KOEPE SYSTEM WINDER DELIVERED TO SUMITOMO COAL MINING CO., LTD.'S HONBETSU VERTICAL SHAFT

By

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I. INTRODUCTION

We are now manufacturing the winding equipments for vertical shafts, under a technical cooperation agreement with Demag A. G. and Siemens Schuckertwerke A. G., Germany. It is our sincere desire to introduce here, the Koepe system winder, which was recently delivered by us, to Sumitomo Coal Mining Co., Ltd. It is the recording winder ever to be completed in Japan, as described in detail here.

1) This is the first time, in Japan, the double rope system winder was constructed.

A tendecy in the winding equipment for the main vertical shaft is the enlargement in size, as the result of the increase of the winding depth due to the development of mining and the increase of the winding capacity due to the centralization of transportation.

In the large winder, the multi-rope system has been found to be more economical, compared to the conventional single-rope system. This is the first case, in Japan, where equipment, using the double rope system, for vertical shaft was completed.

2) In Japan, this is the largest AC winder with a reduction gear.

Up to now, the direct coupled DC winder has been used with a main motor having a capacity around 1,540 kW, in Japan. Recently in view of the rapid progress in the various techniques, it is now economically possible to adopt AC winder with a reduction gear. Not only is this winder the largest of its kind in Japan, but it also holds a leading position in the world of mining.

3) The first 6 kV AC winder.

Recently, in Japan, there is a marked tendency for higher voltage, by applying 6 kV instead of 3 kV. Compelled by this tendency, this winder was built to adopt 6 kV in view of its large capacity. Up to now, a frequent reversing operation such as in winders has never been applied to a 6 kV power supply. Plans are now under discussion by our Company on the possibility of developing a 6 kV high voltage magnetic contactor.

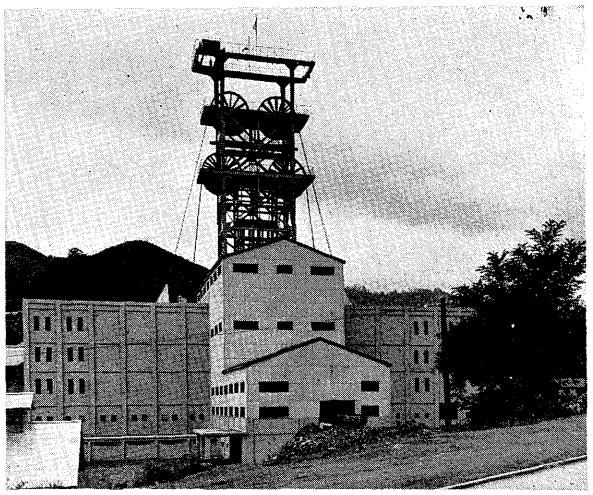


Fig. 1. General view of Honbetsu vertical shaft

4) It is manually operated by low frequency control with an automatic retardation device.

In order to obtain the operation characteristics equivalent to a DC winder, the low frequency control system was adopted. Consideration is now being given on the possibility of a new control circuit, depending on the results obtained from experience, heretofore. Accordingly, though this is manual operation system, the operation characteristics are equivalent to a DC winder, essentially, because it has a constant torque acceleration, an automatic constant deceleration and a continuous low speed.

II. OUTLINE ON THIS EQUIPMENT

Honbetsu vertical shaft is a air inducing and transportation shaft having a diameter of 6.4 m and is equipped with skip and cage winding. This cage winding equipment is used in transporting men, hoisting mine waste, transporting materials and also for hoisting supplementary coal. Each cage has four decks. Each deck is capable of loading sixteen persons or a 2 m^3 coal car. This pit-head is located 80 meters above sea-level, and the pit-bottom is 550 meters below sea-level (at 340 meters below sea-

level, there is a mid-gallery). In future, the pit-bottom will be developed at 760 meters, 970 meters, and finally 1,180 meters below sea-level. At the top and bottom of the pit, there are each one stage platform for loading cars and also each two stage platforms for loading men. The winder, which has a rating suitable to the final winding depth, is a double rope system narrow type Koepe winder installed ground and is driven by a wound rotor type three phase induction motor through a reduction gear. This is manually operated by means of low frequency control with a automatic retardation device. The data of this cage winding equipment are described as shown in Table 1.

