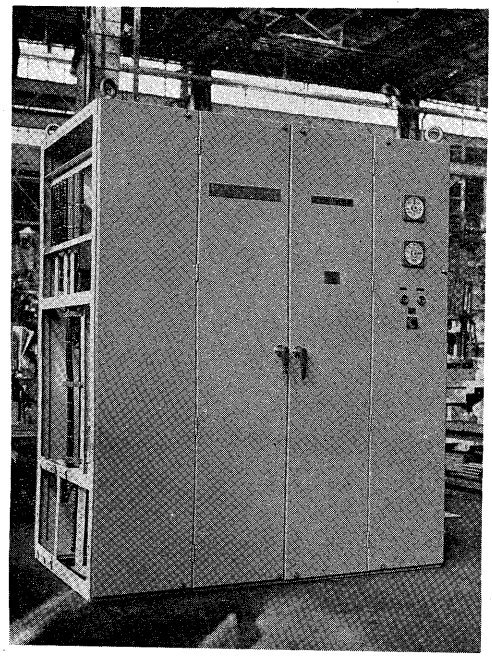

Fig. 6 Control panel for two cutter motors

field resistor of the generator (*FR 11*) is regulated and the generated voltage of the main circuit is finely changed from zero to 500 V. Then the speed of the motor is finely controlled from zero to 600 rpm at constant torque.

Moreover when handle is operated from 1 to 2 the field resistor of the motor (*FR 11* and *FR 12*) is minutely regulated and then its speed can be controlled from 600 to 900 rpm at constant output.

(3) When an operator wants to stop the motor, the main handle must be returned to the position zero of its dial, and its speed will decrease. Then when the voltage of the main circuit is reduced under 50 volts, special magnetic contactor (*SC*) closes its contact " SC " and as a result the current flows over the demagnetizing coil (*J 13*) of the generator, so as to put out the residual voltage. Thus the motor stops rapidly.

(4) The following protective devices have been furnished. As mentioned above the load fluctuation of the cutter is so severe that even if the master controller is settled to let 100% current flow at steady condition, but the actual current will be fluctuates from 100 to 200%. Therefore we designed the motors and this generator in order that 150% current can continue to flow for 15 minutes and 200% current for 1 minute. Moreover motors and generator are equipped with the following protective devices—overcurrent relay (*OL 11*) which trips instantaneously by 250% current of the rated current, thermal type overcurrent relay

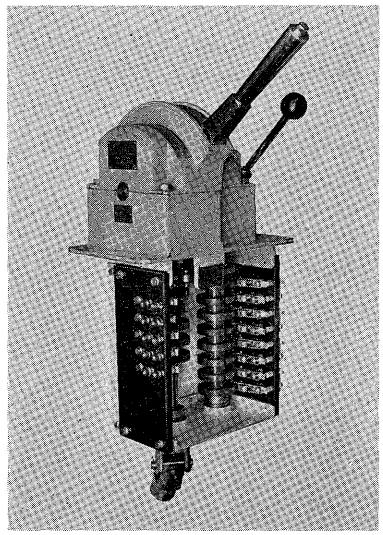

Fig. 7 Master controller for cutter motors

(*TOL 11*) which trips in 15 minutes by 150% current or in 56 seconds by 200% current, and air circuit breaker which instantaneously cuts the main circuit by 300% current. In addition to this we equipped with a disconnecting switch of the field circuit (FL) of generator, this switch protects the motor against the overspeed when the field current of cutter motor is interrupted by the faults. If the main handle is not returned into the position zero in dial, an operator cannot change the auxiliary handle into " forward rotation " or " reverse rotation " because of its mechanical interlock. Excepting this if a fault happens under the above-mentioned condition at the position (2), these equipments will be naturally interrupted its function.

