WINDING EQUIPMENT FOR CENTRAL MINE-WASTE BLIND SHAFT OF SUMITOMO COAL MINING CO., LTD.

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I. PREFACE

Our Company has recently completed the winding equipment for a vertical blind shaft at Sumitomo Coal Mining Co. Ltd. The equipment is of the newer type composed to the conventional standard type, for instance the four rope Koepe winding system or the one man control system of the winder and the decking equipment is a first case in Japan. To adopt these new systems, each component of the equipment has also the modern construction.

II. OUTLINE OF EQUIPMENT

The Blind Shaft is schemed in relation to the main shaft, which has been described in our previous issue (FUJI DENKI REVIEW Vol. 7 No. 1). The shaft connected with the plug gallery (−340 mL), excavation gallery (−550 mL), and the future excavation gallery (−760 mL), and is used for transporting mine-waste, materials and persons. Presently, however, it is alternated to the −760m L and connected to the sump gallery (−658 mL) for the main shaft,

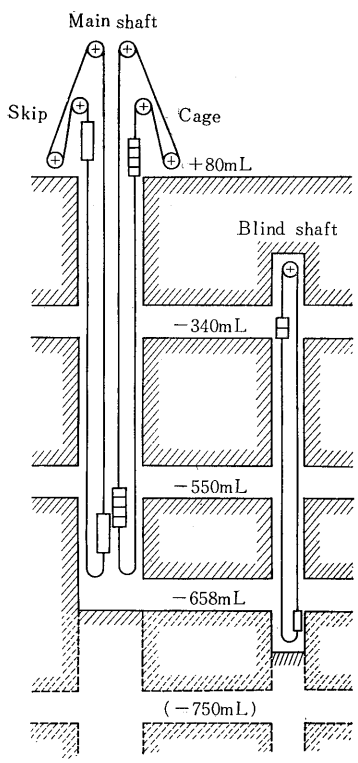


Fig. 1 Relation between vertical shafts and horizontal galleries

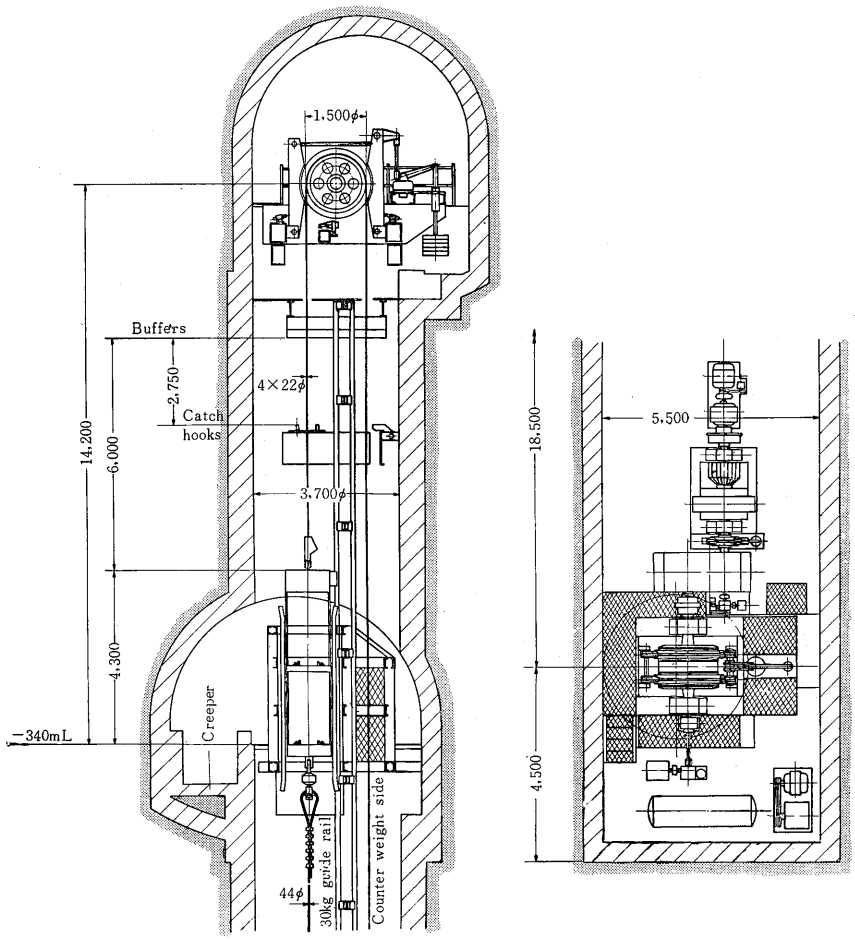


Fig. 2 Installation of winder

in place of the gallery (−760 m) and is used for transportation of dropped coal from the skip winder. The diameter of the shaft is 3.7 m, and the winding system is of the single truck cage winding system with a counter-weight. The cage consists of two decks, each deck is capable of taking in either 2 m^3-coal car or 15 persons.

The main ropes are of the four filler type strand ropes, while the tail rope, only one rope, is of the multi-strand rope, and the guide is of the one side rail guide. The winder is of the four rope Koepe system with a special narrow magazine installed at the top of the shaft, and therefore, the head sheave or guide sheave was not used. The winder is driven by a wound rotor type induction motor through a reduction gear which has an automatic retardation controlling device by dynamic braking system with a creep speed motor, and is operated from a distance, i. e., from the −340 mL decking platform. Because of this, the pneumatic remote control system for braking was adopted. The data on operation are as follows:

***Table 1* Operation data**

Winding depth	210/420 m
Net load	
Mine-waste 2 cars	6,000 kg
Men 30 persons	1,200 kg
Unbalance load	4,750 kg
Winding speed	4 m/s
Winding time	
Required time to wind up (210 m)	59.5 s/cycle
Required time to wind up (420 m)	112 s/cycle
Pausing time during mine-waste loading	25 s/cycle
Main ropes	
Diameter	4×22 mm
Weight	4×1.85 kg/m
Tensile strength	165 kg/mm^2
Guaranteed breaking force	4×27.3 t
Tail rope	
Diameter	1×44 mm
Weight	1×7.44 kg/m
Maximum rope tension	
at mine waste winding	15.81 t
at men winding (counter weight side)	10.06 t

