automatically switched over to DC operation by storage battery in the event the AC power source is stopped, continuing to furnish a supply of oil to the unit until the converter stops.

VIII. CONCLUSIONS

Thus we close our introductory notes on this set. This electrical mechanism represents the aggregate of our Company's technical achievements in various fields, and we are of firm belief that the above results were obtained only by the close cooperation of each and all of the designing and test sections and plants which participated. This set was immediately disassembled after factory tests, and two of the main motor armatures, fly-wheel and the intermediate shaft bearing bridge which exceeded the limits imposed by rolling stock were delivered by ship, and the remainder by overland transportation to the client, the Chiba Iron Refinery. It is now undergoing installation there, and when it commences operation this August it will be a testing stone for twin drive mills in our country. Undoubtedly, it will contribute greatly to the development of our steel industry.

The rolling manufacturer in this case is the UE Co. (United Engineering & Foundry Co.) of the United States, with our Company supplying the main drive electrical apparatus. Technicians and engineers were dispatched by our Company to hold technical consultations with the UE Co. staff, and today with a perfect organic and synthetic installation completed, we wish to express our heartfelt gratitude to Mr. J. H. Taylor and the many other members of the UE Co.'s technical staff who most willingly shared with us at that time many of their invaluable opinions and ideas.

(30th, May 1944)

ON THE RECENT SMALL INDUCTION MOTORS

By

Yoshio Adachi (A. C. Mach. Div., Eng'g. Dep't.)

Kazuo Hikone (Industrial Div., Mie Works)

Synopsis

It is a great character that the latest induction motor being made small and light by application of new insulating materials and improvement of cooling method, on the other hand, special design have been developed according to several uses. In former, common type motors have been generally used for special purposes of each industries, but the most comfortable motors are designed and constructed recently, by connection between makers and customers. This tendency is seemed to be acceralated more and more in future. We describe special designs and application on small motors.

I. FOREWORD

New insulating materials and improvement in cooling methods have resulted in the latest induction motors becoming much smaller and lighter.

It is now only common sense to use PVF covered round wires for stator coils, and PVF covered flat wires are gradually coming to be used.

It is well-known that the insulation covering thickness of PVF covered wire are the same as enameled wire, thus improving the space factor of copper wire in the stator slot, making possible smaller dimension iron cores than when using double cotton covered wire.

Many new insulating materials and products with various trade names have made their appearance overseas, and it is now relatively simple to obtain these locally. For example, if one brand which is quite strong considering its thinnes, is used for slot insulation, the tendency towards smaller and lighter motors will be stimulated.

Hitherto, enclosed type motors were about the same size as open types, but our company's new type motor has improved cooling efficiency by using a powerful fan of larger outer dimensions, newly devised cooling wind channels, and as a result is 30-40% more light in weight than open types. With such new cooling method devised, enclosed ventilated type general purpose motors

much smaller than the former open types are now being produced. Electric characteristics and temperatures meet JIS requirements with ease.

Outside fan cooled motors with newly devised terminals and leg attachments, with rims all over the cover surface to obtain maximum cooling effects are now being designed. For large capacity outside fan cooled type motors, a large number of pipes are lined up inside the outer frame. The hot air from the inner of motor is blown on the pipes by an inside fan while the outer fan sends cool air into the pipes, the whole being based on an effective transfer of heat. Compared with the former rim types, this type is 20–30% lighter in weight.

Thus the recent trend towards smaller and lighter induction motors has been making much headway, and in the past few years, induction motors have undergone great changes. Hitherto, ordinary, general use motors have been applied to many specific uses in various fields of industry, but as of late, by keeping close and constant contact with the clients, special electric motors are being designed and produced which are best suited to the purpose it is to serve. As we are convinced that this tendency will continue to develop, we wish to introduce some aspects of this tendency for your general information.

II. SUBMERSIBLE TYPE MOTORS

Underground water supplies are tapped by means of wells at various plants and mines where an abundant industrial water supply is necessary. Deep well pumps are used often for building water supplies, and also for draining mines and construction sites.

Until now these pumps were submerged with the motor operating on the ground with a long intermediate shaft connecting the two, and the whole being operated from a pump room on the ground. Using this type of motor, bearings must be placed at every one or two meter intervals, and if the well was deep, the number of bearings would be multiplied. If oil was used for lubricating the bearings, lubricating arrangements would be necessary. Because of this long intermediate shaft, the utmost care would be required in assembling and installing it, not to speak of the shortcoming of a very great construction cost.