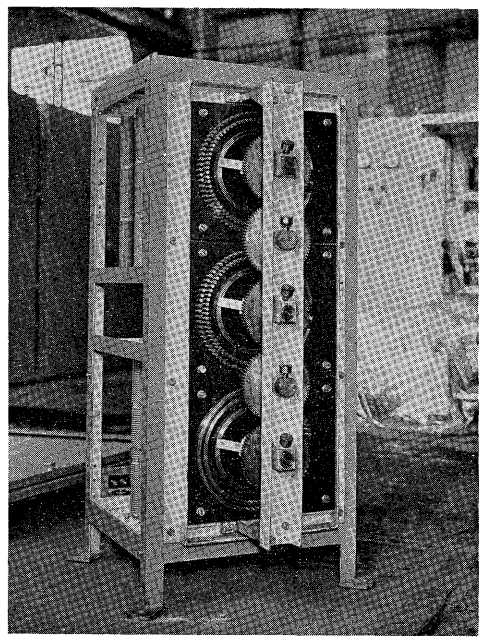

Fig. 8 Field regulator for cutter motors

2. One Winch Motor

The winch of this dredger has three drums for swing, ladder hoist and spud hoist. This which, therefore, requires a small-size alternating current motor for an emergency.

1) Construction of Main Motor

Fig. 9 shows the general view of the main winch motor. In contrast with the cutter motor, this motor is installed indoor and its vibration is smaller. In spite of that we designed almost the same construction of the motor as that of the cutter motors. As for a marked point of difference it is given the construction of the motor is drip-proof and the ventilation system is simpler than of the cutter motor. Besidesthis motor is equipped with magnetic brake at the shaft end of the brush side because of being used for swing, ladder-hoist and spud-hoist.

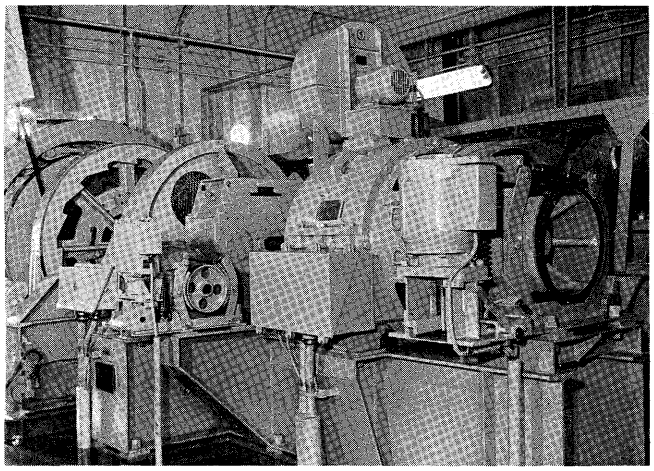

Fig. 9 Winch motor

2) Specification of Main Motor

Open drip-proof forced ventilated separately excited direct current motor,

VGM 304/24–6, 110 kW, 240 V, 505 A,
0～600 rpm constant torque control,
600～900 rpm constant output control,
120% load 2 hours, 200% load 1 minute,
6 poles, B–class insulation

Accessories :—

One-motor driven cooling fan,
NV 27.5+ORC 281–4,
0.55 m^3/sec, 40 mm Aq.
0.55 kW, 440 V, 60 c/s, 1,750 rpm.

One-magnetic brake,
RC 8021/DC 12,
200 kg–m, 220 V, direct current,
Continuous rating, 750 sw/hr

3) Control Method of Main Motor

Fig. 10 shows simplified connection diagram for winch motor. It can be seemed as the simplified control device for cutter motor.

4) Emergency Motor

This is utilized when troubles take place to above-mentioned main winch motor or its exclusive main machines and apparatuses. This is wound rotor type induction motor and is able to be driven by the source of following slip service alternator for the common use on board. In this case it is necessary

