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RATIONALIZED LABOR-SAVING RADIO CONTROL EQUIPMENT

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I. INTRODUCTION

The application of radio control equipment has been icreasing recently because of the shortage of labor force. Six years ago, Fuji Electric developed the "Crane Master" radio control equipment for crane and so far more than 150 of these units have been supplied and are operating satisfactorily. This equipment has the following outstanding features:

1) Safe and efficient operation

Operator can control the crane while he follows the movement of crane and confirms the surrounding conditions.

2) Saving of personnel efficiency

Since the crane operator is located at ground level, he can perform other duties.

3) Improvement of working conditions

Cranes are usally located in places which are subject to poisonous fume, dust and dirt, high temperature, high humidity. By adopting the Crane Master, operator can control the crane from a place both safe and less unhealthey.

Radio control equipment for diesel hydraulic locomotives was developed on the basis of the techniques used in the Crane Master. This has been used for rationalization and labor saving purposes in the transport department of steel works and by virture of this radio control, the number of personnel required for a locomotive is cut to one half.

This article gives an outline of the two types of radio control equipment mentioned above.

II. CRANE MASTER

1. Outline

This equipment allows for radio remote control of all crane operations and is applicable to any type of crane. According to the Radio Law in Japan, radio operator's licence is not necessary for Crane Master operator, because this equipment utilizes very weak radio wave. The constructive features of Crane Mater are as follows:

1) Compact size and light weight

In case of B type which controls three motors in two steps, the weight of transmitter is only 2.3 kg which means less fatigue for the operators.

2) Highly reliable protective circuit is provided

The self-check circuit developed by Fuji Electric (Patent No. 523168) is employed in this equipment so that chance of misoperation is eliminated. Since the wiring between electronic components are arranged on printed circuit boards as well as the wiring between printed circuit boards, high reliability is insured.

3) Easy Operation

All of the crane operations including inching, can be performed with the same feeling as in the case of the manual operation.

4) Internal fault detecting circuit is provided

This circuit insures protection against any faults which happen to occur in the equipment.

2. Equipment Construction

The equipment consists of an FM transmitter and FM receiver and has such accessories as receiving antenna and battery charger. The specifications for each component are as follows.

1) FM transmitter

(1) Transmitter

Frequency: 130 to 140 MHz band

Frequency stability: within $\pm 0.005\%$ at -15% of source voltage and ambient temperature of -10 to $+15$°C

Modulating system: equivalent frequency modulation by crystal-controlled phase modulation, field intensity of less than 15μV/m at 100 meter distance from the transmitter.

(2) Signal oscillator

A tuning-fork controlled oscillator is used and the frequency stability is less than $3\times10^{-3}\%$. The signal frequency range is between 400 and 1,000 Hz.

(3) Battery

Type: Fully enclosed nickel cadmium battery

Rated voltage: DC 15 V

Capacity: 225 mAh (10 hour rate)

