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HIGH LIFT ELEVATOR FOR BLIND MINE SHAFT DELIVERED TO NITTETSU MINING CO., LTD.

Makoto Inagaki
Industrial Application Engineering Dept
Masauki Yoshida
Kawaski Factory

I. INTRODUCTION

This equipment was the first vertical mine shaft elevator equipment manufactured in Japan. It employs a newly developed hoist device which also serves as an elevator and is based on Fuji Electric's time-proven shaft winding techniques. The shaft elevator has been installed in the Shinyama blind vertical shaft at the Kamaishi mine of the Nittetsu Mining Co., Ltd. in Iwate prefecture. This shaft has 5 levels (7 levels in the future) of horizontal galleries branching off from it at intervals of about 50 m. This fully automatic high-speed elevator is specially intended for the transport of mining personnel and is aimed at greatly improving the efficiency of getting the miners into the mine.

This type of shaft elevator is easier to make into a standard series and is also simpler to handle than previously used shaft elevator equipment for transporting personnel. It can therefore be utilized in all types of mines as well as a wide range of industries and will very probably become highly popular in the future.

Official tests on this elevator were completed in June, 1968 and it is now operating in good condition. This article will give an outline of the equipment.

II. OUTLINE OF THE EQUIPMENT

The Shinyama shaft is a blind vertical shaft with a rectangular cross-section of 2.1 × 3.6 m. The transport system is a single-track cage hoist system with a counterweight. The present depth is 210 m, but this will be extended to 310 m in the future. All equipment is planned so that it can be used without any major changes when the extension is made. The cage is of the single deck type with a capacity of 20 persons. The main rope from which this cage is suspended consists of two filler-type strand ropes which have undergone pretension treatment to minimize elongation over long periods of use. The balance rope is special in that it consists of a flat rope with a rubber cover; the first time that this type of rope has ever been used for this purpose. The winder employs the blind vertical shaft top equipment system so that a rope canal or a guide sheave are unnecessary. The winder is driven by a dc motor employing a thyristor Leonard system, the first time that such a system has been used in Japan for mine shaft winders. Operating data for this equipment is given in *Table 1.*

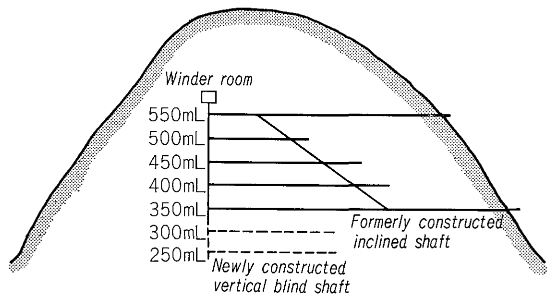


Fig. 1 **Relation between vertical shaft and horizontal galleries**

Table 1. **Operating Data of Shinyama Vertical Blind Shaft**

Item	First Plan	Second Plan
Winding Distance	210 m	310 m
Net Weight Personnel (20)	1500 kg	
Unbalanced Load	793 kg	812 kg
Winding Speed	3 m/sec	
Winding Time	80 sec	114 sec
Main Rope Diameter Weight Tensile strength Guaranteed breaking strengh	 2×30 mm 2×3.47 kg/m 180 kg/mm² 2×53.2 t	 2×31.5 mm 2×3.83 kg/m 2×58.6 t
Balance Rope Sectional dimensions Diameter of ropes Weight	 23 mm×150 mm 8×8 mm 6.94 kg/m	 — — 7.66 kg/m
Maximum Rope Tension	5.74 t/2 ropes	6.70 t/2 ropes

