5-7 Outline of Various Train Radio Systems in JR

Table 1 Train Radio System Used in JR Conventional Lines

Line	Purpose	Range of communication	Frequency/ communication system
Yamanote and Keihin-Tohoku lines (started in 1981)	For communications between dispatchers and train drivers, as well as for communications in the event of ATC failure	Driver ←→ Dispatcher	400 MHz band Duplex 1 CH
Joban line (started in 1966)	For emergency communications between wayside and train drivers at accident. Used to prevent secondary accidents, as well as for communications to support ATC.	Driver ←→ Dispatcher (emergency communications) Train ←→ Train Wayside ←→ Train (stop signal for train protection)	150 MHz band Half Duplex 1 CH Protection radio 1 CH
Yokokawa - Karuizawa section (started in 1963)	For communications between drivers in double-header operations in the section	Main engine driver ←→ Auxiliary engine driver (communications for joint operation) Main engine driver ←→ Station manager/ engine depot manager; Auxiliary engine driver → Station manager/ engine depot manager (emergency communications)	400 MHz band Duplex 2 CH
Aomori - Hakodate ferryboat information service (started in 1962)	For communications between limited express train and wayside for information on ferryboat services	Train conductor — Related office (via switchboard) Reporting the number of train passengers and ferryboat information	150 MHz band Duplex 1 CH

Table 2 Train Radio Systems Used in JR Shinkansen

	Category		Tokaido/Sanyo Shinkansen	Tohoku/Joetsu Shinkansen
1	No. of channels ( ) - No. of channels actually used		Dispatcher system (operation) 2 CH Dispatcher system (passenger service) 2 CH Exchange system (service/public) 6 CH Total 10 CH (10 CH)	Dispatcher system (operation) 4 CH (4) Dispatcher system (passenger service) 2 CH (2) Exchange system (service/public) 12 CH (6) Data processing system 6 CH (3) Total 24 CH (15 CH)
2	Line quality	Service area (calling range)	More than 99.9%	More than 99.99%
		Calling S/N	S/N 35 dB or more throughout 90% of the entire line	S/N 40 dB or more throughout 99% of the entire line
		Connection stability (code error rate)	More than 99%	Less than 1×10^{-4} for 1,200 bits/sec
3	Radio system	Radio system	Space wave multiplex (base station only)	LCX
		Frequency	Base station 400 MHz band 3 waves Mobile station 400 MHz band 10 waves	Base station 400 MHz band 1 wave Mobile station 400 MHz band 24 waves
4	Output		Base station 40 W Mobile station 4 W	Base station 2 W Mobile station 4 W
5	Antenna		Base station : Grid parabola, corner reflector, Yagi 8-element Mobile station: Uni-polar array, two-way switching (longitudinal)	Base station : Leakage coaxial cable Mobile station: Slot array 4-element composition
6	Public telephone service		Public telephone service between trains and wayside cities A B: Calling via switchboards	Nationwide public telephone service B A: PB dial calling A B: Calling via switchboard

5-8 Classification and Allocation of the Existing Level Crossings between Ghaziabad and Kanpur

Class		Number
Type	A	12
	B	27
	C	127
	Total	166
Interlocked with gate signal		51

where:

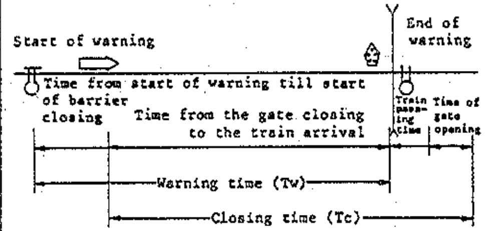
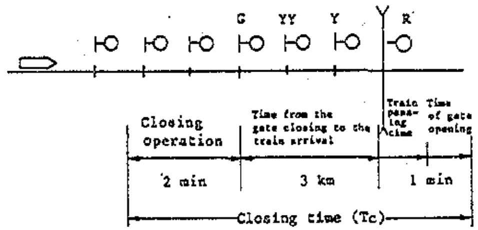
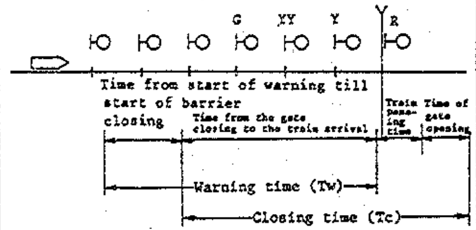
	Train-vehicle units per day
A	More than 14,000
B	More than 6,000
C	More than 5,000

5-9 Comparison among Level Crossing Control Systems

Table 1 Level Crossing Control Systems of India and Japan

Type / Item	Japan	India	Improved method
Basic conception	1) To warn the passersby on the road of train approach	1) No warning of train approach to the passersby on the road	1) To warn the passersby on the road of train approach
	2) Timing of warning : the timing so that a passersby who has entered into the level crossing before the warning begins can safely cross it, and that matches the emergency braking distance of train.	2) The gatekeeper is informed of the train's approach from the adjacent station by telephone, etc. beforehand.	2) Automatic barrier operation and, in case of accident at level crossing, manual operation by the gate keeper.
	3) Automatic barrier operation	3) The gatekeeper manual closes the gate well in advance of the train's arrival on receipt of the announcement of train approach.	3) Gate signal is commonly used with the block signal
Interlocking with signal	1) No interlocking	1) At the level crossing at a busy road, the interlocking between of gate and gate signal makes to allow 'go' to the gate signal after the gate has completely closed.	1) Interlocking between every level crossings and gate signals is provided.
	2) In the event of accident at level crossing, manual or automatic operation of special warning signal light to inform the train driver.		
Safety	1) In case of level crossing facilities failure, the safety of passersby is ensured by automatically closing the barrier.	1) Gate signal indicates 'Stop' when the adjacent station fails to make the train approach announcement, or when the gate-keeper foregets the train approach announcement or fails to close the gate.	1) 'Stop' is indicated on the gate signal when the gate closing operation is interrupted by passersby or vehicles in the level crossing.
	2) When a passersby remains within the level crossing after the warning time an accident may occur.	2) 'Stop' is indicated on the gate signal when the gate closing operation is interrupted by passersby or vehicles within the level crossing.	2) 'Stop' signal is manually indicated on the gate signal when a passersby remains within the level crossing after the gate has closed.
			3) Gate is automatically closed for the safety of passersby by the fail-safe operation in case of facilities failure.

Table 2 Calculation of the Traffic Suspension Ratio by Each System

Item \ Type	Japan	India	Improved method
Level crossing	Mainly unmanned level crossing	Manned level crossing	Manned level crossing
Warning and gate barrier closing operation			
Warning time (Tw)	Without fixed time control TW = 33 ∿ 71 sec.	———	Without fixed time control Tw = 2 ∿ 4.3 min
	With fixed time control Tw = 33 sec		With fixed time control Tw = 2 min
Closing time (Tc)	Without fixed time control Tc = 1.0 ∿ 1.9 min	Tc = 4.1 ∿ 5.4 min	Without fixed time control Tc = 2.4 ∿ 4.9 min
	With fixed time control Tc = 1.0 ∿ 1.3 min		With fixed time control Tc = 2.4 ∿ 2.6 min
Road traffic suspension rate (η)	Without fixed time control η = 24.0%	η = 93.5%	Without fixed time control η = 70.9%
	With fixed time control η = 19.3%		With fixed time control η = 47.3%

cf a) η is calculated based on the standard train diagram.
b) Gate specifications are based on JRS.22551-1D (A type).
c) Closing method is the total closing with one pair of barriers(Full barrier).
d) Calculation is made for the train traffic in 2,000.

5-10 Speed Indicator and Preliminary Speed Indicator

1. Speed Indicator

The speed indicator, installed on the block signal in the rear of the home signal, is to realize safe and efficient train operation by informing a driver of the speed limit at the turnout. One digit is considered sufficient for the indicator. Visibility distance of over 150 meters is necessary allowing a driver 4 ∿ 5 seconds to correctly read the numerical figure, who is operating a L. Exp. train in the rear of a signal indicating Y, at a speed of approximately 120 km/h.

2. Structure of Speed Indicator

In view of the visibility of 150 meters, use of a light source by LED or optical fiber is not suitable. In this appendix, therefore, a description is provided on a speed indicator using incandescent lamps. An indication part of the indicator is as shown in Fig. 1.

The indicator is equipped with 26 V 8 W incandescent lamps, an indicator board of dark coating, and covered with a transparent polycarbonate plate.

The indicator can be controlled by compact relays or a microcomputer device.

3. Preliminary Speed Indicator

In case the speed limit of the turnout is 70 km/h or higher, other trains than L. Exp. and Mail/Exp. are apt to reduce the speed to a greater degree than actually required in the rear of Y signal indication, resulting in a lower operating efficiency. To avoid this, at stations where there is a speed limit higher than 70 km/h, a preliminary speed indicator is installed on the block signal in the rear of that furnished with a speed indicator, to preliminarily indicate that the speed limit is higher than 70 km/h.

The preliminary speed indicator can be of a simple structure, with a single incandescent lamp, for example, but the visibility distance should be over 150 meters so that the driver operating the train at a speed of 160 km/h can acknowledge the indication.

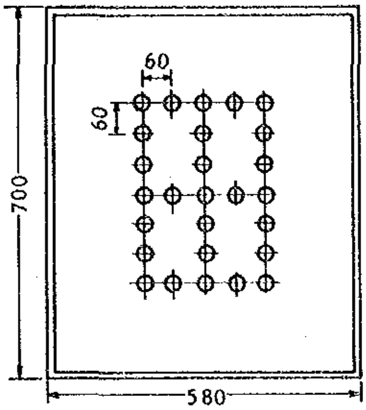


Fig. 1 Array of Lamps for Speed Indicator

5-11 Format of Report on Defective Devices of Shinkansen

A	Serial No.		Date of preparation		Prepared by		Tel. No.
	Name of equipment room		Belonging		Electric Maintenance Center	Electric Maintenance Branch	Reporter
	Name of equipment	A. Track circuit transmitter & receiver B. CTC code modulator & demodulator C. CTC transmitter & receiver D. Signal code transmitter & receiver E. Train number receiver F. Train type receiver G. Train type information accumulator			H. Number of train counter I. Train detector J. Power source devices K. Relay L. Insulation transformer M. Others		
	Name or type of rack		Unit name		Type		
	Circuit name or track circuit name		Serial No. of device		Date of failure		
	Manufacturer		Date of manufacture		Serial No.		
	Reason for discovery	During regular operation, inspection, repair, others ( )					
	Phenomenon	Not operable, unstable, poor performance, breakdown, wear, overheat, poor insulation, self-recovery, others ( )					
		(Description)					
	Remedy	Replacement, field repair, abandonment, others ( )			Date of previous repair		
		(Description)					
	Remarks						
B	Faulty parts	Transistor, diode, zener diode, resistor, capacitor, coil, transformer, wiring, fuse, solder, PCB, contact point, terminal, others ( )					
		(Kind of type)					
	Remedy	Adjustment, replacement, repair, others ( )					
		(Description)					
	Condition and location of faulty part (Indicate in circuit diagram.)						
	Inspection data						
	Date of acceptance		Date of preparation by company		Prepared by		Tel. No.

Note: 1. This report is attached to faulty equipment. Part A should be filled out by an Electric Maintenance Center (Branch). Part B should be filled out by the Manufacturer.

2. The Electric Maintenance Center (Branch) should send a copy of this report to the related railway operating division.

5-12-(1) Improvement of Signal Lamp

The original signal lamps were imported from the U.S.A. by Japan National Railways in 1924. Later, the lamps were produced in Japan, and called the A-type lamp. In the 1960's modernization of signalling facilities was progressed, resulting in the rapid increase in number of colorlight signals, and the problem of the life of the signal lamp attracted attention. Studies were done to improve the life and reliability of the A-type signal lamp. Consequently, a life of 2,000 hours was achieved at the rated voltage. However, the special filament structure featured poor productivity, and lamps with a longer life were difficult to produce at low cost. As an alternative, the standard operating voltage was dropped to 90 - 80 percent of the rated value to extend the life to 5,000 hours. In addition, a signal lamp filament burn-out detector was developed in 1966 and mounted in major signals. Since this detector could detect burn-out of a filament in two, a lamp could be replaced before the whole filaments was burned out. In 1970, mass production car headlight bulbs were modified into signal lamps to replace the A-type lamps, and called G-type lamps. The G-type lamp has a filament configuration suitable for mass production. The filament is in two parallel lines arranged at different levels, and is equipped with 3 filament terminals: the main filament terminal, sub filament terminal, and common filament terminal. The life of the G-type lamp is 9,000 hours for the main filament, and 5,000 hours for the sub filament at the rated voltage. Therefore, the probability of simultaneous burn-out of the main and sub filaments is extremely low. In this respect, the filament burn-out detector can be more effectively used, and the reliability of signals has become extremely high.

5-12-(2) <u>Digest of Standards for Signal Lamps</u>

1. Ratings

Table 1

Type	Rating		Standard use voltage V	Major use
	Voltage V	Power consumption W		
A-type	30	40	24 ∿ 27	Multiple type colorlight signal
G-type	30	45	24 ∿ 27	Multiple type colorlight signal, Route indicator, Hump shunting sign, Train approach indicator for level crossing

2. Performance

2.1 Optical Characteristics

Table 2

Type	Filament	Test voltage V	Initial characteristics			Hold rate of luminous flux (2) %	Life hours
			Power consumption W	Luminous flux Lm	Efficiency (1) Lm/W		
A-type	-	30	40 ± 4	400 ± 80	10	80 or longer	2,000 or longer
G-type	Main filament	27	20 ± 2	140 ± 25	7	80 or longer	9,000 or longer
	Sub filament	27	20 ± 2	160 ± 30	8	80 or longer	5,000 or longer

Note: (1) The figures for efficiency are rounded numbers.

(2) The hold rate of luminous flux is an expression of the ratio in percentage of the luminous flux at 1/2 of the life of the lamp being compared to the luminous flux at the initial characteristics. In the case of G-type, however, the value at 3,000 hours is taken.

2.2 Vibration Characteristics

The lamp should withstand the test conditions given in Table 3 over 24 hours.

Table 3

Item	Condition
Frequency Hz	10 ∿ 1,000
Acceleration m/s^2	9.8 constant
Cycle	6 minutes per 1 cycle
Direction of vibration	Vertical as the lamp is set in the standard position for actual use
Voltage	Test voltage

2.3 Adhesiveness

The adhesiveness of the base should be 1 N.m or greater.

2.4 Insulating Resistance (only for G-type)

The resistance between the terminals and the metal section should be 10 Mohms or greater at 500 VDC.

2.5 Withstand Voltage (only for G-type)

The terminals and metal section should withstand 1,000 V or higher of commercial frequency for over one minute.

3. Structure, Shape, and Dimensions

As shown in Fig. 1 and Fig. 2.

4. Test Method

Table 4

Item	Method
Initial characteristics	Apply 40 minutes aging at 120% of the test voltage till the characteristics become stable. Then, test the lamp for power consumption and total luminous flux.
Hold rate of luminous flux	As shown in Note (2) of Table 2.
Life	Set the lamp with the lamp axis horizontal. Apply no vibration. Measure the time till the filament burns out.
Vibration characteristics	Set the lamp on a vibration tester in the standard position as it is actually used in the field. Apply DC or AC (50 or 60 Hz, close to sine wave) of the specified test voltage. Perform the test under the conditions given in Table 3.
Adhesiveness	Gradually apply a torsional moment between the base and the glass bulb.
Insulation resistance	Measure with a 500 VDC megger
Withstand voltage	Use a withstand voltage tester, and apply 1,000 VAC (50 or 60 Hz).

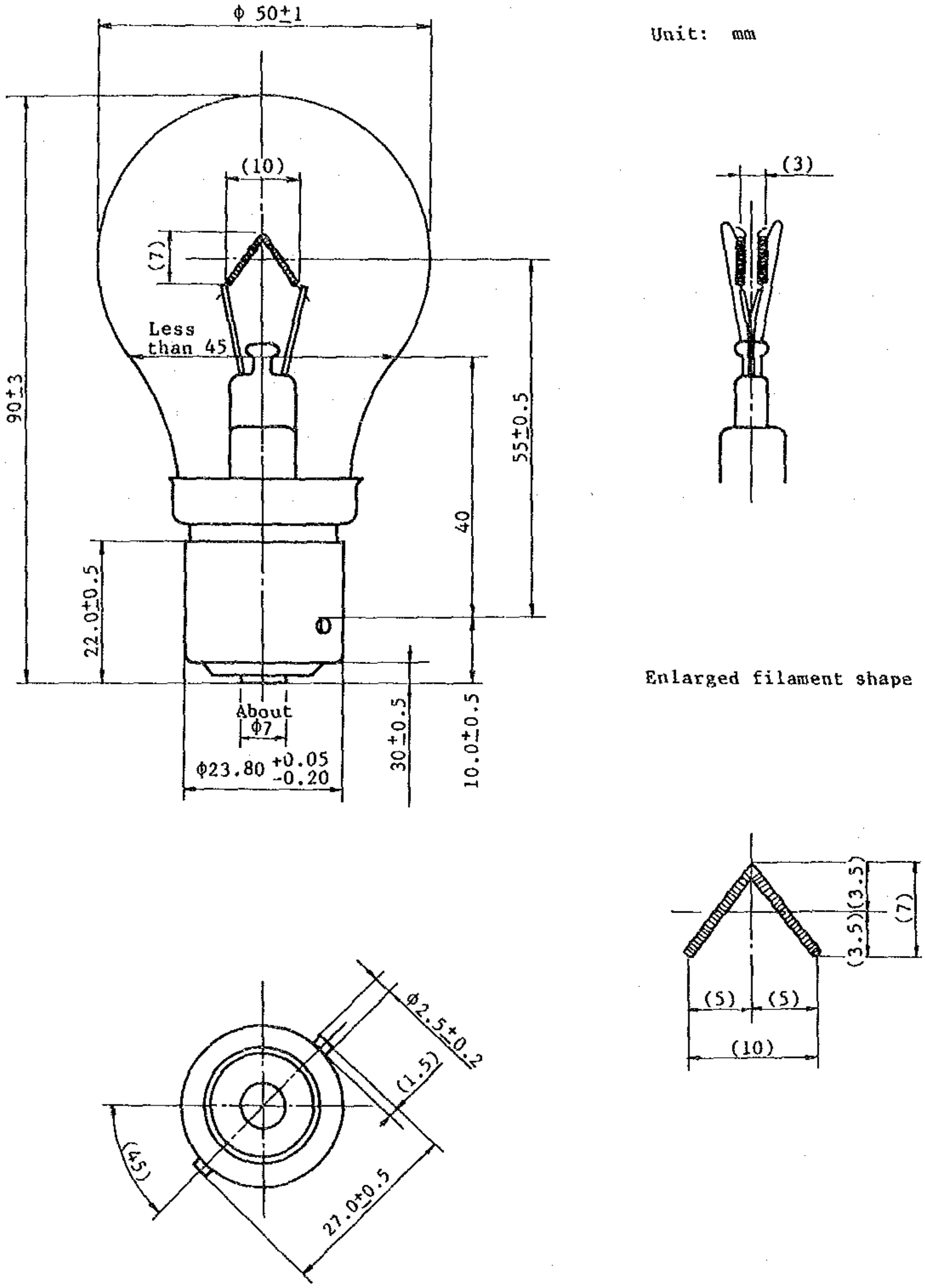
5. Sampling Test Method

Table 5

Test item	Sample size	Number of specimen for acceptance
Dimensions	10	0
Structure, outlook, indication	20	2(1)
Initial characteristics	10	1
Life	5	0
Base adhesiveness	5	0

Note: (1) Two specimens shall not have defects in the same test item.

Unit: mm



Remark: Figures in ( ) are standard values.

Fig. 1 A-type Signal Lamp

Unit: mm

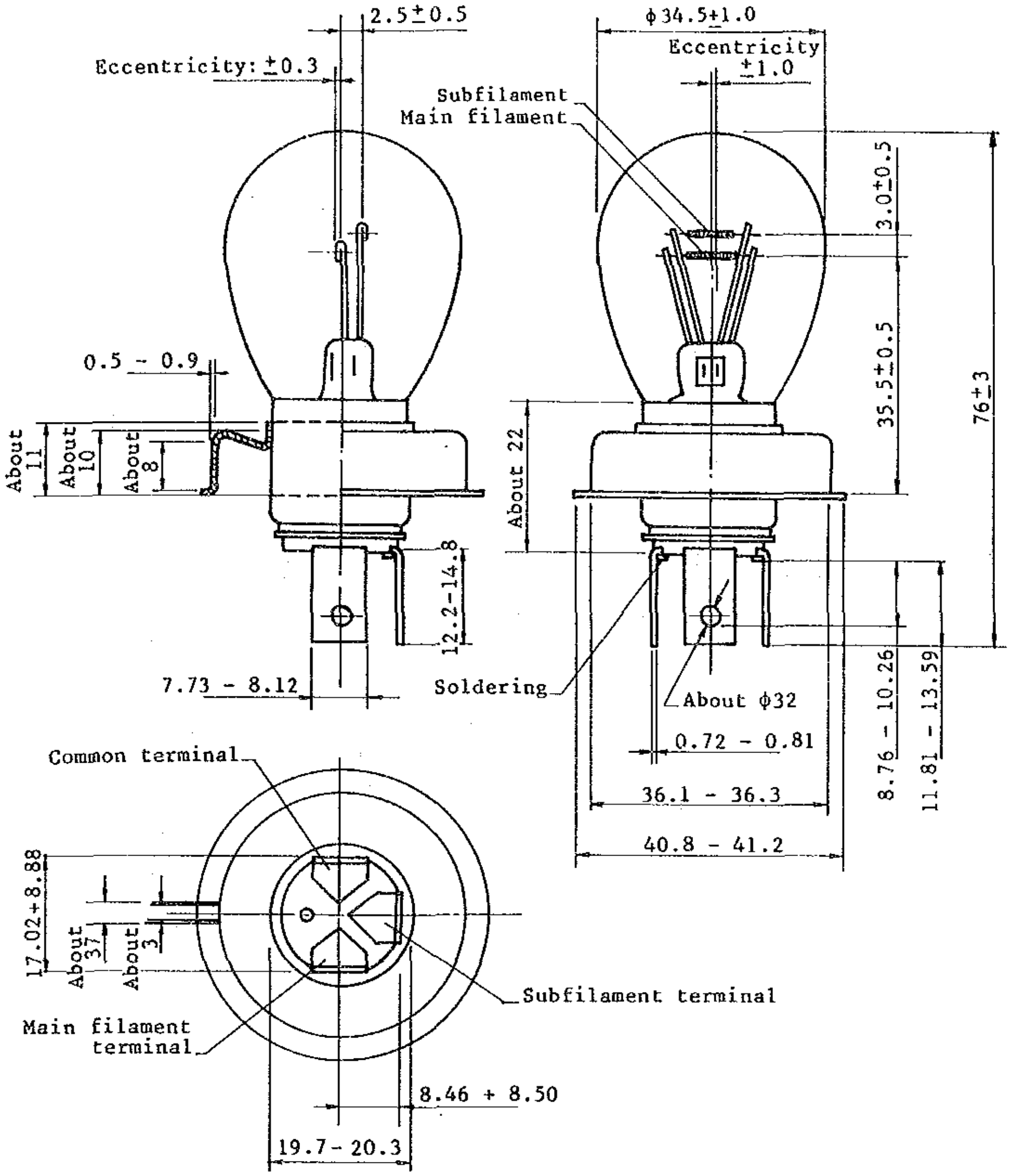


Fig. 2 G-type Signal Lamp

5-13 Outline of Automatic Inspection Car for Electrical Equipment (for Shinkansen)

1) Inspection cycle

Basically, an inspection will be executed every 10 days.

2) Inspection crew

Two for signalling and two for telecommunication.

3) Inspection car data processing

At present, the inspection car can run at a speed of 210 km/h and inspect the conditions of ground facilities.

The high accurate data obtained through inspection are processed by a computer. The outline of the processing is as follows.

a) Analog data and digital data ("Warning data" exceeding permissible values) are printed out on-board. The inspection crew can command a field survey, if necessary.

b) Collected inspection data (see Table 1) is recorded on MT, and sent to the central control center.

c) Inspection data on MT is processed the next day, and resultant maintenance data can be provided as lists from each SMIS terminal.

Table 1 Major Inspection Data of Automatic Inspection Car

Common data	Track	Substation	Overhead equipment	Signalling	Telecommunication
. 10 km point signal . 1 km point signal	. Unevenness (Transversal) . Twist . Cross level . Alignment . Guage (Transversal) . Vehicle shake acceleration (Vertical) . Vehicle shake acceleration (Transversal) . 20 m chord unevenness (Right and left) . 20 m chord alignment (Transversal) . Long wave unevenness (Left) . Axle weight (Transversal) . Lateral pressure (Transversal) . Derailment coefficient Q/P (Transversal) . Noise level . Axle box acceleration (Transversal)	. Changing over time . Changing over total time . Abnormal voltage in feeding circuit . Contact wire voltage	. Contact wire height . Contact wire deviation . Contact wire hard point . Contact wire gradient . Obstacle . Contact loss and contact loss rate . Contact pressure of pantograph . Pole location . Location of overhead wire crossing	. ATC track circuit current . Jointless track circuit current . ATC frequency . Jointless track signal frequency . ATC instantaneous indication change . Unbalance factor of traction current . Additional wire track circuit current . Wayside device for point detection . Track circuit current . Train number coil . Leakage current level of adjacent track circuit	. Field strength . Signal level . Noise level . Pilot level . Radio station characteristics . Combination test . Momentary failure
			. Wear of contact wire and sliding width . Contact wire deviation . Contact wire height		

5-14 Electrical Equipment Maintenance Control by Shinkansen Management Information System (SMIS)

1) Purpose

The Shinkansen Management Information System (SMIS) provides timely information to the related organizations both in administrative and field sector, greatly contributing to achieve highly efficient maintenance of rolling stock and ground facilities.

2) Fundamental policy of the system

- To employ a general purpose data base, hierarchical structured programming, high-level language, etc. to realize easy design, maintenance and high data security.
- To adopt on-line connection with the automatic centralized monitor system to improve information collection/distribution efficiency.
- To use intelligent terminals to improve operability and enable local data processing.

3) System structure

The overall structure of the SMIS is shown in Fig. 1.

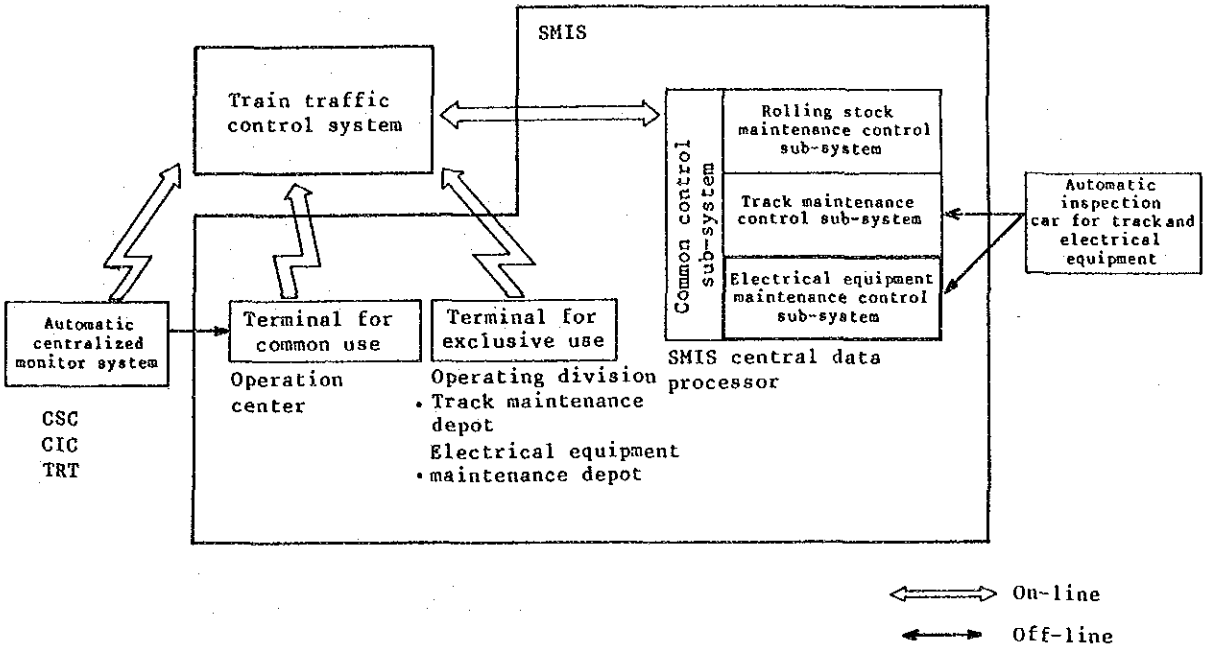


Fig. 1 Overall Structure

4) Electrical equipment maintenance control sub-system

The electrical equipment maintenance control sub-system composes one sub-system (for signalling, telecommunication, substation and overhead equipment) of the SMIS. This sub-system analyzes various data supplied by the automatic inspection car and provides various useful data such as statistical and time-sequencial failures data. The construction diagram and the outline of the function of the sub-system are shown in Fig. 2 and Table 1, respectively.