In order to remove the above defects and pump up water more efficiently, the pump and motor should be directly connected and both placed underwater, with the water being pumped by the pump situated above the motor. For this, a submerged motor is necessary. Although the dimensions of the well causes some difference, motors up to 75 HP output are totally submerged, using the totally submerged type motor. Figure 1 shows an example of this type and is a 20 HP submerged type motor. The motor bearings are water lubricated and capable of the load, and absolutely water proof special insulated wire is used for the stator coil. Special consideration has been given to protecting the iron core, shaft, and stator frame from rust. The system wherein compressed air is delivered inside from a pipe on the ground when the motor output exceeds 75 HP has been adopted. The cooling effects of these motors are quite satisfactory. Due to the water circulating outside of the motor, making possible the use of a smaller iron core.

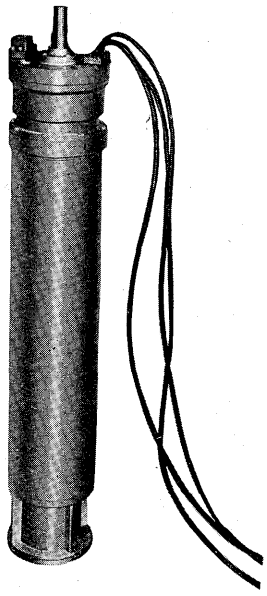

Fig. 1. Submersible type Induction Motor.

The lack of intermediate shafts reduces cost, and the minimum time and labor required for its installation is a further advantage. It is thought that this type of motor will be used widely, replacing the old deep well type pumps.

III NEW CONTROL SYSTEM FOR CRANE MOTORS

It is preferable to use a DC motor with Leonard control for cranes and other similar load equipment, but the high cost of installation prevents its use on every occasion. A simpler method is to use a wound rotor type induction motor with secondary resistance speed control for lifting, controlling speed when lowering through single phase control by changing connections of the stator coil. However, a shortcoming of this particular method was the difficulty of obtaining low speeds when lowering heavy loads or lifting light loads. To overcome this difficulty, an asynchronous frequency changer was used, connecting the motor stator at the first lift notch and first lowering notch of the controls to the low frequency circuit of approximately f/10 c/s, and not to the power source circuit commercial frequency of f c/s, thus enabling the motor to operate at the low speed of about 10% of the synchronous speed.

The asynchronous frequency changer resembles the wound rotor type induction motor in its elec-

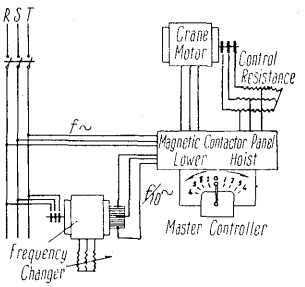

Fig. 2. New Control System of Crane Service Motor.

tric and mechanical structure, but has an extra commutator which is connected to the rotor coil for changing frequencies. The power source is connected to the rotor coil after passing through this slip ring, the secondary coil being the stator coil.

The AC frequency appearing on the commutator side can be adjusted within narrow limits by inserting resistors into the stator coil in proportion to the slip frequency. The capacity of the frequency changer for the lifting motor may be small, about 1/10. At the first lifting notch, the motor is fed power by the frequency changer generating a starting torque of about 70% of the rated torque. At the second notch, the motor is directly connected to the power source circuit, and the suitable speed is obtained by means of a control resistor. Because the control curve is smooth, in order to stop the load, it is reversed to the first notch. The load will almost be in a suspended state if a full load, and will be lifted slowly if light. If it is reversed to the 0 notch, the brake is activated immediately.