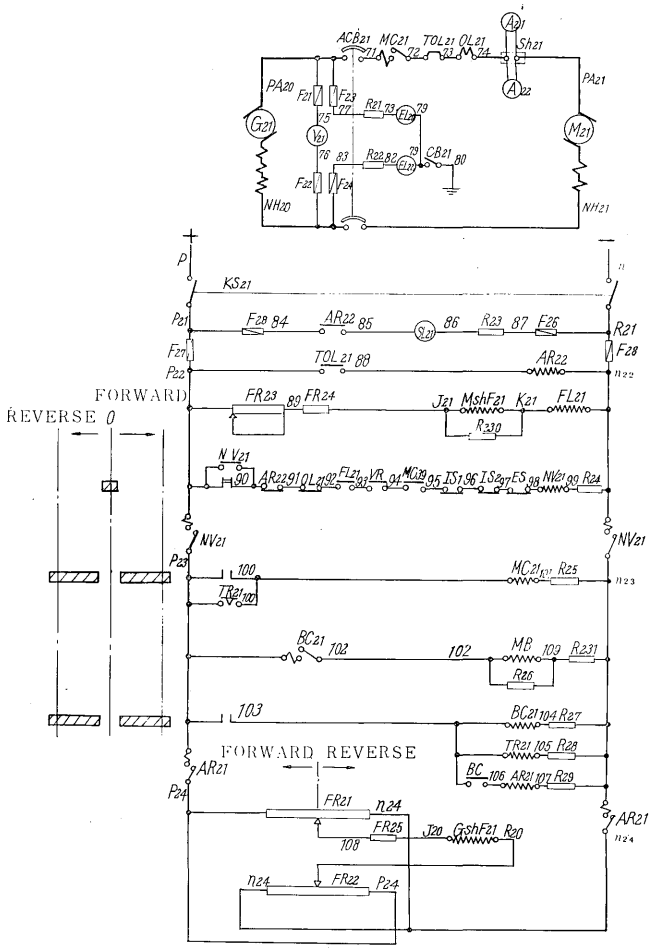

Fig. 10 Simplified connection diagram for winch motor

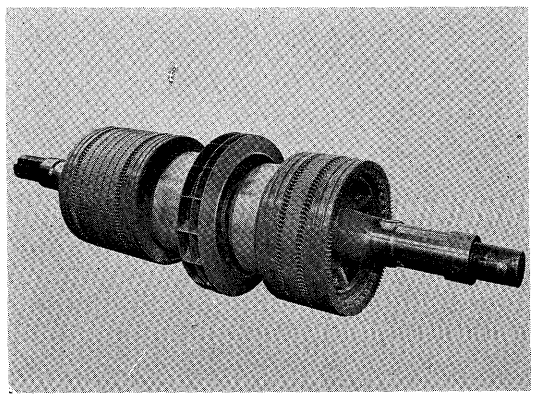

Fig. 11 Aarmature DC generator

to move gear beforehand emergency position by means of clutch.

Specification of emergency motor is shown as follows.

Open drip-proof wound rotor type induction motor,
hVRW 1371–6,
30 kW, 440 V, 60 c/s, 1,150 rpm
Accessories :
One-magnet brake, RC 8021 20/2,
36 kg–m, 40% ED, 120 sw/hr, 440 V, 60 c/s

3. One Set of Direct Current Generator for Cutter Motors and Main Winch Motor

Each of above-mentioned cutter motors and main winch motor provides exclusively direct current generator respectively. These armatures are arranged in tandem on the common shaft both end of which are supported by two pedestal bearings. As shown in *Fig. 12,* its outer view is compact form and commutator and brushes are concentrated to the center. Moreover cooling system is carried out by collecting air from both side of generator to the center and exhausting out, which protects armature against the dirt by brush wear dust and makes maintenance and inspection of brushes easy. Outer frame can be divided into two parts for the purpose of maintenance in an emergency. We show the specification of this group of generators below.