Table 1. Operation data for cage winding equipment of Honbetsu vertical shaft

Time	Initial	Final
Winding depth	645 m	1,275 m
Net load		
men 64 persons	4,160 kg	
mine waste 3 cars	9,000 kg	
coal 4 cars	8,000 kg	
Winding speed	12 m/s	
Net winding time	67.2 s/cycle	120 s/cycle
Main rope		
diameter	2×54 mm	2×54 m
weight	2×12.96 kg/m	2×12.96 kg/m
tensile strength	2×165 kg/mm²	2×195 kg/mm²
guaranteed breaking force	2×198 t	2×234 t
Tail rope weight	25.92 kg/m	25.92 kg/m
Maximum rope tension		
at men winding	36.48 t	52.96 t
at mine waste winding	44.12 t	60.0 t

III. MECHANICAL EQUIPMENT OF WINDER

The Koepe wheel has a 5.5 meters diameter and is completely welded and has skin-stress construction. This is to increase the strength, to help minimize the weight, limit the DG^2 and also has a composed view. The rope-lining was made by Becorit Co. of West Germany. It is a combination lining, (Becorit-Kombinationsfutter), which is made of combining tanned leather, rubber and canvass. The rubber plays a vital part in adjusting any tension difference between two ropes.

The main shaft is supported by two plain bearings with oil rings, which are mounted in robust and steel welded pedestals against the continuous upward force. The shaft is directly coupled with the reduction gear by a forged coupling.

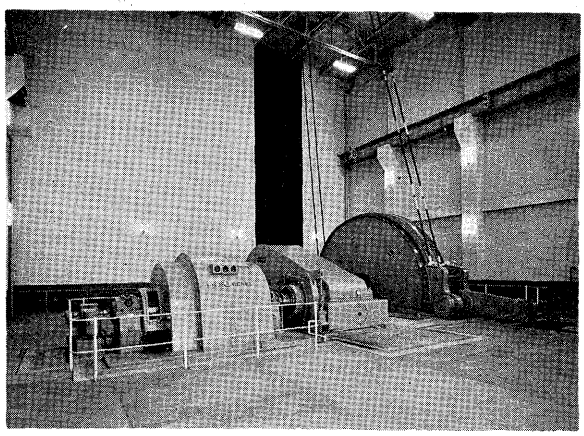


Fig. 2. Winder

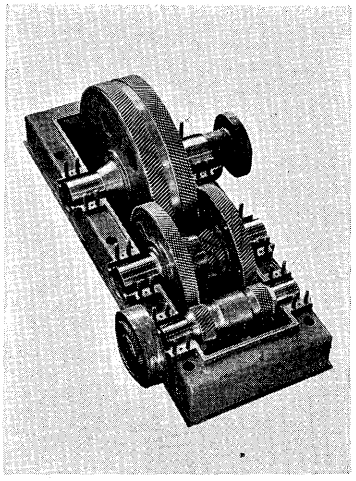


Fig. 3. Gear reducer

This reduction gear was built by Demag of West Germany, and having a gear ratio of 14 : 1, Its maximum normal transfer torque is 73,700 mKg and has precise two stage double helical gear. The accuracy of this gear is equal to Japan's standards first class gear which is classified by The Japanese Gear Industrial Committee. The teeth on both pinions and wheels were built of special steel and forced lubrication was applied in the gearing part. The bearings, which are the forced lubricating plain bearing type, were welded together to the gear case. In this construction, the center of bearings is not deflected by load, and a excellent accuracy at a manufacturing shop is hold after the installation at a user. Our factory has now achieved the equipment to manufacture this class of reduction gear.

For shaft coupling between the reduction gear

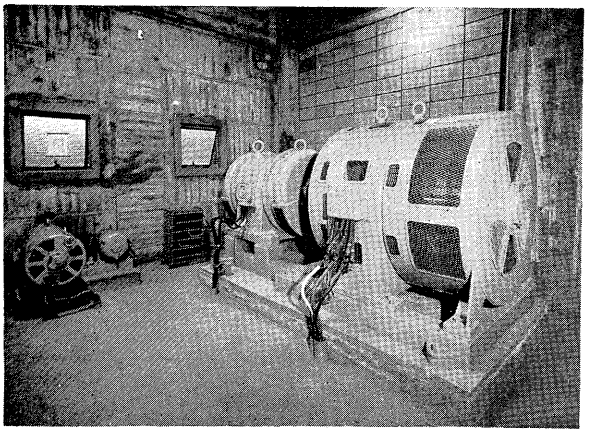


Fig. 4. Low frequency generator

and the main motor, Bibby coupling made by Malmedie & Co., West Germany was used because of its flexibility and ability to absorb shock.

The main brake is of the under-fixed post type and prepared for the Koepe wheel, the equipment is also equipped with a sub-brake to absorb inertia of motor rotor, Biby coupling and high speed pinion shaft of the reduction gear.

IV. ELECTRICAL EQUIPMENT FOR WINDER

The main motor is a three phase wound rotor type induction motor having capacity of 1,540 kW, speed of 585 rpm, and power supply is 6,300 V 50 c/s. The winder is so designed as to have robust construction and to withstand severe operating conditions. The bearings, which are mounted in the pedestals, are the plain bearings with oil rings. Ventilation is made by forced air supplied from outside by a turbo fan through an automatic air filter made by AAF Co., USA.