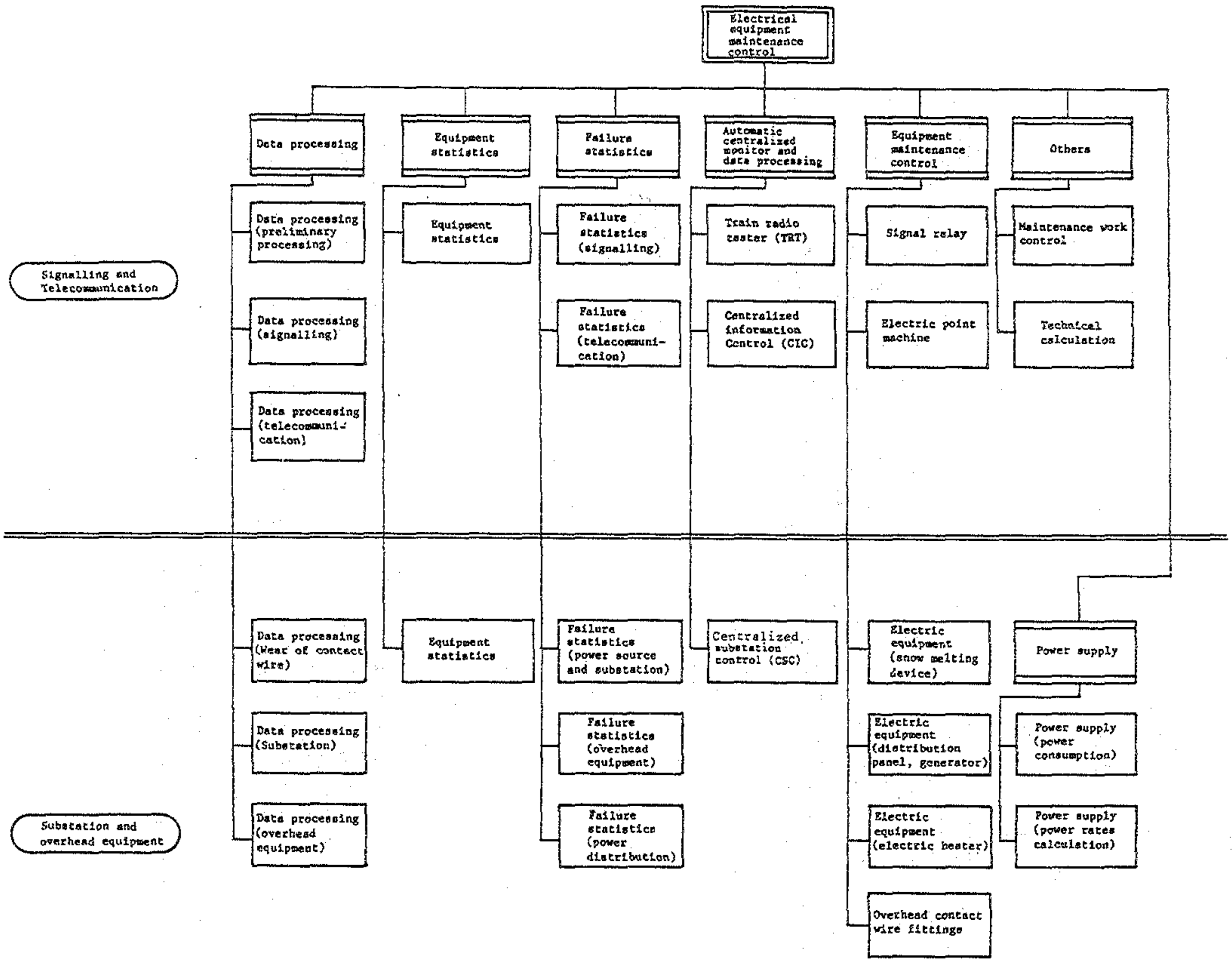


Fig. 2 Structure of Electrical Equipment Maintenance Control System

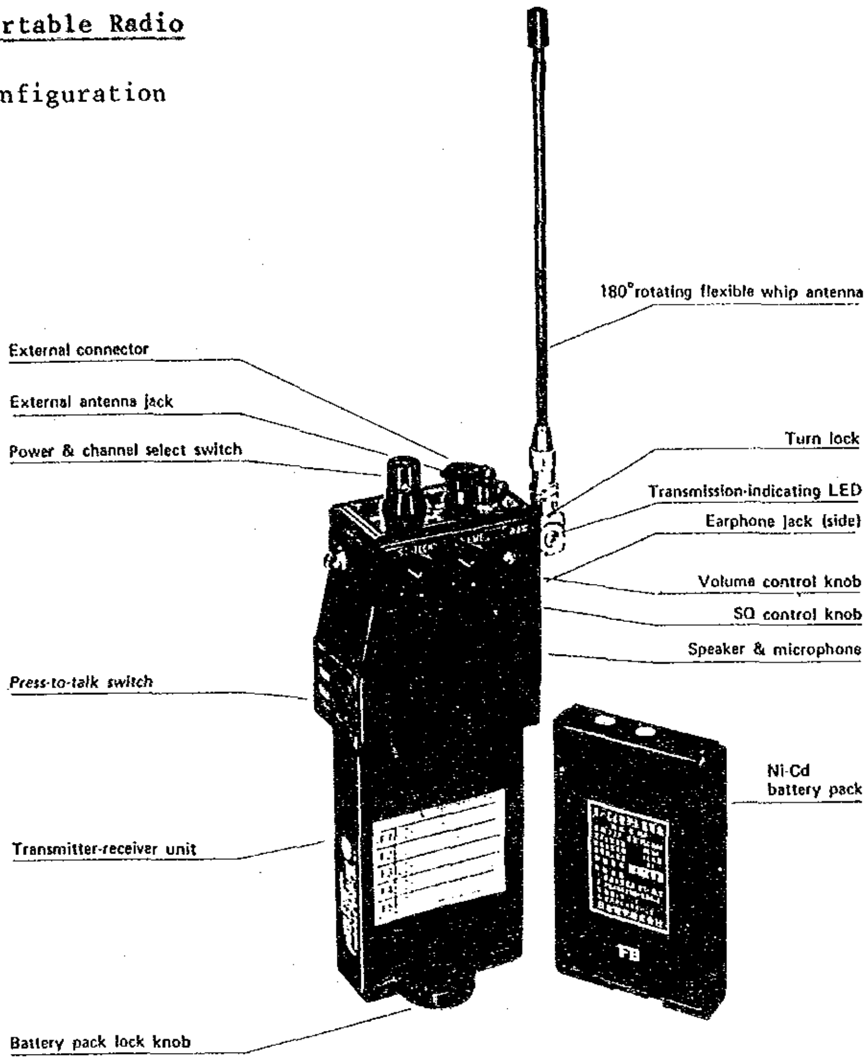
Table 1 Outline of Functions of Electrical Equipment Maintenance Control System

Classification	Detailed classification	Outline
Automatic inspection car data processing	Preliminary processing	Point information (location of 10 km wayside device, tunnel, bridge, and other information needed for each processing) necessary for on-board processing is recorded on a magnetic tape.
	Contact wire wear control	Contact wire wear data obtained by the inspection car is processed; time sequential control of wear data and various maintenance control lists are provided.
	Substations	Changing over time, abnormal voltage in feeding circuit obtained by the inspection car are processed, and various maintenance control lists are provided.
	Overhead equipment	Contact loss rate, contact wire height, and contact wire deviation are processed, and various maintenance control lists are provided. Simultaneously, the contact wire evaluation index for overall judgement is provided.
	Signalling	ATC track circuit current data obtained by the inspection car is processed, and various maintenance control lists are provided.
	Telecommunication	Data related train radio obtained by the inspection car is processed, and various maintenance control list are provided.
Statistical processing	Equipment statistics	The number of equipment is maintained for each increase or decrease to be used for failure statistics processing.
	Failure statistics	Processing of failure data input from a terminal on occurrence of failure is processed, and various maintenance control lists are provided.
Equipment control	Centralized Substation Control (CSC)	Data of operating condition of each substation equipment (number of operation of AC circuit breaker and switch-over breaker, inspection data of remote control system, protection relay, etc., and load current) obtained through CSC are processed, and various maintenance control lists are provided.
	Train radio tester (TRT)	Mobile station failure data and inspection data by train radio tester are processed for each train make-up, and various maintenance control lists are provided.
	Centralized information control (CIC)	Data obtained by Centralized Information Control are processed, and various maintenance control lists are provided.
	Electric equipment control	Replacement data of the electric snow melting device is maintained from terminals, and various maintenance control lists are provided.
	Contact wire fittings control	As to contact wire fittings of a relatively high replacement rate, aging is grasped from replacement data maintained from terminals, and various maintenance materials are provided.
	Signal relay control	Replacement data of signal relays used for interlocking devices are maintained from terminals, individual operation number is obtained, and various maintenance control lists for replacement plan are provided.
	Electric switching machine control	Replacement data of electric switching machine maintained from terminals are processed to obtain individual operation number, and various maintenance control lists for overhaul inspection plan are provided.
Electric power . Power supply		Power index data of substation obtained from Centralized Substation Control is processed, and various maintenance control lists for power consumption are prepared. Electric power rate is also calculated from power supply result from terminals.

Classification	Detailed classification	Outline
Others	Technical calculation	Contact wire structure calculation is processed on various input conditions from terminals.
	Application for maintenance work	For working without power supply, work application from terminals are transmitted to CSC. Replies to such applications are transmitted to terminals.

5-15 Portable Radio

Configuration



Type ATR-150P1 Portable Radio

Performance Specifications

General	
Frequency range	145 to 165 MHz
Number of channels	1 to 5
Power source	DC 7.5V ±10%, 450 mAH Ni-Cd battery pack
Battery life per charge	8 hours
Communication mode	2-way press-to-talk (simplex)
Temperature	-10 to +50°C
Size	165 mm (H) x 60 mm (W) x 38 mm (D)
Weight	520 g including battery pack

5-16 AWS System in the World

Table 1 Classification

Control method	Data transmission	Speed check		Brake	Characteristics
Inter-mittent	Contactor	Not equipped		Emergency	1. Less ability to follow signal indication change 2. Easy to extend ajoining lines 3. Low cost
	Magnet	On-ground	Spot	Emergency	
	Spot coil Inductor Transponder	On-board	Spot	Service and emergency	
			Continuous		
Continuous	Track circuit Wires btw. rails	On-board	Continuous	Service and emergency	Contrary to the above

Table 2 Application

Control method	Data transmission	Speed check		Brake	Name of AWS or railways
Inter-mittent	Contactor	Not equipped		Emergency	(France) Crocodile
	Magnet	Not equipped		Emergency	(England) AWS
	Spot coil	Not equipped		Emergency	(Japan) ATS-S
		On-ground	Spot	Emergency	(Japan) Nagoya Railways
	Inductor	On-board	Continuous	Emergency	(Germany) Indusi-BWU
	Transponder	On-board	Continuous	Service & emergency	(Japan) ATS-H (Egypt)
Continuous	Track circuit	On-board	Continuous	Service	(Japan) Seibu Railways
	Wires btw. rails	On-board	Continuous	Service	(Germany) LZB

5-17 Remote Monitoring System

Table 1 shows examples of the equipment to be subjected to collective surveillance.

Fig. 1 shows an outline of the remote monitoring system. A sensor is attached to each item to be monitored. All the sensors on the facilities in the station yard are directly connected to the failure display board. Information of facilities located between stations is transmitted to the station by means of the central monitoring device and input to the failure display board. The failure display board prepares information to be transmitted to the center and inputs it to the CTC system. The failure information transmitted by the CTC system is displayed on the monitor board of the control center.

There are various types of central monitoring devices such as analog systems, frequency division types, time division systems, etc. Fig. 2 shows the principle of an analog type central monitoring device which can use a cable of even fairly poor transmission quality. when there is no failure of the facilities in the section to be monitored, local power source B is supplied to the station facility and CR relay is energized to indicate the correct condition. If some facility should fail, the sensor relay of the facility drops to cut off power source B, and connects resistors Rx and Ry to the circuit. The station facility, by means of power source A and the Wheatstone bridge, measures the value of Rx, and then, by means of the pole change relay, measures the value of Ry. Since there are 10 different values for each of Rx and Ry, a total of 100 conditions can be detected in combination.

Table 1 Facilities to be Monitored by the Remote Monitoring System

Name of facility	Item to be monitored	Serious failure	Slight failure
Signaling facilities (Station yard) Signals	Bulb filament burn-out		○
Points	Deviations of lock bar		○
	Faulty switching	○	
Interlocking device	Failure of control system	○	
	Failure of monitor unit		○
Signal power source	Failure of one system		○
	Total breakdown	○	
Cable	Poor insulation		○
(Facilities located between stations) Signals	Bulb filament burn-out		○
Level crossing facilities	Failure of control system	○	
	Failure of barrier motor		○
	Voltage drop		○
Telecommunication facilities Exchange	Failure	○ Failure of 2 signal generators	○ Failure of 1 signal generator
Carrier system	Failure	○ Failure of basic rack	○ Pilot level drop
Wireless transmitter and receiver	Failure	○ Failure of power amplifier	○ Pilot level drop
Wireless terminal station facilities	Failure	○ Failure of line amplifier	○ Pilot level drop
Power source facility	Failure of 1 system		○
	Total breakdown	○	
Air conditioning system	Failure	○ Radio station	○ Exchange station
Electric clock	Failure		○
Communication cable	Poor insulation		○

Note: Monitoring for telecommunication facilities shall be carried out at the no maintenance staff stations.

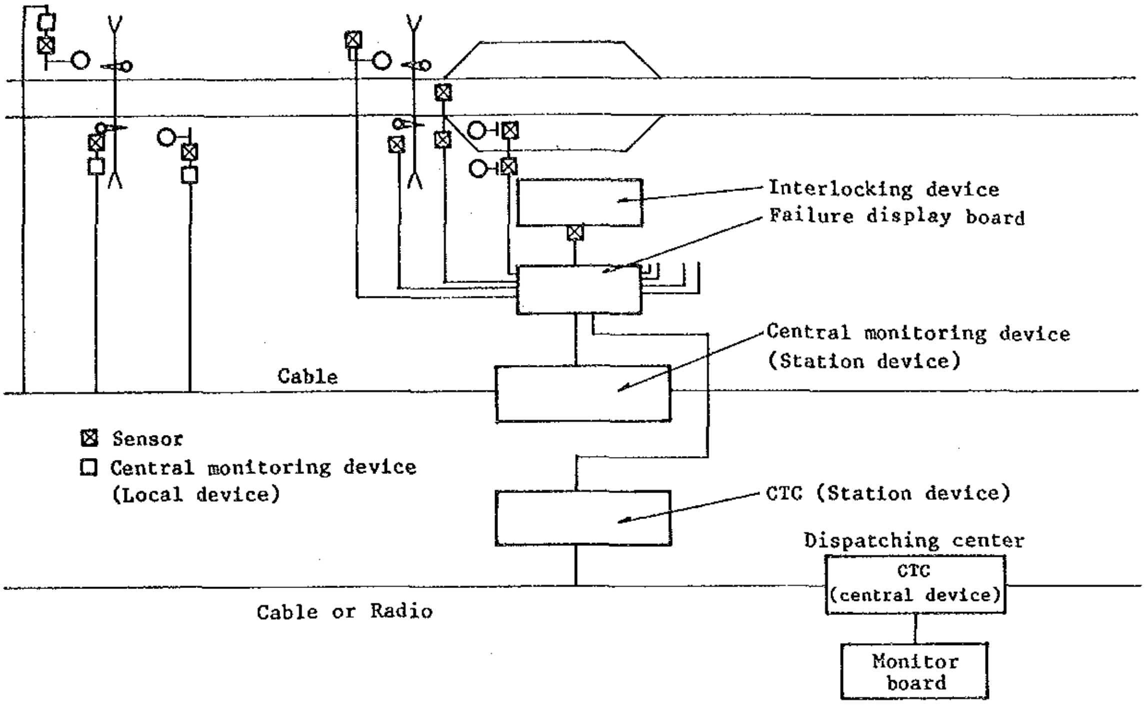


Fig. 1 Outline of Remote Monitoring System

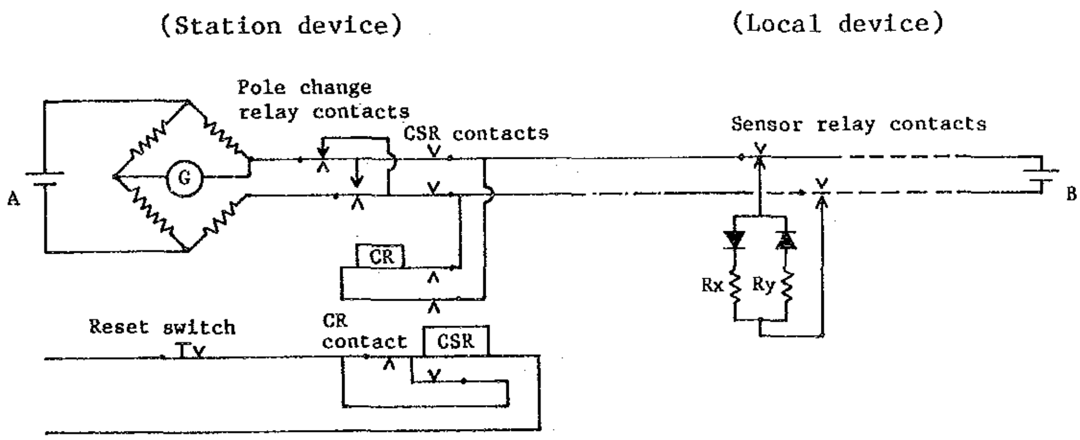


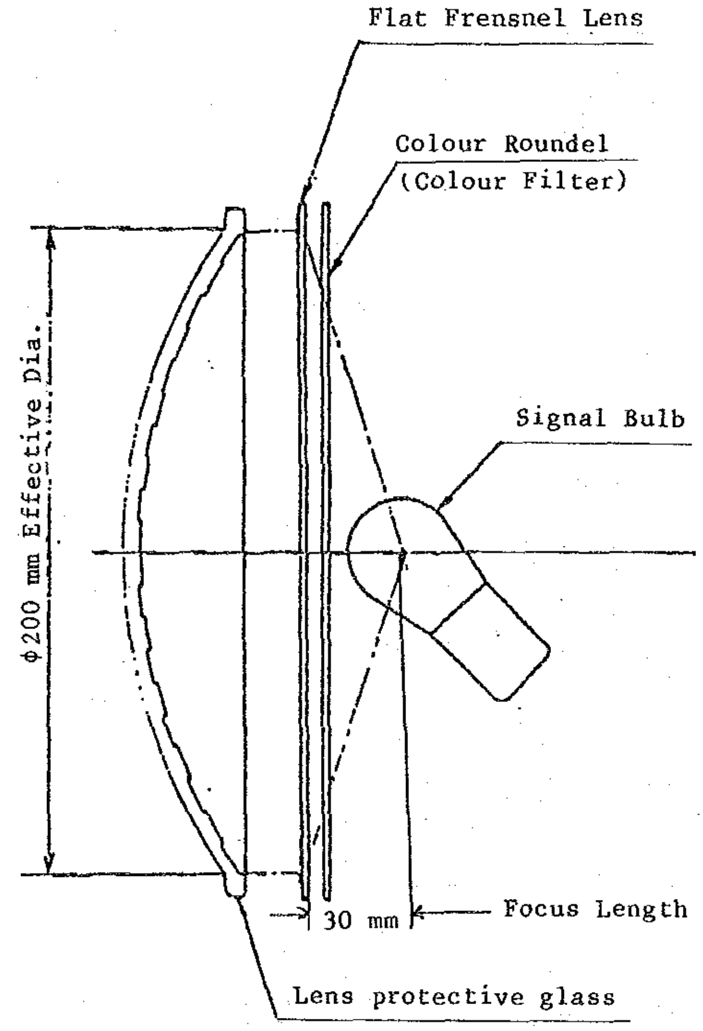
Fig. 2 Principle of Central Monitoring Device

5-18 Example of Signal Lens of Long Visibility

1. Major Particulars

Lens	Lens effective diameter	200 mm
	Composition	Flat type frensnel lens (with colour filter)
	Material	Polycarbonate
Signal bulb	Rate	30 V 15W/15W
	Luminousness	27 V 120 ℓm (only main filament)
Range visibility	Rated voltage x 90(%) 27 V	More than 1.5 Km
	Rated voltage x 73(%) 21.9V	More than 1.0 Km

2. Configuration



5-19 Relation between Turnout Number and Alignment of Locking Devices in JR

	Turnout number	Number of drive	Alignment	Type of machine	Characteristic	
					Max. switching force	Withstanding thrust force
Conventional Line	<16	1	Fig-1	NS-A	300 kg	Max. 2000 kg
	≥16	2	Fig-2	G-CL	300 kg	Max. 2000 kg
New Corridor	≥16	2	Fig-3	TS	800 kg	Max. 2000 kg

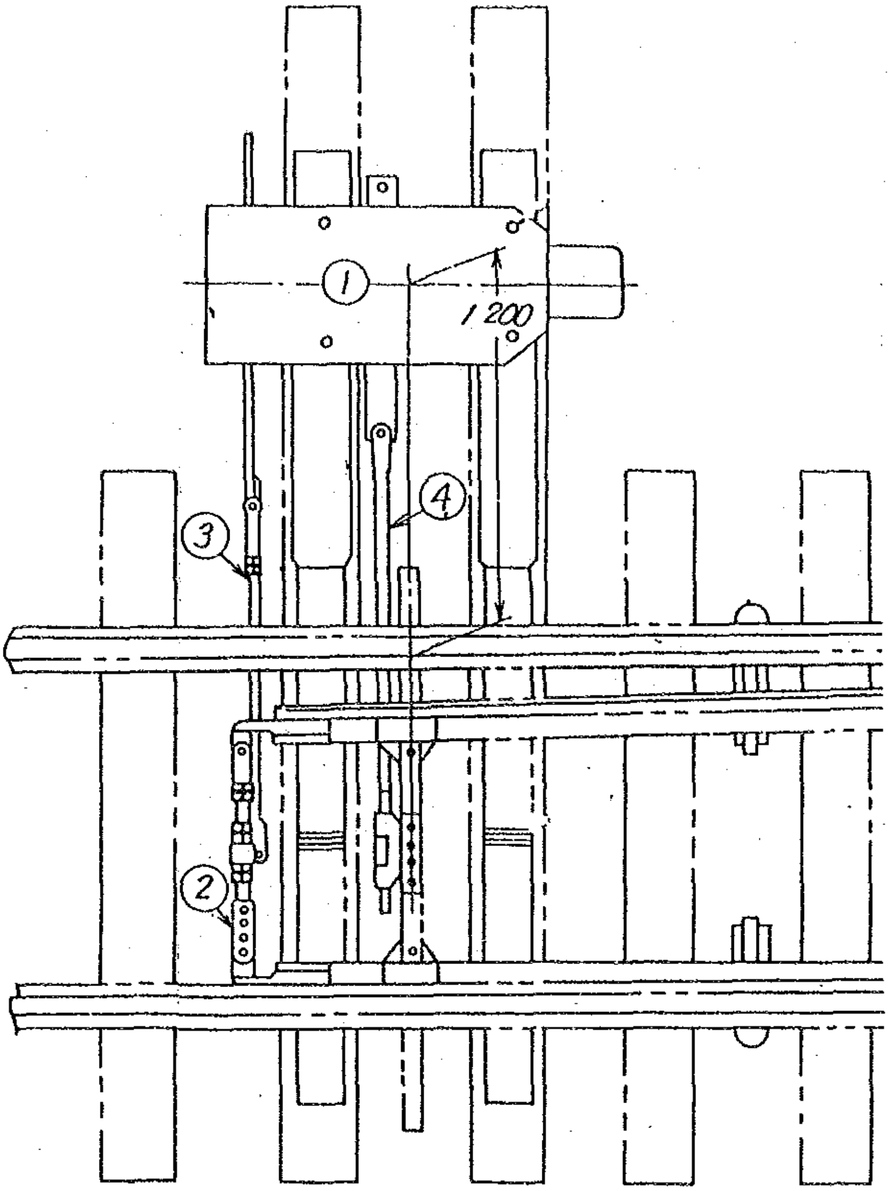


Fig. 1 Installation of Locking Device for NS-A Type Point Machine

No.	Description
①	Point machine
②	Lock stretcher bar
③	Lock rod
④	Drive rod

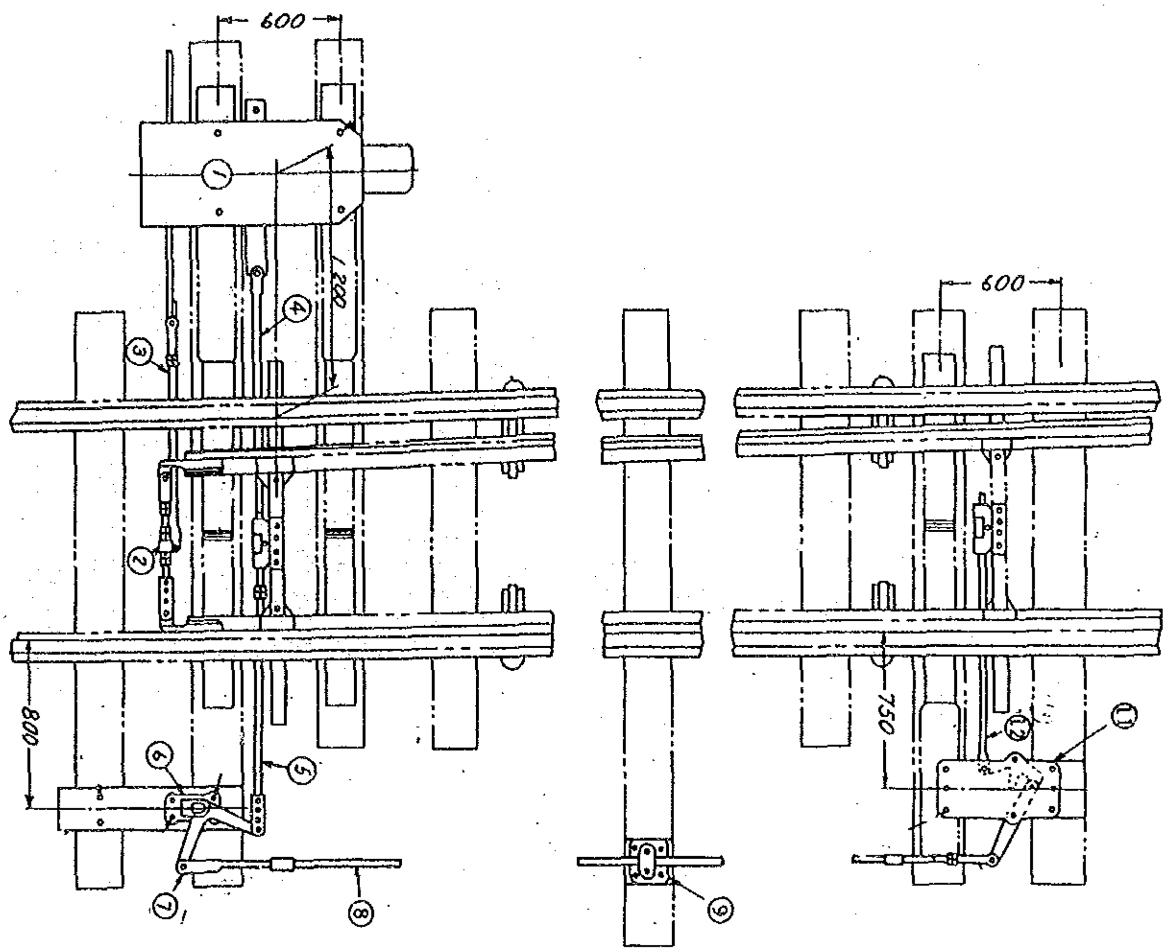


Fig. 2 Installation of Locking Device for G-CL Type Point Machine

No.	Description	No.	Description
①	Point machine	⑦	Jaw
②	Lock stretcher bar	⑧	Iron signal pipe
③	Lock rod	⑨	Rod carrier
④	Drive rod	⑩	Jaw
⑤	Insulation link	⑪	Escapement crank
⑥	Crank	⑫	Drive rod