III. MACHINERY

The arrangement of this equipment, in respct to the shaft and the winder, is shown in *Fig. 2*. The blind shaft has, generally adopted such installation method of the winder, as the winder is installed in the winding room, which is located in the upper level gallery, and the ropes are conducted from the winding room toward the head sheaves at the top of the shaft, passing in an oblique direction through a rope gallery. By comparing aforesaid method, the present method has the following merits:

1) The winder is placed on top of the shaft eliminating the necessity of a rope gallery.
2) Having adopted the four rope system, the winder is smaller in size, carring into the pit is convenient, and the winding room needs only the size of the main gallery.
3) The diameter of the winder's drum can be adjusted to the center distance of the shaft's transporting vessels, eliminating the necessity of guide sheaves.
4) As the rope is comparatively small, it is not only easy to manufacture, but also convenient in handling, and minimizing the bending time by sheaves to one third, eliminating lateral vibrations extend its life.

1. Main Part of Winder

The main specification of the winder are as follows:

Koepe wheel: The diameter is 1.5 m, 4 rope system with a special rope magazine.
Main brake: Under supporting post type.
Main reduction gear: Double helical, two-stage reduction, ratio: 11.5 : 1
Auxiliary brake: Pneumatic, interlocked with a main brake.
Main coupling: Gear coupling
Motor coupling: Cardelis coupling

The Koepe wheel is of all-weld skin-stressed construction, having four rope grooves and two brake

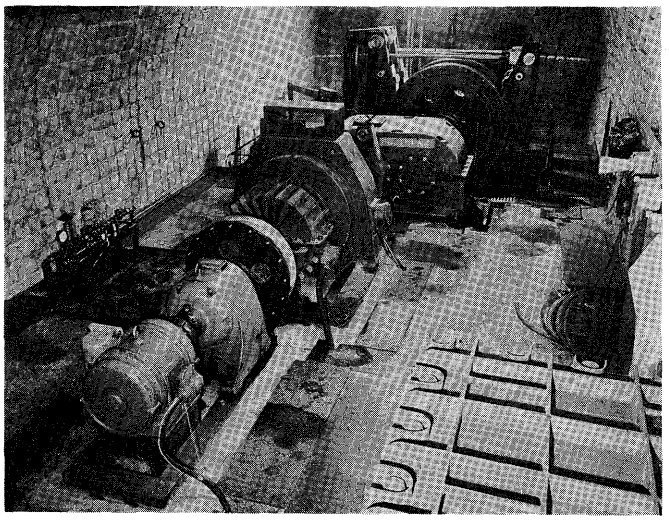


Fig. 3 Winder

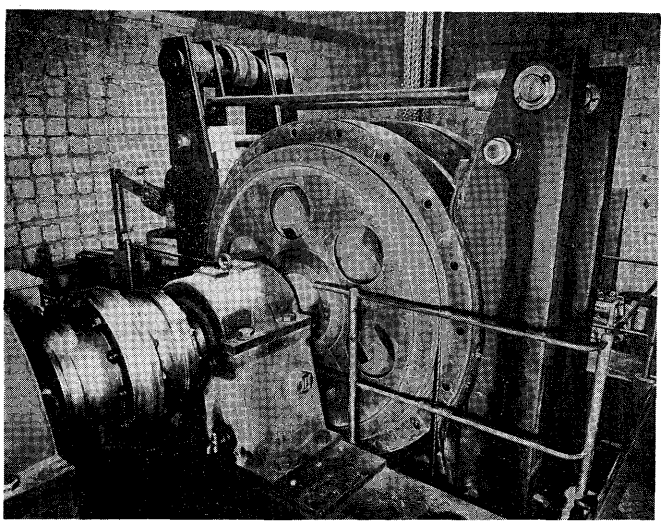


Fig. 4 Koepe wheel

rims between each groove. The rope grooves have PVC lining, which was manufactured and supplied by the Kautex Company. The reasons for adopting the poly-vinyl resin as a lining material were:

The resin has an extreme anti-abrasion characteristic and is capable of withstanding large rope contact pressure caused by such kind of the blind shaft winder which the Koepe wheel is designed to be smaller in diameter. Elastic quality of this material eliminates the unbalance tension of ropes, which often occurs on multi-rope winding system, and is very suitable for underground use because of its non-inflammable and anti-corrosive characteristics. Generally, in the case of the multi-rope system, in which the diameter of the wheel is small, it requires a wider brake rim, to obtain the necessary braking force. This especially applies to the blind shaft winders,

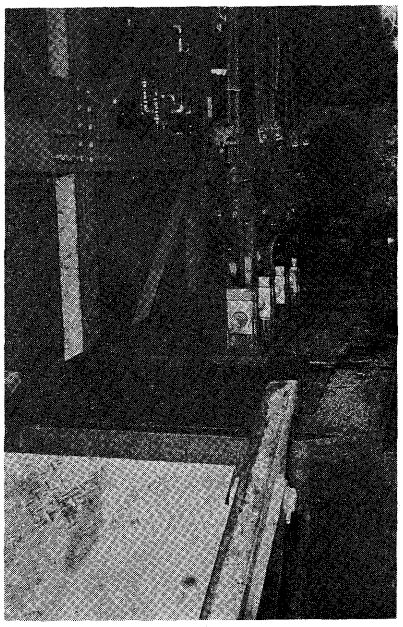


Fig. 5 Four rope clamps

but the wide wheel is undesirable. This is avoided by the new method which is to arrange the brake rims between the rope grooves, and these rims have a diameter of 1.75 m, which are larger than the wheel. The space between the brake rims constructs rope magazine, and regardless of the narrow type, the winder can be used for installation of ropes.