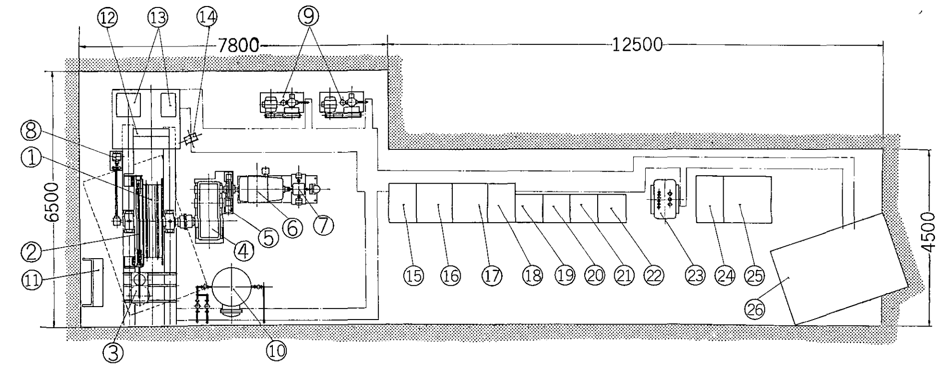


Fig. 2 **Plan of winder room**

① Koepe wheel
② Main brake
③ Brake engine
④ Main reduction gear system
⑤ Auxiliary brake
⑥ Motor
⑦ Speed detector
⑧ Depth indicator
⑨ Air compressor
⑩ Air receiver
⑪ Air pressure regulator
⑫ Meter panel
⑬ Operating handle stand
⑭ Fault indicator panel
⑮ Auxiliary circuit cubicle
⑯ Control relay cubicle
⑰ Control relay cubicle
⑱ D-c main circuit cubicle
⑲ TRANSIDYN control cubicle
⑳ TRANSIDYN supervisory relay cubicle
㉑ Unit cooler cubicle
㉒ Thyristor cubicle
㉓ Thyristor transformer
㉔ High tension power receiving cubicle
㉕ Control source cubicle
㉖ Entrance

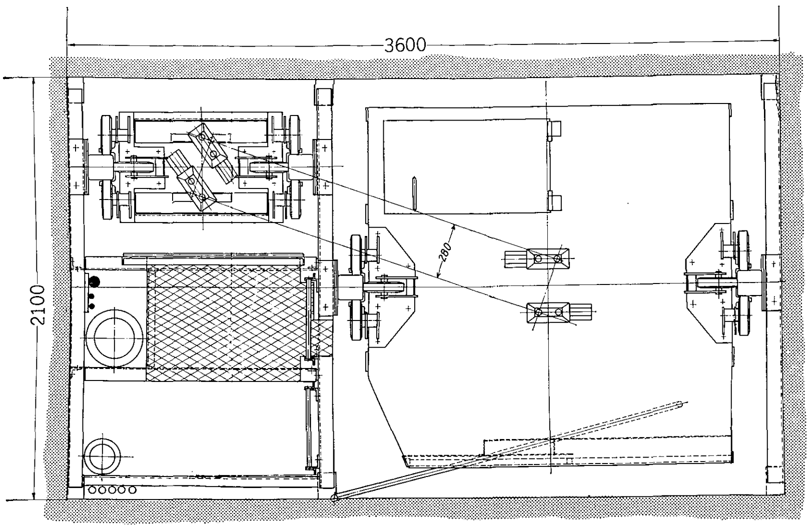


Fig. 3 **Horizontal section of shaft**

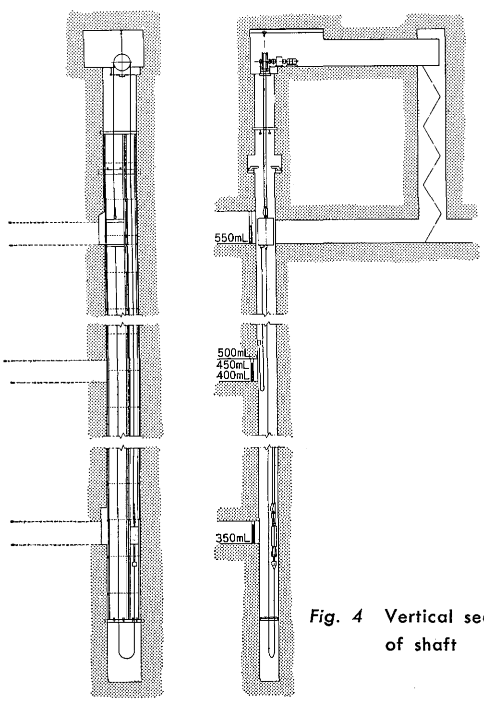
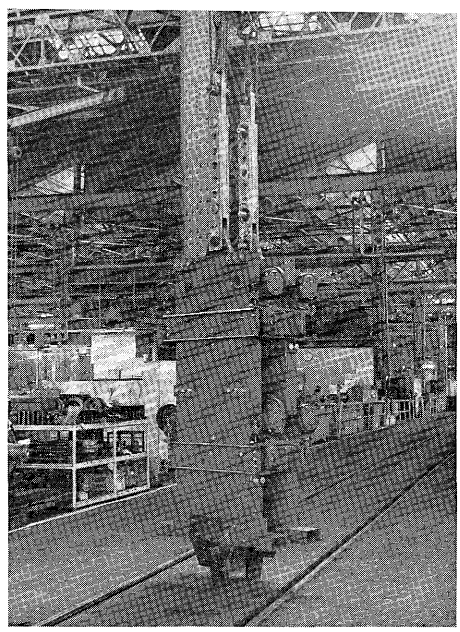