2) FM receiver

Frequency: 130 to 140 MHz band

Receiving system: crystal controlled double super heterodyne system

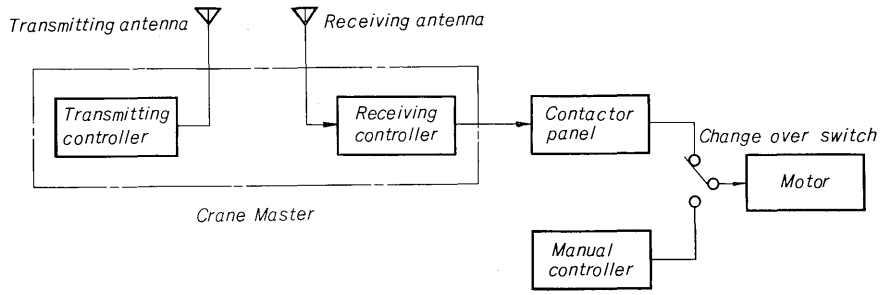

Fig. 1 Conceptional block diagram of Crane Master

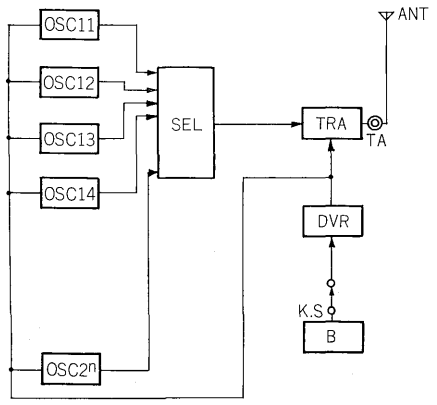

Fig. 2 Block diagram of transmitter

Sensitivity : S/N ratio of less than 20 dB for antenna input of 2 μV
Power source : AC 200/220 V (50/60 Hz)
Regulation : $\pm 15\%$
Ambient temperature : -10 to $+50$°C

3. Crane Control System

Fig. 1 shows a block diagram of crane master. The crane master can be used for radio control of all types of control. As an example, the possible radio controlled operations for a ceiling travelling crane are described below.

1) Switching of main crane power supply.
2) Forward/reverse control and speed control of travelling, side walking and hoisting motors.
3) Control of thruster brake.
4) Control of alarm, illumination, etc.

4. Circuitry

The circuitry is as shown in *Figs. 2* and 3, and operation is as follows. As is shown in *Fig. 2*, by switching on KS, the OSC_{11-2n} begin to oscillate at their respective frequencies and TRA commences to transmit the carrier frequency. The carrier frequency is frequency modulated by the output of OSC. SEL is a manually operated rotary switch which is used to select the output or outputs of OSC_{11} to OSC_{2n} to be connected to the modulation input terminal of TRA in accordance with the handle position.

The radio wave is received and demodulated by the FM receiver (REC) and selectively amplified by

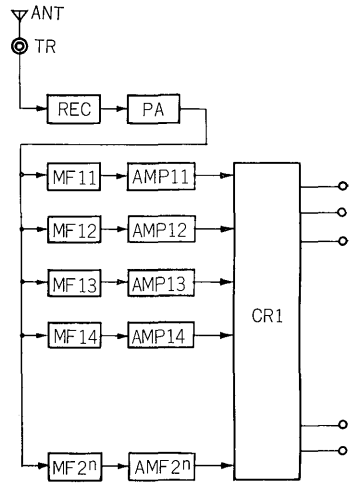

Fig. 3 Block diagram of receiver

MF_{11} to MF_{2n}. From the amplified output, check 1 picks up right signals to energize respective control relays. By making contact of control relays, the magnetic contactor accommodated in a control panel is actuated and the starting step of motor is progressed in a time-limit way.

5. Explanation of Self-Check Circuit

In the case of heavy noise interference, the conventional measure was to make the equipment inoperative for the purpose of safety. Such easy-going method results in frequent interruption of crane operation and makes the radio control unpractical where there is much electrical noise. In this equipment, however, there are two types of signal: one is a simultaneous operation signal which shows how many signals are sent simultaneously. Another is an operation signal which indicates the intended crane operation. By combining these two signals, only the relay for the desired operation is operated and by removing the power source from other circuits, the chance of misoperation due to noise interference is completely eliminated. In the case of three basic operations (such as travelling, side walking and hoisting), the block diagram of self-check circuit is shown in *Fig. 4*.

Explanation of operation :

(a) When there is no operation instruction

Since output is given by NOT circuits 1 and 2, INHIBIT circuits 1 and 2 become non-conducting and there is no power supplied to the relay circuits. Therefore, even when there is noise equivalent to the basic operations, there is no misoperation, since the power source of the relay circuits is interrupted.