All gears, which compose the main transmission, are made of special steel, treated with high frequency quenching, then the surfaces of the gear's teeth are precisely finished by Maag Company's gear grinding machine. Their accuracy is classified as class 1, which is well over class 3~6 specified and required by the Japan Industrial Standard (JIS B 1702) for gear to be used for winder. The gear shaft is supported by spherical roller bearings, and the bearing hausing is welded together with a gear case, which has all the necessary parts fitted compactly inside. The gear teeth and bearing are lubricated by the oil spray lubrication system which is done automatically by rotating the gear. By adopting this construction, in spite of the small size of the reduction gear, it can withstand severe alternating loads, eliminates the necessity of maintenance, suitable for no-man operation, free of undesirable excess noise and heat losses, which is undesirable for underground use.

Consideration must be given, in the case of installing the winder on the top of the blind shaft, to the many possibility of the foundation to shift. To compensate this, all shafts, including the motor shaft, are coupled with superior flexible couplings, such as, gear couplings, Cardelis couplings, Fawick air clutchs, Rubflex couplings, etc., according to its transfer torque and speed. For the same reason, the bed was also divided as much as possible for precautionary measures. On the other hand, the supporting frames were constructed in such a way as to permit the winder to be moved without moving the motor if and when the center of the shaft should shift.

2. Cage and Counter Weight

The cage is consisted of two decks, each deck is capable of taking in 2 m^3 coal car. Doors can be attached when used for transporting persons. The counter weight is constructed of four blocks, each block is individually connected with a main rope, each has its individual guide frame, which can joint these blocks together, and can slide up and down automatically, according to elongation of the ropes. So unbalance in tension of the ropes will be automatically avoided. Therefore eliminates the undesirable load balance triangle lever, which is also undesirable for safety, in case the rope should break, and less capable in its ability to correct rope unbalance. That is, each rope is connected directly with the main rope clump, fixed to head frame of the cage, and it is unnecessary to supervise the tension

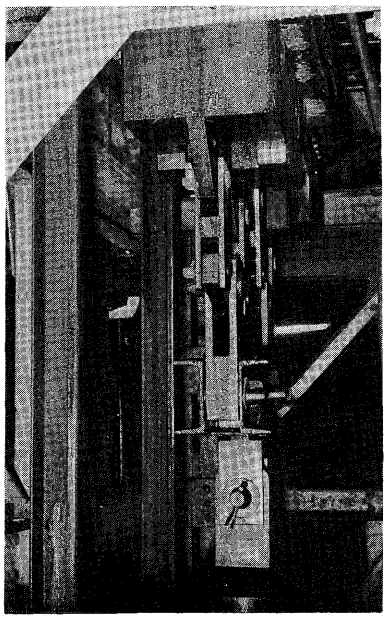


Fig. 6 Tail of counter weight

of rope. Because this is the first equipments adopting this method in Japan, experiments are being conducted on rope tension by fitting the equipments with four oil pressure type tension meters, so called the "Statimeter", which fixed on the under-side ceiling of the cage. These meters are for taking direct reading of tension of each rope.

As shown in *Fig. 7*, the cage and the counterweight are guided individually with two guide rails on a bunton installed between them. As the loading of mine car into the cage at the −340 mL gallery is in the opposite direction, compared with the other gallerys, therefore Steinfurth type car stoppers are mounted on the decks. The cage is also furnished with mine car lockers besides the abovementioned stopper on the deck of the cage because the guides are attached on the side of the cage. The locker

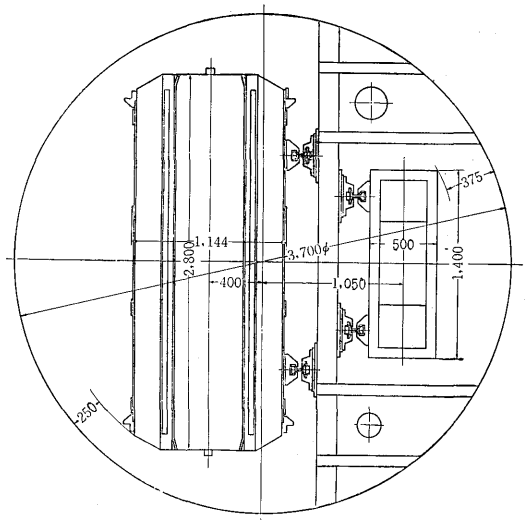


Fig. 7 Horizontal section of shaft

is operated by means of a pneumatic cylinder installed on tilting platform.

3. Cage Decking Equipment

The cage decking equipment is of pneumatic operating type, and consists of shaft doors, tilting platforms, a safety hook on front of the shaft, a car pusher, a car brake and an operating desk. The length of platform is 1 m at the −340 mL gallery, 1.75 m at the −550 mL gallery and 2.5 m at the 760 mL gallery, and a operating desk on the −340 mL gallery is united with a control desk of the winder. At the −760 mL gallery (at present −658 mL), there is no car pusher or car brake, which is to be installed in the future.

IV. Electrical Equipment

1. Driving Equipment

For remote operation of the winder from the upper gallery platform, the operation must be easily carried out, that is, control of the winder must be automatic to some degree, as an operator has further to control the decking equipment, he is therefore unable to supervise the winder directly. To be concrete, retardation shall be automatic, the cage shall reach to its stopping point with stable creep speed, and the stable creep speed shall be obtained even at deck-change. The low frequency control developed by Siemens-Schuckertwerke and our Company would be satisfactory for the above features, but it would be not economical when large horse power is not required or explosion proof construction is required for blind shaft. Now, the dynamic braking system has been adopted, as shown in *Fig. 9*. To simply automatic controls, we have planned synthetically GD^2 of rotary machine, a weight of the counter weight and dereleration and so the retardation is able to adapt dynamic brake under any load.