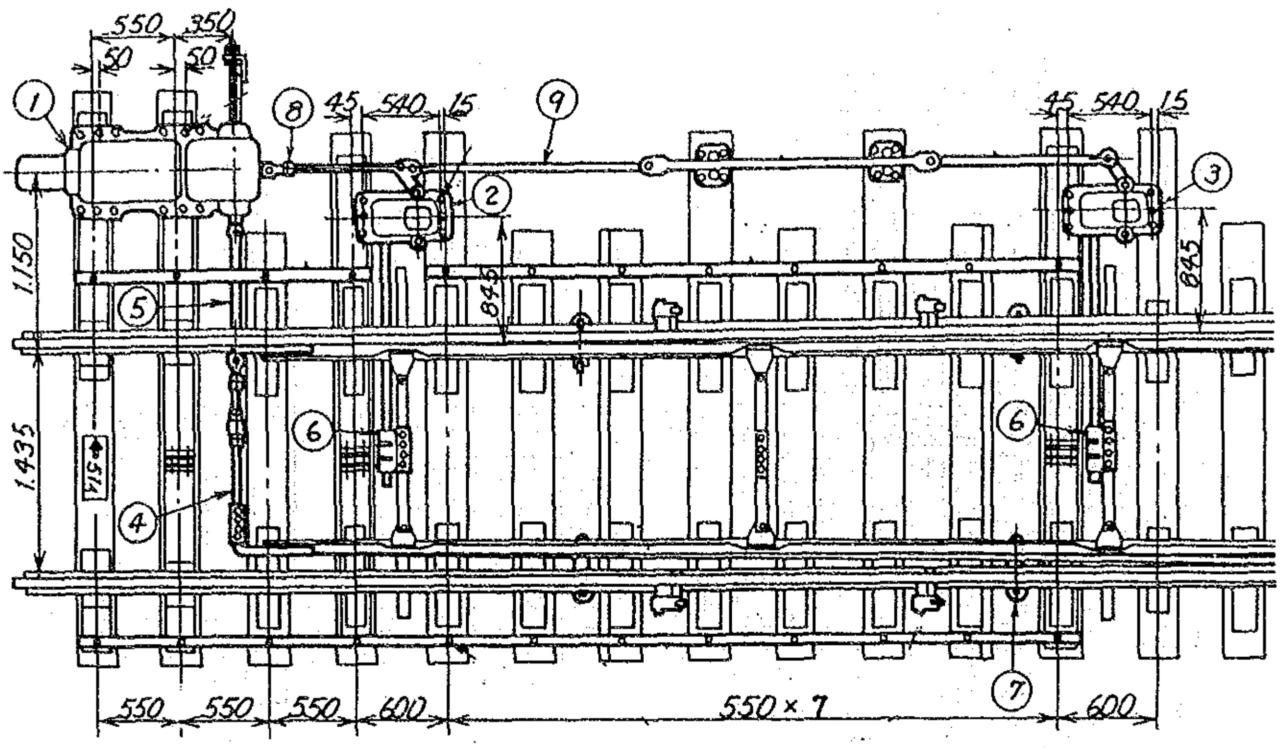


Fig. 3 Installation of Locking Device for TS Type Point Machine

No.	Description	No.	Description
①	Point machine	⑥	Drive lug
②	Escapement crank	⑦	Point wear preventor
③	Escapement crank	⑧	Link
④	Lock stretcher bar	⑨	Link
⑤	Rock rod		

5-20 Signalling System of the New Corridor

(1) Signalling

- Signal Safety Facilities
  - ATC Device
    - Wayside Device
      - Instrument Room
        - T.C. Transreceiver (Concentrated)
      - Track Circuit (T.C.)
        - Track loop (Over-run Prev.)
      - Feeder Auto Change-over Sw.
    - Cab Device
      - Pickup
      - Receiver
      - Cab Signal
  - CTC Device (Refer to Fig. 1)
    - Central Control Office
      - Code Conversion Detector
        - Transreceiver
      - Control Panel
      - Indication Panel
    - Station Instrument Room
      - Code Conversion Detector
      - Transreceiver
    - Train No. Device
      - Wayside Device
        - Wayside Unit
        - Receiver
      - Cab Device
        - Cab Unit
        - Transmitter
  - Station Signal Safety Device
    - Interlocking Device
      - Instrument Room
        - Interlocking Device
        - Control Panel
      - Point Sw. Device
      - Track Circuit
  - Other Facilities
    - Location Detection Device
      - Wayside Device
      - Cab Device
    - Train Protection
      - ATC Controller
      - Clearance Obstruction Detector

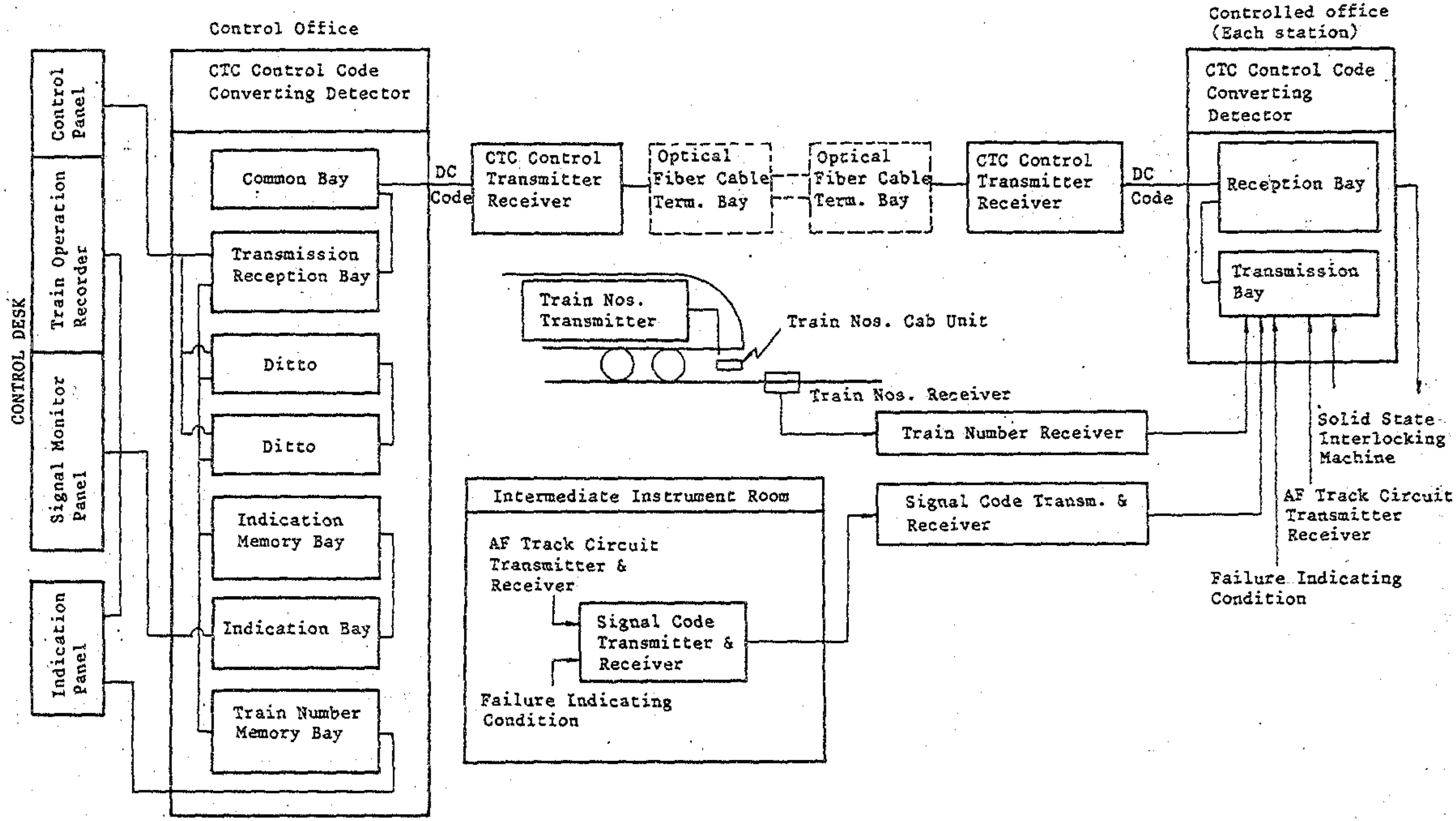


Fig. 1 Circuit Constitution Diagram of CTC Equipment

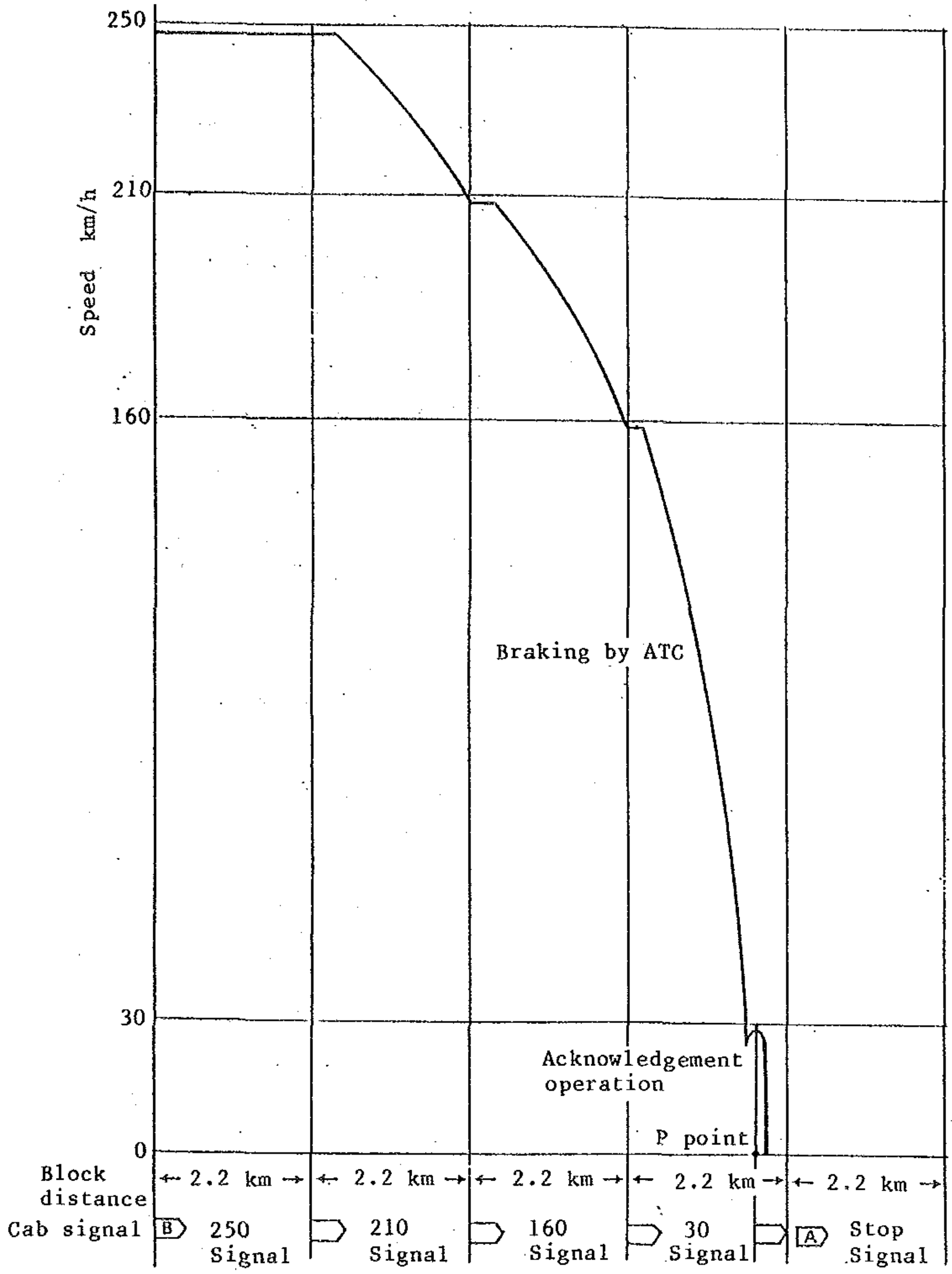
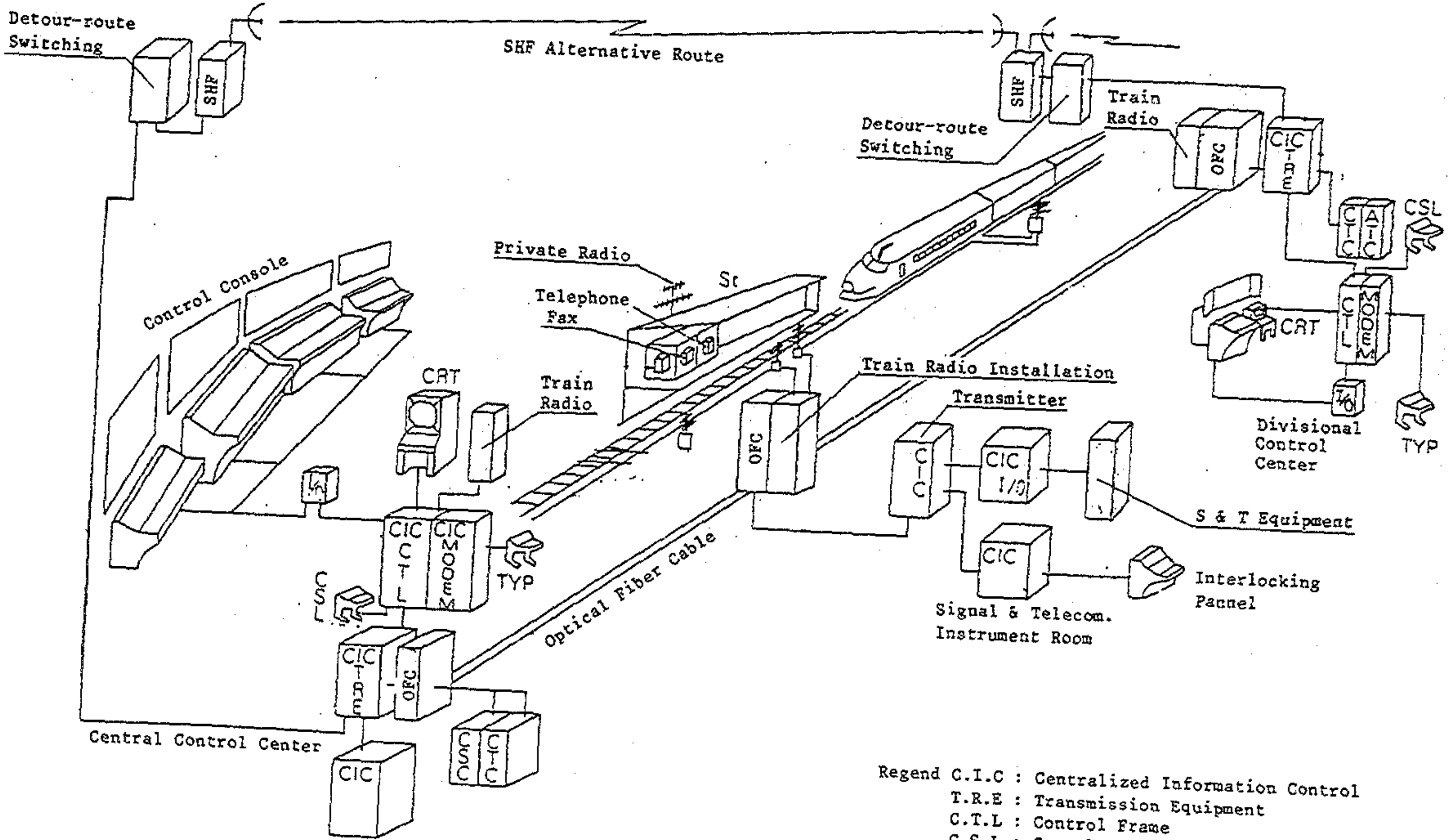


Fig. 2 Operating Curve by ATC (Between Stations)

5-21 Telecommunication System of the New Corridor

- Telecom. Facilities
  - SHF Radio
    - Radio Transmitter & Receiver
  - Cable Transmission
    - Carrier Telephony
    - Carrier-Frequency Terminal
    - Coded Exchange Device
    - Multiplexer & Relay Unit
  - Train Radio
    - Automatic Telephone Exchange
    - Wireless Carrier Telephony
    - Wireless Telephone Transmitter & Receiver
    - Wireless Telephone Repeater
  - Communication Line
    - Optical Fiber Cable
    - Intermediate Repeater
    - Carrier Telephone Repeater
  - Terminal
    - Maintenance Radio & Private Radio
    - Facsimile Equipment
    - Telephone Dispatcher
    - Inter Call Telephone
    - Automatic Telephone
  - Control Center
    - Dispatcher Equipment
    - Transmission Equipment
    - Automatic Route Control Equipment
    - Monitor Equipment



Regend C.I.C : Centralized Information Control
T.R.E : Transmission Equipment
C.T.L : Control Frame
C.S.L : Console Type Writer
O.F.C : Optical Fiber Communication Equipment

Fig. 1 Configuration of Telecommunication System

5-22 Typical Instruments for Repair and Maintenance of Signalling Electronic Devices

Equipment	Instrument	Cause
Solid-state interlocking Electronic level crossing controller	Logic analyzer Tester Synchroscope Voltmeter	. Software errors . External errors (Field devices, operation handling) . Hardware failure (Processor, modules, sheets) . etc.
Centralized traffic control Automatic train control A.F. track circuit (Transmitter & Receiver)	Level meter wave analyzer X-Y recorder frequency-counter Synchroscope signal generator	. Deterioration of modules and sheets . External noise . Logical error . etc.
Train number transmitter & Receiver	Delayed wave analyzer	. Hard and logical error

6-1 Countermeasures for Frequent Trippings of Feeder Circuit Breakers at Substation

The problem IR is now facing in supplying electric traction power is the fact that feeder circuit breakers at the substation make extremely frequent trippings -- the problem that should be solved immediately.

The numbers of breaker trippings are not the same, varying with the feeding zones and seasons. Some breakers trip more than 100 times a month, and others only 4 or 5 times.

For reference, the trippings of circuit breakers installed at JR's substations average 4 or 5 times a year, with the exceptional cases such as typhoons and other natural disasters.

1. Problems

These frequent trippings give rise to frequent suspensions of power supply to trains. Attention must be given to the following actual conditions:

(1) Under the current system, the feeder circuit breaker, connected to the secondary side of substation transformer, is commonly used for both up and down lines; therefore, when a trouble happens to one line, the power for the another sound line must be suspended, making a power suspension chance double.

(2) After circuit breaker tripping, the interrupters of SS/FP, SSP and SP will be manually closed one by one controlling from the center. Thus, this series of the closing work requires some minutes.

These trippings will bring about the following problems:

(1) Interrupt the train operations.

(2) Shorten a service life of a circuit breaker, necessitating more maintenance.

Unless these problems are solved, therefore, the trippings will cause a grave adverse effect in attaining the increase in track capacity and the 160 km/h high-speed train operation.

2. Causes

The causes of breaker trippings include:

(1) Birds. Some records say the 70 ∿ 80% of the total breaker trippings were due to birds.

(2) Flashover of the air gap installed on the roof of electric locomotive (connected in parallel to the primary side of transformer)

(3) Flashover of the OHE insulator, frequently happen during the foggy season of December and January, and in the heavily air polluted area.

(4) False working of distance relay due to load current

3. Countermeasures

It will take long time and great effort to settle out all these matters. However, there are measures that can be taken immediately such as:

(1) Measures to remove the causes of circuit breaker trippings.

1) In the bird-inhabited area:

- A large number of bird nests are found. So it is recommendable to take measures to prevent nesting at places which are liable to cause ground fault. (See Fig. 1.)

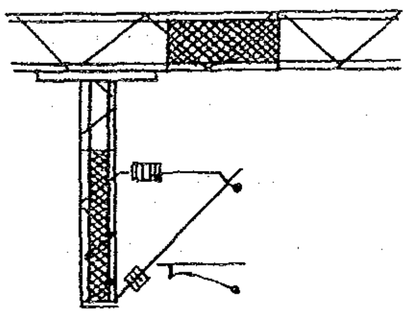


Fig. 1 Places Effective in Preventing against Bird Nests

For example, it would be effective to insert a net of insulation material, such as plastics, inside the beam.

- Strengthen the insulation, such as fixing an insulating plate below the bottom of beam or covering an insulating tube to the catenary wire, when the clearance between the bottom of beam and the catenary wire is small, especially at overbridge.

2) Change the air gap between horns provided on the roof of electric locomotive; adopt a gapless arrester for electric locomotive.

3) Review the setting of distance relays in use and improve its characteristics.

At present the MHO relay is used as a distance relay, and its selecting capability of load and fault currents is limited. Therefore, it is desired that a distant relay with parallelogram characteristics be developed as early as possible. (See Appendix 6-7.)

4) Survey the actual status of insulator flashovers by areas, seasons and causes, and clean or strengthen insulators in specific areas if required.

(2) Measures to shorten the power stopping time after tripping

1) Adopt the high-speed, automatic reclosing method for circuit breakers. This method recloses a circuit breaker automatically 0.5 second right after it trips. When reclosed and retripped, the circuit breaker will be locked for further action.

From JR's experiences, it can be expected that the adoption of this method makes it possible to reclose about 80% of the total breakers that have tripped. In other words, in most cases it shortens the power stopping time to mere 0.5 second. According to "Single Pole SF-6 Circuit Breakers 25 kV AC: Specification No ETI/PSI/66/Rev. 1 (9/84)," the rated operating sequence of the circuit breaker is specified to be "O-0.3 sec-CO-3 min-CO." Therefore, this 0.5 second time is applicable.

2) Make it automatic to operate the interrupters of SS/FP, SSP and SP sequentially. At present, interrupters are manually operated from the control center. The automation will reduce the interrupter operation time to the matter of seconds. This method is especially effective in the Delhi area where the feeding system is complicated with many interrupters installed.

(3) Measures to shorten the time for detecting a fault point. As described above, the transient faults -- about 80% of the total circuit breaker trippings -- will be solved by adopting the high-speed, automatic reclosing method. However, it is necessary to detect the remaining lasting faults of 20%, by making a time-consuming patrol. Introduce fault locators at each substation and then any fault point will be located with 0.5-1km accuracy, making it possible to drastically reduce the detecting time. Two methods are detailed as follows:

1) In the existing feeding system where the up and down lines are connected in parallel at SP and SSP, the accuracy of a fault location becomes deteriorated. Therefore, after re-tripping in reclosing, open all interrupters of SP and SSP, close the interrupters of SS for the up and down lines separately, and then a fault point can be located with accuracy.

2) Open all the parallel interrupters for up and down lines before the CB recloses in 0.5 second by providing low voltage relays to each SP and SSP. Then the fault point can be located with high accuracy at a time of retripping with feeding current comparators which are provided to each feeder line.

6-2 Substation Supervisory Remote Control System

The JR's latest substation supervisory remote control system using a microprocessor is outlined below:

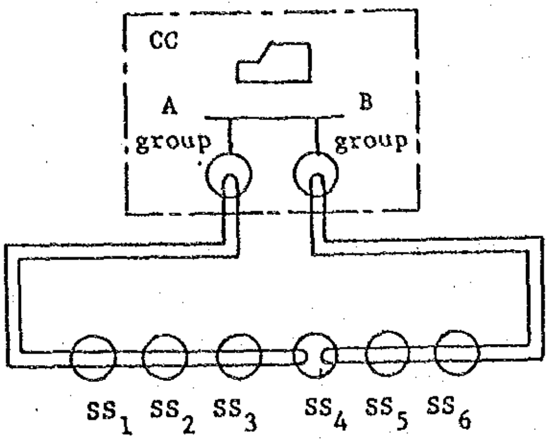
1. Features

(1) A communication circuit is constructed in the form of a loop to highten the reliability of transmission line connected to CC, SSs, SPs and SSPs. When a trouble arises in the line, the part in trouble will be automatically cut off, and at the same time the circuit will be automatically reformed; therefore, only one trouble will not hamper the operation of trains. Fig. 1 illustrates the configuration of communication circuit and a principle diagram showing how to deal with a circuit trouble when it happens.

(2) The supervisory remote control system, using a microprocessor and LSI (Large Scale Intergrated Circuit), can control many items and collect a large volume of information;

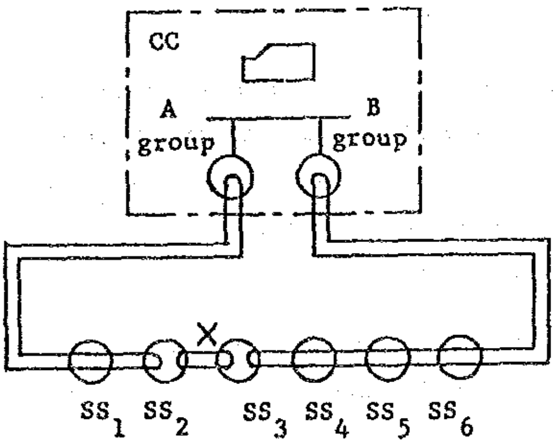
1) In addition to the function of controlling devices separately, it is capable of one-touch control of feeding circuit structure, and of overall control when suspending a feeding over a certain section, making the control simpler with smaller handling errors.

2) It can compile information on many items of the controlled point so that dispatchers can make a right judgment.



a. Composition of Circuits When Normal

SS_1, SS_2 and SS_3	controlled by A group
SS_4, SS_5 and SS_6	controlled by B group



b. Recomposition of Circuits When in Trouble on the X Marked Section

SS_1 and SS_2	controlled by A group
SS_3, SS_4, SS_5 and SS_6	controlled by B group

Fig. 1 Composition and Recomposition of Circuits When a Trouble Arises

3) Capable of printing out the time sequential record of controlling every device and their working conditions, also of the power consumption at each substation in the form of a daily report, making the equipment management easier.

4) Capable of collecting various data necessary for maintenance of devices, such as the values of feeding voltage, load current, fault current, operating frequency of devices, and controlling frequency, and the number of temporary stagnations of the remote control system, making their maintenance more easy and efficient.

5) Selfdiagnosis function, that is capablity of detecting parts in trouble by itself, makes the system highly reliable.