Fig. 4 **Vertical section of shaft**



F.g. 5 **Counterweight**

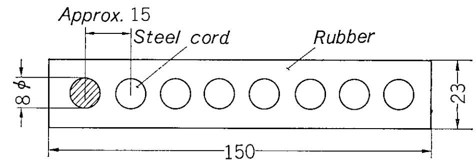


Fig. 6 Section of balance rope

III. SHAFT INSTALLATION

As shown in *Fig. 3,* the vertical shaft cross section consists of the cage track, counterweight track, and ladder path ; all of which form a single track system. This system is arranged so that the area occupied by the counterweight is as small as possible. The ladder in the vertical shaft is used for inspections or emergencies and extends from the topmost buffer to the sump at the very bottom of the shaft. Every 4 meters there is a landing which is separated from the counterweight track by a wire netting.

The guide is made of a standard size of rectangular steel pipe appropriate for the shaft elevator. The surface of the guide undergoes metal spraying treatment. It is fixed by special metal fixtures every 4 m to the buntons. This special fixture is unique to Fuji Electric and can be adjusted in any direction within a radius of 15 mm. The elevator provides a smooth, comfortable ride because of the guide system and the shock absorbing effect of the rubber rollers attached to the top and bottom of the cage. During full-speed operation, the horizontal vibration acceleration of the cage has been shown by actual measurements to be less than 0.15 g throughout the entire length of the shaft.

The cage is of the single deck type with a capacity of 20 persons. The door has a manually operated slide system made of a lightweight alloy. The cage is of sealed construction with an escape hatch in the ceiling and is water-proof to prevent the penetration of water dripping in the shaft. A convenient operation panel is arranged on the inside wall of the cage, as well as a magnet-type telephone and signal bell. The tail cord cable for electric signals is positioned on the bottom of the cage so as not to interfere with the operation of the balance rope.

The counterweight employs the divided-type automatic rope tension control system which has already proven satisfactory in the blind vertical shaft of the Honbetsu mine of the Sumitomo Mining Co., Ltd. In this equipment the conterweight is divided into two parts, and the parts are equal in weight and each of them is connected to one of two main ropes. The two parts are held tightly together by means of a guide frame and the tension in the two parts is always equal because both parts are automatically slid up and down according to the rope elongation. The main feature of this construction is that the rope need not be adjusted over long periods of use.