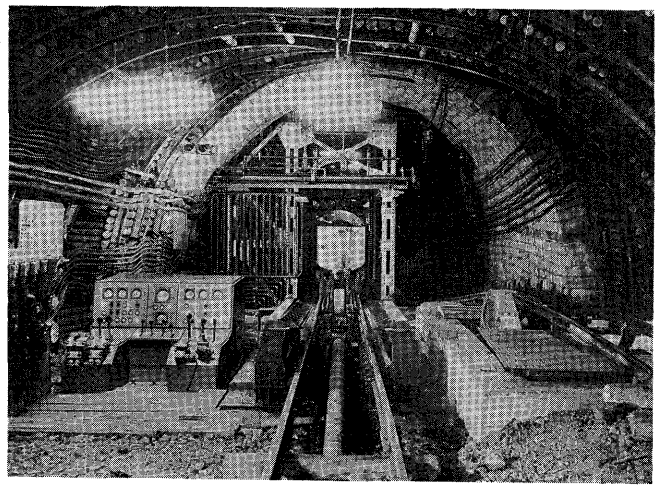
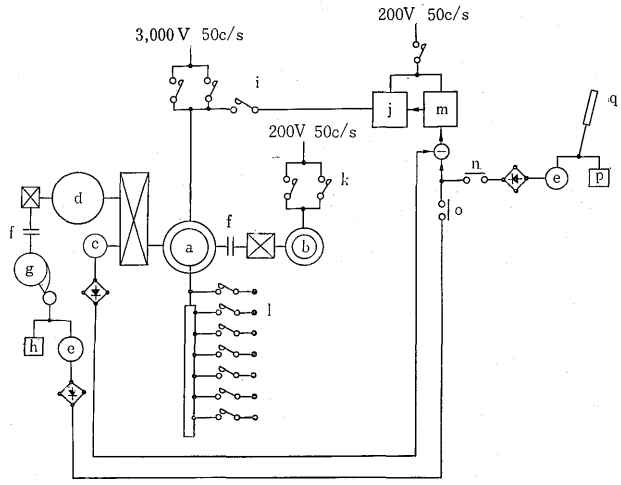


Fig. 8 Platform, −340 mL



a: Main motor
b: Aux. motor
c: Pilot generator
d: Koepe wheel
e: Control transformer
f: Air clutch
g: Retardation cum
h: Commanding switch for 2ry resistance
i: 1ry changing-over contactor
j: Magnetic amplifier (power stage)
k: Reversible contactor
l: 2ry resistors and shortcir-cuiting contactor
m: Magnetic amplifier (PID re-gulator)
n: (manual)
o: (automatic)
p: Master switch
q: Master control handle

Fig. 9 Connection diagram for dynamic braking system AC winder with a creep speed device

Furthermore, the equipment is additionally equipped with the final creep speed device.

1) Main motor

The main motor is of safety increased explosion proof, wound rotor type, three phase induction motor having the capacity of 265 kW 585 rpm 3,000 V 50 c/s. Pressure tight explosion proof construction has of cause been applied for the slip rings, robust pedestal type oil ring lubricated sleeve bearings have been used and the motor has two free shaft ends capable of coupling with the creep speed device.

2) Creep speed device

Auxiliary motor to be used for the creep speed device is of safety increased explosion proof, squirrel cage rotor type, three phase induction motor having the capacity of 22 kW 970 rpm 200 V 50 c/s. The motor has been used so that it is possible to obtain $^1/_{12}$ winding speed. The motor was coupled with the main motor through an auxiliary speed reduction gear of 1 : 20 and Favick air clutch.

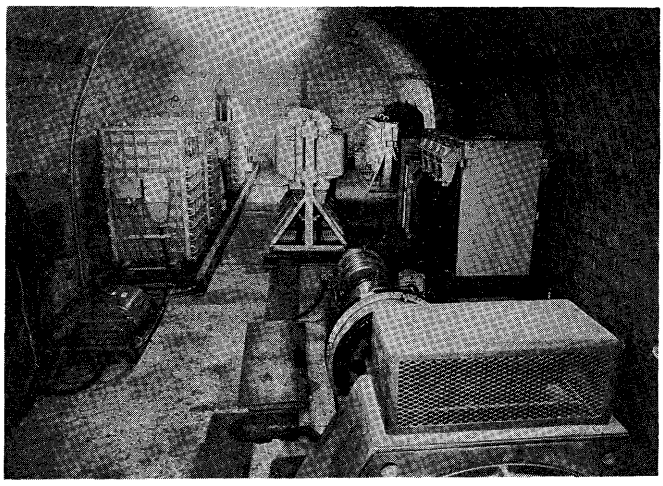


Fig. 10 Electric room

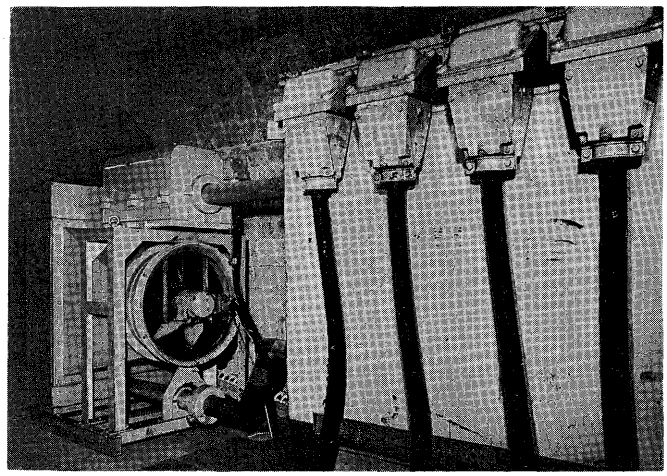


Fig. 11 Secondary resistor

3) Electric source for dynamic brake

The electric source for the dynamic brake is oil immersed explosion proof type magnetic amplifier, and the power supply is single phase 200 V 50 c/s, output is DC 90 V (maximum above 140 V) 85 A 10% ED. By this, the main motor capable of generating above 200% braking torque. In order to perform an automatic control, a PID magnetic regulator was also installed at the input side, which was built in an one lock-bolt type box of pressure tight explosion proof construction.