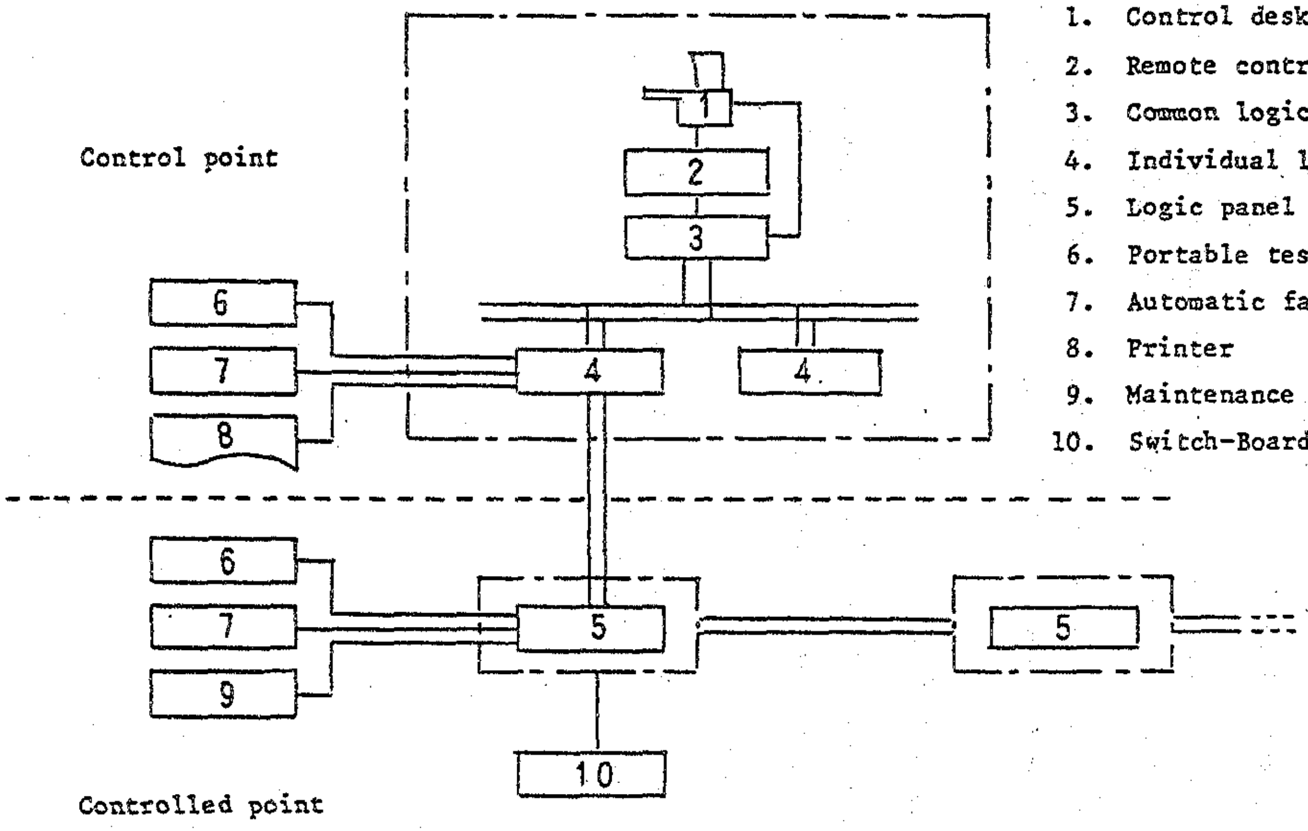
(3) Being static, the system is small in size. Having almost no movable parts, the system is easy to maintain and has a longer service life.

2. Block Diagram of System Composition

Fig. 2 shows the block diagram of the supervisory/remote control system. Main parts of the system are:

(1) Control desk

By using CRT on control desk, it controls the power supply system and all the other devices.



1. Control desk
2. Remote control logic device
3. Common logic panel
4. Individual logic panel
5. Logic panel
6. Portable testing device
7. Automatic fault recorder
8. Printer
9. Maintenance data processing equipment
10. Switch-Board

Fig. 2 Block Diagram of the Supervisory/Remote Control System

(2) Remote control logic device

This is a controlling purposes processor, capable of controlling devices automatically, separately and totally, and also of dealing with figure display to CRT.

(3) Common logic panel

This is a device for mutually making interface among control desk, remote control logic device, and individual logic device. It stores control information and output the conditions of equipment at a controlled post to CRT display or the control desk when receiving answer-back signals.

(4) Individual logic panel

It is provided for each group. It controls transmission of such information as supervision of the condition of communication lines, the collation of sending/receiving codes, and supervision of temporary stagnations of control signals. It also creates codes necessary for testing the system.

(5) Logic panel

It is provided at the controlled point. It works as the interfaces with the control center, adjacent controlled points and with the switch-board.

6-3 Outline of AT Feeding Circuit and Connections of Substation, Sectioning Post and Sub-sectioning Post

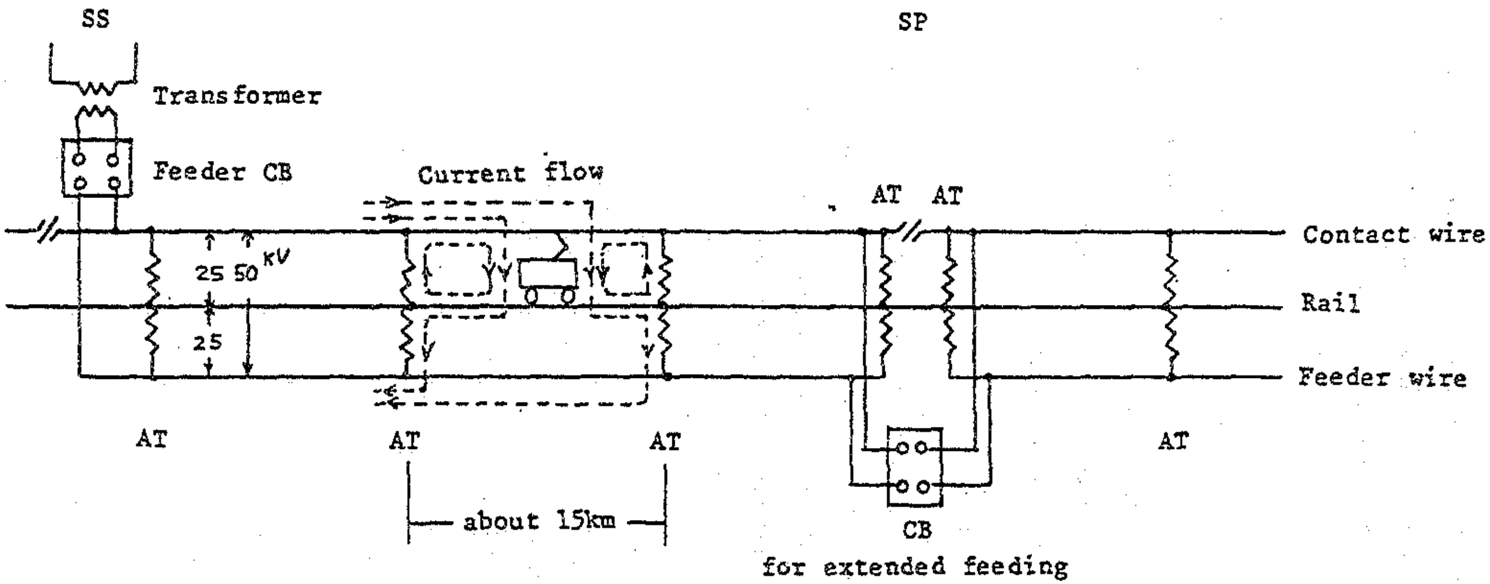


Fig. 1 Outline of AT Feeding Circuit

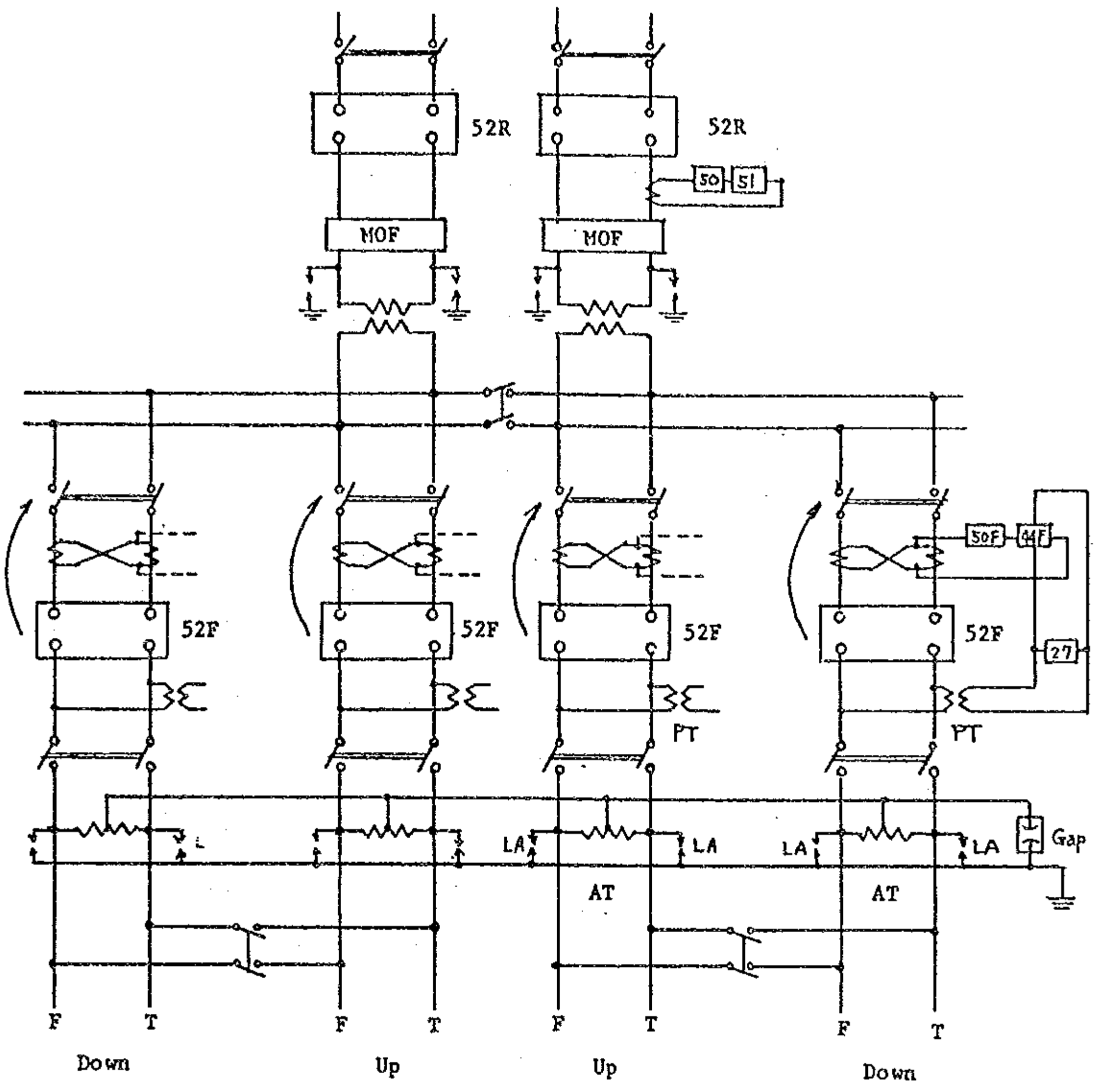


Fig. 2 Standard Schematic Diagram of Traction Substation for AT Feeding System

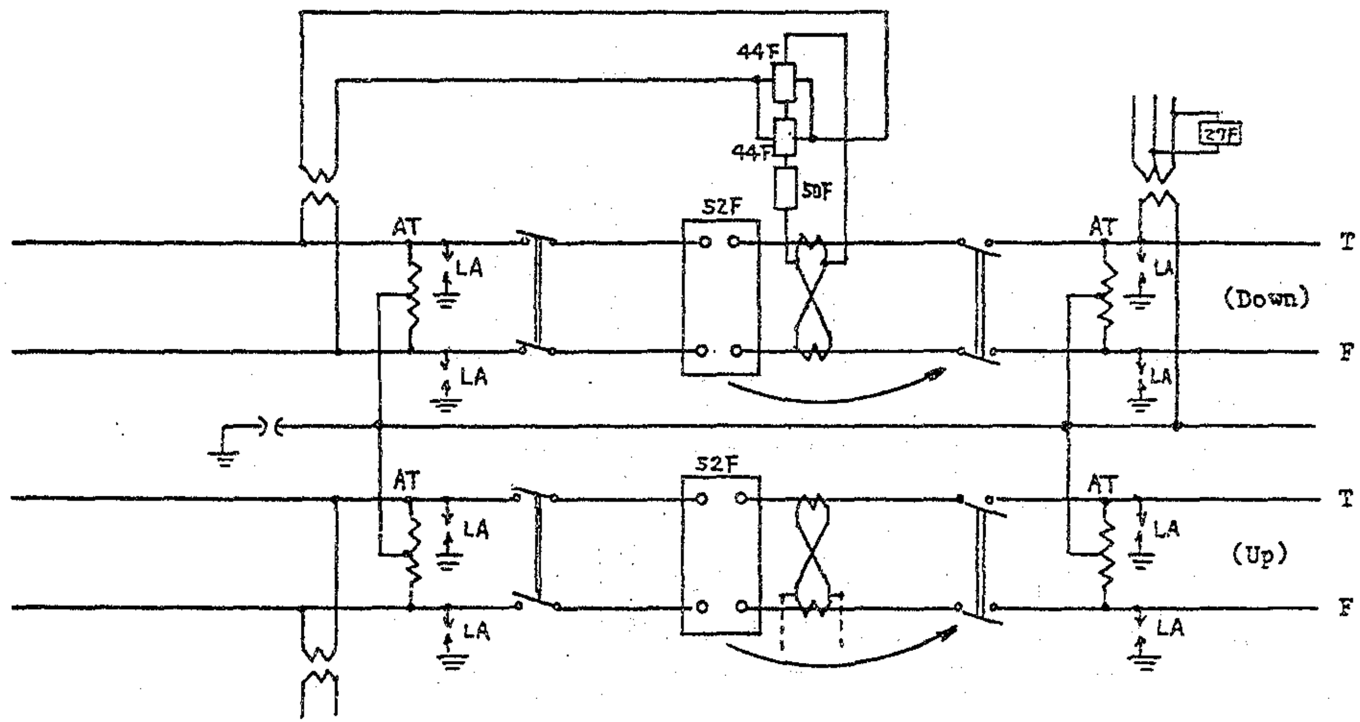


Fig. 3 Standard Schematic Diagram of Sectioning Post for AT Feeding System

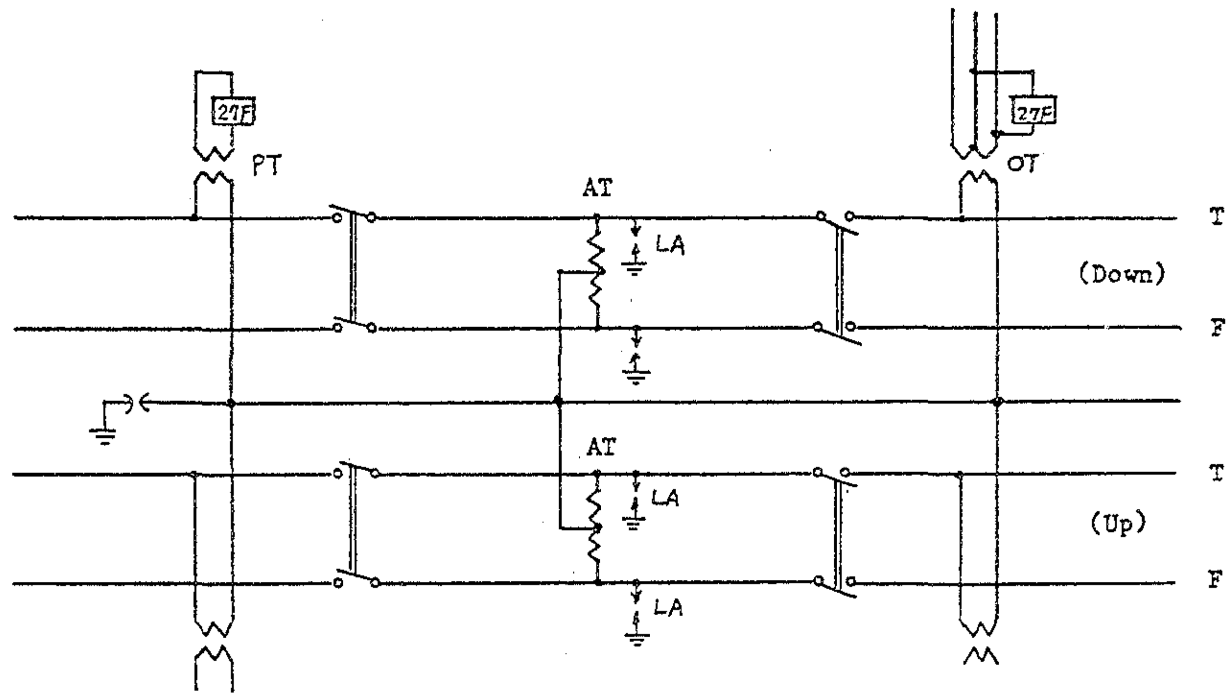


Fig. 4 Standard Schematic Diagram of Sub-Sectioning Post for AT Feeding System

6-4 Shunt Capacitor Equipment

In cases where a shunt capacitor is to be installed at substation to improve the power factor of load current, the following points must be taken into account to prevent abnormal phenomena and damages to the shunt capacitor equipment.

1. Important Items on Shunt Capacitor Equipment

(1) Inductive reactance value of series reactor of shunt capacitor equipment

Fig. 1 shows the circuit of traction power supply, and Fig. 2 its equivalent circuit.

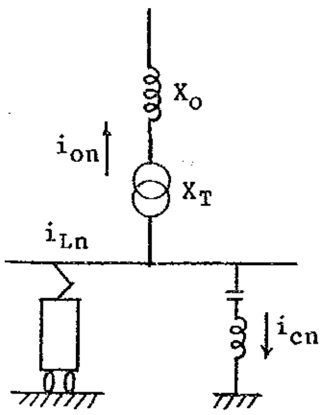


Fig. 1 Traction Power Supply Circuit

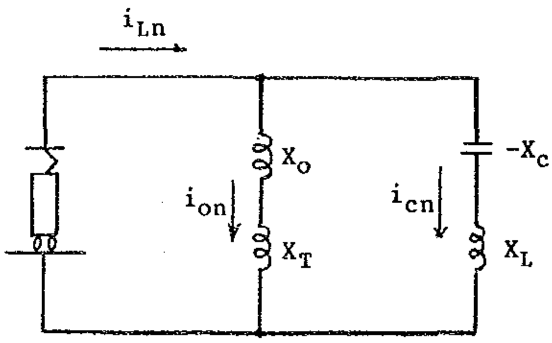


Fig. 2 Equivalent Circuit

where Xo : Inductive reactance of power source
X_T : Inductive reactance of main transformer
$-X_C$: Capacitive reactance of shunt capacitor
X_L : Inductive reactance of series reactor of shunt capacitor

When a study is to be made of high harmonic current in the traction power supply circuit, an electric motive unit is considered to be its source.

The following equation represents i_{cn} and i_{on}:

$$\left.\begin{aligned} i_{cn} &= \frac{(Xo + X_T)n}{(Xo + X_T)n + (nX_L - \frac{Xc}{n})} \cdot i_{Ln} \\ i_{on} &= i_{Ln} - i_{cn} \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (1)$$

where n : degree of high harmonic

Note the above equation, denomination, the second term. If $(nX_L - X_c/n)$ turns to be minus, i_{cn} or i_{on} or both will become greater than i_{Ln}, and the high harmonic current generating from the electric motive unit will be amplified with the shunt capacitor equipment.

The load current contains high harmonic current which exceeds the 3rd harmonic current, such as I_3, I_5, I_7 .....; therefore, it is necessary for the shunt capacitor equipment to be inductive in the frequency area above the 3rd high harmonic frequency (3 X 50 = 150 Hz).

Fig. 3 shows the characteristic of $(nX_L - Xc/n)$ when $X_L = 0.13$ Xc.

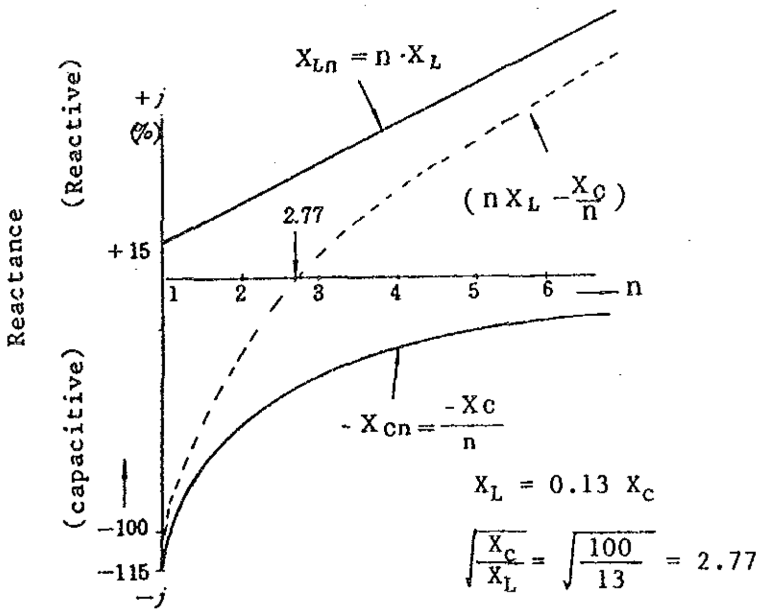


Fig. 3 Reactance of Shunt Capacitor Equipment vs. Frequency

(2) Transient phenomena

1) Inrush current when closed

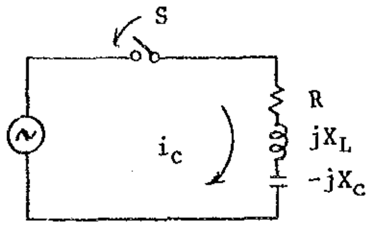


Fig. 4 Equivalent Circuit of Shunt Capacitor Equipment

Wnen S is closed in the circuit of Fig. 4, i_c is expressed by the following equation:

$$
\begin{aligned}
ic &= Ic(\sin\omega t - \varepsilon^{-\alpha t}\frac{\omega o}{\omega}\sin\omega o t) \\
&= Ic\left\{\sin\omega t - \varepsilon^{-\alpha t}\sqrt{\frac{Xc}{X_L}}\ \sin(\omega\sqrt{\frac{Xc}{X_L}})\ t\right\} \quad \ldots (2)
\end{aligned}
$$

where

Ic : rating current of shunt capacitor

ω : angular velocity (rad/sec)

$\omega o = 1/\sqrt{LC}$ (rad/sec)

$X_c = 1/\omega c$: capacitive reactance of capacitor at 50 Hz

$X_L = \omega L$: inductive reactance of series reactor at 50 Hz

Fig. 5 shows wave forms of inrush current.

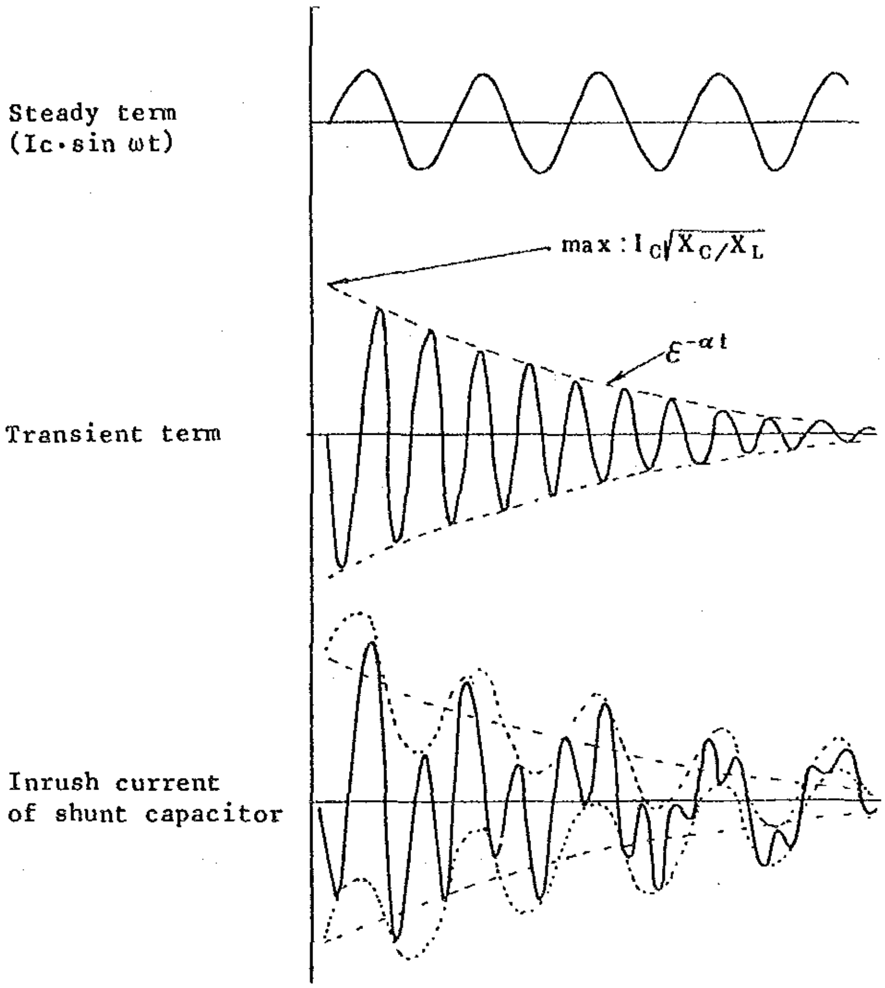


Fig. 5 Wave Forms of Inrush Current

Maximum theoretical value of inrush current and frequency are expressed by:

$$i_c \max = I_c \times \left(1 + \sqrt{\frac{X_c}{X_L}}\right) \qquad \text{..................} \quad (3)$$

$$f_{ic} = 50 \times \sqrt{\frac{X_c}{X_L}}$$

When $X_L = 0.13X_c$, i_c max will be 3.8 times as large as the rated current, and frequency 2.8 times. Therefore, the capacitor must be capable of withstanding the inrush current.

Should the capacitor be equipped with a fuse, it is necessary for the fuse not to blow due to the inrush current. If a fuse in a certain unit capacitor is blown, the total capacitive reactance value, X_c, will increase, and the resonance frequency will become higher, and this will cause the amplification of high harmonic current. Basically, therefore, it is not recommendable to use a fuse in unit capacitor. When the unit capacitor is detected defective, it is necessary to cut off the whole shunt capacitor from the circuit with circuit breaker.

2) Transient over-voltage of capacitor

The capacitor must be capable of withstanding the transient over-voltage shown in Equation (4).

$$e_c \text{ (max)} = E_c (-\cos \omega t + \varepsilon^{-\alpha t} \cos \omega o t) \quad \cdots\cdots (4)$$

3) Transient over-voltage of series reactor

The series reactor must be capable of withstanding the transient over-voltage expressed in Equation (5).

$$e_L \text{ (max)} = \omega L \; I_c \cos \omega t + \frac{1}{\omega c} I_c \varepsilon^{-\alpha t} \cos \omega o t \quad \cdots\cdots (5)$$

4) Recovering voltage appeared to CB terminals when opened

In cases where CB is to be installed on the shunt capacitor equipment, it is necessary to use a CB which will not restrike, since recovery voltage, which is two times as large as the power source voltage, will arise between CB terminals when CB is opened.

(3) Ferranti effect

Install a shunt capacitor, and, when there is no train load, the voltage, $(X_O + X_T) I_c$, will go up (Ferranti effect), exceeding the power source voltage. It is necessary to keep this voltage within the allowable value.