Low frequency generator for low frequency control is of the stator excited type commutator machine having capacity of 200 kVA, 400 V 2.5 c/s, (so called SK machine) driven by a cage rotor type induction motor having capacity 200 kW, 1,000 rpm. The voltage for a SK machine is high, compared with its capacity, as a result of the 6,300 V power supply. The segment voltage is therefore inevitably high, but sparkless commutation has been obtained by our superior technique of design. The exciter is a commutator type frequency changer having capacity of 8.5 kVA (so called RUF machine) to change the frequency from 50 c/s to 2.5 c/s. The RUF machine is driven by a reaction motor having capacity 2 kW 1,500 rpm, by using cone pully type variable ratio coupling, the frequency can be adjusted to 2～3 c/s.

Controlling of the primary side, 6,300 V 50 c/s, of the main motor is achieved by the before mentioned newly developed magnetic contactors (KF 926 III-6/150 type), and the controlling of 400 V 2.5 c/s is achieved by 3 kV class magnetic contactors having insulation of 6 kV between ground to phase

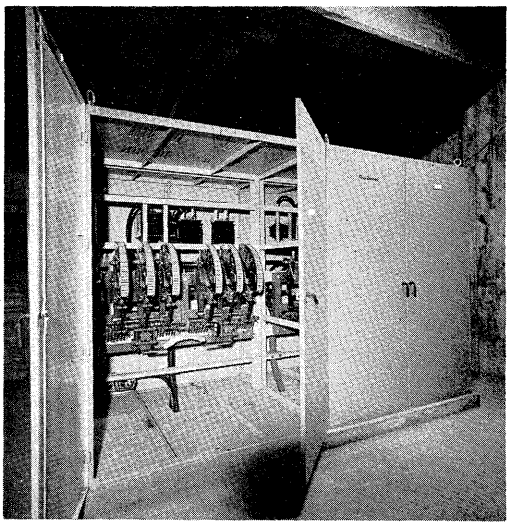


Fig. 5. Primary change-over contactor cubicle

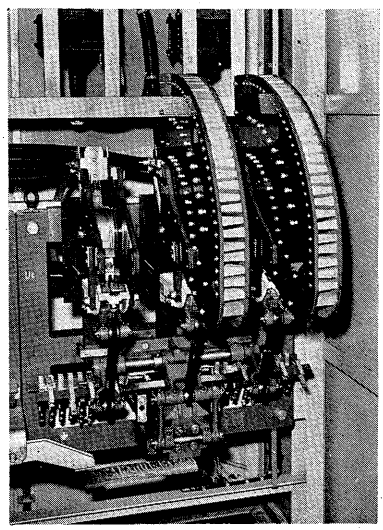


Fig. 6. 6 kV magnetic contactor

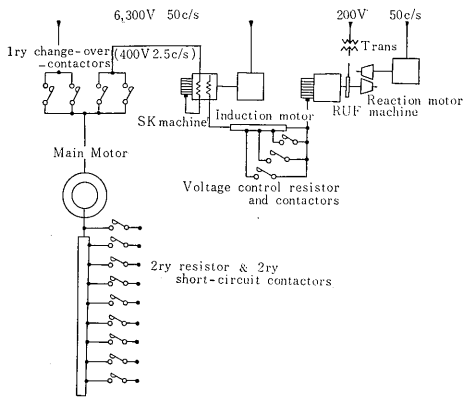


Fig. 7. Main circuit diagram of low frequency control

or phases (KF 926III–3/150 type), these contactors are built in cubicles. And the secondary resister is of the self cooled type grid iron resister, and has 10 steps controlled with low tension magnetic contactors (K 717III–12LU type) built in the cubicle. The last step is, especially controlled by three contactors connected in parallel to guarantee high reliability.

The abovementioned main motor's speed-torque characteristics are curved as shown in Fig. 9.

The brake engine is a quick acting pneumotic operated brake having rated pull of 15 ton under air pressure 5 kg/cm^2 (JM 515 type). This brake can function in three different ways; pneumatic service braking, pneumatic emergency braking and gravitational emergency braking. A compressed air braking cylinder, weight holding cylinder, braking lever and emergency braking trip magnet are mounted on the welded construction frame. A pressure regulator is mounted on the side of the frame. Built inside the frame there are a magnet tripping switch, control valve for the holding cylinder and link mechanism.