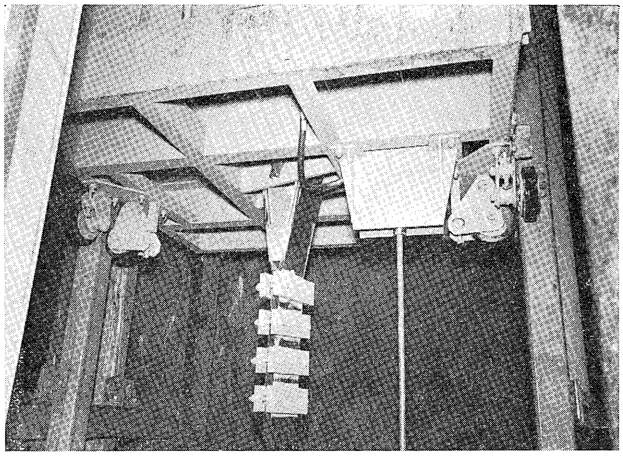


Fig. 7 Balance rope and tail cord cable

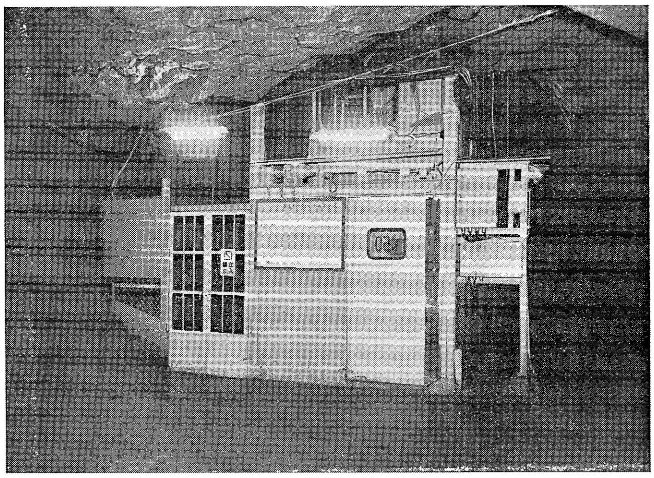


Fig. 8 Shaft door with SB-motor drive

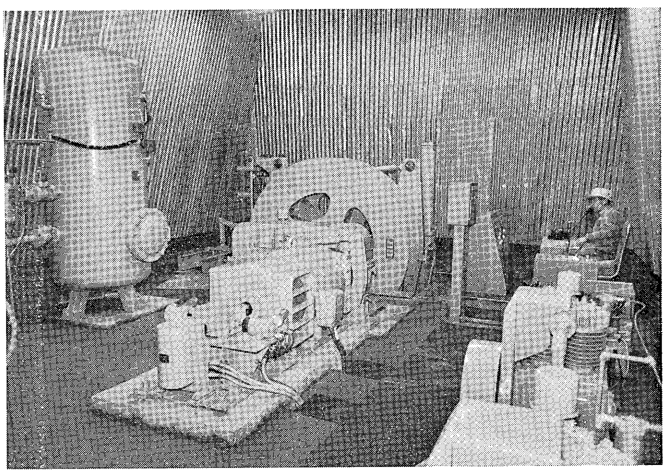


Fig. 9 Winder

The balance rope is a flat rope covered with rubber and as shown in *Fig. 6,* the sectional dimensions are 23 mm × 150 mm. The construction is almost the same as a steel cord belt and consists of coating rubber and 8 wire ropes which are arranged in a straight line with alternate left and right hand lays. This balance rope is highly suitable in that it prevents any damage to the tail cord cable which is suspended from the bottom of the cage and also is sufficiently corrosion proof because of the rubber coating. It is also flexible since the hardness factor is low and handling is easy.

At each shaft level, there is a level door with SB motor drive through which personnel can enter or leave the elevator. The motor is an SB motor containing a brake mechanism, and drives a chain via a worm gear. The door automatically opens when the cage arrives at the level. Next to the level doors, there is an operating panel indicating cage direction and a magnet-type telephone.

IV. WINDER

1. Specifications of Main Mechanical Parts

Koepe wheel: Diameter: 1.85 m, double-rope system

Main brake: Lower fulcrum post type
Quick acting pneumatic type

Main reduction gear system:
Two-stage helical gear ratio 24.2:1

Auxiliary brake:
Pneumatic action post type (synchronized with main brake)

Main shaft coupling:
Gear coupling

Motor coupling:
Flexible coupling (as per JIS) with brake rim

The Koepe wheel is made of steel plates welded together and contains 2 rope grooves, a rope magazine for changing and attaching the rope, and a brake rim on one side. The rope lining is made of synthetic rubber and possesses a high coefficient of friction as well as a sufficient safety factor in respect to rope slipping. The main reduction gear is made completely of special steel. Lubrication is by the splash lubrication system and operation is extremely quiet.

2. Specifications of Main Electrical Parts

Motor: Dc motor, separate excitation, drip-proof fully protected, self ventilation type.
60 kw, continous rating: 600 rpm, 220 v.

Motor control source:
Thyristor static Leonard system, 3-phase bridge cross connection, capacity 220 v, 550 amp continuous rating, forced ventilation with internal cooler.
Oil-immersed self-cooled thyristor transformer. Capacity 100 kva 50 Hz.
Voltage ratio 3 kv/2 × 220 v

Brake Differential lever system pneumatic type service and emergency brake, and counterweight type safety brake.
Rated lifting capacity 2000 kg
Pneumatic pressure 5 kg/cm^2

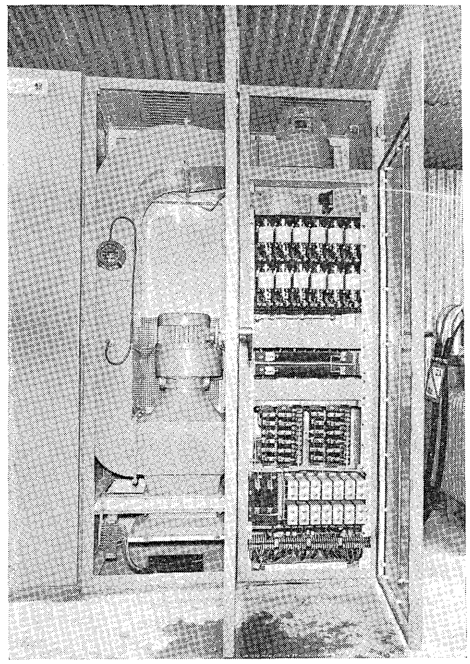


Fig. 10 Thyristor cubicle with cooler

When deciding on the type of drive system to use for the shaft elevator, the following points were considered.