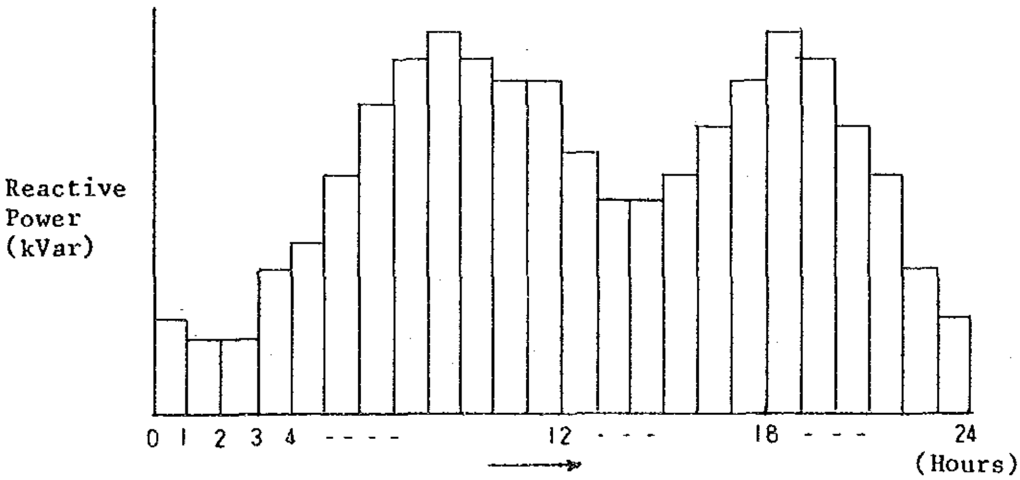
where X_0 : Inductive reactance of power source

X_L : Leakage reactance of transformer

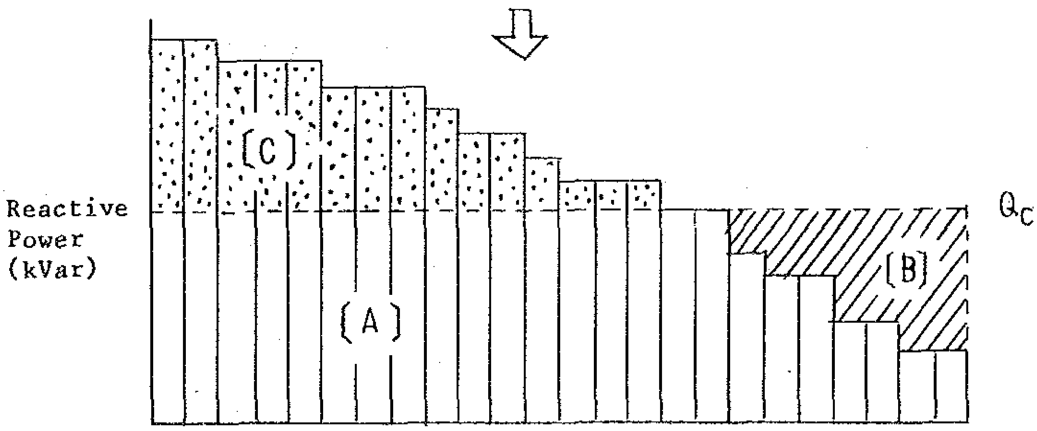
I_c : Rating current of shunt capacitor

(4) Capacities of shunt capacitor and power factor

Assume the variations of the reactive power measured at a certain substation, as shown in Fig. 6 a. Arrange them in order from the largest, and Fig. 6 b. shows the density distribution of reactive power.



a. Measured Reactive Power



b. Density Distribution of Reactive Power

Fig. 6 Reactive Power Distribution

Install a shunt capacitor, Qc value, and the power factor will improve from Equation (5) to Equation (6).

Power factor before improvement

$$\cos\theta_1 = \frac{P_L}{\sqrt{P_L^2 + Q_L^2}} = \frac{P_L}{\sqrt{P_L^2 + (A + C)^2}} \quad \cdots\cdots\cdots\cdots\cdots (5)$$

Power factor after improvement

$$\cos\theta_2 = \frac{P_L}{\sqrt{P_L^2 + (Q_L - KQ_c)^2}} = \frac{P_L}{\sqrt{P_L^2 + C^2}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (6)$$

where $K = \frac{A}{A + B}$

A : □ area (kVarH) H

B : ▨ area (kVarH) H

C : ⬚ area (kVarH) H

2. Study on Shunt Capacitor Equipment at Panki SS

(1) Constants of the existing shunt capacitor equipment

1) Constants

C : 16 units, 1022 kVar at 25 kV
unit capacitor : 9.2 kVar, 7.5 kV

L : 11.316Ω at 50 Hz, continuous current 49.2 A

2) Study

The following values are obtainable from the above constants.

a. Capacitive reactance of capacitors at 50 Hz

$$X_c = \frac{(25\ \text{kV})^2}{1022\ \text{kVar}} = 611.5\Omega$$

b. Ratio of X_L to X_c

$X_L / X_c = 11.361 / 611.5 = 0.0186$

(1.9% of X_c)

c. Resonance frequency

$$f = \frac{1}{2\pi\sqrt{LC}} = 366.8 \text{ Hz} = 7.34 \times 50 \text{ Hz}$$

(2) Problems

1) Over-current of shunt capacitor and high harmonic current interference with power source

The value of X_L is 1.9% of X_C, and resonance frequency is 7.34 X 50 = 366.8 Hz. Therefore, the shunt capacitor amplifies 7th, 5th, and 3rd harmonic currents. In other words, it gives over-current to the shunt capacitor, and high harmonic current interference to the power source.

2) Blowing of unit capacitor fuse and breaking of capacitor

Since the value of series reactor is not appropriate, the probability of fuse blowing and capacitor breaking is high. Causes are:

a. Over-current of shunt capacitor due to the amplification of high harmonic current shown in 1).

b. As can be seen by Equation (3), i_c max flows about 8 times larger than the rated current.

c. The capacitor is breakable due to the over-current or over-voltage. The over-current in the above a. and b. will break the capacitor.

d. When the fuse of a unit capacitor is gone, the resonance frequency of shunt capacitor equipment will become higher. As a result, the amplification of high harmonic current will be enhanced, and the inrush current enlarged. In other words, it can be assumed that capacitors will break one after another due to the domino effect.

(3) Recommendations

1) The value of series reactor of shunt capacitor at the Panki Feeding Post is not appropriate. Therefore, it is suggested that this series reactor be improved immediately. Check on X_L of shunt capacitor equipment at other feeding posts and substations, and improve if necessary. It is recommendable that the value of X_L be 13-15% of X_c.

2) It is essential that the series reactor should not be saturated due to the fluctuation in load current and the transient phenomena that arise when the shunt capacitor equipment is closed. When the value of X_L becomes close to 11% of the value of X_c, parallel resonance in the 3rd harmonic frequency to the inductive reactance on the side of power source ((X_O + X_T) in Fig. 1) might take place.

3) The use of a fuse is effective in protecting a unit capacitor, but pernicious to the shunt capacitor equipment. Therefore the current protection method must be re-studied.

4) In cases where CB is to be used for shunt capacitor equipment, it must be well capable of closing and opening the leading current.

6-5 Series Capacitor Equipment

In cases where a series capacitor is to be used to reduce the voltage drop due to inductive reactance of transformer or feeding circuit, important items that should be taken into account are as given below:

1. Connection Method and Allowable Ohm Value of Series Capacitor

(1) Series capacitor for main transformer

1) Connection method

To compensate the leakage reactance of main transformer, connect a series capacitor in series on the secondary side of transformer.

a. The voltage compensation effect is the same even when a series capacitor is connected on the primary side of transformer, but this is not economical since the insulation level of the series capacitor against ground will be higher.

b. In connecting a series capacitor on the secondary side of transformer, it is economical to connect it on the negative side as shown in Fig. 1.

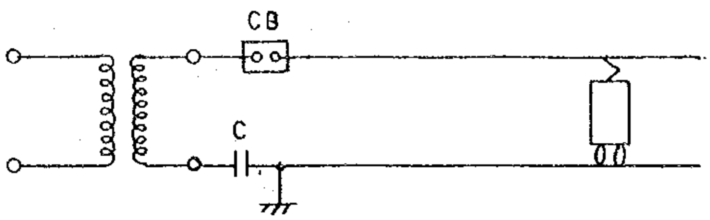


Fig. 1 Series Capacitor for Main Transformer

2) Ohm value

Appropriate ohm value at 50 Hz of series capacitor is 80-90% of the main transformer leakage reactance at 50 Hz. If the ohm value is made larger than this, an abnormal phenomenon, such as a fractional harmonic oscillation, will arise when CB is closed.

(2) Series capacitor for feeder circuit without BT

1) Connection method

Insert series capacitors in series with the contact wire and dispersedly according to the amount of load and the voltage value to be compensated, as shown in Fig. 2.

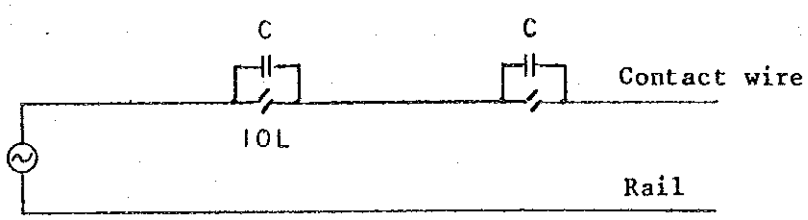


Fig. 2 Series Capacitors for Feeder Circuit without BT

2) Ohm value

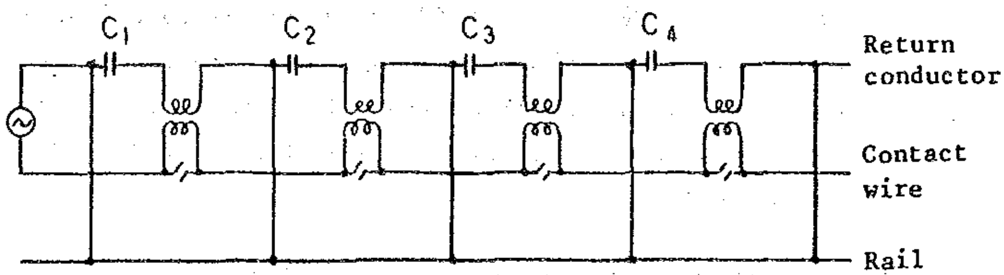
From JR experiences, appropriate ohm value at 50 Hz of series capacitor at a place is approximately 5Ω. That is, let the inductive reactance of return conductor is at 0.5Ω/km. A 5-Ω capacitor will be installed every 10 km.

(3) Series capacitor for feeder circuit with BT

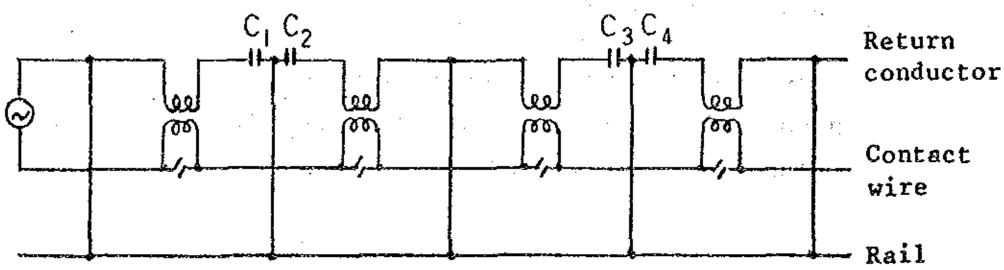
1) Connection method

a. Whether a series capacitor is connected on the side of contact wire or return conductor, the voltage compensation effect is the same; however, the latter is more economical.

b. The number of places where series capacitors are to be installed will be decided according to the size of load and the voltage value to be compensated. However, in cases where series capacitors are to be provided at every BT, install them in a concentrating way as shown in Fig. 3 b., rather than 3 a., because maintenance is easier.



a. Dispersing Installation



b. Concentrating Installation

Fig. 3 Series Capacitors for Feeder Circuit with BT

2) Ohm value

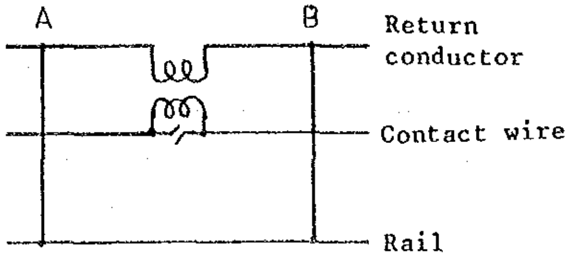


Fig. 4 BT Feeding Circuit

The ohm value of series capacitor to be inserted in a BT circuit will be the inductive reactance value of return conductor between A and B.

For reference, JR experiences show that the inductive reactance value of return conductor is approximately 0.5Ω /km at 50 Hz. That is, if the distance between boosting lines is 2.6 km, the value of capacitor to be inserted will be 1.3Ω .

2. Protection device

When a short-circuit fault occurs in a circuit where a series capacitor is installed, a short-circuit current of that circuit flows in that series capacitor. It is considered not economical to provide a series capacitor that is capable of withstanding this short-circuit current. As a countermeasure, gap and bypass contactor will usually be provided in parallel with the series capacitor.

Protective gap for use with series capacitor is to be provided with the following features:

a. Uniform and stable sparking characteristics
b. Robust construction with sufficient mechanical strength and short time over current characteristics
c. Self arc quenching abilities.
d. Minimum and easy maintenance requirements.

After sparking the gap, the bypass contactor is closed within 10 ms to bypass the gap.

Fig. 6 shows a circuit diagram for this application. The most remarkable difference from ordinary applications is that a device specially developed for the prevention of subharmonic oscillation due to frequent switching of no load traction transformer is incorporated with capacitor. The device comprises a saturable reactor and resister connected in series, and delivers low impedance discharging circuit for the low frequency voltage across capacitor induced by inrush current of no load transformer.

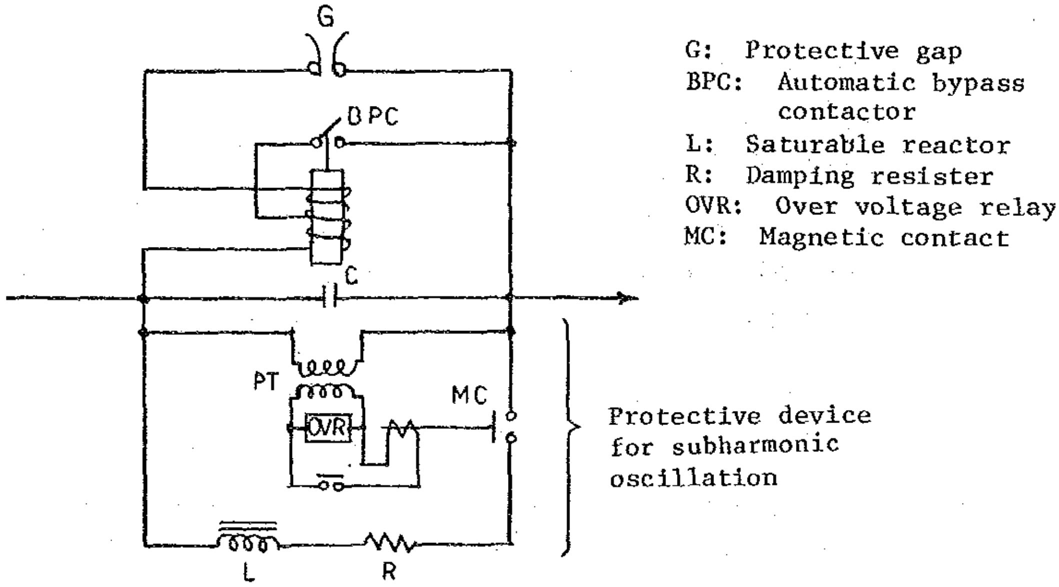


Fig. 6 <u>Connection of Series Capacitor for AC Electrified Railway</u>

6-6 Thyristor Control Reactor (TCR)

A study has been made of a TCR, shunt capacitor and thyristor-controlled shunt reactor provided at the end of feeding zone. Normally, keep the shunt capacitor and shunt reactor in parallel resonance. When the feeder voltage drops, the reactor will be accordingly automatically controlled by thyristor, and leading reactive power supplied to the feeding circuit. Consequently, the power factor seen from the substation will be improved, and the voltage drop in the feeder circuit reduced.

1. Composition of TCR

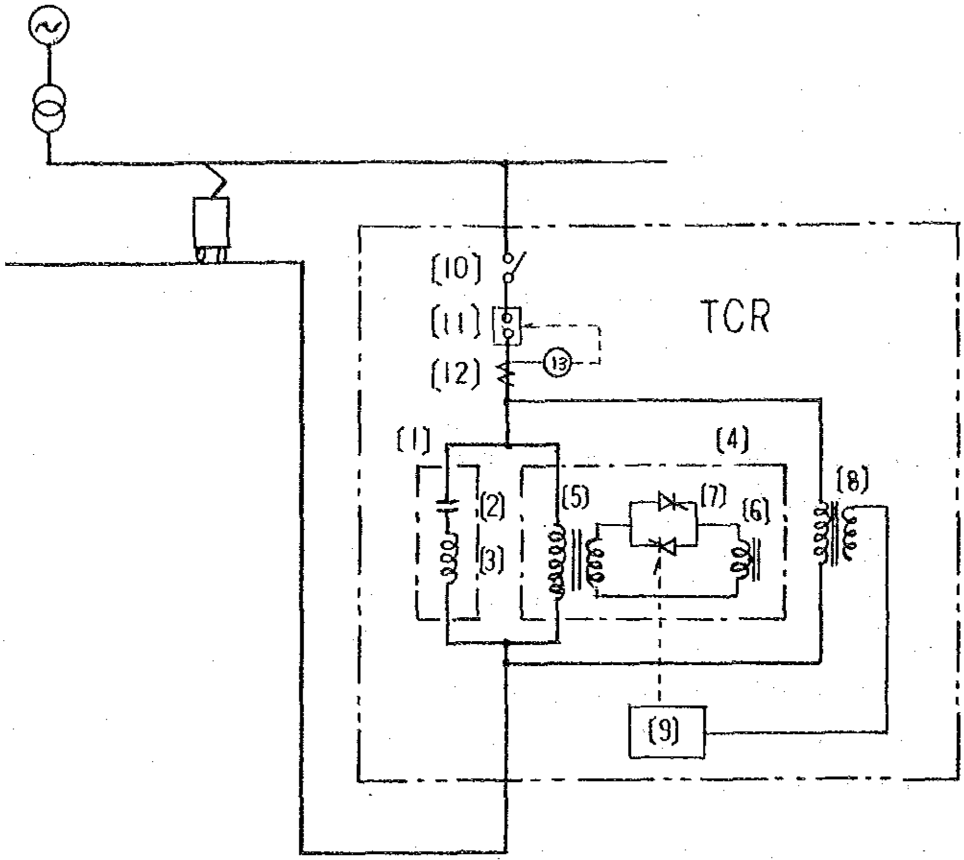
Fig. 1 shows the composition of TCR.

(1) Shunt capacitor branch [1] is a capacitor in terms of a function, but, when to be used as a traction feeder circuit, it needs series reactor [3]. For the reason why the reactor is required and the reactance value required for the reactor, see Appendix 6-4, Shunt Capacitor Equipment.

(2) In principle, it is enough to put the thyristors of inverse parallel connection and the reactor in series for shunt reactor branch [4].
Actually, however, in designing hardware, since connecting thyristors directly with the 25 kV circuit will make the equipment expensive for their protection, provide transformer [5], set the secondary voltage of the transformer, for example, at 2,000 V, at which the thyristors are controllable, and connect thyristors [7] and reactor [6] with the secondary winding circuit.

(3) Make the value of reactance, including the leakage reactance of transformer [5], so that shunt reactor branch [4] and shunt capacitor branch [1] will be in parallel resonance.

(4) Conduct the control of TCR by detecting the feeder voltage with operating transformer [8].



[1]	Shunt capacitor branch	[8]	Operating transformer
[2]	Shunt capacitor	[9]	Thyristor control device
[3]	Series reactor	[10]	Disconnecting switch
[4]	Shunt reactor branch	[11]	Circuit breaker
[5]	Transformer	[12]	Current transformer
[6]	Reactor	[13]	Over current relay
[7]	Thyristor		

Fig. 1 Connection Diagram of TCR

2. Outline Design of TCR

To study the features and effects of TCR, its approximate constants are required; therefore, an outline design is made of two kinds of capacities. Taking into account the load in the Section, the maximum leading current that TCR can supply is assumed to be at 300 A and 600 A.

Table 1 shows the main features of TCR.

Table 1 Main Features

Item	Feature	Rating of TCR		No. of Fig. 1	
		600 A	300 A		
Shunt Capacitor	Rating voltage	31.1 kV	31.1 kV	[2]	[1]
	Rating current	600 A	300 A		
	Rating capacity	18.6 MVA	9.3 MVA		
	Capacitive reactance	52.7Ω	105.4Ω		
Series reactor	Rating voltage	3.58 kV	3.58 kV	[3]	
	Instant voltage	27.5 kV	27.5 kV		
	Rating current	600 A	300 A		
	Rating capacity	2.15 MVA	1.07 MVA		
	Inductive reactance	6.85Ω	13.7Ω		
Transformer	Rating voltage (pri/second)	27.5/2 kV	27.5/2 kV	[5]	[4]
	Rating current (pri/second)	600/8,250A	300/4,125A		
	Rating capacity	16.5 MVA	8.25 MVA		
Reactor	Rating voltage	2 kV	2 kV	[6]	
	Rating current	8,250 A	4,125 A		
	Rating capacity	16.5 MVA	8.25 MVA		
	Inductive reactance	0.242Ω	0.484Ω		
Thyristers	Single phase,			[7]	
	Inverse parallel connection				
	Phase control				
	Rating voltage	2 kV	2 kV		
	Rating current	8,250 A	4,125 A		
Operating transformer	Rating voltage (pri/second)	27.5kV/220V	27.5kV/220V	[8]	
	Rating capacity	10 kVA	10 kVA		
Thyristor control device	Voltage control			[9]	
Disconnecting switch	Rating voltage	27.5 kV	27.5 kV	[10]	
	Rating current	600 A	300 A		
Circuit breaker	Rating voltage	27.5 kV	27.5 kV	[11]	
	Rating current	600 A	300 A		
	GCB				

Given below for reference is the calculating process on the main equipment in the case of the rated current 600 A:

(1) Shunt capacitor, [2] of Fig. 1

Suppose inductive reactance of series capacitor is 13% of capacitive reactance of shunt capacitor;

1) Capacitive reactance at 50 Hz

$$Xc\ (1 - 0.13) = \frac{27.5 \times 10^3}{600}$$

$$X_c = 52.7\ \Omega$$

2) Rating voltage = 27.5 kV x 1.13 = 31.1 kV

3) Rating capacity = 31.1 kV x 600 A = 18.6 MVA

(2) Series reactor, [3] of Fig. 1

1) Inductive reactance at 50 Hz

$$X_{SR} = 52.7 \times 0.13 = 6.85\ \Omega$$

2) Instant voltage = 27.5 kV

3) Rating voltage = 27.5 x 0.13 = 3.58 kV

4) Rating capacity = 3.58 x 600 = 2.1 MVA

(3) Transformer, [5] of Fig. 1

1) Voltage ratio = 27.5 kV/2 kV = 13.75

2) Secondary winding current = 600 A x 13.75 = 8,250 A

3) Rating capacity = 2 kV x 8,250 A = 16.5 MVA

(4) Reactor, [6] of Fig. 1

1) Rating voltage = 2 kV

2) Rating current = 8,250 A

3) Inductive reactance = 2 kV/8,250 A = 0.242 Ω*

* Including transformer leakage impedance at 2 kV base.

4) Rating capacity = 2 kV x 8,250 A = 16.5 MVA

3. Precondition of Calculation

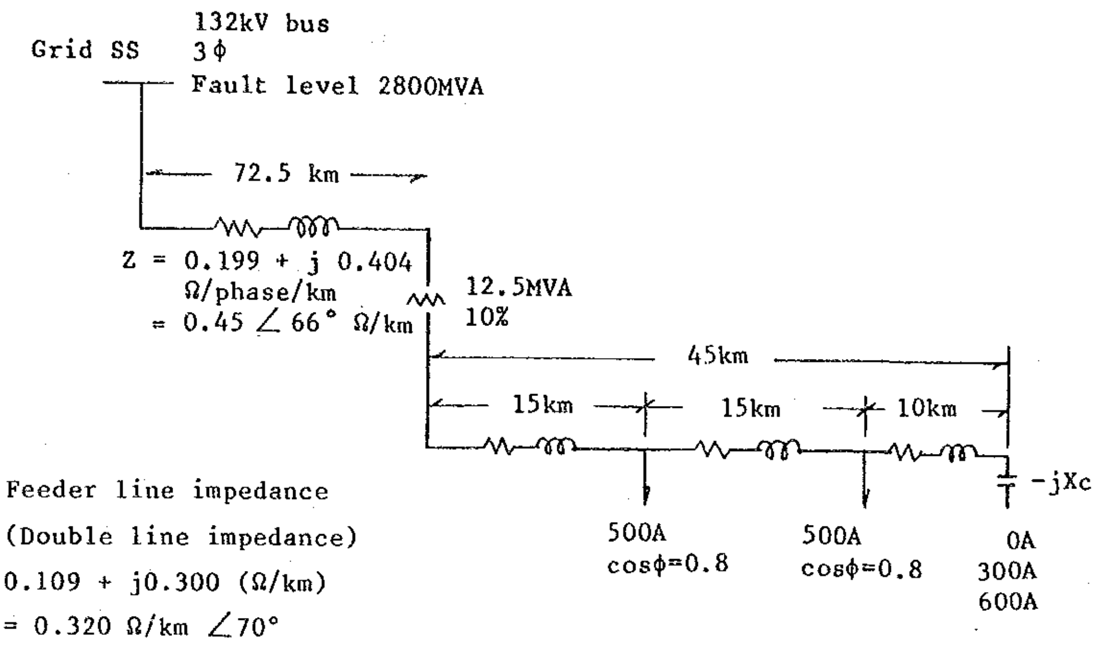


Fig. 2 Precondition of Calculation

Circuit constants are all converted to be at 27.5 kV base.

1) Power source impedance at 27.5 kV base, Xo:

$$Xo = j2\frac{V^2}{P} = j2 \times \frac{27.5^2 \times 10^6}{2,800 \times 10^6} = j\ 0.54\ \Omega$$

2) Transmission line impedance at 27.5 kV base, X_{TM}:

$$X_{TM} = 2\ (0.199 + j0.404) \times \left(\frac{27.5}{132}\right)^2 \times 72.5$$

$$= 1.25 + j\ 2.54\Omega$$

3) Transformer impedance at 27.5 kV base, X_T:

$$X_T = j\frac{V^2 \times \%Z}{100 \times P} = j\frac{27.5^2 \times 10^6 \times 10}{100 \times 12.5 \times 10^6} = j6.05\ \Omega$$

4) Feeder line impedance, X_L:

(0.109 + j0.3) x 15 = 1.635 + j4.5Ω/15 km

(0.109 + j0.3) x 10 = 1.09 + j3.0Ω/10 km

5) Load impedance, Z_{L1}, Z_{L2}:

The loads of the up and down lines are given as a whole: namely, impedance, about that for 500 A (cos ϕ = 0.8), is provided each at the two points, 15 km and 30 km.

6) Capacitive reactance of shunt capacitor, Xc:

Capacitive reactance is so assumed that the current is to be about 300 A (and 600A).

Impedance map is shown in Fig. 3.

4. Results of Calculation and Review

Fig. 4 shows the results of calculation.

(1) Improvement effect of feeder voltage

13.4 kV at the load point at the 30 km point without TCR provided will improve to be 18.1 kV when the leading current, 300 A, is supplied with TCR provided, and 22.4 kV when 600 A. The improvement effect of feeder voltage is remarkable. The voltage at the end of feeding zone will slightly rise above that at the secondary load point, raising no particular problem.

(2) Improvement effect of power factor

Assume the power factor of load is 0.8. The power factor from substation is 0.69 when TCR is not provided. This will improve to be 0.87 when the leading current, 300 A, is supplied with TCR provided, and 0.98 and 600 A. The improvement effect of power factor is as large as that of feeder voltage.

(3) Supply current reduction effect attended with power factor improvement

When TCR is not provided, the substation supply current will be the load current in total, but if the leading current, 300 A, is supplied, it will be reduced by 11% to 89%, and 600 A, by 13% to 87%, respectively.

(4) Power losses of TCR

See Fig. 1 and Table 1. One of the biggest TCR problems is the power losses of shunt reactor branch [4]. That is, in the case of 600 A, the capacity each of transformer [5] and reactor [6] is 16.5 MVA, the reactor having 8,250 A at 2 kV. In the case of 300 A, 4,125 A.

Assume that the total power loss due to transformer and reactor is 2%. Losses will be 330 kW when 600 A is on. Furthermore, thyristor loss, and 8 kW, if the forward drop is 1 V, must be added.

Actually, the current of reactor being controlled with thyristor when there is a load, these losses will not be always made; however, the value of losses as described above is considered too large.

Expenses to be required against power losses will become much larger than part of the demand charges reduced through the improvement of power factor.

(5) Cost of TCR

The cost of a 300 A TCR is higher than that of a substation to construct.

(6) Others

Studies should have been made of the control method of TRC, high harmonic current, and high harmonic voltage that appears in the feeder circuit, but they have been omitted because the problems involved in (4) and (5) are so important and serious.