At the first notch for lowering, the motor is connected to the lowering side of the frequency changer, obtaining a smooth control curve having no actual connection with the load. It is quite easy to make the speed to be 12%~20% of the synchronous speed when lowering with full load. At the second lowering notch, resistors are inserted into the motor rotor to obtain greater slip,

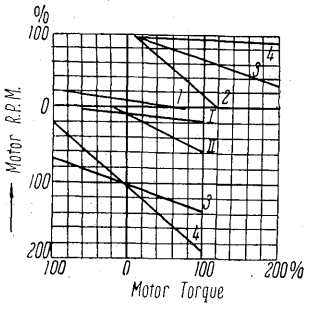

Fig. 3. Characteristic Curve of Crane Service Motor at New Control System.

making possible intermediate speeds with medium or heavy loads. At the third or fourth lowering notch, the motor is directly connected with the lowering side of the power source circuit. If it is returned to notch 1 from any notch above the synchronous speed, it is braked immediately to lowering curve II and is switched to lowering curve I after a certain period of time. When returned to the 0 notch, the brakes will immediately start working.

The DC control method, two motor method and Creep Speeder method are used for crane motor control, but it is thought that the above mentioned new method surpasses all these by far.

IV. MOTOR PULLEY

At coal mines, in and out of mine pits, and for general conveying purposes, motor pulleys are put in use in various ways. However, those hitherto could not be said to be quite satisfactory because of breakdowns, lack of durability, oil leakage and difficulty of dismantling and repair.

As a result of joint research with the Seiki Kogyosho, we have completed a standard 2~10 HP model which does away with all these faults.

Hitherto, most motor pulleys had fixed shafts with a rotating outside frame, but our Company adopted the system whereby the outside frame is fixed and the shaft rotates. By using this system, electrical characteristics improve and the balance of the rotating body becomes highly accurate, cutting vibration to a minimum. Installation is quite simple requiring only that both shaft ends which are pressed into the fixed sides be supported. The cable extends outside of the shaft tip making its handling very convenient.

A totally enclosed outside fan type motor is used with special consideration given to rise in temperature. As it is designed especially for high revolution power, it can well withstand voltage fall and overloading.

The ordinary type, explosion proof safety type, or explosion proof pressure resisting type motor is used depending on the location where it will

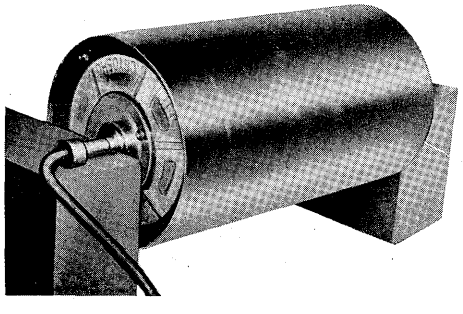

Fig. 4. Outer View of Motor Pulley.

be put in use. Our Company's explosion proof pulley motor is based on JIS C 0901 "Explosion proof construction of electrical machines for coal mines" and is fully resistant to internal motor explosions, caveins and other extraordinary outside pressure and rigorous use. A grand clamp is attached at the cable exit preventing its exposure and also damage to the cable. Furthermore, portable conveyors are being used in warehouses, and we are manufacturing pulley motors of less than 1 HP for this purpose. Structurally speaking, there is not much difference from those of over 2 HP and as the motor pulley weight is less than 30 kg, it has proved quite popular.

V. HIGH RESISTANCE CAGE ROTOR TYPE MOTORS

For iron refineries and other plants where high starting torque and high slip characteristics were necessary, the method of inserting secondary resistors in wound type motors have been used hitherto. However, as wound type motors use slip rings and brushes they are inferior regarding maintenance and handling when compared with cage rotor type motors, which are structurally simple and highly reliable.

In the case of totally enclosed motors, the rotor resistance must be increased in order to obtain high torque and high slip characteristics. Among the losses that arise in the motor, although the heat generated by the stator coil and iron core are cooled directly by the contact of outside air on the stator frame, the large amount of heat generated by the rotor can only be cooled through air gap or the bearing parts, resulting in an easily heated motor. This causes it to be much larger in size than an all-purpose motor with the same output, making it difficult to fully realize the characteristics of a cage rotor type motor. The high resistance cage rotor type motor with specially constructed rotor has been designed for obtaining high starting torque and high slip chracteristics with a cage rotor type motor. The heat loss is for the most part generated by the high resistance loop, connecting with the extended cage rotor bar. Very effective cooling is performed by having the high resistance parts act as a fan, reducing the temperature of the entire motor. The inside coils have been totally enclosed by a shielding plate, making possible a small, light, totally enclosed motor. The tilting table motor delivered to the Kawasaki Iron Refinery is one example, and this has gained satisfactory results, enduring frequent repetition of starting and stopping operations.