(b) When there is one operation instruction

Since there is no output from NOT circuit 1, INHIBIT circuit 1 becomes conductive. As the selector circuits (1 to 3) do not yet operate, power is supplied to relay circuit (1 to 3) through A line. However, at this time there is one operation instruction

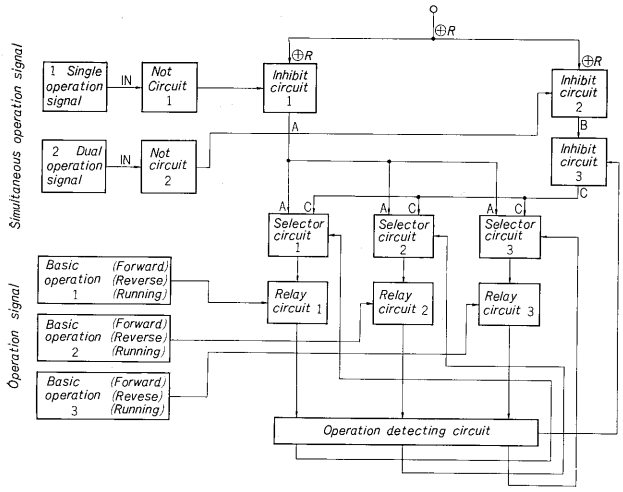

Fig. 4 Block diagram of self-check circuit

of the basic operations (1 to 3) and only this designated relay operates.

For example, when the relay circuit 1 is designated, operation is as follows. The relay operation is detected by the operation detecting circuit, instructions are given to the selector circuits (2 and 3) of the relay systems and the input of these selector circuits (2 and 3) is switched from *A* to *C*. Since INHIBIT circuit 2 is non-cnoductive at this time (INHIBIT circuit 3 does not receive an instruction from the operation detecting circuit and is conductive), there is no power supplied to the *C* line and the power source of the relay circuits (2 and 3) is interrupted.

Therefore, for the same reason as given in (*a*), there is neither misoperation nor interruption due to the influence of noise.

(c) When there are two operation instructions

Since there is no output from NOT circuit 2, INHIBIT circuit 2 becomes conductive (the INHIBIT circuit 3 remains conductive). Therefore, power is supplied to the *C* line and to relay circuits (2 and 3). However, when for example an instruction is given at this time to selective circuit 2 in addition to relay circuit 1 which has already been operated, the operation of this relay circuit is detected by the operation detecting circuit and by giving the instruction to selective circuit 2 of the relay system which received the operation instruction, the input of selective circuit is switched from *C* to *A*. Selector circuit 3 is not altered and the power source is introduced from the *C* line.

At this time, relay circuits 1 and 2 operate and the 2 simultaneous operations are detected by the operation detecting circuit. A signal is given to INHIBIT circuit 3 and the power supply is removed from the relay circuit 3.

Therefore, for the same reason as given in (*a*), there is no misoperation or interruption due to the influence of noise. *Fig. 5* (*a*) and (*b*) show outer views of the FM transmitter and FM receiver respectively and *Fig. 6* shows the operating conditions.