4) Magnetic contactors and resistor

Primary side of the main motor is connected with the high tension power source through two 150 A high tension magnetic contactors and with a dynamic braking source through a 100 A low tension magnetic contactor. Both contactors were built in pressure tight explosion proof construction contactor boxes. An oil immersed explosion proof metal resistor was adopted as a secondary resistor, and the oil was cooled by a fan cooled type oil recooler, having heat exchanging capacity of 50 kW. This resistance is adjustable in seven stages by one lock-bolt type pressure tight explosion proof contactor boxes. And a $1/\sqrt{3} \times 220$ A low tension magnetic contactor was built in each contactor box.

2. Brake

The winder brake heretofore in use, and developed by our Company, was Siemens type quick action pneumatic brake, which had a braking pressure regulator attached to a braking engine, controlled through a mechanical link by a brake handle on the control desk. This newly developed brake is of the pneu-

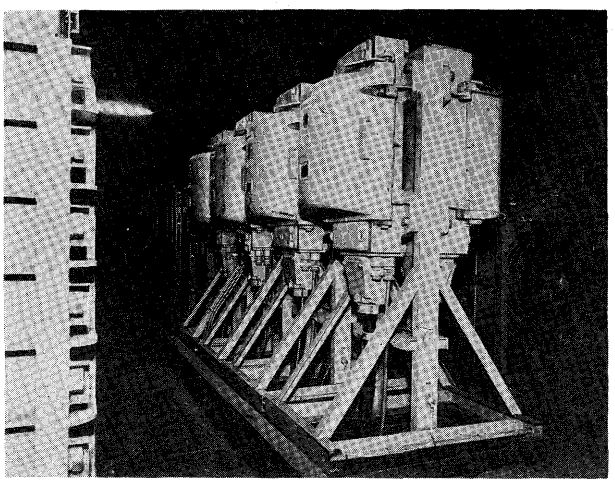


Fig. 12 Short-circuiting magnetic contactor boxes

matic remote control system, as shown in *Fig. 13*, and have the following merits:

1) The location of a control desk can be freely selected and the assembling of connection parts can be done with ease because there is no link connecting the brake and the control desk, there is only piping to distribute pressurized air. In this case, the control desk was installed at the platform located in the distance of 30 m from the brake.
2) Since outstanding pneumatic remote control was used, braking time for an emergency was very short, and in this case it required only 0.2 seconds, in general arrangement, less than 0.1 second.
3) Though an automatic operation was not used in this instance, it is very easy to apply, for this installation that can be changed over to manual operation.
4) The pressure regulator can be conveniently situated for supervision. Gum washer and diaphragm were used, and there are no precise contact sufaces to be fitted for, so, there is nothing to worry about dust entering inside the compressed air, which facilitates easy maintenance and supervision for compressed air.

This system was developed by Siemens recently, it will be adopted by us, as our standard for the winder brake.

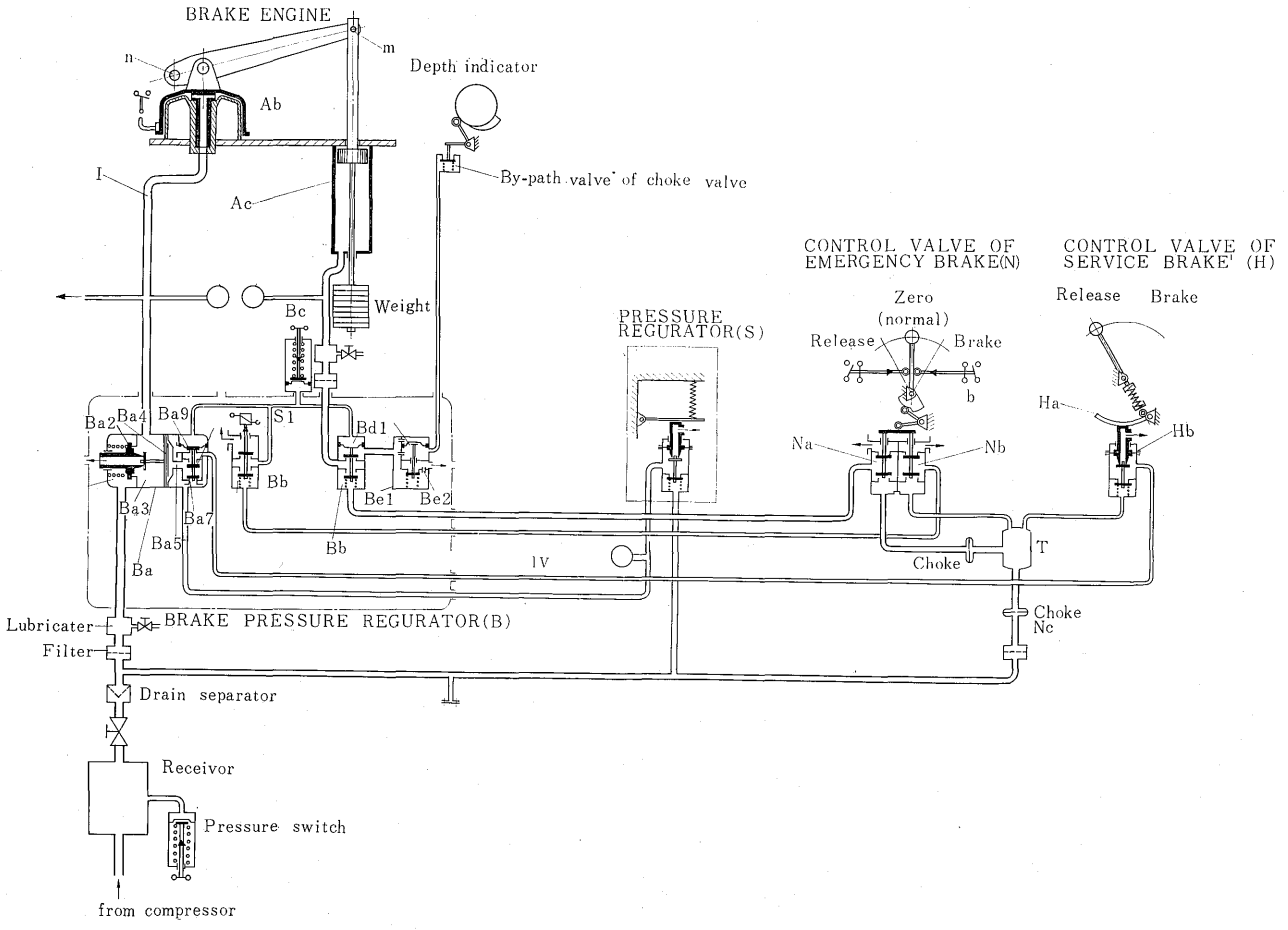


Fig. 13 Piping diagram for braking device

The essential part of the brake engine is as in the past, that is, a service brake cylinder *Ab* and a holding cylinder with emergency weight *Ac* are connected by means of a differential lever, and the brake is used as an adjustable pneumatic service brake, a pneumatic emergency brake, or a counter weight type emergency brake, all in one.