1) Generator for Cutter

Open drip-proof separately excited shunt direct current generator,
aVGMD 351/35,
500 kW, 500 V, 1,000 A, 720 rpm
150% load 15 minutes, 200% load 1 minute,
8 poles, B–class insulation

2) Generator for Main Winch

Open drip-proof separately excited shunt direct current generator,
aVGM 351/8, 125 kW, 250 V, 500 A, 720 rpm,
125% load 2 hours, 200% load 1 minute,
8 poles, B–class insulation

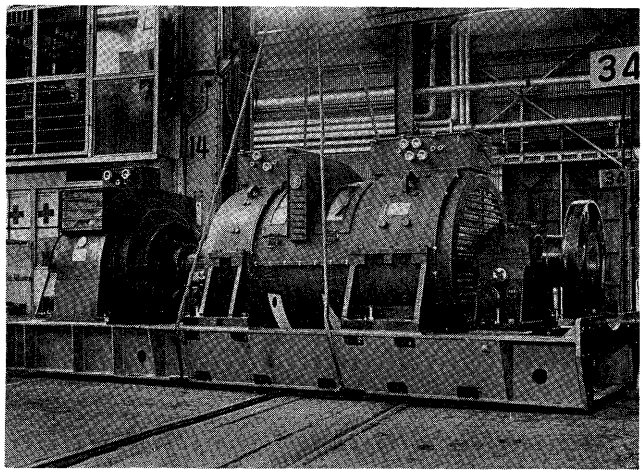

Fig. 12 DC and AC generators

4. Common Exciter Set

As the ship service power is alternating current, we prepared with motor-generator set as exciting source for various kinds of direct current machines and apparatuses. This specification is as follows.

(1) Open drip-proof direct current shunt generator,
VGM 145,
16 kW, 220 V, 72.7 A, 1,720 rpm,
4 poles, A-class insulation.

(2) Open drip-proof squirrel-cage type induction motor,
VRK 782–4,
20 kW, 440 V, 60 c/s, 1,740 rpm,
4 poles, A-class insulation.

5. Control Panel

Control panel for cutter, control panel for winch and auxiliary control panel for other miscellaneous circuit, are of enclosed drip-proof type, and are installed to be arranged side by side.

6. One Main Alternating Current Generator for Ship Service

Ship service generator is positively necessary for general power service and lightings. Main generator, as shown in *Fig. 12,* is coupled with above mentioned direct current generators on a common bed and is driven by diesel-engine. As for this alternating current generator we adopted self-excited compound type by which our Company had taken the initiative of other makers in munufacturing generator for the Nagaramaru ordered by Nihon Yusen KK. in 1958. The specification is as follows. Open drip-proof self excited compound alternator,
CVF 295/26–10,
250 kVA, 450 V, 60 c/s, 720 rpm,
power factor=80%, B-class insulation

The exciting apparatuses are built in switchboard. In addition to this we manufactured a 100 kVA self-excited compound alternator driven by a exclusive diesel engine as auxiliary power service.

V. MAIN MACHINES OF THE DAISHINMARU

The Daishinmaru was built by Osaka shipbuilding Co. Ltd. It is a 2,000 PS diesel pump dredger, and all of its machines are to be operated by the self excited alternator. *Fig. 13* shows its simplified network. And the specification and number of the main machines for the Daishinmaru is as follows.

1. One Main Generator

Open drip-proof self-excited compound alternator,
CVF 445/25–12,

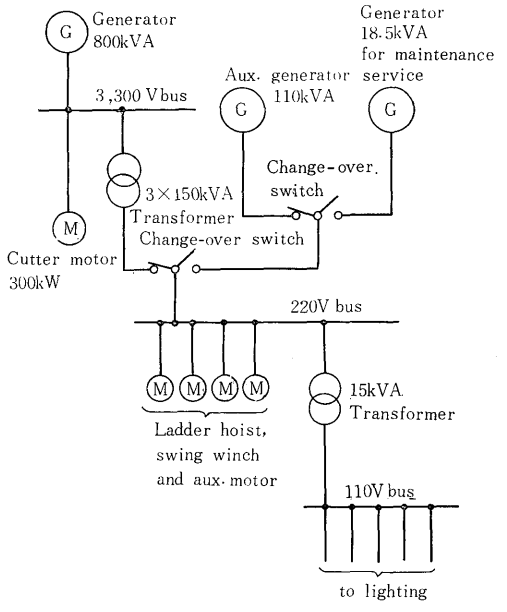

Fig. 13 **Network for the Daishin maru**

800 kVA, 3,300 V, 60 c/s, 600 rpm,
power factor=80%, A-class insulation

2. One Auxiliary Generator

Open drip-proof self-excited compound alternator
CVF 265/24–10,
110 kVA, 220 V, 60 c/s, 720 rpm,
power factor=80%,
A-class insulation