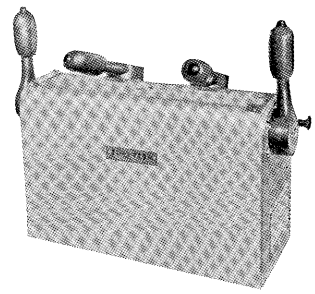

Fig. 5 (a) FM transmitter for Crane Master

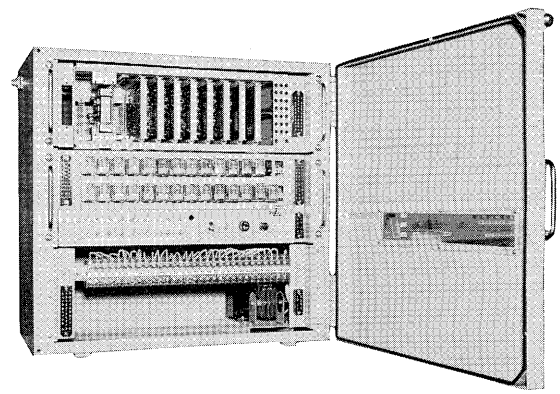

Fig. 5 (b) FM receiver for Crane Master

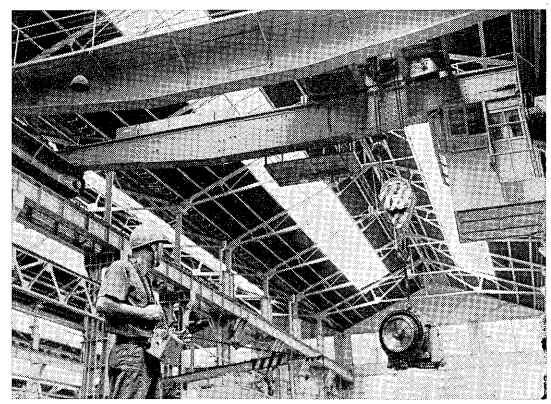

Fig. 6 Remote control of crane using Crane Master

III. RADIO CONTROL EQUIPMENT FOR DIESEL LOCOMOTIVES

1. Outline

This equipment was developed on the basis of the techniques used in the Crane Master. The outstanding features are as follows.

1) This equipment ransmits very weak radio waves and, so, any driver can operate it since no radio operator's licence is required.

2) Handling the master controller and the brake handle in the driving cab are equivalent to the handling dial switches of FM transmitter and the operational feeling is designed to be similar as much as possible.

3) There is always fail-safe operation in case of interruption of radio waves, external noise, etc.

4) The transmitter is suitable for outdoor use.

5) Dead-man equipment is provided in case the operator loses consciousness during operation

2. Construction of the Equipment

This equipment consists of an FM transmitter, an FM receiver and a DC/DC converter. The accessories are a receiving antenna and a battery charger.

The specifications of the components are almost the same as those of the CRANE MASTER. The points of difference are given below.

1) Receiver

Control source DC 24 V

2) DC/DC converter

Type: Inverter—single phase, forced commutated type transistor inverter
Rectifier—Single-phase, bridge connected diode

Input	DC 24 V	Variation range: 20 to 31 V
Output	DC 12 V	4.9 A
	DC 15 V	0.56 A
	DC +24 V	1 A
	DC 24 V	0.5 A
	DC 90 V	30 mA

3. Transmitter

As is shown in *Fig. 8*, the transmitter is attached to the body of the operator by means of a shoulder or a waste band. FM transmitter is housed in a drip-proof aluminum case with dimensions of 150 mm (heiget) × 260 mm(width) × 90 mm(depth) and consists of an FM transmitter, signal generator, voltage stabilizer, a battery and various types of switches. On the right side of the case, the foward/reverse dial switch and key switch are attached on the left side, there is a powering dial switch, and on the top of the case are push button switches for sand spray and emergency stops and a snap switch for the illumination lamp are provided.

The forward/reverse dial switch has 1E, N and 2E notches and contains an co-axially arranged push button switch which employs a reed switch for brake hold. The key switch has three positions: stop, drive and dead-man release, and is used for switching the transmitter power source and performing dead-man release.