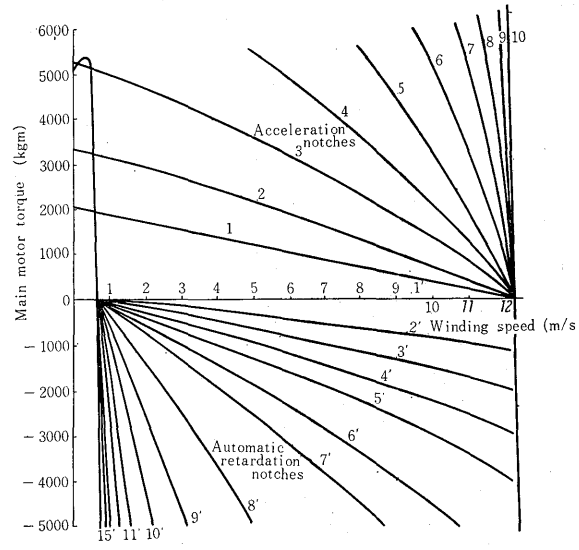
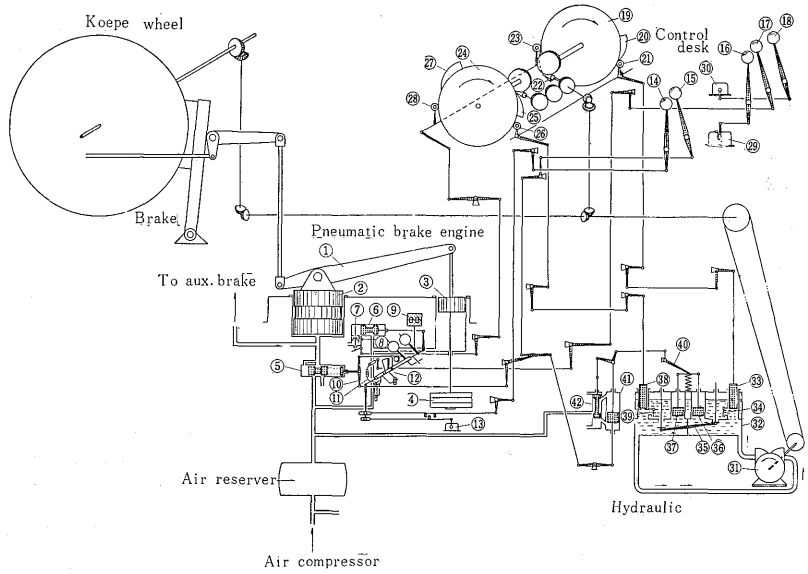


Fig. 8. Speed-torque characteristic curves of main motor

Control of the service brake is done by operating a pressure regulator linked with the service brake handle on the control desk. The braking pressure is done, based on a stroke of the pressure regulator, in spite of a pressure variation of



[Brake engine]
1. Brake lever
2. Service brake sylinder
3. Holding sylinder
4. Emergency weight
5. Pressure regulator
6. Control valve
7. Short-circuit valve
8. Choke valve
9. Trip magnet for emergency brake
10. Differential lever
11. men-coal change-over link
12. Emergency braking pressure controller
13. Switch for magnet

[Control desk]
14. Emergency brake handle
15. Service brake handle
16. Master control handle
17. Men-coal change-over handle
18. Auto-manual change-over handle
19. Cam disc (for east cage)
20. Cam for throttle valve
21. Roller lever
22. Cam lever for opening of by-pass valve
23. Roller lever
24. Cam disk (for west cage)
25. Cam for throttle valve
26. Roller lever
27. Cam for by-pass valve
28. Roller lever
29. Master controller
30. Auto-manual change-over switch

[Speed controller]
31. Oil pump
32. Valve compartment
33. Throttle valve
34. Check valve
35. Circulating valve
36. Piston
37. Piston
38. Throttle valve
39. Check valve
40. Link
41. Servo-motor
42. Pilot lamp valve

Fig. 9. Mechanism of brake engine and control desk

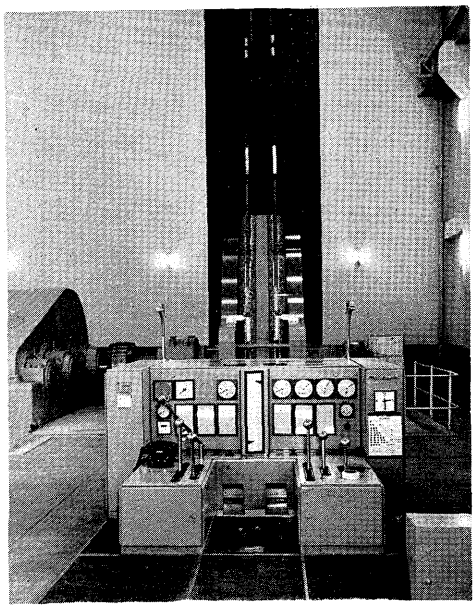


Fig. 10. Winder control desk

the compressed air source. Emergency braking is made by demagnetizing the tripping magnet and operating the pressure regulator. The braking pressure can be controlled suitably for winding either coal or men. This demagnetizing of the magnet is done by either the magnet tripping switch operated by the emergency brake handle of the control desk, or a magnetic contactor connected to the protection gears. While the pneumatic emergency brake is taking steps, the compressed air in the weight holding cylinder is slowly discharged from the control valve through the choke valve, and the full braking force by the counter weight is applied after stop of the winder. If a cage is near the pit top, the gravitational emergency brake will act quickly, by means of a short circuit valve operated by a depth indicator. This brake engine is also equipped with the following devices ;

1) a mechanical inter-lock device to lock loose of next service braking when a braking shoe is worn away.
2) an oiler for compressed air supplied to the braking cylinder and holding cylinder.
3) an automatic oiler for the pressure regulator and controlling valve.
4) a manual oil supply for starting the equipment after operation has spopped.