Our Company has further made progress along this line, and a motor of new structure is now being designed and produced. Not only for iron refineries, but a wide field of use where high slip characteristics are required is anticipated for tiis motor.

VI. CORROSION PROOF TYPE MOTORS

Ordinary standard type motors devoid of any special consideration for their specific uses have been used hitherto at chemical plants and other places where corrosive chemicals and gases are handled. Because of this, the motor's outer cover, cooling fan, bearings and grease have been damaged by chemical fluids and gases, necessitating frequent overhauls and repairs. This shortens the life of motors, and the loss in production due to frequent stops of machinery becomes a major problem.

The corrosion proof type motor was produced to overcome these defects, its cover being made as smooth and level as possible to prevent chemical fluid deposits from forming on it. The most durable anti- acid, alkali paint has been high temperature baked on to prevent corrosion. In order to prevent corrosion of the bolts used in the various parts, their heads are completely buried and filled in with a special compound stopping bolt head corrosion from making motor overhaul impossible. Fitting parts, shaft penetration parts,

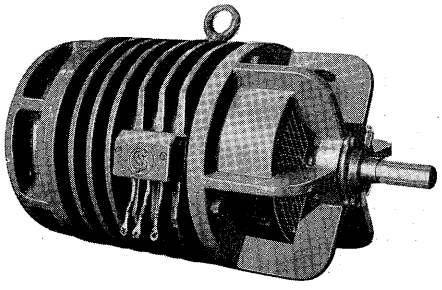

Fig. 5. Cage Rotor type, Tilting Table Motor with Special Rotor Construction.

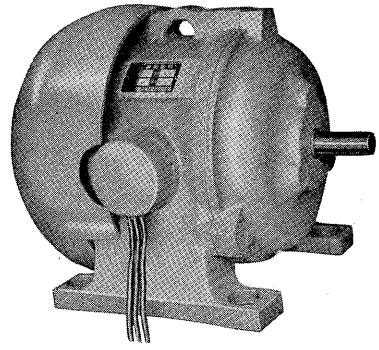

Fig. 6. Totally Enclosed Fan-cooled type Corrosion-proof Motor.

terminal extraction openings etc have been effectively and adequately treated to stop corrosive chemical fluids from entering inside the motor. Ample consideration has been given to the internal structure, such as the fan being special constructed of corrosion proof alloys, and corrosion proof paint baked on the rotor surface. Many other features combating corrosion are introduced in this motor. Many such excellent corrosion proof motors have been already manufactured, delivered, and are operating with excellent results. The role they will play in the chemical industry in the future should be a major one.

VII. SYNCHRONISED OPERATION OF COMBING CARD MOTORS

In operating eight or nine combing cards in parallel and winding the sliver from them on one balling head, a cage rotor type motor is generally used with each card, starting and stopping without relation to the others.

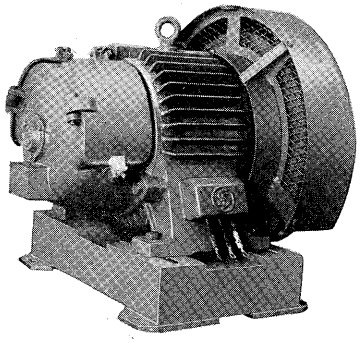

Fig. 7. Balling Head Motor with Flywheel.

In this case, as in the double or triple card operation in wool spinning, the synchronized operating method using our original wound type motor has been adopted. Several of these sets have already been delivered to the Kanegafuchi Textile Mills, Kanematsu Wool, Daishin Textile Mills, Kureha Textile Mills plants, obtaining fine results. By this method not only each card, but the balling head is run at the same speed, being started and stopped simultaneously. This eliminates entirely sliver scrap when starting or stopping thereby promoting efficiency. While in operation, each machine is run at the same speed resulting in uniform and better quality product. It is started very gently without the shock which is felt when using cage rotor type motors, and a characteristic of this method is that it does not put a strain on the mechines. Controlling the operation of this method is extremely simple and easy. Synchronized starting and stopping is performed smoothly and accurately by operating the controller handle. The method of operation has been improved recently making possible by switching either single or multiple operation. This makes possible disconnection of one machine from any group for blade sharpening or repair, and prevents unsynchronization when a machine being operated by itself is connected and synchronized with the others.