1) Since the system is for passengers, the ride must be comfortable and the speed must be constant, no matter what the load.

2) It must be easy to obtain a stable creep speed so that the cage stops exactly in the correct position at each level.

3) Equipment parts must be simple, reliable and easy to automate.

4) Simple protection and easy maintenance is especially necessary because of the various adverse conditions to which equipment within the shaft is exposed.

The static Leonard system has recently become increasingly popular. Fuji Electric has a wide range of experience in the production of static Leonard systems and utilized it in this shaft elevator equipment since it filled all of the above conditions.

The motor output is determined by calculating the RMS output on the basis of the operating cycle established in the calculating method for Fuji Electric gearless elevator motor outputs. This drive cycle is the ascent of the cage containing the total effective load from the shaft center position up one level—8 sec. stop—descent over the same distance with 1/3 of the total load—8 sec. stop—subsequently repeated. Factors concerning the precisely selected maximum required torque and the safety factor for passenger systems were added to the output. And because this is a self-cooled motor the thermal conditions guaranteed for creep speed operation (0.3 m/s) one way over the full shaft length (future: 310 m) at the total effective load for shaft inspection etc. were also included in the determination of the output.

The brake is based on the West German Mining Standards so that the sustained safety factor at maximum unbalanced load must be 3×and the deceleration for descent at equal loads must be 2 m/s^2. For these reasons this shaft elevator employs a newly developed effective small-size quick-acting pneumatic brake engine. Brake control utilizes the TELEPERM-TELEPNEU remote control which has proven its excellence in many applications including the winder at the Joban Colliery. This system has a rapid response so that the accuracy of the cage arrival position is within ±10 mm at each level.

Special considerations resulting from adverse conditions of locations are as follows.

Since this is a blind shaft, protection against high humidity as well as protection against corrosion due to nitrous acid gas generated during explosions assume special importance. For these reasons all conductors in the motor such as the coils and lead wires, except for the commutator, are carefully insulated with a material consisting mainly of glass.

The thyristor equipment consists of Fuji Electric's standard draw-out type thyristor element units contained in an enclosed cubicle. A special cooler provides forced circulation of inner air insulated against external air. An air to air heat exchanging system is used in which internal heat is transferred to the exterior.

3. Automatic Control Equipment

The automatic control, supervisory and protective equipment is all of the TRANSIDYN system. Since there is considerable literature already published concerning the TRANSIDYN, details are omitted here.

The TRANSIDYN has excellent control functions due to quick response characteristics and high amplification factor of transistor. This equipment uses Fuji

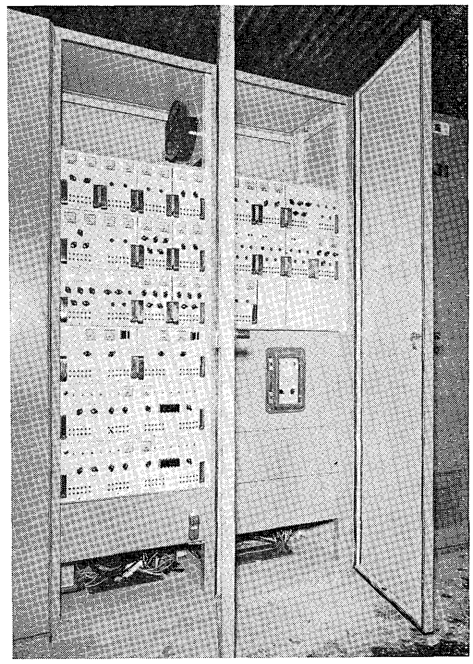


Fig. 11 TRANSIDYN cubicles

Electric's standard high capacity control equipment in which adjustment and checking are easy becausc all of the control devices are arranged in individual units. An external view is shown in *Fig. 11*. On the left is the automatic control equipment cubicle and on the right, the supervisory and protective equipment cubicle. The whole cubicle is completely enclosed and self-cooling so that there is no contact with the external air. The plug parts in all units are gold-plated so that contact will not deteriorate and there is no chance of corrosion.

Fig. 12 is a block diagram of the automatic control system. The individual parts are explained in sequence as follows.