3. One Cutter Motor

A deep slot squirrel-cage rotor type induction motor is adopted as the cutter motor. A cage motor itself is simple and firm construction in the electrical and mechanical points, but we made this motor more firm in the specialty as a cutter motor. A large compound angular contact type radial ball bearing is used at non-driving side against the thrust of the rotor weight because of inclined operation. As for the cooling system of this motor, between the stator core and the steel-sheet outer shield many pipes were set and a large fan that is fixed on the shaft on non driving side, sends the cooling air through these pipes and exchanges the heat of the motor, so that no rain or spray of seawater might get into the motor. This structure need not a care of decrease of insulation resistance. Moreover, to make assurance double sure the drain cock is fitted on the under part of the driving side to prevent moisture may condensate by the action of breathing.

At starting the cutter motor, we took the way of reduced voltage method using the auto-transformer in order to reduce the starting current and consequently expect less fluctuation of source voltage and thus fortunately, at starting of cutter motor, it needs a small starting torque if an operator starts the motor at half way in water. Two steps of revolution i. e. 710 and 590 rpm can be choosen in accordance with the condition of dredging. And speed change is performable by changing the terminal connection in the terminal box. The load fluctuation of the cutter motor is so severe as we mentioned above that motor's maximum torque is more than 220 %.

The specification is as follows :—

Outdoor use totally enclosed pipe ventilated three phase pole changing cage rotor type induction motor,
ONRK 325/36–1210,
300 kW, 3,300 V, 60 c/s, 590/710 rpm,
A-class insulation

4. One Static Krämer Set for Swing Winch

On the contrary, in the case of the No. 2 Fuyomaru, the speed of this cutter motor cannot be changed according to conditions of circumstances. Therefore, it is necessary to make special devices for changing the speed of the swing winch. For instance, if the swing winch is to be operated at constant speed even when cutter meets with a rock, the cutter will advance just rolling over the rock and the dredge pump cannot play for the ordinary purpose issuing out only water like a ordinary pumps. So accurate speed controlling device is necessary for the effective work of dredging. Then the operator has to keep an eye on the vacuum gauge which shows the quantity of sand and soil. And when he finds in the gauge that a vacuum goes down, he should change the swinging speed to break a rock more slightly.

We adopted an induction motor as the mover of this swing winch because only alternating current is available in this boat. As for the speed control systems of squirrel-cage motors, there are the pole change system and the frequency control system. The former is the most general method and has been used for the many cases of deck auxiliaries on merchant ships. But its rush current when pole changed, brings a large fluctuation of source voltage, moreover speed steps are so wide and coarse for swing winch, even if we designed a motor more skilfully. The latter is the method of controlling the revolution by changing the frequency of its electric source. In this way, technically nonstep controlling is possible, but it is not practical to install a variable frequency generator with regard to the cost of equipment.

Consequently, we now came to employ a wound rotor type induction motor. With the speed control system of this motor, there are four kinds of methods—the most ordinary secondary resistance control system, the combination system with a commutator motor, the combination with a rotary converter, and the combination with a commutator frequency changer. The secondary resistance control

system is the way of the lowest initial cost. However, apart from the case of short time use such as that of crane, this system is not the best way for the swing winch because the heat loss of resistor would be very enormous in case of continuous service. While the other three methods do cost much more because of using at least two more DC motors except the main wound motor and at the same time the more wide space for those motors come to be necessary, though those make effective speed controlling possible. So they are not satisfactory too. Considering those matters carefully, we decided to take the static Krämer system. This system had been developed by using our excellent silicon rectifier, and its principle brought the same effect as in the case of supplying the secondary side of wound motor with AC voltage just equal to the ship frequency. *Fig. 14* shows its brief diagram. In general, when feeding