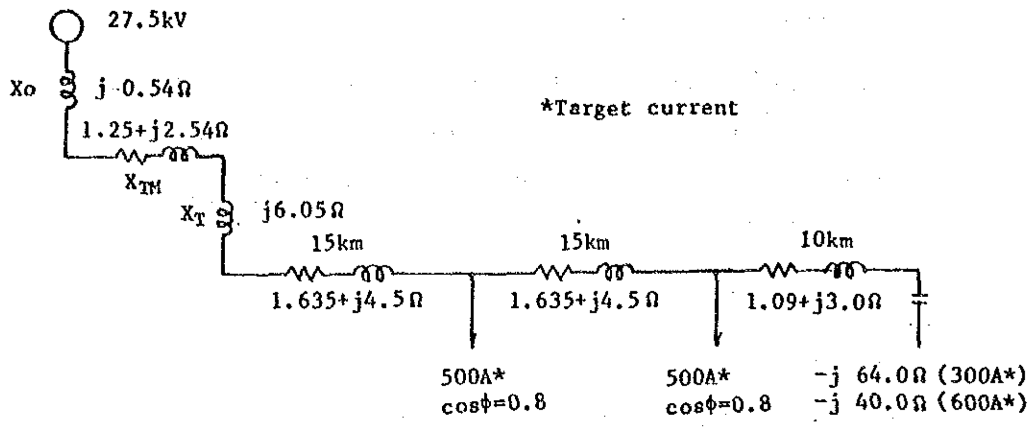


Fig. 3 Impedance Map

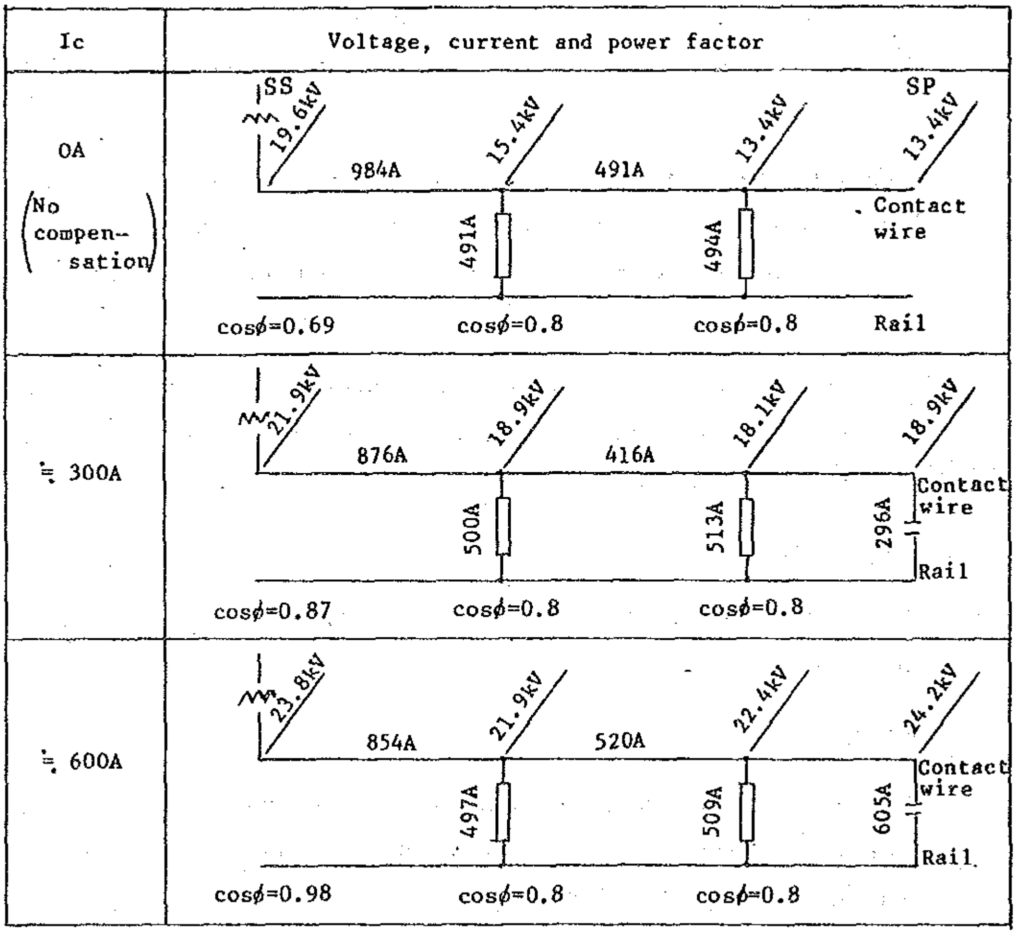


Fig. 4 Voltage, Current Distribution and Power Factor

5. Conclusion and Recommendations

TCR will improve the power factor and also will be effective in reducing the voltage drop; however, it is considered not practical to use it because its power losses is strikingly large and its cost is much higher than a substation.

To improve the power factor, it is much better to install shunt capacitors at substation. See Appendix 6-4.

For reducing the voltage drop, it is recommendable that series capacitor to compensate the leakage reactance of main transformer and the inductive reactance in the feeder circuit be provided. See Appendix 6-5.

In any event, for the Section where the future load current is expected to increase two times or more than the present one, the best solution is to add 6 more substations.

6-7 Distance Relay

What are most basically required for distance relay? They are:

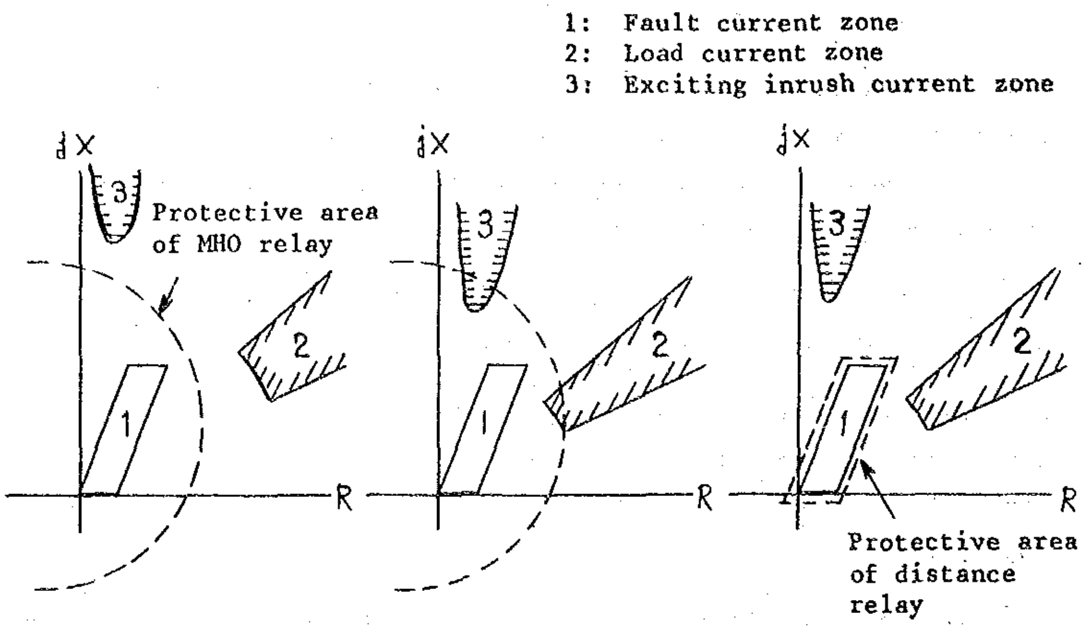
- assured detection of feeder circuit faults; and

- non-malfunction due to load current and exciting inrush current to no load transformer of rolling stock.

The MHO relay is now used as a distance relay at IR's substations. As is shown in Fig. 1 a. the MHO relay is capable of selecting the fault current when the load current is small, but not capable when the load current is large as shown in Fig. 1 b.

To solve this problem, the distance relay of semiconductor static having parallelogram characteristics has been developed. Fig. 1 c. shows the characteristics.

It is convenient for this semiconductor static type distance relay to obtain the protection area desied, but if high harmonic component is contained in the feeder voltage/current, this protection area might be changed; therefore, this point must be taken into account for designing.



a. Selection between load and fault current when load current is small

b. Selection between load and fault current when load current increases

c. Protection area of parallelogram type distance relay

Fig. 1 Protection Area of Distance Relay

6-8 Automatic Inspection Device for Substation Equipment

On JR's existing lines, the automatic inspection device is used to inspect switchboards at substations, sectioning posts and sub-sectioning posts automatically and efficiently. There are two types of device, one fixed aboard the motorcar and the portable.

1. Switch-boards to be Inspected

At AC substation: Main switch-board, power receiving and sending switch-board, transformer switch-board, AC feeding switch-board, and high-tension power distribution switch-board.

At DC substation: In addition to the foregoing switch-boards, rectifier switch-board, and DC feeding switch-board.

2. Kinds of Inspection

(1) Overall inspection

In the form of various signals such as operating command signals and fault detecting signals, voltage and current are to be sent from the inspection device to the switch-board, and the functions of the switch-board, that is, whether or not the mechanical/electrical interlocking and fault indication have been performed correctly within the allowable time, are checked. Every sequence of the switch-board functions and the operations of equipment are inspected. Take the closing of a circuit breaker for example, it is actually closed by command signal, response time measured and recorded. Depending on the type of switch-board, the number of items to be inspected ranges from 15 to 20.

Inspection results are to be judged in such a way as given below:

- Good : Switch-board and other equipment have functioned correctly within the allowable time.
- Caution: Response has been made as expected, but timing not appropriate.
- Bad : No response.

When judged to be "Caution" or "Bad", the circuits concerned are to be inspected again individually, necessary adjustment and repair made.

(2) Protective relay inspection

The operational characteristics of protective relay are to be inspected. The inspection is to be conducted when the protective relay has been found abnormal during the overall inspection or when it is deemed necessary otherwise. Voltage/current generator for inspecting the protective relay and other instruments are provided on the operating panel of the inspection device.

3. Inspection Method

Connect the inspection device with the switch-board to be inspected by a special cable of 120 cores and a coupler. To do this, the switch-board must be equipped with a receptacle, with some modification of circuit connection to enable automatic inspection.

4. Construction

Fig. 1 is a block diagram, outlining the construction of the automatic inspection device.

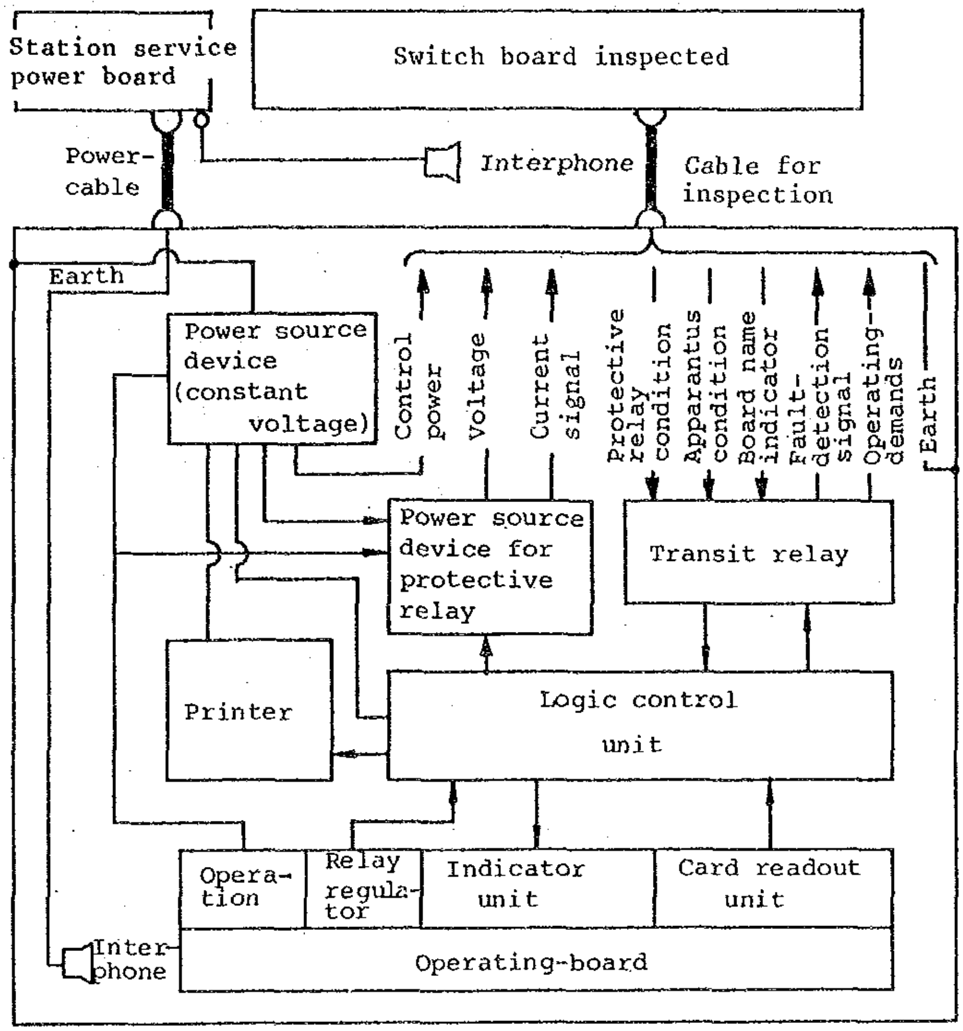


Fig. 1 Block Diagram of Automatic Inspection Device for Substation Equipment

5. Effects

(1) Operations and characteristics of substation main equipment, such as mechanical/electrical interlocking, protective relays, circuit breakers, disconnecting switches, can be checked under the same conditions as actual.

(2) All date are to be automatically recorded. Therefore, it is possible to prepare figures and data for maintenance. Comparison of previous and present data will serve to judge the deteriorating status of equipment and forecast the occurrence of failure.

(3) Since no circuit disconnection or dismantlement of protective relay terminals is required inspection is highly reliable; that is, if the terminals are dismantled for inspection, there might be a chance for them to be loosely tightened or circuits to be misconnected, resulting in failures.

(4) With the use of the automatic inspection device, the inspection time may be greatly reduced, from the average three hours to only 10 minutes for a team of three inspectors to inspect one switch-board.

6-9 Performance of Simple Catenary System

1. Wave Propagation Velocity and Train Speed

In order to collect current with contact wire in good order and without trouble, it is necessary to keep stable contact force between the contact wire and the pantograph.

When a train runs with the pantograph sliding the contact wire, the contact wire is distorted and the distorted waves propagates in it. In case the train speed is the same or faster than its propagation velocity, the contact wire behind of the pantograph will vibrate heavily as shown in Fig. 1.

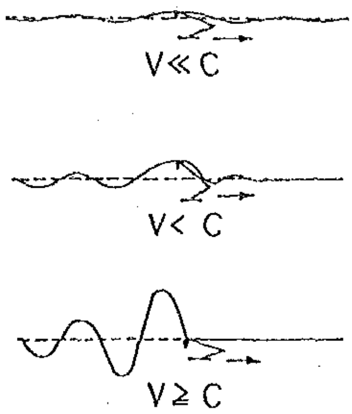


Fig. 1 Models of Contact Wire Waves

Under the condition of $V \geqq C$, an abnormally big force will work between the pantograph and the contact wire, and either of them may be damages. Theoretically, therefore, the speed less than the wave propagation velocity allows the current collection with pantograph. Generally, a speed, some 70% of the wave propagation velocity is considered to be the maximum allowable speed.

C, the wave propagation velocity, is obtained using the following formula:

$C = \sqrt{T/\rho}$ .... (A)

where T: Wires tension (N)

ρ: Mass of unit length of OHE wires (kg/m)

2. Spring Constant

Since the catenary wire is supported at every supporting point, it is difficult for them to move at the supporting point, but easy inbetween the span. Fig. 2 shows the features of static uplift of three catenary systems - simple, stitched and high tension simple - when a constant force is added.

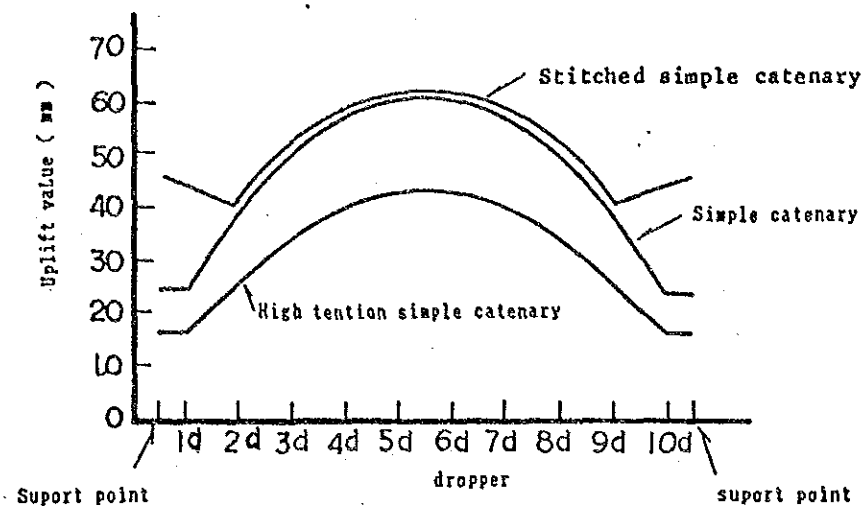


Fig. 2 Static Uplift Characteristics
(in cases 50 m span. uplift force 98N (10 kgf))

These curves can be considered to be the locuses of pantograph contact strips when they move very slowly, so slowly to the extent that their vibrations are negligible. This curve is attributable that the spring constant varies within the span.

It is the smallest in the middle of the span, and the largest at the supporting point.

3. Resonance Velocity

One of the most serious problems involved in the interaction between catenary and pantograph systems is a large contact loss that arises repeatedly over each span. This contact loss occurs due to the mechanical interaction of the catenary and pantograph systems. In general, Vc, the resonance velocity, at which the vertical movement of the pantograph becomes extremely large, is expressed by the following formula:

$$Vc = \frac{S}{2\pi}\sqrt{\frac{\bar{K}}{M}\left(1 - \frac{1}{2}\varepsilon^2\right)} \quad \ldots\ldots \text{(B)}$$

where $\bar{K}$: The average value of spring constant

ε: Variation ratio of spring constant

$\varepsilon = (K_{max} - K_{min})/2\bar{K}$

S: Span length

M: The total equivalent masses of pantograph, catenary and contact wires.

There are two ways of increasing Vc in the above formula. One is to make $\bar{K}$ larger, and the other to make M smaller.

4. Resonance of OHE System and Pantograph

The movements of contact wire and catenary wire on a simple or compound catenary system are almost the same. Namely, the OHE system has natural vibration where its wave length is the same as the span length, between the supporting points where the catenary wire is fixed. While the pantograph shows the complicated vertical movement due to the corelation between different static uplift values at different points in the span and the natural vibration cycle. Fig. 3 shows the pantograph locuses by train speed on simple catenary system.

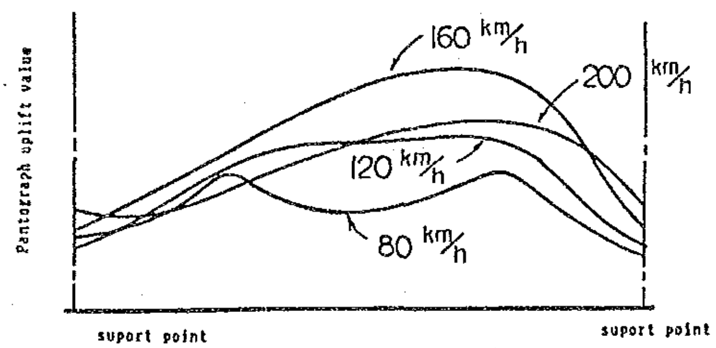


Fig. 3 Pantograph Locuses of Simple Catenary System

The vertical movement of the pantograph like this will bring about a change in contact force against the contact wire due to the inertia of pantograph, and, when this change is extremely big, will give rise to a large contact loss. And this is what is called the resonance of a single pantograph. Fig. 4 illustrates the contact loss rate, and uplift value, actually measured on JR's simple catenary systems.

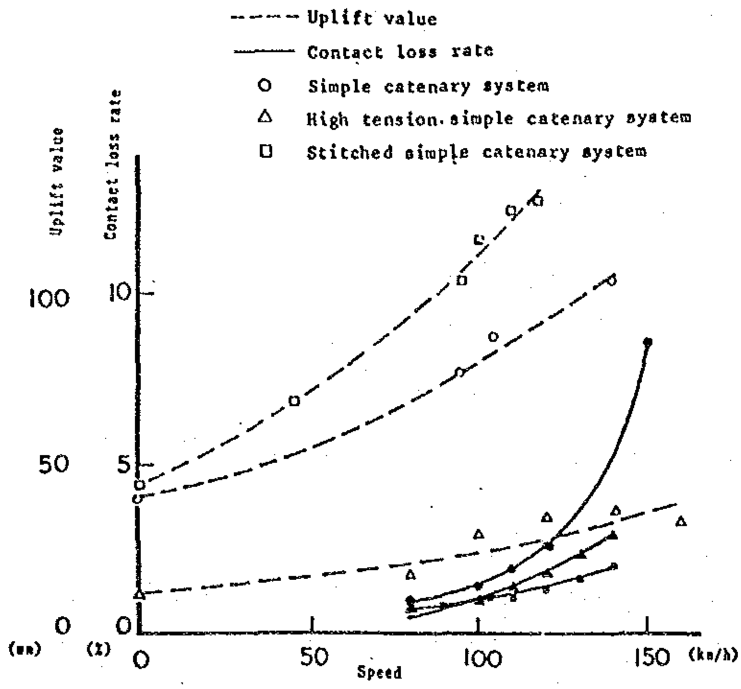


Fig. 4 Uplift Value and Contact Loss Rate Actually Measured on JR's Simple Catenary Systems

As can be seen in Fig. 4, the contact loss rates of both the stitched simple catenary and the high tension simple catenary systems are better than that of simple catenary system.

When a train with plural pantographs runs, plural pantograph resonances will arise due to the different mechanism. This is caused by the coincidence between the natural vibration cycle of contact wire and the running cycle of pantograph. Therefore, the rear pantograph, the worse will have the worse current collection characteristics.

6-10 JR's Shinkansen OHE under AT Feeding System

Table 1 The Features of JR's Shinkansen OHE

Type of catenary system	High tension compound
AT feeder wire	ACSR 330 mm^2
Protective wire	ACSR 95 mm^2
Catenary wire	St 180 mm^2
Auxiliary catenary wire	Cu 150 mm^2
Contact wire	Cu-sn 170 mm^2
Tension length	1500 m
Regulated or unregulated	Regulated
Span length	50 m
Stagger	$\pm$15 cm
Height of contact wire	5.0 m
Section on main line	Insulated overlaps
Current carrying capacity	1020 Amps

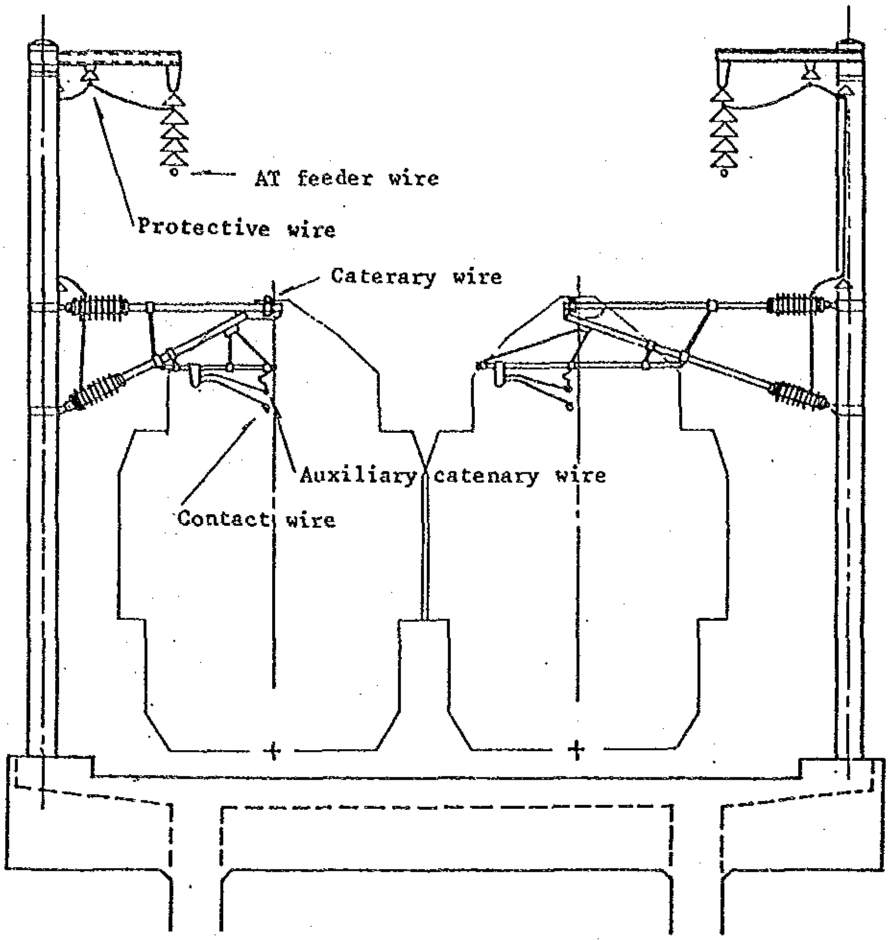


Fig. 1 JR's Shinkansen OHE Under AT Feeding System

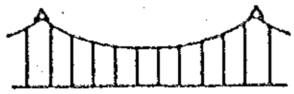
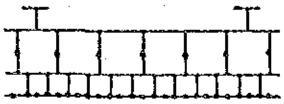
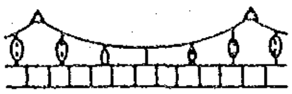
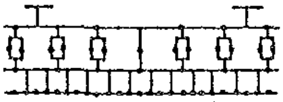
6-11 Outline of Computer Simulation Technique on OHE Characteristics

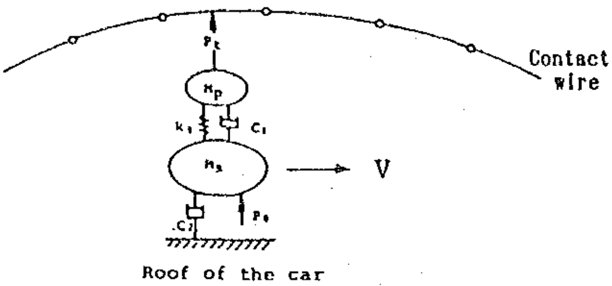
JR does a great deal of analysis through computer simulation for solving complicated phenomena of current collection such as in the case of overlapping, hard spots, and deformed catenary systems.

A catenary line is composed of such fittings as droppers and hangers attached to wires such as contact wire and catenary wire, etc. Also the pantograph is a complicated assembly of a slider, a pan, retaining springs, a main frame, main springs, dampers, etc.

It is almost impossible to analyze theoreticaly such complicated structures as they are, while the simulation method enables us to handle the system as it is. For this purpose, therefore, a suitable model is required. The Fig. 1 illustrates the models of overhead system and a pantograph.

The most important thing in a simulation method is how well reality can be expressed; and this is pursued by comparing the test results with an actual value.