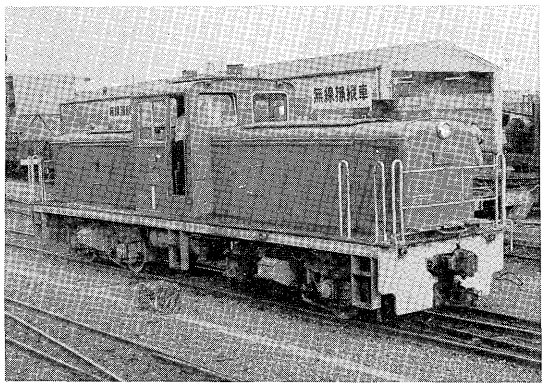

Fig. 7 Radio controlled diesel hydraulic locomotive

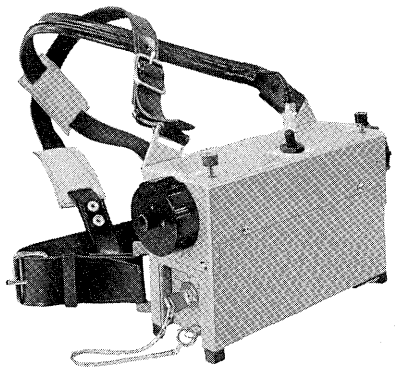

Fig. 8 FM transmitter for radio controlled diesel hydraulic locomotive

The powering dial switch has 9 notches: 5N, 4N, 3N, 2N, 1N, *N* (neutral), brake hold, normal brake and emergency brake. It has a co-axially arranged push button switch for an alarm horn. When the transmitter is tilted continuously more than 70° from vertical, the deadman switch accomodated in the transmitter operates and the emergency brake is applied to stop the locomotive.

The battery is a fully enclosed nickel cadmium battery with a rated voltage of 15 V and a capacity of 225 mAh. The battery must be exchanged every 8 hours and recharged. The receiving antenna is located in the shoulder band to improve the operability of the transmitter.

4. Receiver

The receiver is a metal enclosed stationary type with dimensions of 850 mm(width) × 470 mm(height) × 400 mm(depth). It is attached to an angle frame by means of four resiliant rubber. It is supplied from a 24 V locomotive battery and controls locomotive operation through power relays.

Inside the receiver, there are 4 sections; viewing from the front, the receiving and selecting section is on the upper left, the stop and skid detecting section is on the lower left, the central panel section

is in the center and the relay panel section is on the right. Each section is connected by means of a multiple connector to ease maintenance and checking work.

The receiving and selecting section consists of the FM receiver, the mechanical filter and a low frequency amplifier. The radio wave received by the antenna is fed into the receiver through a coaxial cable and after it is demodurated by means of the crystal controlled double super-heterodyne FM receiver, it is selectively amplified by the mechanical filter and low frequency amplifier. It then operates the corresponding relays in the relay panel.

The stop detecting section gives out a stop signal when the width of a pulse train from the contactless pickup attached to the intermediate shaft of the reverser exceeds a preset value. The skid detecting section gives out a skid signal when the rate of increase of the width of this pulse train exceeds the specified value.

The central panel section contains indicator lamp group for confirming the operations of the radio control equipment, test push button switch, key switches and a receptacle for battery charging. The key switch has three positions: Drive, Power supply and Dead-man Reset, and is operated in common with the key of the transmitter.

The relay panel consists of the miniature relays which are directly operated by the output of the low frequency amplifier and the power relays. All of these relays are of plug-in type. Since the FM receiver is highly sensitive, a squelch circuit is provided in order to prevent misoperation caused by internal noise when there is no signal. To prevent misoperation due to external noise, Fuji Electric's patented signal discrimination type self-check circuit and the low notch priority circuit are provided. With these, the following advantages are obtained:

1) When either one of the dial switches is in the *N* position, the reverser does not assume the front or back position even if noise equivalent to forward or reverse running is received.

2) When the forward-reverse dial switch is in the *1E* (or *2E*) position and the powering dial switch is in the *N* position, the locomotive never change to powering even if noise equivalent to powering is received.

3) When, for example, during powering the switch is in *3N* and a noise signal equivalent to *5N* is received, the locomotive remains in *3N*. However, when a signal equivalent to *1N* or brake notch is received, the locomotive is changed over to *1N* or brake notch.