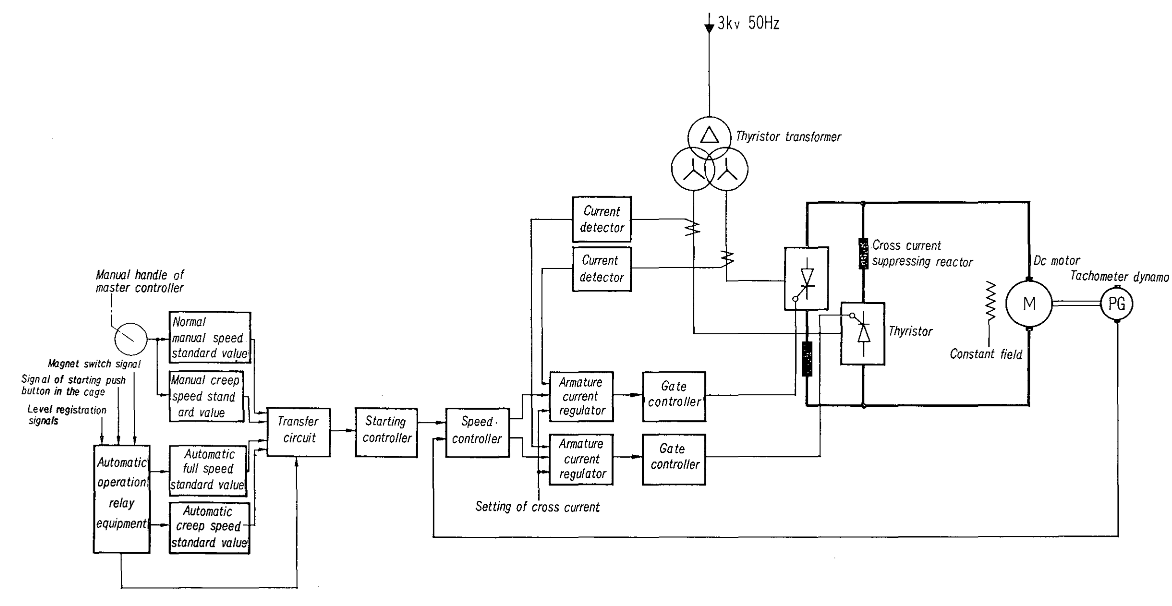


Fig. 12 Block diagram of automatic control circuit

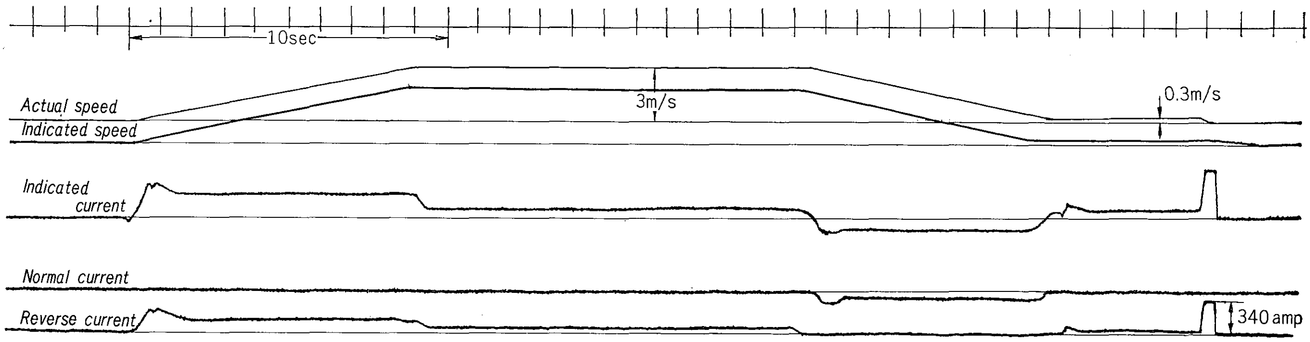


Fig. 13 Oscillogram for automatic operation

1) Winding speed standard generating equipment

The standard winding speed has a full speed value (equivalent to 3 m/s) and a creep speed value (equivalent to 0.3 m/s) for automatic operation. For manual operation, there is a manual speed signal obtained by rectifying the output of the synchro-machine connected to the handle of the master controller. The manual speed signal can be selected for 2 positions: maximum equivalent to 3 m/s for standard operation and maximum equivalent to 0.3 m/s for creep speed operation during shaft inspection, overwinding etc. These maximam values of standard speeds can all be steplessly adjusted.

The standard winding speed value is selected by switching the circuits according to the type of operation, and then applied to a starting controller. This controller is a type of integrator and when only the final speed signal is applied as input, it dispatches a speed signal with constant acceleration or deceleration to the next speed control loop. In this way, a stable, comfortable ride is possible.