Kind of system	Real Installation	Analyzed model	Code
Simple			N.S
Stitched Simpe			S.S
Compound			N.C
Composed Compound			C.C



Pt: Contact force between contact wire and pantograph

Po: Uplift force of pantograph

Mp: Equivalent mass of pantograph

Ms: Equivalent mass of main frame

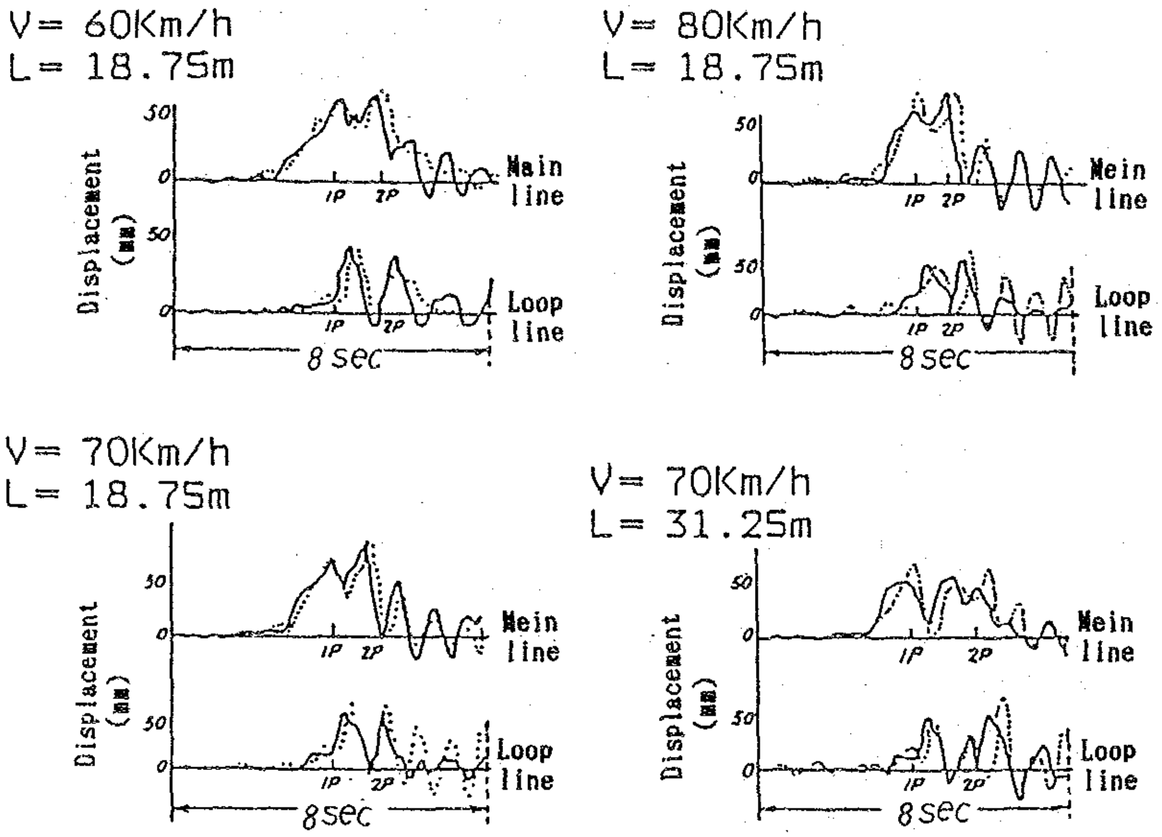
Kl: Spring constant of pantograph

Cl: Damping constant between pan and main frame

C2: Damping constant between main frame and foundation frame

Fig. 1 Simulation Models of Overhead Contact System and Pantograph

Fig. 2 illustrates a comparison of the measured value by test with the result of simulation at the displacement of the turn out in case of varied train speed. The results show how well the displacement coincide. The simulation method is established through such confirmation. Using this method, research is being done on the influence of speed, pantograph interval and uplift on the overhead system. Contact loss ratio, pantograph's up and down motion, contact force as well as the uplift can be grasped through the simulation method, which are very useful to find out the actual dynamic characteristics of OHE system and pantographs.



v : Speed

L : Distance between the first and second pantographs

1P: Passing time of the first pantograph

2P: Passing time of the second pantograph

Fig. 2 <u>Comparison of Measured Value with Simulation Result</u>

Fig. 2 shows a comparison of the uplift waveform, while Fig. 3 is a comparison of the maximum values of uplift at each position. In either case it can be seen that they coincide well with the measured values.

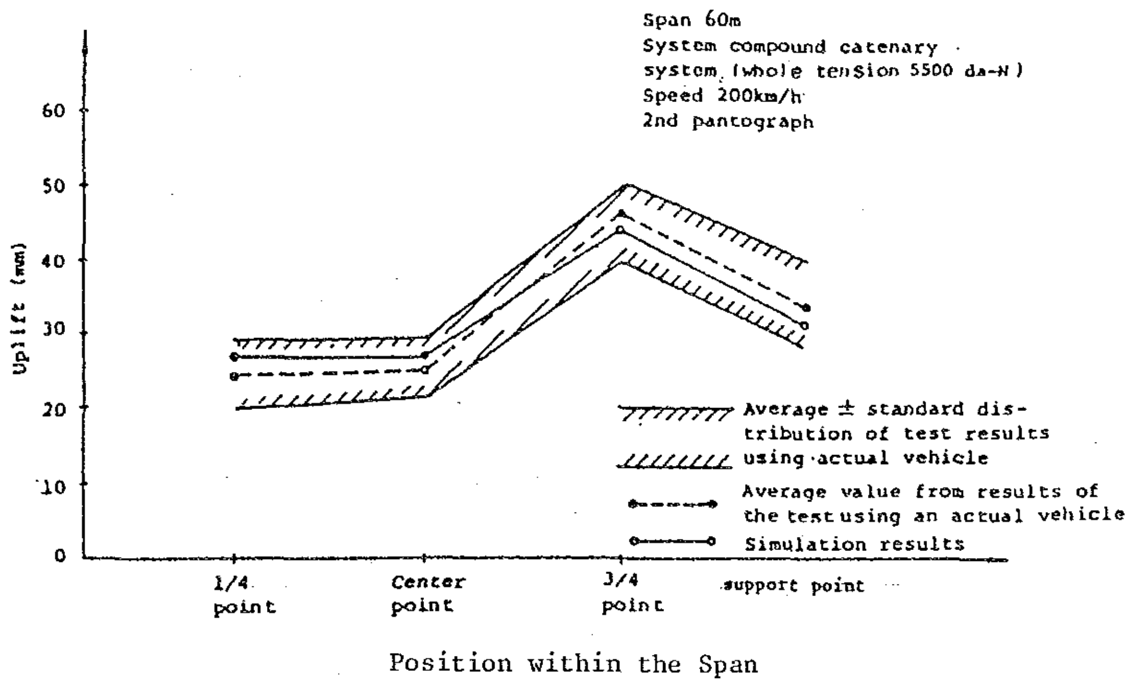


Fig. 3 Measured and Simulated Uplift Values of High Tension Compound Catenary System

6-12 Simulation Contents in Reference to OHE Characteristics at the Speed of 160 km/h

1) Existing OHE system

a) Basic conditions

For computer calculation, the OHE system is supposed to be composed of 8 spans, the both ends of which being fixed.

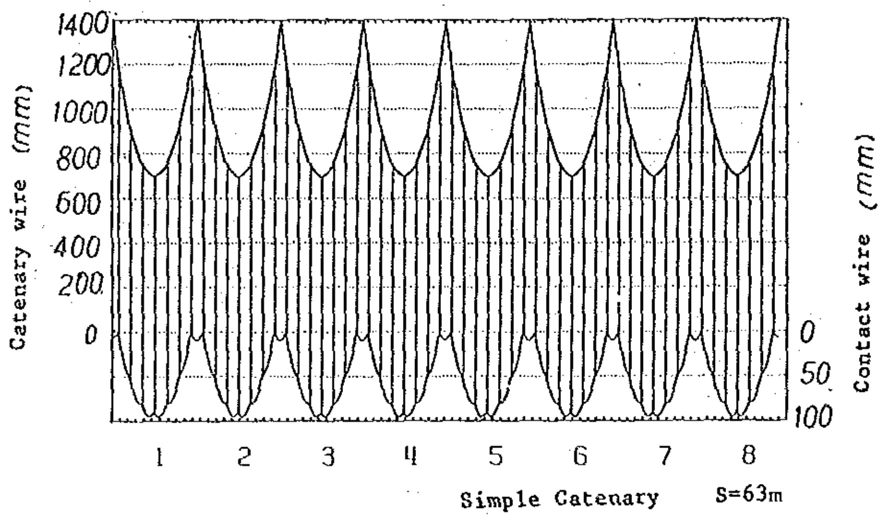


Fig. 1 OHE System Model

It is assumed that the pantograph AM-12 is a single-mass model with 32 kg equivalent mass and that the pantograph uplift force is 65 N (6.5 kgf) when the car is at static condition and 114 N when running at the speed of 160 km/h. Fig. 2 shows the pantograph model.

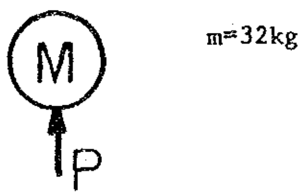


Fig. 2 Pantograph Model

b) Results

Fig. 3 shows the pantograph locus and contact force in reference to the existing OHE system.

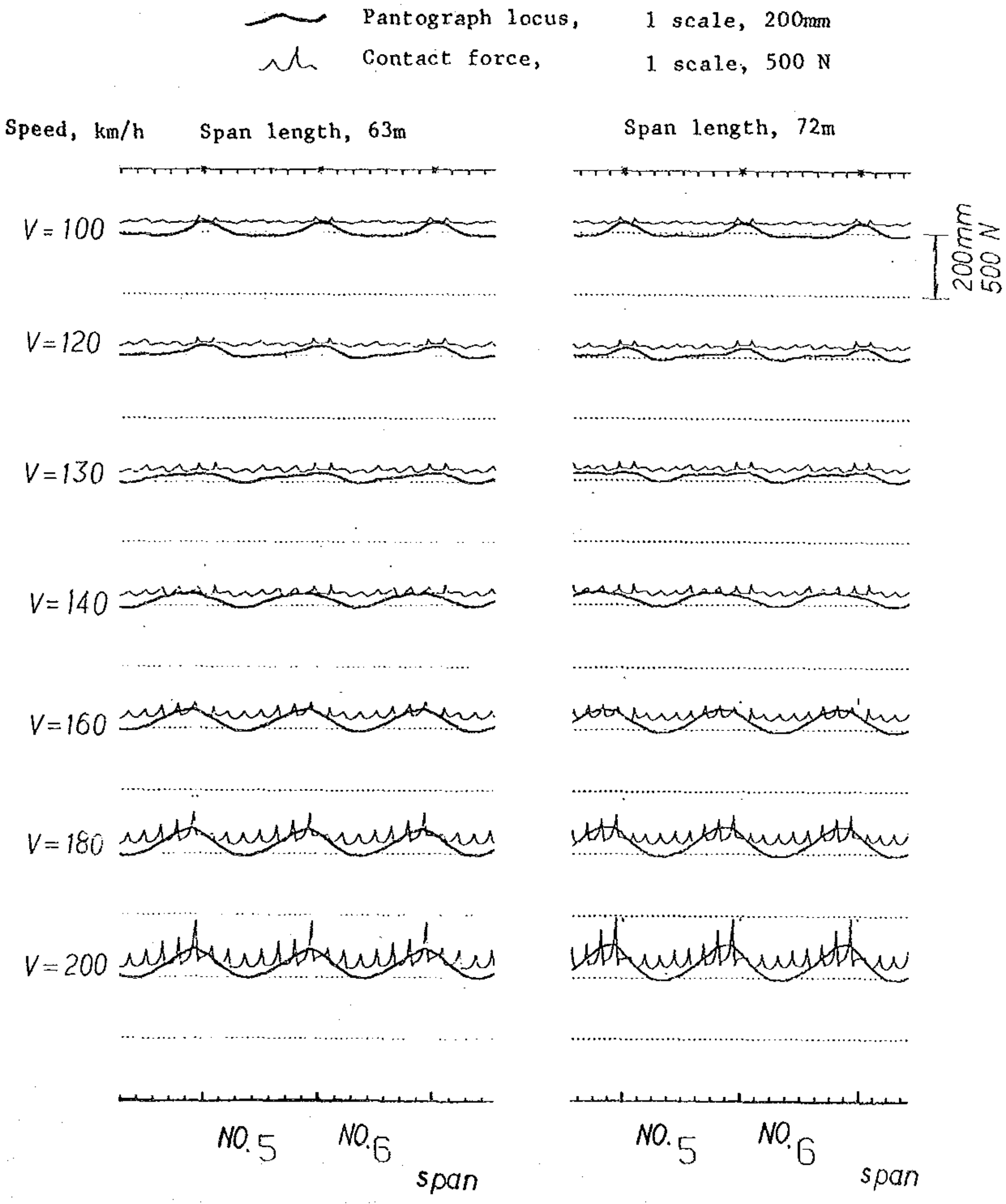


Fig. 3 Pantograph Locus and Contact Force

As can be seen, the faster the up-and-down motion of pantograph, the larger the vibration amplitude, and also the faster the speed, the stronger the contact force.

Fig. 4 shows the correlation between contact loss ratio and speed, and Fig. 5 that between pantograph vibration amplitude and speed. The contact loss ratio is less than 3% when the speed is 160 km/h, and the pantograph vibration amplitude is 80 mm when 160 km/h.

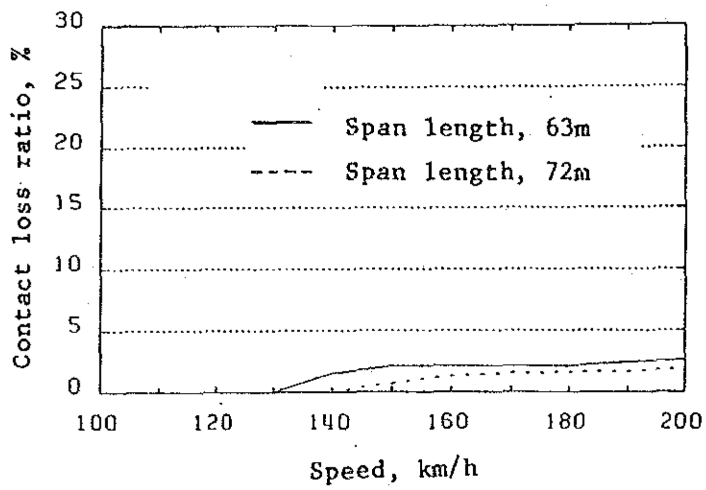


Fig. 4 Contact Loss Ratio vs. Speed

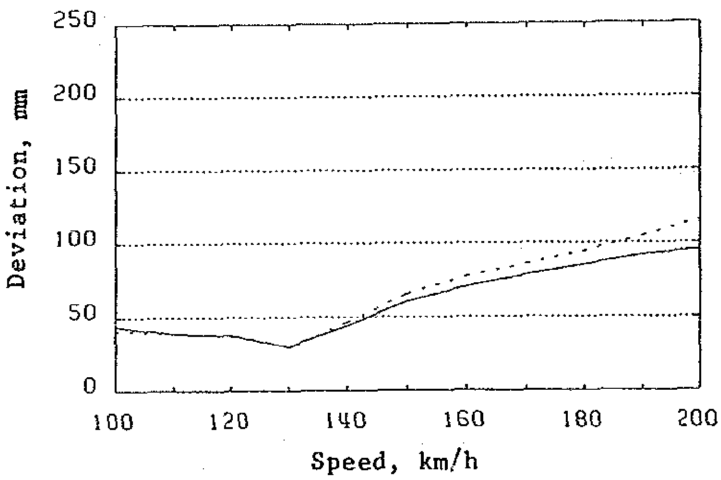


Fig. 5 Pantograph Vibration Amplitude vs. Speed

Fig. 6 shows the uplift at each point in a span moving with time passing. The uplift moves 63 m (the length of one span) in about 2.2 seconds when the speed is 100 km/h, and also 63 m in about 1.4 seconds when 160 km/h. Residual vibration barely occurs when the speed is 100 km/h, but it does when 160 km/h.

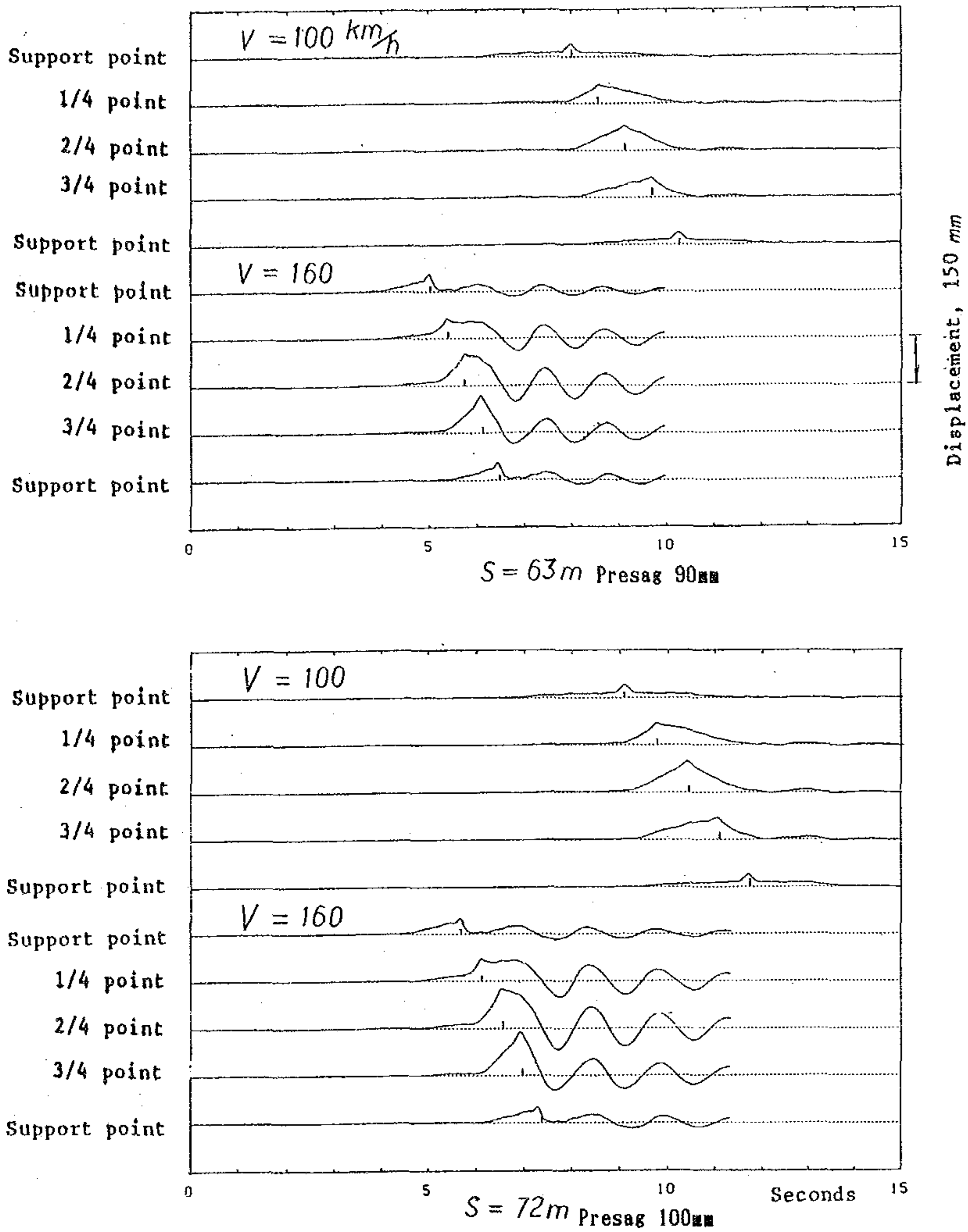


Fig. 6 Uplift and Vibration at Each Point in a Span

Fig. 7 shows the relations between contact wire uplift and speed at the support point of the 5th span, the 1/4 point, the 2/4 point (the span center), and the 3/4 point.

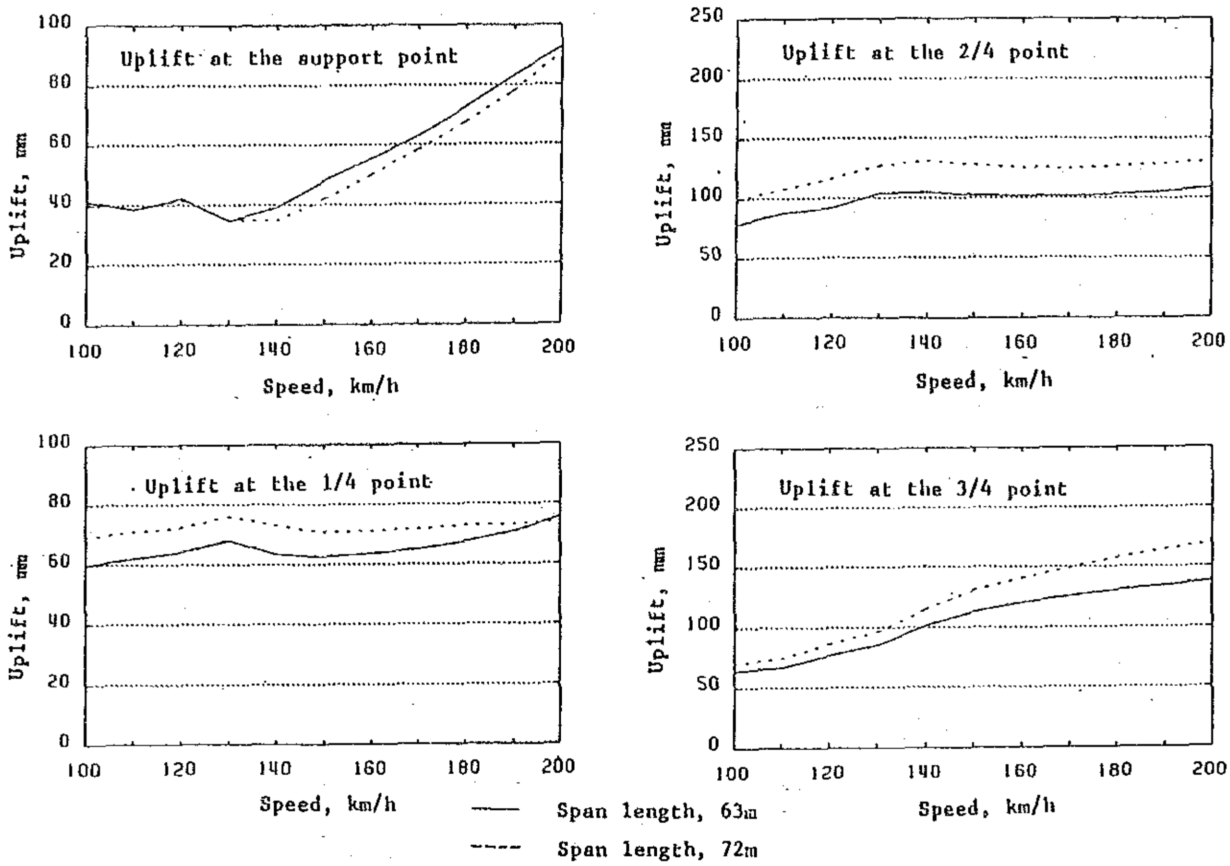


Fig. 7 Uplift at Each Point in a Span and Speed

c) Simulation conditions

Simulation has been made under the following conditions:

- Simple catenary

Catenary wire	cdcu 65 mm^2
Tension	1,000 kgf
Contact wire	Hard drown copper 107 mm^2
Tension	1,000 kgf

- Span length 63 m/72 m
- Presag 90 mm/100 mm
- Contact wire gradient ratio 0
- Dropper distance 9 m, equal distance for easier calculation
- Number of running pantographs 1
- Pantograph type AM-12
- Pantograph equivalent mass 32 kg
- Pantograph uplift force at static 65 N
- Pantograph uplift force at 160 km/h 114 N*1

*1 Aerodynamic lift at high speeds is taken into account, lift characteristics is assumed to be the same as PS16.

Table 1 Shows the Pantograph running speeds and uplift forces.

Table 1 Pantograph Running Speeds and Uplift Forces

Running speed, km/h	100	110	120	130	140	150	160	170	180	190	200
Uplift force, N	84	88	93	97	102	108	114	120	127	134	141

2) Upgraded OHE system

a) Simulation conditions

Simulation conditions are the same as those in 1)-c), except that the tension each of catenary wire and contact wire is changed from 1,000 kgf to 1,200 kgf.

b) Simulation results

Pantograph locus and contact force are shown in Fig. 8, pantograph running speed vs. contact lost in Fig. 9, and pantograph running speed vs. vibration amplitude in Fig. 10.

The pantograph locus and contact force show the same tendency as that shown in Fig. 3 of the existing OHE system simulation. That is, the faster the pantograph running speed, the larger the pantograph vibration amplitude and contact force.

Fig. 9 shows the contact loss smaller than that in Fig. 4. The contact loss at the speed of 160 km/h is about 2% when the span length is 63 m, and 0.5% 72 m. These values are fairly better than 2.1% and 1.2%, respectively, in the case of the existing OHE system simulation.

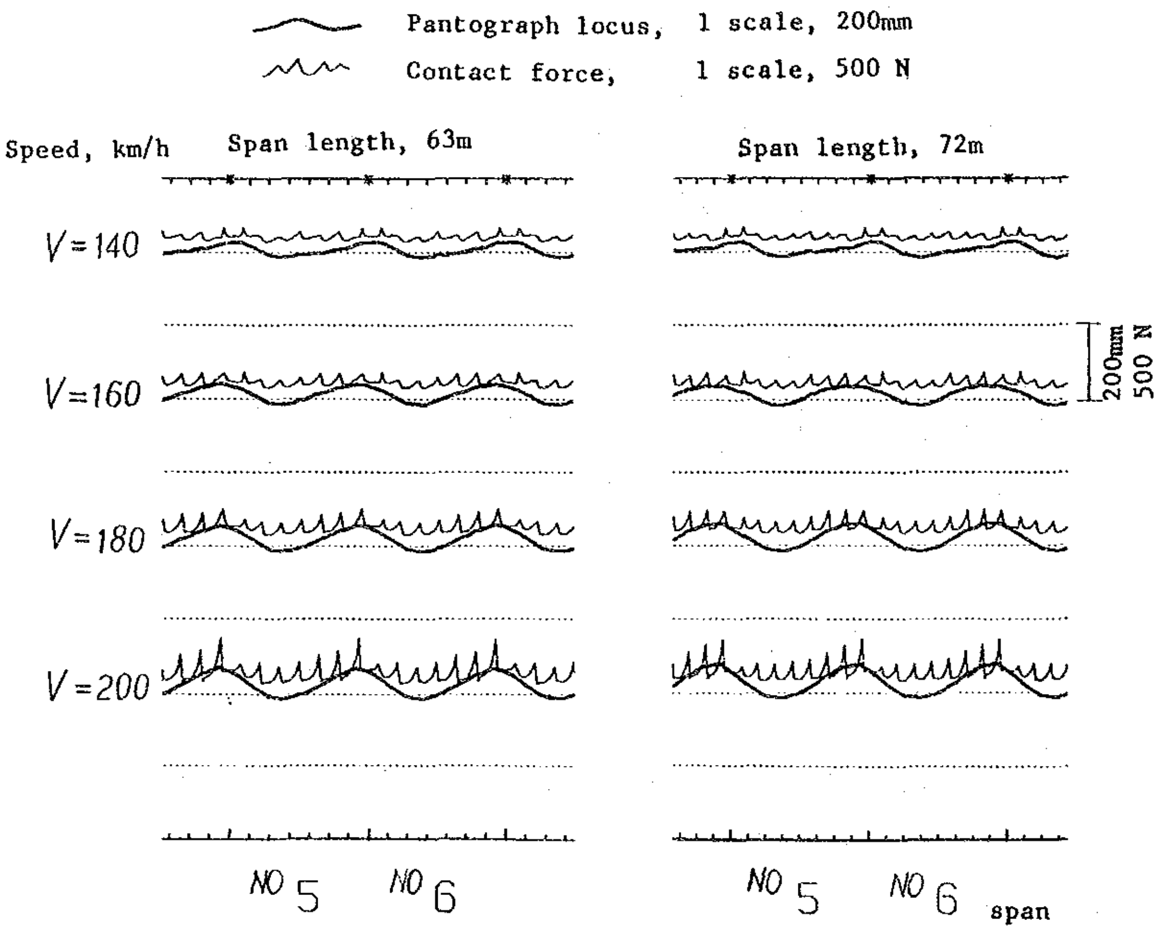


Fig. 8 Pantograph Locus and Contact Force

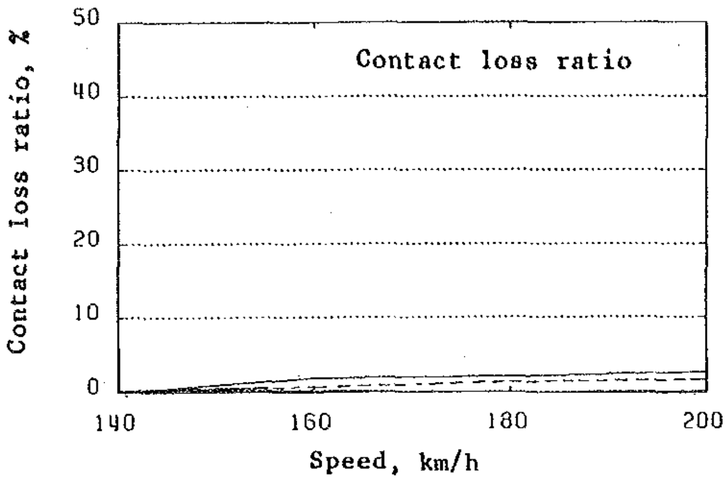


Fig. 9 Pantograph Running Speed vs. Contact Loss

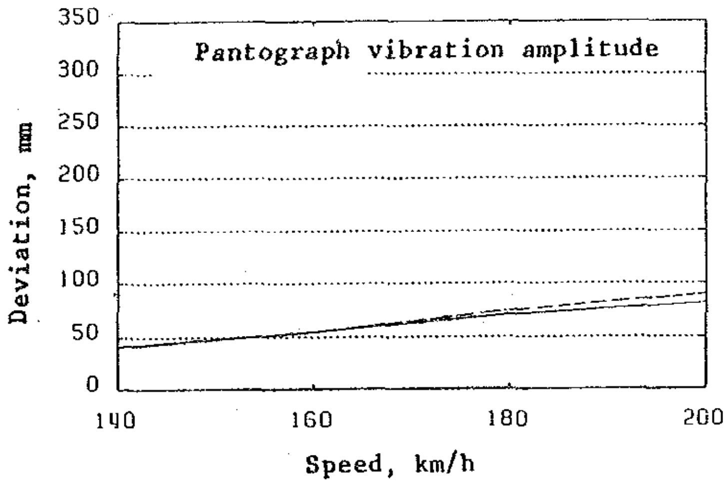


Fig. 10 Pantograph Running Speed vs. Vibration Amplitude

The pantograph vibration amplitude is about 55 mm at the speed of 160 km/h, about two-thirds of 80 mm on the existing OHE system.