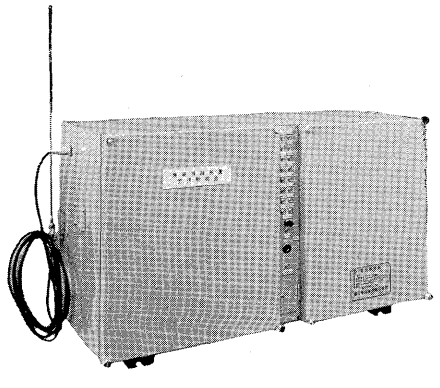

Fig. 9 FM receiver for radio controlled diesel hydraulic locomotive

5. DC/DC Convertor

The only power source for this radio control equipment is a 24 V battery for locomotives. From this the following power supplies are required:

1) DC 15 V for the FM receiver
2) DC 12 V for the relay and indicator lamps
3) ±DC 24 V for the stop and skid detecting circuits
4) DC 90 V for battery charging

A DC/DC convertor is provided for above purpose and further to prevent misoperation and break downs of the transistors due to surges which may arise when the magnetic valves on the locomotive side are interrupted. This converter consists of a single-phase forced-commutated transistor inverter, an automatic voltage regulator, a multi-winding transformer, a diode bridge groups.

The DC 24 V of the battery is converted into a 400 Hz AC voltage by the transistor inverter and after being stabilized by the automatic voltage regulator, it is transformed into the required DC voltage by the transformer and the diode bridge.

The convertor is housed in a steel plate case with dimensions of 350 mm(width) × 475 mm(height) × 460 mm(depth).

IV. OPERATION CONTROL

1. Preparatory Operation

Preparatory operation consists of starting the engine, and establishing the control air pressure and lubricating oil pressure. First, the manual/remote changeover switch in the driving cab is placed in the manual position and the engine is started in the same way as with the manual operation. After a short idle run, the control air pressure and lubricating oil pressure are established.

2. Check Operation

When the manual/remote changeover switch is advanced from the manual position to the check position, and the key switch is placed in the power supply position, the receiver power source is activated. However, since the power source of the control circuit of the locomotive is not yet activated, only dummy notch test can be effected by means of indicator lamps on the central panel.

Table 1 **Operating sequence of magnetic valves**

Notch	Fuel magnetic valve			Brake magnetic valve			Engine	Brake
	FMV_1	FMV_2	FMV_3	SMV	RMV	EMV		
5N	○	○	○	○	○	○	5N	Release
4N	○	○		○	○	○	4N	Release
3N	○		○	○	○	○	3N	Release
2N	○			○	○	○	2N	Release
1N		○	○	○	○	○	1N	Release
N		○		○	○	○	Idle	Release
Hold		○		○		○	Idle	Hold
Normal		○				○	Idle	Normal
Emergency		○					Idle	Emergency

The circle ○ indicates the commutated condition.

Table2 **Protective operation**

	Engine		Torque converter "neutral"	Internal alarm		External alarm			Sand spray	Emergency brake
	Idle	Stop		Bell	Buzzer	Patrol lamp	Horn	Pneumatic horn		
LO pressure down		○	○	○		○	○			
CW temperature up					○	○	○			
TC oil temperature up					○	○	○			
Control air pressure down	○		○			○	○			○
ATS	○		○						○	○
Skid						○		○	○	
Dead-man	○		○			○	○		○	○
Fault of receiver	○		○			○	○		○	○
Interruption of radio wave	○		○			○	○		○	○

3. Remote Operation

The manual/remote changeover switch is turned to the remote position and the forward/reverse dial switch is set at $1E$ or $2E$ position and the powering dial switch is advanced to $1N$, the locomotive is started. When the powering dial switch is advanced to a higher notch, the locomotive is accelerated.

Table 1 shows the operation of the fuel magnetic valve and the brake magnetic valve in respect to each notch of the powering dial switch, as well as the condition of the locomotive in these cases.

4. Protective Operation

Table 2 shows protection of the locomotive under abnormal conditions. When the emergency brake is applied, reset is performed by turning the powering dial switch to the emergency position after both of the dial switches have been turned to the N position. However, during dead-man operation only, reset operation is performed after the key switch in the driving cab of the locomotive is set to Dead-man Reset.