Compressed air source for the brake are serviced from a station service air which has an air reservoir having capacity of 3 m^3. Then there is a decrease in pressure, a pressure in the reservoir is pumped up automatically by means of a motor compresser used especially for this purpose.

Instruments, handles, switches, signal devices and the depth indicator, which are necessary to drive the winder, are built in the winder control desk. The instrument panel is located in front of the control desk and the vertical double track type depth indicator at the center, other instruments and illuminating indicators are mounted on both sides. The depth indicator is driven by the Koepe wheel's shaft through a motor operated differencial correcting device, these two control cams rotate by a worm gear in the indicator, and at the same time, two indicating needles rise up and down by the turning of screw shaft and nuts. The indicating plate is normally illuminated in green, but at deceleration state in red, just like a chameleon. The cams can control the following devices ;

1) a braking point alarming device.
2) a retardation command switch.
3) to back the master control handle.
4) the choke valve of the speed controller.
5) a directional selection switch for the automatic corrector.
6) a over-winding switch.

Indicator correction is done by a handle. This handle is pushed outside the panel by use of a foot pedal, located on the lower part of the switch panel. This handle is then used to correct the indicator. But this correction can be done only at service braking, so the inter-lock is furnished. Auxiliary switches are mounted on the lower part of the panel. The following handles are localed on the lower front part of left and right paneles. A master control handle, an auto-manual change-over handle, a coal winding-men winding change-over handle, a service brake handle and a emergency brake handle. These handles are completely inter-locked to guarantee fool proof operation of the equipment, such as, the auto-manual change-over handle and the coal winding-men winding change-over handle can be only operated when the master control is set at the zero point,

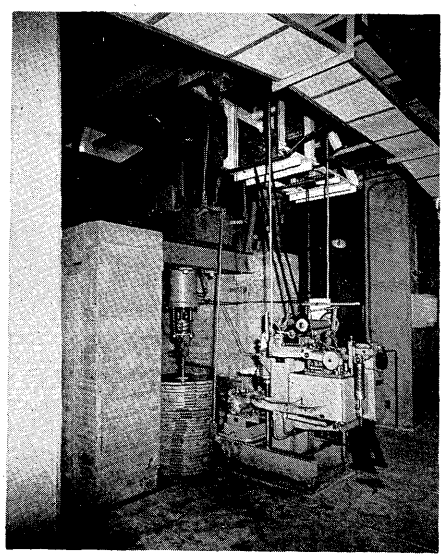


Fig. 11. Hydraulic speed controller

and the service brake is set at the braking position. When it is desired to turn the emergency brake handle to the zero position after turning the handle from the braking position to the free position, the master control handle must be at the zero position and the service brake must be set at the braking position.

Slow speed—full speed change-over pedals, deceleration adjusting pedals and a emergency foot switch are located on the floor of the control desk. Also a link-mechanism is furnished for the abovementioned slow speed—full speed change-over pedals, which can also act only when the master control handle is at the zero position and the service brake is at the braking position.

Under the floor, the abovementioned differential correcting device and hydraulic speed controller are installed. The latter is prepared for supervising of the winding speed at the full speed running or the retardation range, and furthermore of the passing speed at the pithead.

If the speed goes over the limit, this controller will automatically operate the service brake to avoid the use of the emergency brake, by suppresing over-speed or over-winding.

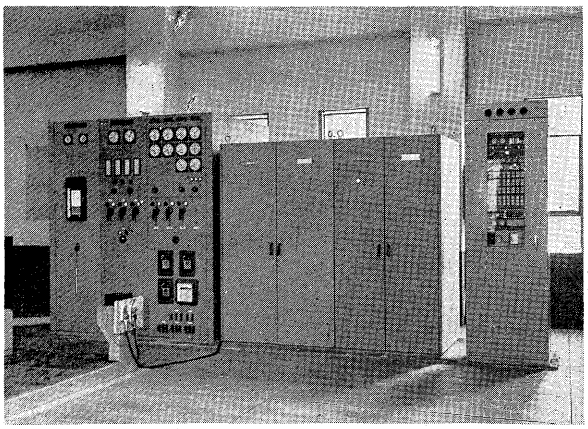


Fig. 12. Shaft signal panel, control and supervisory panel, low tension switch cubicle and relay cubicle from left to right

This apparatus is also equipped with ; 1) a pump which feeds oil in proportion to the speed of the winder, 2) a valve room with a variable choke mechanism which detects the oil pressure related a variation of the oil quantity, 3) a pilot valve and servo-motor which amplify the piston movement of the valve room by air pressure, 4) an oil damper. A rotary oil pump is driven by the Koepe wheel shaft and the choke valve in the valve room is driven by the cam of the depth indicator.