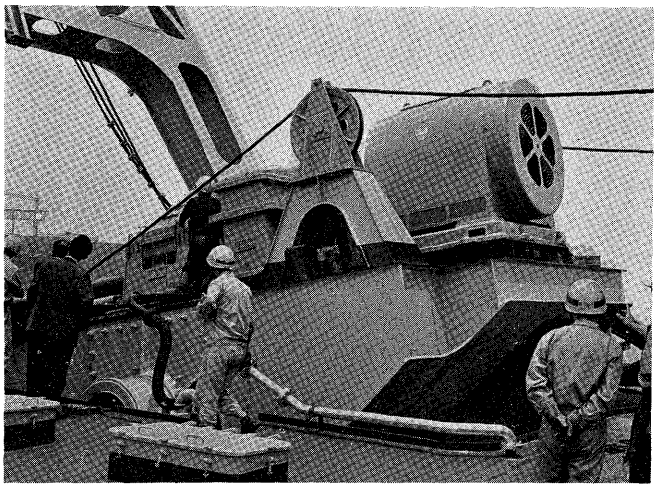

Fig. 14 Outdoor totally-enclosed fan-cooled AC motor for cutter

the slipring of wound motor with the voltage whose direction is just opposite to that of the voltage generated in the secondary winding, the speed will slow down according to the same principle as in the case of increasing secondary resistor. When operating the wound motor it is easy to control the direct current voltage by controlling the field regulator of the direct current machine. In this way, we succeeded in controlling the speed smoothly from 630 rpm to 360 rpm. This set is as follows:

One open drip-proof three phase wound rotor type induction motor,
VRW 1872–10,
55 kW, 220 V, 60 c/s, 700 rpm,
A-class insulation
and
one open drip-proof direct current machine
VGM 265,
25.2/0.9 kW, 168/33 V, 360/630 rpm,

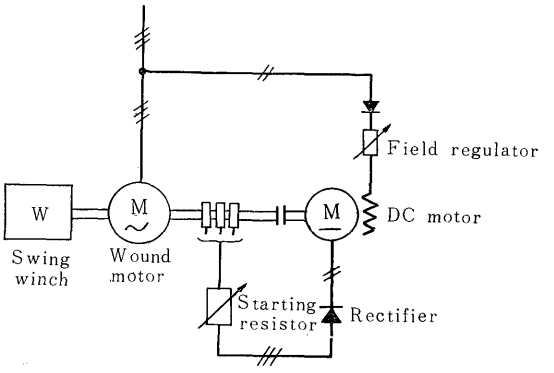

Fig. 15 Simplified connection diagram for static Krämer set for swing winch

A-class insulation
and drip proof control panel.

5. One Ladder Hoist Motor

The speed control system of this motor uses a general secondary resistance control system.

The specification is as follows:—

Open drip-proof three phase wound rotor type induction motor,
hVRW 1872–10,
75 kW, 440 V, 60 c/s, 720 rpm, 30 min. rating,
A-class insulation

6. Two Spud Hoist Motors

Ditto but hVRW 1871–10, 55 kW.

7. Three Power Transformers

Oil immersed self cooled single phase transformer,
150 kVA, 60 c/s
Input side: 3.45–3.3 (rating)–3.15–3.0–2.85 kV
Output side: 220 V.

8. One Main Switchboard

This switchboard consists of 800 kVA high voltage generator panel, 300 kW high voltage cutter motor starting panel, 3 × 150 kVA transformer panels, 110 kVA low voltage generator panel and low voltage feeder panel. It is measured 5,400 mm wide, 2,350 mm height, 1,800 mm depth and is very deluxe switchboard for this kind of dredger.

VI. CONCLUSION

Recently the ratio of sand and water to be sucked up which shows the efficiency of pump dredging becomes larger and larger and it varies according to the state of dredging grounds. Our Company will continue to research and, further, to improve the sand-water suction ratio and to develop an automatic control of dredging into a higher condition for greater efficiency.