The acceleration and deceleration can be adjusted simply by turing the controller knob.

2) Speed control circuit

The speed signal from the starting controller is compared with the actual speed value from the tachometer dynamo which is connected to the motor output shaft, and then applied to the speed controller. In the speed controller, the integrated time of drive parts is compensated by a PI regulator and a plus or minus armature current signal is given (depending on the polarity of the speed deviation) to the armature current control system.

The armature current control system is provided for the cross-connected normal and reverse thyristors (1 group each). The armature circuit time constant is compensated for by a PI regulator. In the armature current control system, specified cross current control also takes place between the normal and reverse thyristors.

4. Brake Control Equipment

The brake control equipment employs the well-known TELEPERM-TELEPNEU control system. Considerable literature is available concerning this system and it will not be explained here. In this shaft elevator equipment, the emergency brake pneumatic pressure can be switched to strong or week at the bottom and top of the pit and in the shaft. In this way shocks during emergency operation in the shaft are very weak because no sudden stopping is required. For manual operation, the brake power can be controlled smoothly by the output of the synchromachine connected to the service brake handle. Even if the maximum service brake pressure should develop due to some error during full speed operation, the safety factor is large enough that the rope will not slip. The small-size quick-acting pneumatic brake engine is shown in *Fig. 14* and if this small size is used to its best advantage, the brake engine can be connected not only with the winder and crane but also the automatic control equipment so that there will probably be many requests for the use of this device in the optional deceleration control.

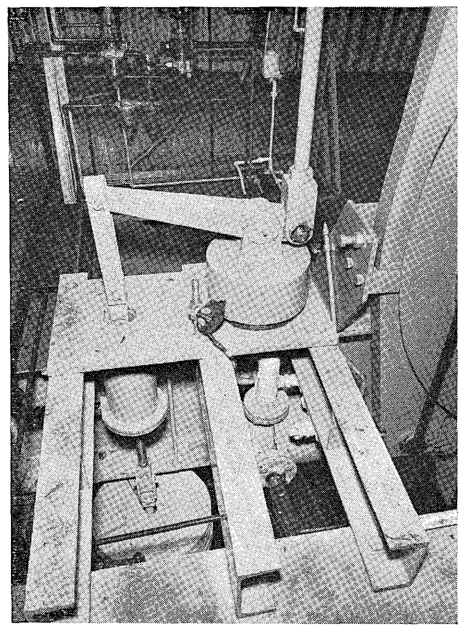


Fig. 14 Small-size quick acting brake engine

5. Automatic Operation

The operation system of this equipment can be called an automatic elevator system since no operator is required in the winder room and the user can operate the elevator as he wishes between each shaft level. This special feature is not found in previously used vertical shaft winders. When this system was designed, sufficient consideration was paid to the vertical shaft winder operation and the safety factor. In this way, an individual automatic operating system was established based on the selective/collective system used in automatic elevators for general buildings.

1) Tail cord cable

The tail cord cable suspended from the bottom of the cage is used to convey starting signals and emergency stop signals from inside the cage to operate the automatic operating equipment in the winder room. It also serves to transmit single tone shaft signals to and from the winder room as well as conversations by the magnet-type telephone to the winder room, supervisory room and all level landings.

As shown in *Fig. 15*, the tail cord cable core consists of 8 wires for control and two wires for the telephone.

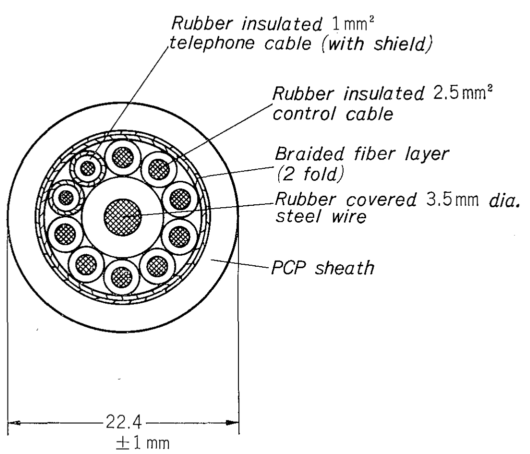


Fig. 15 Section of tail cord cable

2) Magnet switch

For automatic operation, the magnet switches are exclusively used for detection of cage travelling position, deceleration signal, braking signal at cage arrival position, detection of arrival, level speed supervision at the top and bottom of the pit, and detection of overwinding. A cam mechanism synchronized with depth indicator is not employed, since, in a shaft elevator with optional operation at several levels, cam mechanism becomes so complicated that it is not practical. Since Fuji Electric already has considerable experience in the production and practical use of vertical shaft winders, the reliability of the magnet switch has already been confirmed and it is therefore used in this equipment. With this switch, multilevel shaft operational control is greatly simplified.