The output shaft of the servo-motor is connected with the service brake lever, by using a differencial link, suitable braking force can be obtained, in accordance with a variation of the winding speed. In the case of Honbetsu's vertical shaft, the maximum winding speed will not exceed 112% of rated speed at full speed range or deceleration range. And the maximum speed at the pithead will not exceed 4 meters per minutes. The oil pressure detecting part is furnished with an automatic temperature regulator which keeps temperature constantely 50°C to prevent a change of characheristics caused by oil temperature variations. Near the control desk, there are a shaft signal panel and a controlling-supervising panel which are mounted with instruments, conrol switches and signal lamps for preparing winding operation, and illuminating fault indicators.

V. CONTROL

At first we shall explain the operation in automatic retardation. In this case the automatic-manual change-over handle is positioned on " automatic ". When a signal " to wind " is received by the vertical shaft signal, the master control handle is turned to the correspondent direction and then the service brake handle is turned to " to loosen ". So the corresponding 50 c/s side's contactor in the primary change over contactors' group being energised by the master switch inter-connected to the master control

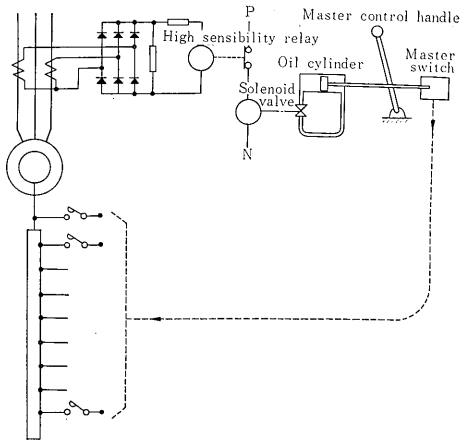
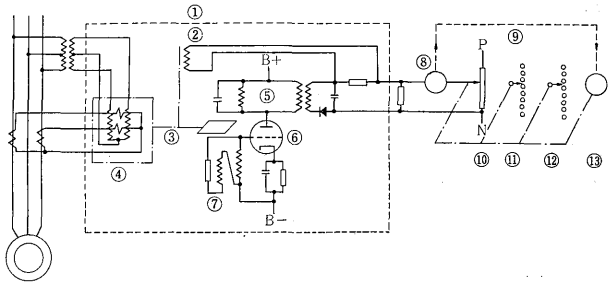


Fig. 13. Explanatory diagram of constant torque acceleration control

handle, the main motor generates a starting torque and the winder begins to start after extinction of the service braking force.

Here after according to the progress of the operation of the master control handle, the secondary resistors being short circuited step by step, the winder accelerates. In this case, in order to achieve acceleration of constant torque, when the primary current of main motor exceeds a rated value, the master control handle is made to restrain its removement by cutting off the flow path of oil cylinder by a solenoid valve which is interconnected with the control handle by detecting the rated value with a high sensitive relay. Moverover when the speed attains to 100%, the secondary resistors are complete-

ly short-circuited automatically irrespective of the position of the master control handle by means of a centrifugal speed switch and then over speed in case of lowering the load is prevented. In this case an illuminated letter " regeneration brake " being given on the control desk and at the same time an alarm of bell being given, the operator is given an instruction to proceed the master control handle up to the full speed notch and automatic deceleration is surely carried out.



1 Torque balance type converter
2 Compensation coil
3 Control wing
4 Electrodynamometer type measuring element
5 Plate coil
6 Orcillator tube
7 Grid coil
8 High sensibility relay
9 Retardation selector
10 Load measuring track
11 Switching track for 1 ry & 2 ry contactors
12 Switching track for voltage control contactors
13 Progress coil

Fig. 14. Explanatory diagram of load measuring device

The retardation is a constant deceleration system, however on acount of the deep depth and the large moment innertia the speed reduction with motor torque does not neccessitate but the speed reduction is exercised by the power cut or low frequency brake.

In this case it is most important to generate a suitable torque at the same time as the beginning of the retardation in order to have safety and high efficiency in operation by preventing a slip of rope and by sure and speedy stoppage, for this purpose a load measuring device is equipped. The load measurement begins after judging the winder is put in the full speed operation elapsed a definite time after the secondary resistors are completly short circuited. The load value is detected as an input power of the main motor which is converted to DC current by means of a torque balance system converter.

The torque balance system converter posseses an electrodynamometric type measuring element same as 3 phase wattmeter and a metallic adjustable wing fitted upon its movable shaft changes the coupling condition of plate grid in an electron tube HF oscillator and variates its output current and comes to a stand still when the torque of measuring mechanism is balanced with the torque of compensating coil excited by the output current. The output DC voltage of the converter and the divided DC voltage of load measuring track of retardation selector are poked each other and following pulses are given to the selector coil by a high sensible relay and a polarity relay until these become in a balance condition. In the retardation selector, tracks are provided which control switch-in and switch-off for primary change-over contactors and contactor groups of secondary short-circuit and adjustment of low frequency voltage, so if the notch is proceeded to the position corresponding to the load a suitable torque is generated at beginning of retardation. Further after the proceed of the notching is finished an illuminated letter " change-over of automatic retardation finished " is given on the control desk. If the master control handle is turned back before the indication is not lighted the control can be carried out in the retardation manual.