A 5 HP, 8-pole motor is used for the card, and a 3/4 or 1/2 HP, 8-pole motor for the balling head. The only load on the balling head is the friction resistance, and a flywheel is attached to the motor so that it can perform starting and stopping operations in synchronization with cards having a large GD^2.

VIII. SPINNING MOTORS

Direct starting and clutch starting systems are used in operating loom motors. The latter does not require a large starting torque, and having the advantage of a more compact construction, this system has gradually been adopted for more and more looms.

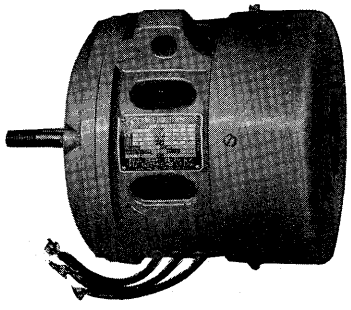

Fig. 8. Loom Motor with Flywheel (0.4 kW 6 pole)

Because of its structure, loom operation constantly requires sudden changes in the necessary torque. By flywheel effects, a larger peak load can be smoothened, reducing the required volume of power. The starting time is very short with the clutch system, as the flywheel can be attached to the motor itself, thereby smoothening operation and improving electrical characteristics. Our Company has been supplying various loom makers with flywheel attached motors for the past five years, and they have been very favorably received.

A point requiring special consideration for spinning motors is prevention of dust. For dust-proof construction, it must be totally enclosed so that cotton dust suspended in air cannot enter the motor, or it must be an extremely open type (ultra-open type motor) enabling simple cleaning of the dust attached to the motor without dismantling it. Another method is to construct a ventilation channel under the floor by which cooling air is sucked in for the motor, which is discharged through another channel, barring the

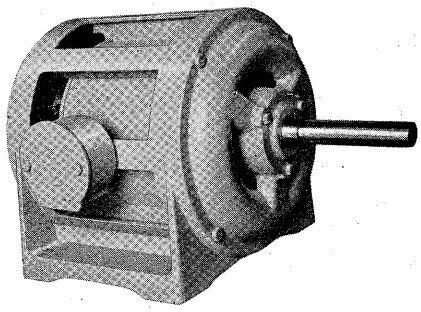

Fig. 9. 10 HP Skeleton type Ring Motor.

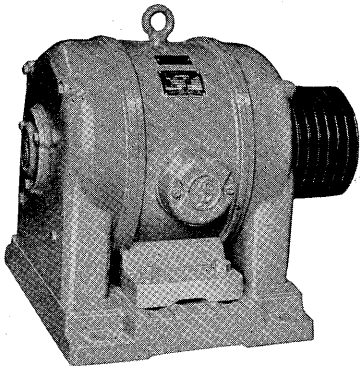

Fig. 10. Duct type Ring Motor.

room air from entering into the motor. Our Company has named the ultra-open type motor the skeleton motor, and the motor with underground ventilation channels the duct type motor. Fig. 9 shows a 10 HP skeleton type motor and Fig. 11 a 10 HP duct type ring motor. The excellent cooling effects of a skeleton type motor result in a high efficiency motor. The duct type motor has proved very popular not only because of its dust proof construction, but because room temperature is not affected by its discharge.

An interesting application of motors to textile industry in the drying fan motor. As the motor is exposed to a hot drying air of 120 degrees Centigrade in this case, much damage has been sustained by the bearings on the operating side causing maintenance difficulties for the user. By using silicon grease for the bearings on the operating side and installing an interior fan on the operating side with special designing to cool the bearing parts as much as possible, the motor proper can now be operated without breakdowns, and with the A type insulation intact. Many of these motors have been supplied to the Takada Iron Works, Daido Wool Spinning, Nippon Wool Spinning Companies, with very great success.

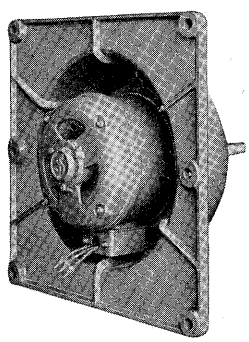

Fig. 11. Special type Fan Motor for Hot Air.