3) Registration panel

On the landing of each level, there is a registration panel which contains a magnet telephone, lamp push button switches for registration of destination, cage position indication lamps, and cage direction indication lamps. The push button switches for registration of destination are provided for all the other levels. These push buttons combine the function of the call signal push buttons for differentiating between the up and down directions at elevator landings in usual buildings with push buttons for registration of destination inside the cage. The signals selected optionally by the users at each level are arranged in priority sequence by means of the memory and description circuit in the automatic operation relay cubicle in the winder room. Therefore, the cage movement is determined by means of a selective/collective system.

Actual operation methods are as follows:

4) Automatic operation method

The user pushes the destination registration button on the registration panel at the landing and waits for the cage to arrive. This signal is memorized directly by the relay circuit in the winder room and the button pushed is illuminated which indicates that the signal has been registered. This operation is not related to the cage position, number or kind of registrations. For the travelling cage to arrive at a certain landing, at least one of the following conditions must be fulfilled up to the time the cage reaches the deceleration point for the landing.

(1) The desired landing must be registered at the landing where the elevator was previously stopped.
(2) The direction of destination of registration from the desired landing must be the same as that of the travelling cage.
(3) There must be no registration from subsequent landings beyond the desired landing.

When none of these conditions are fulfilled, the cage speed does not decelerate and that landing is by-passed. For the cage which has stopped at a certain landing to continue in the same direction when again starting, one of the following conditions must be fulfilled before the cage stops at that landing

(1) Registration must be made from the previous landings for landings beyond the landing where the elevator is presently stopped.
(2) There must be registration from landings beyond that at which the elevator is presently stopped.

Thus, the cage moves by means of priority selection of only those registrations for which direction is same as that in which the cage is then travelling. The registration is selected as follows.

When the cage arrives, the user is informed only by the fact that the selected push-button lamps are extinguished so that no confusion will result even when registrations to the opposite direction have been made at the same landing. Once the cage arrives, the motor operated level door opens automatically, the cage door is opened manually and the passsengers leave and enter the cage. The cage door is closed and when the start button inside the cage is pushed, the level door closes directly and the cage starts. Even if the start button is not pushed, the level door automatically closes after a specified period (can be adjusted within 30 sec.) and after closing is completed, the elevator starts.

While the cage door is opened, the level door does not close and the cage can not start. If the cage door is opened while the level door is closing, the level door will automatically reverse and begin opening again. When all registrations have been completed, the cage stops at the final landing for a specified period of time, and if no new registration is made during this period, the cage automatically returns to the highest level (550 m) and waits there.

6. Manual Operation

The shaft winder can be operated manually in case of shaft inspection, or replacement of the rope or cage.

General operation of the winder is possible using all meters, supervisory panels with indicator lamps, the mechanical depth meter, the handle of the master controller, and the handles of the service and emergency brakes.

7· Protective Equipment

General devices are ommitted and only special devices are outlined.

1) Universal speed supervisory system

This is Fuji Electric's standard supervisory system and it is a contactless type containing a transistor zero amplifier as the main component. The following three types of supervision are carried out and in all cases emergency braking is possible.

(1) Continuous speed supervision

For this control, the output of a separate tachometer dynamo especially for supervision is compared with the speed signal value of the starting controller. An overspeed of 115% (adjustable) of the full speed can be detected.

(2) Level speed supervision

Overspeed detection of 115% (adjustable) of the speed corresponding to the position of detection is possible by means of the supervisory tachometer dynamo and the magnet limit switches located in the retardation zone at the top and bottom of the pit.

(3) Unbalance supervision of the control and supervision techometer dynamos.

Unbalance detection is made by comparing the outputs of both dynamos.

2) Landing and cage safety circuits

Safety is especially important in equipment which carries personnel. In any of the following cases, emergency braking takes place.

(1) When the shaft door opens for some reason at a level other than that where the cage is positioned.

(2) When the cage door opens at times other than when the service brake is engaged and the cage is within the level landing position.

(3) When the cage stops outside the specified level landing position during automatic operation.

(4) When the tail cord cable is cut.

V. CONCLUSION

Through the extensive Fuji experience in the manufacture of vertical mine shaft elevating equipment and semiconductor technology derived from industrial power applications, objectives were satisfied without difficulties.

This equipment features a work rate which exceeds that visualized during the design stage.