When the master control handle is turned back after lighted or the limit switch is automatically operated by means of the cam of depth indicator at biginning point of retardation, the retardation begins and torque instructed by the notch of retardation selector is generated.

Here-after the master control handle is only effective for instruction of run or stop and its speed control ability is taken away.

Under process of speed reduction the voltage of pilot generator coupled to the winder is applied to the high sensible relay through a resistor of process selector track and when the actual speed indicated by the former is higher than the program speed indicated by the latter the speed is reduced by giving a impulse to the coil of retardation selector from the high sensible relay and polarity relay.

This process selector is given a impulse on its coil every 1.5 m of cage run by the impulse generator coupled to the depth indicator and resistance value of the track is variated according to the proceeding

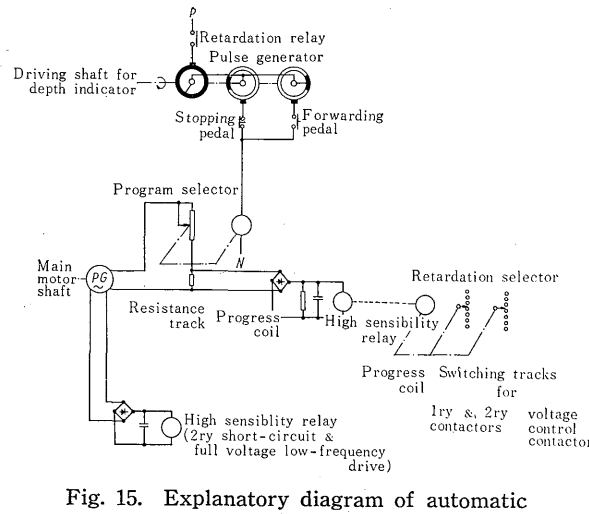


Fig. 15. Explanatory diagram of automatic retardation control

of notch. Compared with a variable resistor operated by the cam of depth indicator hitherto used, in this system an unstable sliding part being eradicated, the program speed is able to be transmitted quite acurately even in case of deep depth.

Foot pedals are provided on the control desk in order to obtain higher acuracy or give freedom and if operate the proceeding foot pedal impulses of two times as many as usual impulse being generated by the impulse generator, the process selector is proceeded more quickly and if operate the hesitating foot pedal impulses being interrupted the process selector comes to a standstill meanwhile. On the other hand the pilot generator is used of a permanent magnet field inductor type AC generator which generates 1,500 c/s at full speed and is designed to obtain a voltage to control acurately creep speed. Thus if the speed comes down by 5% it is detected by the high sensible relay connected to the pilot generator and a exact slow speed operation is maintained by full low frequency voltage drive under the complete short circuit of secondary side, whereby the cage will come to the destination safely. Here the master control handle is operated to " stop " and service brake handle is operated to " brake " then the winder is stopped.

As the beginning of retardation and the controlling during speed reduction are given instructions from the depth indicator as described above there is equipped with an automatic correction device for depth indicator optionally operated in order not to get error due to rope creep or rope slip. Namely when suitable one of four deckes of cage stops surely on the platform this is detected by the magnetic limit switch fitted upon the vertical shaft, which operates a motor operated differential correction device and corrects the depth indicator in a right position. Further during operation of correction an illuminated letter " depth indicator under correction " is given on the control desk, so the next operation is to be carried out after the light indication is put out.

In case of deck change, step on the slow speed change over pedal. Thus by operation of the master control handle a slow speed operation is always carried out by way of secondary completely short circuiting and full low frequency voltage drive.

Nextly we wish to explain simply retardation manual. In this case if the master control handle

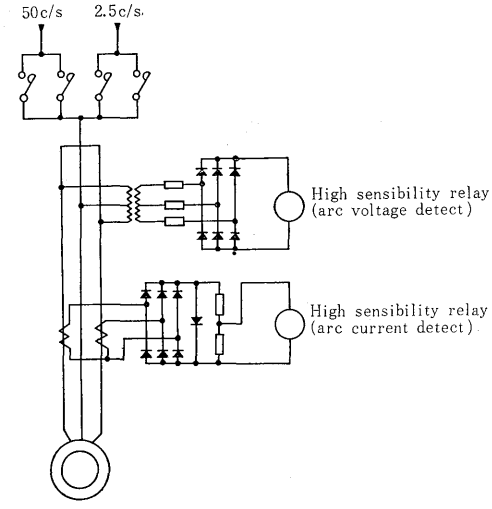


Fig. 16. Explanatory diagram of arc-interlock circuit

is turned back for retardation, first 50 c/s motor torque notch is obtainable nextly 2.5 c/s brake torque notch, at last a slow speed operation is obtained by secondary completely short circuited full low frequency voltage, but also in this case speed comparison function between pilot generator voltage and resistance track of process selector is carried out, when the value of the former is higher, an illuminated letter "speed reduction lagging" is given on the control desk, which urges the master control switch to turn back. Even in the retardation manual when the nominal speed exceeds by 12%, with hydraulic speed controller the speed decreases due to service brake force auto matically given and of course it is considered that the arriving speed to pit head shall not exceed 4 m/s.