A braking pressure regulator *B* and a pressure regulator *S* are fit near the brake engine. A control valve of a service brake *H* to be controlled by a handle and a control valve of an emergency brake *N* are equipped on the control desk. The braking pressure regulator, the brake cylinder and the compressed air source are joined by comparatively large pipes, a control valve and a control of the braking pressure regulator are joined by small controlling compressed air pipes.

The service braking can be done by controlling the control valve's handle of the service brake. If the handle is turned to " brake " from " release ", then a force to add to the valve *Hb* increases in proportion to a position of the handle by an action of the spring and the lever *Ha*. The downward valve is opened by this force so that a compressed air flows in the valve from the air source. When the pressure rises to the value equal to the force of the spring, the valve recloses. Accordingly, a pressure signal corresponding to a position of the handle will be transmitted to the control valve room *Ba 5* of the braking pressure regulator through the control piping IV. By the pressure of *Ba 5*, the diaphragm *Ba 4* is moved to the left hand and the valve *Ba 2* is opened so that a compressed air flows into *Ba 3* and the pipe I. When *Ba 3* is equal to *Ba 5* in pressure, the valve *Ba 2* should close. Consequently, the pressure in the brake cylinder *Ab* will be correspond with the position of the handle of the control valve *H*, and the differential lever is moved around the center *m* generating the corresponding brake force at point *n*.

On the contrary, when the handle is resetted to " release " from " brake ", the lever *Hb* will be pushed upward so as to exhaust air by a pressure of a compressed air which is stronger than the force of the spring. A pressure signal of *Ba 5* will go down, the diaphragm *Ba 4* will move to the right hand, then the exhaust port of the pipe valve will open so as to exhaust compressed air into atmosphere and a pushing up force in the brake cylinder will decrease.

An emargency brake will be carried out by turning the handle of the control valve *H* of the emergency brake to " brake ". That is, the limit switch *b* will be switched off so as to the coil *S 1*, of the magnetic valve *Bb* is demagnetized, then the pressure piping of the diaphragm *Ba 9* of the braking pressure regulator should be exposed in atmosphere. Besides this, demagnetizing for this coil *S 1* can be carried out by means of the emergency foot switch or emergency protection devices. Consequently the diaphragm *Ba 9* will move upward, the valve *Ba 7* will open, and a compressed air of the secondary side of the pressure regulator *S* will flow into the valve room *Ba 5*.

This secondary pressure is adjusted preliminary to suitable value which is to be less than the rated pressure, so that the diaphragm *Ba 4* will move to the left hand, the service brake's cylinder should be supplied with a compressed air equivalent to this secondary pressure in the same way as the service braking, and then a pneumatic emergency braking can be obtained.

The other side, by a demagnetizing of the coil *S 1*, the diaphragm *Bd 1* of the control valve *Bd* to be used for emergency brake will be exposed into atmosphere too, a compressed air in the holding cylinder will be exhausted gradually through the throttle valve *Be* with the adjustable throttle *Be 2*. So, when a maintenance force of the holding cylinder is equivalent to a weight of the counter weight, it goes down with the fulcrum *n*. Since a pressure in the brake cylinder rises by a braking force of the counter weight, a compressed air will be exhaused by the braking pressure regulator so that the brake piston will go down and a braking force on the

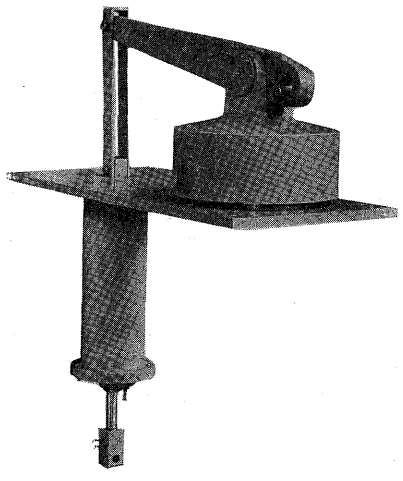


Fig. 14 Brake engine

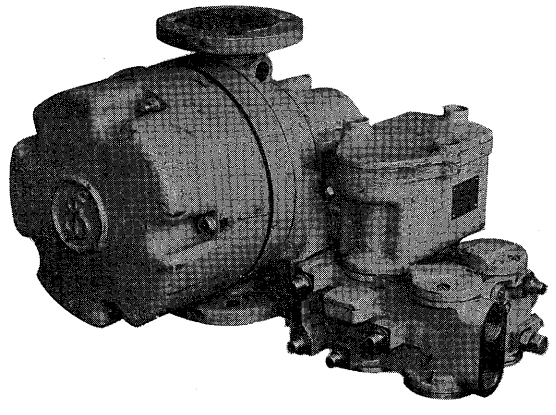


Fig. 15 Brake pressure regulator

point *m* will be kept in constant. When the braking force rises still more and exceeds the pneumatic emergency braking force, a braking force on the point *m* will increase in accordance with a braking force of the counter weight, at last the rated braking force of the counter weight type emergency brake can be obtained and the winder is firmly sustained.