IX. TOOL MACHINE MOTORS

There are many kinds of tool machines, such as the all purpose machine and the specialized machines. To a large extent electric controls have been applied to the mechanism, and for some special machines, the system wherein the motor itself forms the main part has been adopted. Motors are been applied to wider uses more and more.

Among those recently manufactured by our Company, the 2-pole motor to be used for the main shaft of a full back cutter supplied to the Toyoda Koki Co., can be taken as an example. A polishing stone is directly attached to the motor shaft, and is used as a main shaft for the polishing machine. The accuracy of the motor itself is the accuracy of the machine. This required a high accuracy of the movement toward the motor shaft direction of 5 μ, and a radius direction movement of 10 μ.

For this we used two angular contact ball bearings for the operation side bearing structure, and by combining there back to back, a suitable preload was given the bearing.

Thus the above accuracy requirements were fully met. This high degree of efficiency was obtained while the temperature rise of the bearing parts was extremely low, which made this motor quite popular. Furthermore, the structure is so that the tightening part for the pre-load can be easily adjusted without affecting the other parts by removing the outside bearing cover to adapt

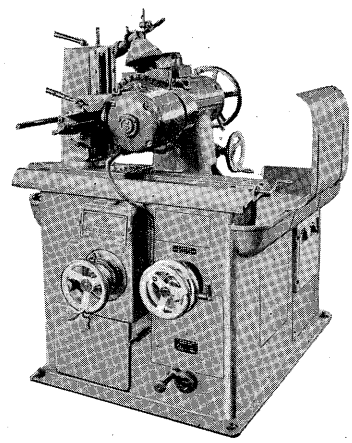

Fig. 12. Special Grinder Motor.

itself to the changes in accuracy while in operation.

X. CONCLUSION

We have given an outline of small and medium capacity induction motors specially designed to meet their various uses. It is regretted that space does not allow us to touch on many others, such as the H grade motors using silicon resin, motors with cone shaped rotors, speed control of cage type motors by magnetic coupling, totally enclosed water cooled type motors which cool the rotor centers with water. There are many other fields remaining in which induction motors may be specifically applied, and we hope that with the kind cooperation and understanding of our clients, we can further the rational use of electric motors.

30,000 kVA A. C. GENERATOR AND WATER TURBINE PRODUCED FOR UTSUBO POWER STATION, KANSAI ELECTRIC POWER CO., LTD., JAPAN

Part 1.—30,000 kVA Umbrella Type A. C. Generator

By

Yoshio Adachi

(A. C. Machine Div., Eng'g. Dep't.)

Synopsis

The umbrella type water turbine generator delivered to Utsubo power station, Kansai Electric Power Co., output being 30,000 kVA, speed 200 R. P. M. is the machine near to the manufacturing limit of umbrella type generator from the relation between output and speeed ; in this respect we may say the machine is the record of product. Since received the order, we devoted ourselves to design and manufacture, gathering all our technics, thus the machine has many such feature that we utilize "Gitter winding" for stator winding, the dimension of the thrust bearing is determined by fully considering the stability of rotor, we used thick steel plates for rotor yoke in order to increase the mechanical strength etc.

Having finished recently and being under installation of it, we report the outline of the machine construction and test result in our factory.

I. INTRODUCTION

The umbrella type water turbine generator deliver to Utsubo Power Station, Kansai Electric Power Co. is directly coupled with a 27,000 kW Francis water turbine, such as hereinafter described, output being 30,000 kVA, and speed 200 R. P. M. Referring to the world-wide examples of water turbine generators, a definite relationship between output and R. P. M. is respectively observed both for ordinary type and umbrella type, as shown in Fig. 1. The present generator attains almost to the limit of manufacturing possibility, and in this respect, we may say it is the record of the umbrella type generator.

Since having received the order, last spring, we devoted ourselves to design and manufacture, gathering all our technics, and having finished recently with satisfactory results of factory tests, and being now under installation, we report the outline of the machine for your reference.

II. OUTLINE OF GENERATOR

As wellknown to the art, the umbrella type A.C. generator has its thrust and guide bearings under the rotor spider, its upper guide bearing being dispensed with. For the reason that the thrust bearing and the guide bearing must be located as nearly as possible to the centre of gravity of the rotor its for stability, the rotor spider has, in