Besides the fundamental operation circuit described above, the interlockings of primary change-over contactors which are most important as an AC winder are paid a special consideration that mechanical interlockings between 50 c/s or 2.5 c/s contactors, arc interlockings as well as electrical interlockings by auxiliary contacts are performed.

These arc interlocking circuits being performed for both arc voltage and arc current, closing of contactors is prevented by the high sensible relay even in case extremely small residual arc energy exists.

One example illustrating osillogram of operation in

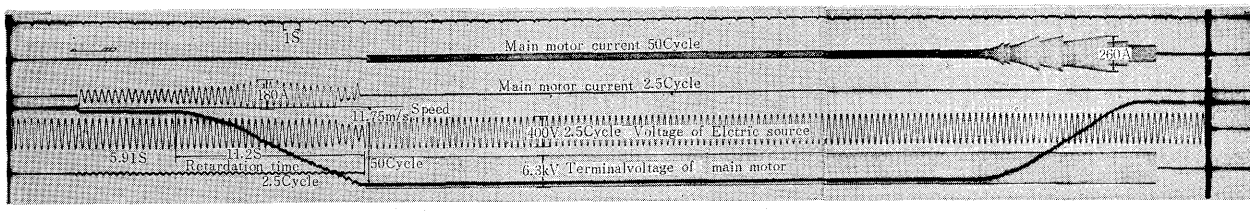


Fig. 17. Oscillogram of operation on 4,160 kg balanced personal load

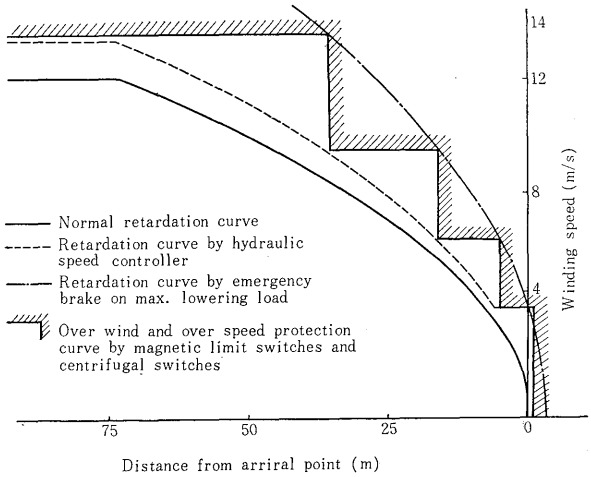


Fig. 18. Explanatory diagram of over wind and over speed protection

case of automatic retardation is shown in Fig. 17.

With regard to protective device, general problems being omitted, we wish to explain the most important protection as a winder against over winding and over speed.

First as a over winding protective device an over winding switch directly actuated by the cages and as its backup protection an over winding switch actuated by the cum of depth indicator are equipped. However the passing speed at the pit head is needed less than 4 m/s owing to the relation of over winding distance of the head frame, for which an over speed protective device for speed reduction range is equipped.

In order to perform reliable protection even in case of rope slip in the Koepe system winder the cage position must be directly detected out and a step over speed protective device by limit switches fitted upon the vertical shaft and centrifugal switches coupled to the winder is considered best. This protective device is not operated at normal operation and when operated it neccessitates that the passing speed at the pit head shall be under 4 m/s at the worst condition. You can clearly understand it by Fig. 18.

Further all protective devices are identified into light accident and heavy accident in which case illuminated letter is given on the control desk or buzzer alarm is given. In the former case the winder is operated as it is and the trouble is eradicated after finished one cycle but in the latter case the winder is stopped instantaneously by emergency brake. These troubles are indicated by illumination on the control and supervisory panel respectively so that counter measures for troubles can easily be made.

VI. CONCLUSION

The present winder can be realized with an ecconomical AC gear system even for such a large capacity and has performance not inferior to DC direct coupling system. We believe that this may be most valuable for your future projection of vertical shaft winding equipment.

Moreover the present paper is only reporting the winder however we herewith wish to inform that our company manufactures complete vertical shaft winding equipment besides the above for instance head sheaves, cages, the mechanical and electrical equipment for mine car circulating systems and head frames and there are a lot of equipment which have now been put in business operation with excellent results.