In case the cage is put near the shaft end, the throttle valve *Be* will be short-circuited by the depth transmitter, and a compressed air will be exposed into atmosphere so the counter weight type emergency brake will be more effective. Even if the magnetic valve *Bb* should not work, an exhaustion of the holding cylinder and an inspiration of the brake cylinder will be made by the emergency brake valve *Na* and *Nb* to compensate a lack of an emergency brake.

For resetting to the normal state after the emergency brake functions, the service brake's handle is so interlocked mechanically that resetting can not be carried out unless the handle is turned to " brake ". That is, the valve *Ba 7* can be changed over by turning the handle of the service brake to " brake ", a pressure signal will control the diaphragm *Ba 4* so that the service brake shall actuate. After that, by turning the emergency brake's handle to " release ", the limit switch *b* closes, the coil of the magnetic valve *Bb* is energized, a compressed air flows into the holding cylinder *Ac*, and the counter weight is to be pushed up consequently to the normal position. If the emergency brake's handle is resetted to " zero ", the winder will be able to operate normally.

Besides the pressure supervising device *Bc* was provided against emergencies such as a leaking of a control piping or dropping of a pressure of a compressed air to function the emergency brake. The air reservoier *T* was provided for the purpose of that the pressure supervising device does not actuate under the normal controlling condition. And the drain separator was also provided at every strategic point in the compressed air piping for preventing solidification of water. The brake cylinder and others was furnished with compressed air-oil sprays for smooth lubrication too.

3. Other Electrical Equipment

The depth transmitter, which sends instructions for the operation of the winder, and other signals, in accordance with the depth of the cage, is equipped near the winder and driven by the Koepe wheel through bevel gears and flexible couplings. This depth transmitter is equipped with a electric differential correction device at its mouth, and has following transmission components ; a ring tube type variable resistor for a depth meter ; a control transformer for hoist speed instruction in retardation control range ; a cam type switch for secondary resistor value instruction ; a right position detecting switch for correction ; an over-winding limit switch ; a exhaust valve for a braker throttle valve. Among them, the components for the retadation signal are of the expanded type, and are designed to send precise signals by operation of an air clutch, when it comes to a starting point of retadation. It is needless to say that all electric equipment mentioned above are of the explosion proof type.

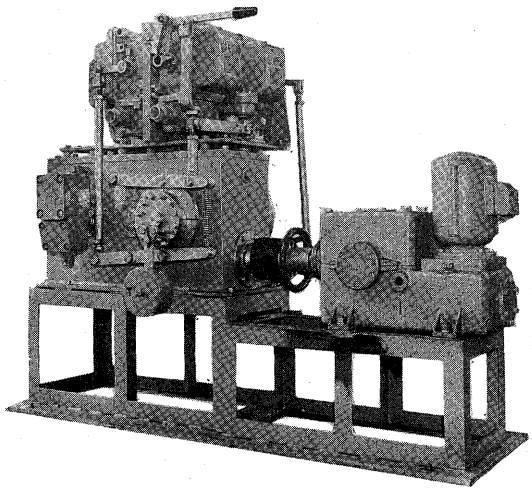


Fig. 16 Depth transmitter

Pressure tight explosion construction type magnetic limit switches are specially installed to expect more accurate detection of the starting point of retadation, the speed supervising point of the retadation zone and the stopping points for each deck of the cage. The over-winding limit switch is also installed in the shaft, which is of the pressure tight explosion proof type, and acts directly with the move of the cage and the counter weight.

On the other hand, the speed transmitter, which sends speed instruction for the winder, consists of the followings ; induction type AC pilot generator for speed detection for retardation control range ; tachometer generator for speed meter ; and centrifugal switch for over speed protection. All of them are

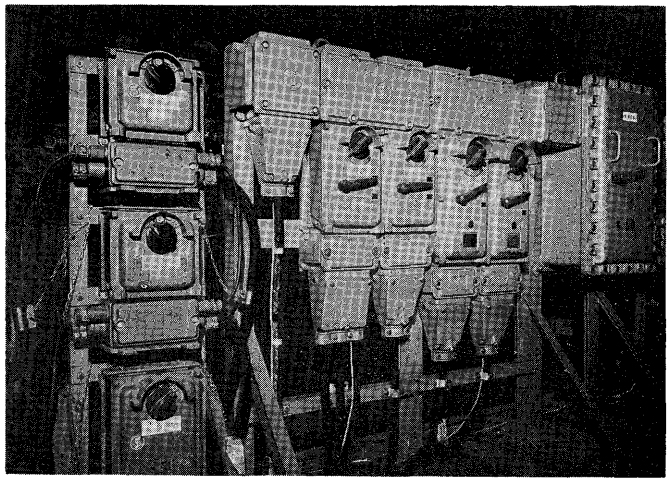


Fig. 17 Low tension switch gears

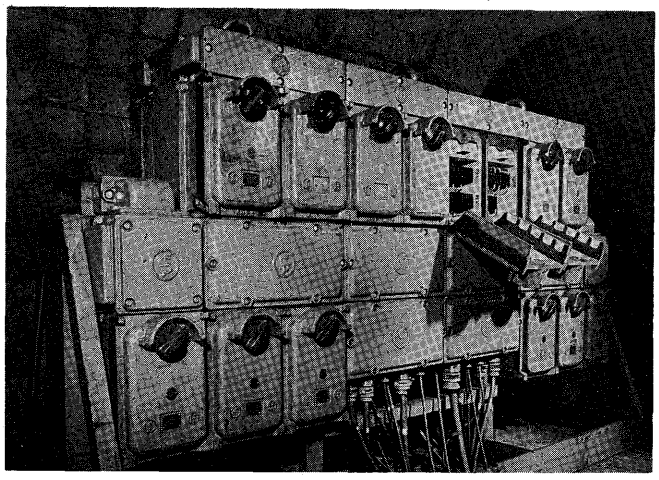


Fig. 18 Relay boxes

of explosion proof construction and driven by the high speed shaft of the reduction gear of the winder. Beside this, a centrifugal switch is equipped with the auxiliary motors.

On the control desk, with the handle and link mechanism, instruments such as various meters, signal lamps, switches, control valves etc. necessary for the operation of the winder and of the deck equipment are installed and arranged effectively and designed to form a safty increased explosion proof construction. High tension switch boxes for the main motor and a step-down power transformer are of pressure tight explosion proof construction housing 150 A 25 MVA high tension magnetic contactor. For low tension power, 200 V electric source is obtained from the 100 kVA three phase oil immersed explosion proof type transformer and supplied to the necessary places through the distribiting air circuit breakers and magnetic switches. These low tension switch gears are of the unit assembling type, which is one lock-bolt type box of pressure tight explosion proof construction. Same thing applys to the control source boxes and to the relay boxes.

4. Operation

Operation of the winder is carried out by a driver operating the master controller's handle on the control desk to the appropriate direction and then operating the normal breaking handle to the position " release ". By doing so, through the master controller connected with the master controller's handle, corresponded primary high tension magnetic contactor is switched in and main motor generates starting torque, on the other hard, as the breaker has lost its breaking force as mentioned above, then the winder starts. At the same time, creeping speed motor begins to race. Hereafter with master controller's handle setting to the forward position, magnetic contactors for secondary resistor short circuit is step by step switched in and secondary resistor is gradually short circuited, thus the winder is accelerated. In case winder speed comes to 100%, secondary resistor is automatically short circuited by the centrifugal switch regardless of the position of the master controller's handle, thus the over speed in case of lowering operation is prevented. On the control desk, other than master controller's handle and service breaking handle, there is a gallery change over handle. Among three galleries, that is −340 mL, −550 mL and −658 mL, previous selection of gallery aimed to go is done by selecting one among two galleries.

In case the gallery change over handle is operated, by the switch connected to the handle, among magnetic limit switches, such as retardation starting point switches, speed supervision point switches for retardation range and stopping switches for each deck, only necessary ones are circuited.

Retardation control is done in both ways, automatically and manually by the auto-manual change over handle equipped on the control desk.

First, automatic retardation control is explained. When the cage arrived at the retardation starting point, instruction for automatic retardation control is sent from the magnetic limit switch equipped in the shaft, and main motor is cut off from the high tension electric source and is connected to the output circuit of magnet amplifier which is the power source for dynamic braking, after the arc-interlock device is recovered. In this state, all secondary resistores are circuited. At the same time, at the depth transmitter, retardation cam for control transformer begains to rotate by the air clutch closing and transmits speed instruction to the speed regulator.

To the speed regulator, voltage of the control transformer and voltage of the pilot generator showing the actual speed of the winder are differencially transmitted, so it carries out automatic regulation to balance these two value. *Fig. 19* is block diagram for automatic retardation circuit. In this control system, the gain of the automatic control loop reduces and the time constant also varies according to the reduction of the main motor. Therefore, the planning of the breaking circuit is very difficult to be always given the maximum function. In this case, by the secondary resistance adjusting switch operated from the retardatio cam, the reduction of the loop gain was prevented.

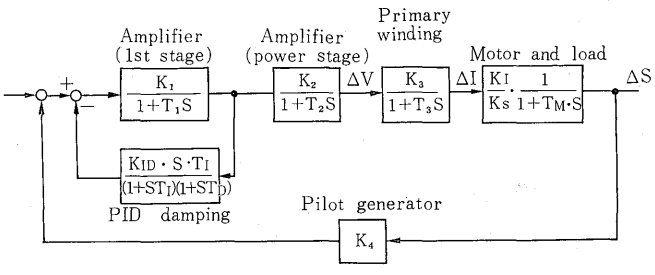


Fig. 19 Block diagram

Thus, when the speed becomes to 1/12, high sensitive relay connected to the pilot generator detects it and closes the air-clutch of the creeping speed device, at the same time, cuts off the main motor from the dynamic breaking power source and the winder is driven in creeping speed by the creeping speed motor. When the cage reaches the stopped position, the magnetic limit switch detects it and sends the illumination signal to the control desk to tell the driver. Then the driver operates the service breaking handle to the position " brake " and returns the master controller's handle to the position " zero " to stop the winder.

In case of decking change, the driver steps the creep speed pedal, then if the main controller's handle is operated, creep speed drive is carried out by the creeping speed device.

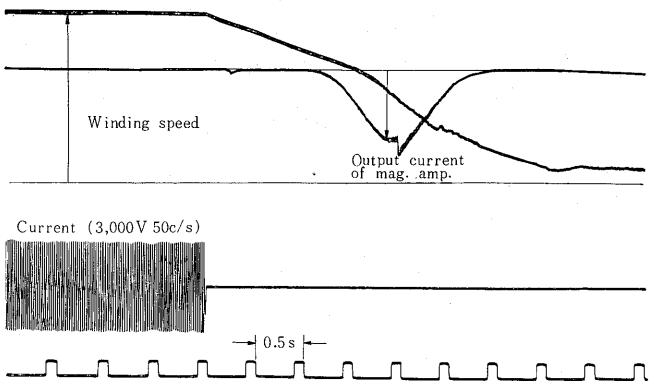


Fig. 20 **Oscillogram of automatic retardation control in case of hoisting 2 mine cars**

When the retardation control is changed to the manual control, at the starting point of retardation control, the alarming bell rings, on hearing the alarm, the driver returns the master controller's handle to make the dynamic braking state, then the winder follows the instruction of the speed volage of the control transformer connected to the master controller's handle.

The above mentioned was the case of regular drive of the winder, but in accident it is necessary to start to drive the winder from the part way of the shaft, it is so equipped with the interlock that regular operation, service braking combined operation or creeping speed operation are carried out in accordance with the cage level.

V. CONCLUSION

Recently in Japan, for the rationalization of transport in the coal mine, the inclined shaft transportation system is gradually replaced by the vertical shaft transportation system. In this trend, it can be said that the advance and improvement in the main shaft winding equipment as well as the blind shaft winding equipment are imperatively important. For this reason, though this equipment introduced here is rather small in scale, the successful accomplishment of this equipment can not be overlooked, we believe.