Fig. 11 shows the uplift at each point in a span along with the time.

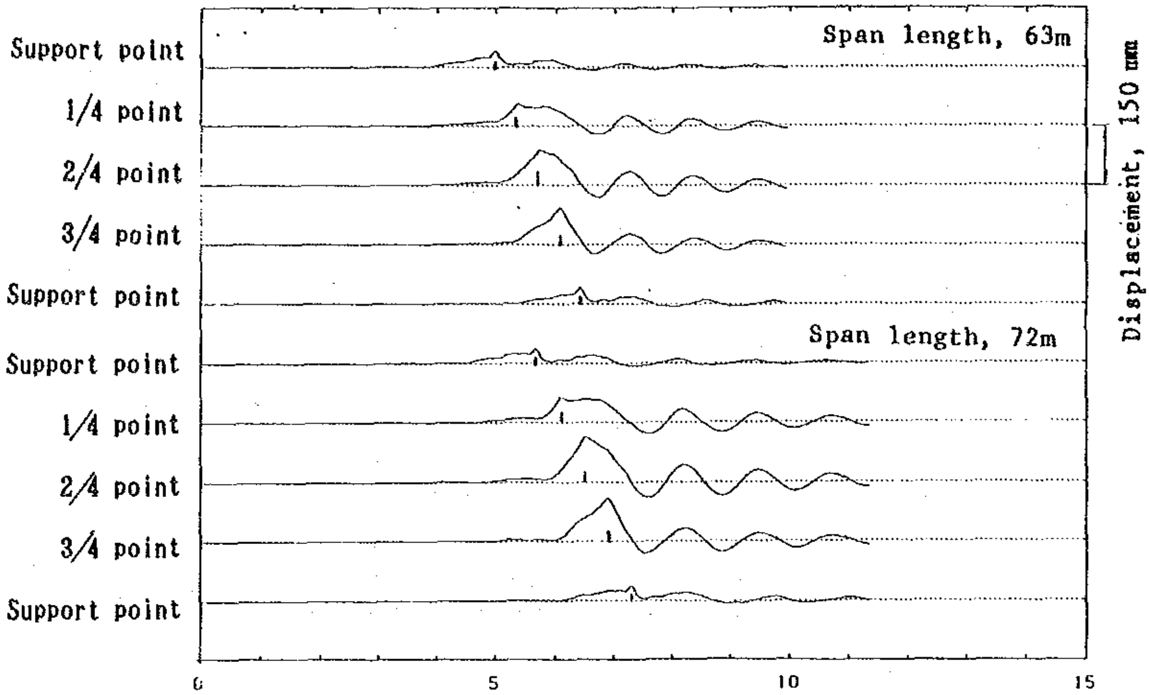


Fig. 11 Uplift at Each Point in a Span and Vibration

Residual vibration exists at the speed of 160 km/h, and this vibration shows the phenomenon similar to that on the existing OHE system (see Fig. 6). Tables 4.4.3-2 and 4.4.3-3 show the natural vibration. As can be seen from these figures, the vibration cycles on the upgraded OHE system are somewhat shorter then those on the existing OHE system.

Fig. 12 shows the relations between the uplift at each point in a span and the speed.

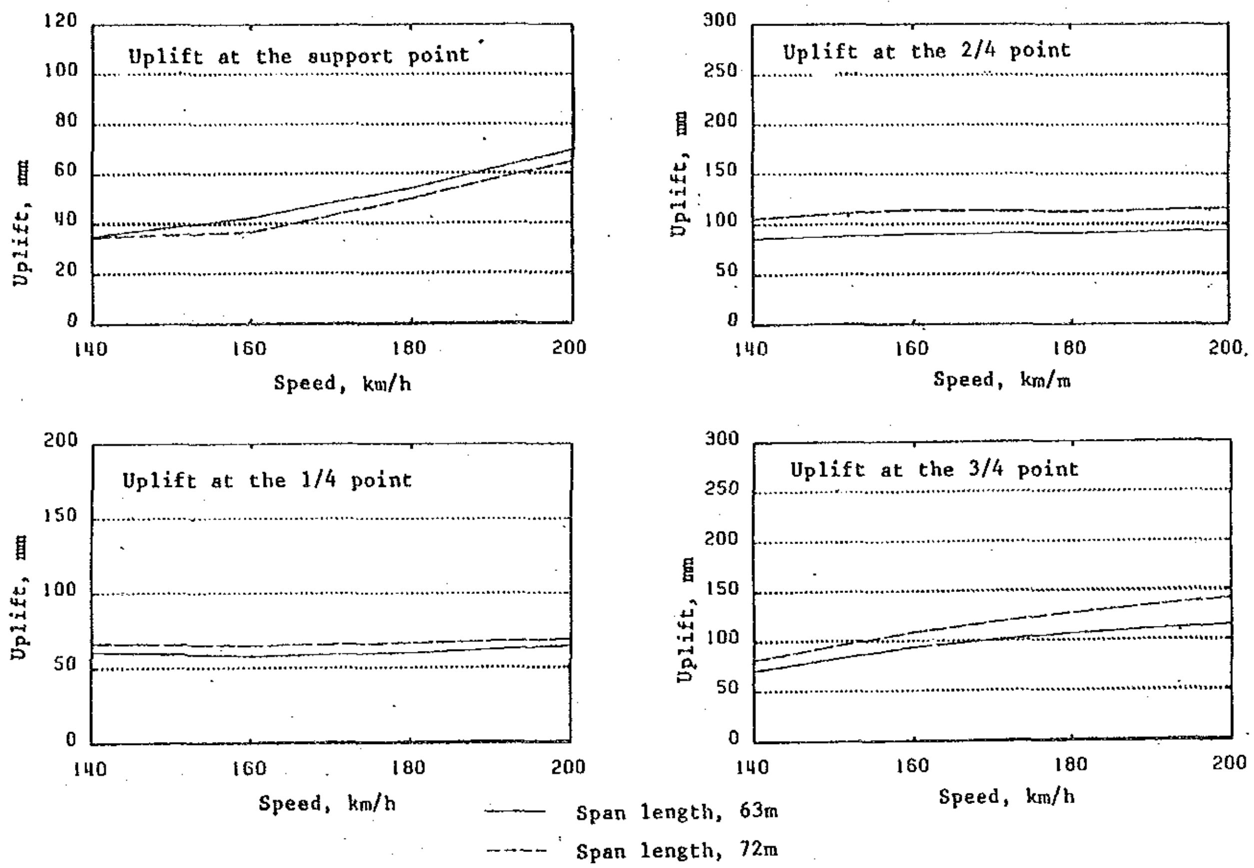


Fig. 12 Uplift at Each Point in a Span and Speed

The uplift at the support point is about 40 mm at the speed of 160 km/h. In other words, this uplift on the upgraded OHE system is smaller compared with that of about 55 mm on the existing OHE system in Fig. 7; and the uplift each at the 1/4 point, the 2/4 point (the span center) and the 3/4 point is also smaller than that in Fig. 7.

3) Two-pantograph running (at upgraded OHE system)

a) Results

Fig. 13 shows the pantograph locus and contact force when the speed is 160 km/h. Both pantographs are of AM-12 type; No. 1 is the front pantograph, and No. 2 the rear. The distance between pantographs each in Diagrams A and B is 21 m, and C and D 34 m; the span each in A and C is 63 m, and in B and D 72 m.

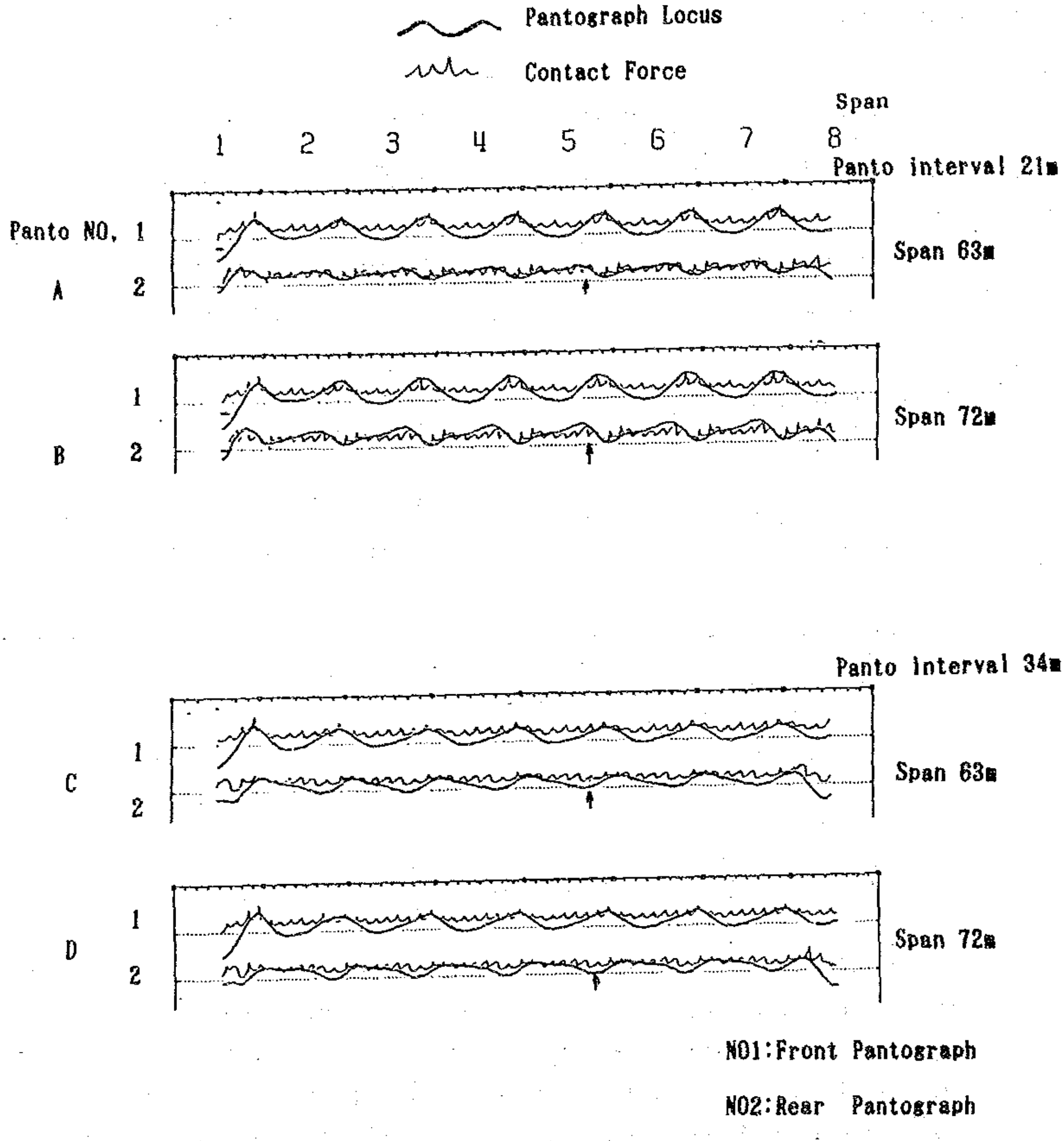


Fig. 13 Pantograph Locus and Contact Force

As can be seen in both the 63 m and 72 m spans, where the distance is 21 m the contact wire is uplifted by the rear pantograph together with the residual vibration, and where 34 m the rear pantograph is passing when the phase of vibration is in reverse (arrow marks).

Fig. 14 shows the relations between the uplift at each point in a span and the pantograph interval along with the time. As can be seen in Fig. 14 in the case that the two trains, one with 21 m pantographs interval and the other with 34 m, are running in a 63 m span at the speed of 160 km, the uplift by the former is larger than that by the latter. In the 34 m intervals residual vibration remaining after the rear pantograph has passed is little. This is because the rear pantograph has passed when the vibration phase of the OHE system is in reverse. On the other hand, there arises some residual vibration in the 21 m interval due to the vibration of OHE system overlapped.

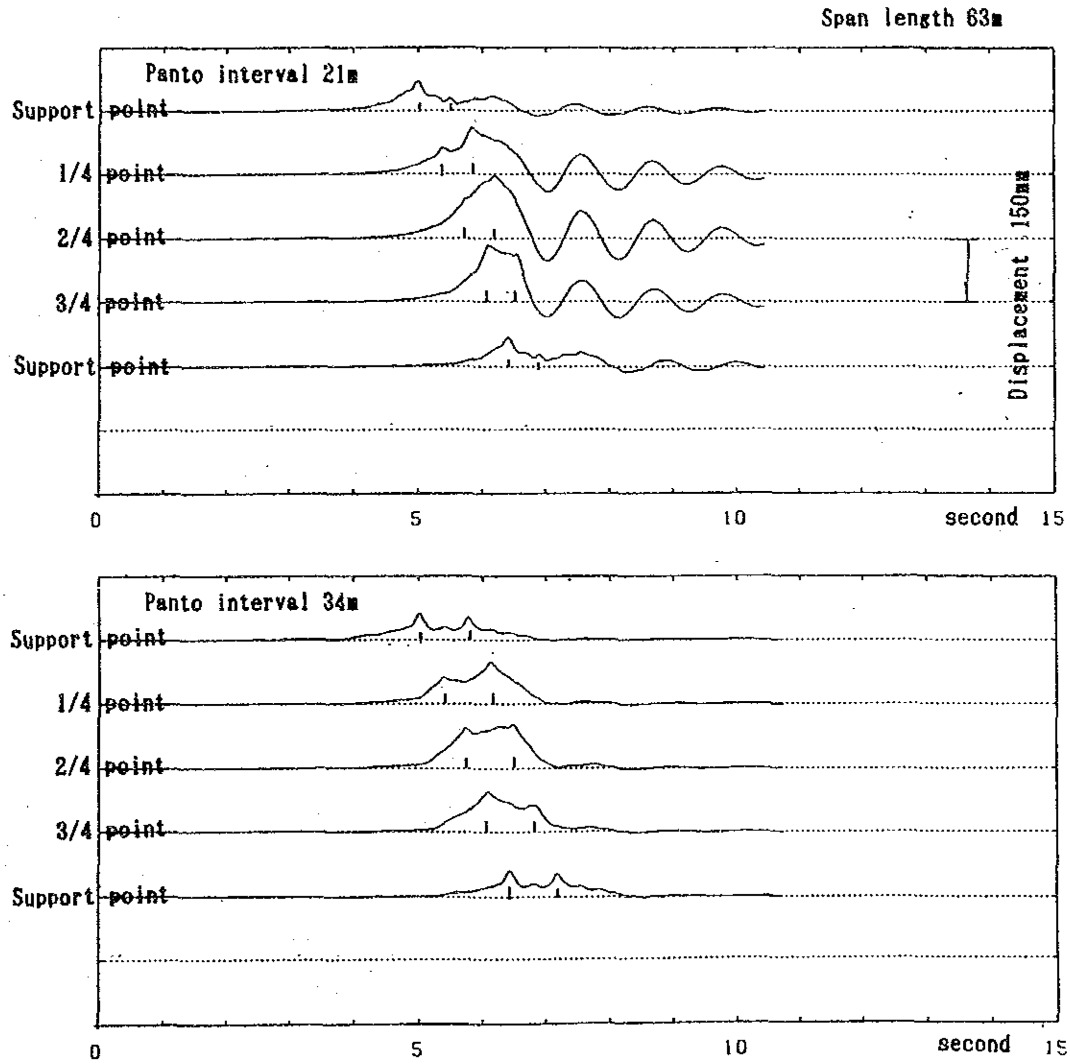


Fig. 14 Uplift at Each Point in a Span and Pantograph Interval

6-13 Computer Simulation Made on Pantographs of Different Mass for Various OHE System (72 m Span)

Computer simulation has been made on the following three combinations:

(i)	Catenary	:	Simple without presag
	Tension	:	1,000 kgf x 2
	Pantograph	:	AM-12, 32 kg (equivalent mass)
(ii)	Catenary	:	Simple with presag 100 mm
	Tension	:	1,000 kgf x 2
	Pantograph	:	AM-12, 32 kg (equivalent mass)
(iii)	Catenary	:	Simple without presag
	Tension	:	1,000 kgf x 2
	Pantograph	:	PS-16, 18 kg (equivalent mass)

Other calculation conditions are the same as those in Appendix 6-12(1).

- As simulation results, Fig. 1 on contact loss shows almost the same tendency up to the speed of 170 km/h referring to both (ii) combination, and (iii) combination. This means that catenary with presag or pantograph of light equivalent mass (PS-16 type) are effective in suppressing contact loss.

  On the other hand, in the case of (i) combination, the contact loss rate is about 5% at 160 km/h.

- Fig. 2 on vibration amplitude shows that the amplitude of vibration made by (ii) combination is the smallest. This means that the pantograph is capable of running nearly at a fixed height.

  In the case of the catenary without presag, the vibration amplitude of pantograph becomes larger. Fig. 3 shows, however, that even with the catenary without presag, change in contact force is small if the equivalent mass of the pantograph is light. This means that the following characteristics of light pantograph to contact wire is good. Therefore, the contact loss (Fig. 1) as in (ii) and (iii) will show the same tendency.

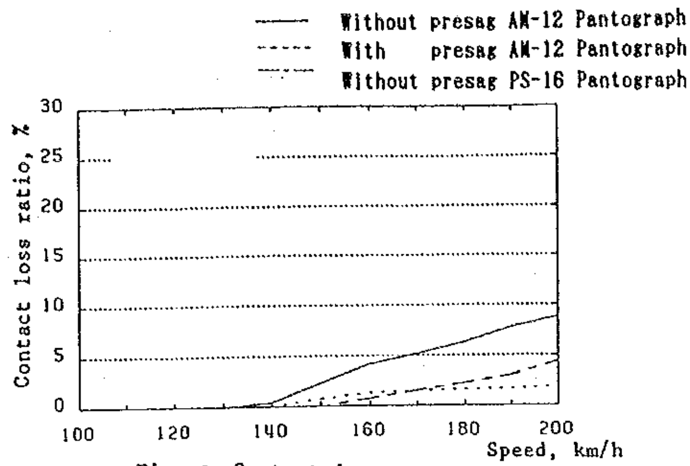


Fig. 1 Contact loss

Fig. 1

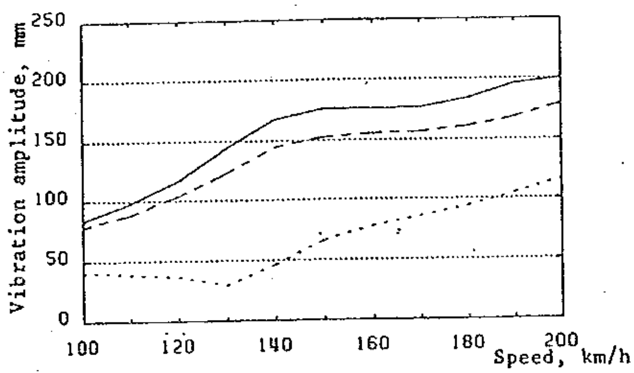


Fig. 2

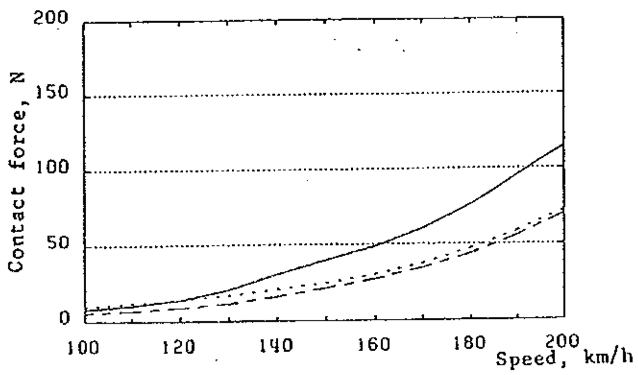


Fig. 3

- Fig. 4 shows the uplift of contact wire at each point given within a span. The faster the speed, the larger is the uplift at the supporting point; however, when the pantograph is light, the uplift is smaller even with the high speed.

In the case of the OHE with presag, the uplift each at the 2/4 point (the center of the span) and the 3/4 is small. This means that the presag is effective in suppressing the uplift of contact wire. Comparing the uplifts at the 2/4 point (the span center) and the 3/4 point, the speed becoming faster, the point where the uplift is maximum moves to the 3/4 point side. (Refer to Appendix 6-9, Fig. 3)

- In the area where the train runs at high speeds, the OHE with presag and pantograph of light equivalent mass is effective to achieve good current collection.

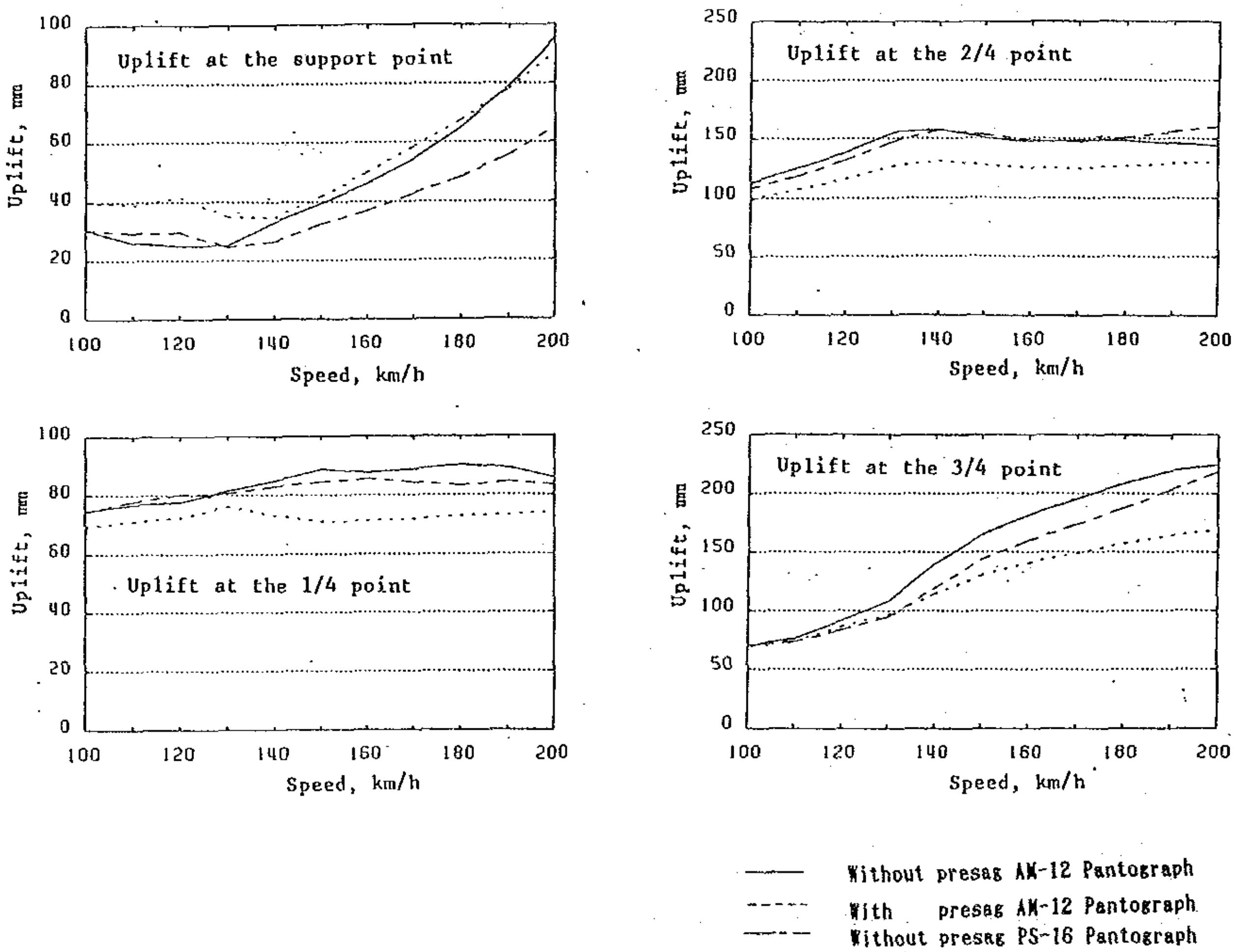


Fig. 4 Uplift of Contact Wire vs. Speed

6-14 Contact Loss

Contact loss means that the contact force of pantograph becoming zero or the contact wire and pantograph are separated affected by hard spot.

The contact loss usually accompanies spark discharge, which brings about a rise in temperature and partial wear to both the pantograph and contact wire. It also brings about surge voltage to the main circuit, threatening insulation. It can be classified by causes, as given below:

(1) *Cyclic contact loss at the support point*

Contact loss period is approximately 0.01 to 0.1 second. It occurs cyclically per span. When a span length is short, multipantographs run closely, or due to the lowered tension of OHE system, it continues over several or more than ten spans. This is considered resulted from the pantograph and catenary system excessively used, which must be prevented.

(2) Contact loss due to non-continuous point

This contact loss occurs when a pantograph shoe is hit by hard spot repeatedly, being a typical one on the OHE system, medium in size and *continued for* 0.001 ∿ 0.01 *second*.

To prevent this contact loss, it is necessary to reduce the hardness of the spot. Overlap is an cause of hard spot together with, dropper, splicer, etc.

(3) Contact loss due to vibration

The pantograph shoe and contact wire have their own natural vibration characteristics.

When either the pantograph shoe or contact wire vibrates, one cannot follow the other with the same vibration, causing contact loss. The contact loss period is 0.001 second or less, repeating cycle approximately 0.01 second, and continues 10 ∿ 100 times.

6-15 Outline of the Electric Inspection Car of JR

The electric inspection car efficiently performs inspections of the OHE equipment, which previously required much labor, at a regular train operation speed.

Its appearance and measuring equipment are shown in Photograph 1 and 2.

1) Items measured

(a) Abrasion of contact wire

By grasping the abrasion conditions of contact wires, a replacement program is made to prevent the breaking troubles of contact wires.

The abrasion conditions of contact wires are continuously measured by the optical equipment whose main features are as follows.

(1) Measuring can be made by day or night.
(2) Four contact wires can be simultaneously measured.
(3) Accuracy of measurement is 0.2 mm on wear width.

(b) Height of contact wire

For proper current-collecting the pantograph requires the uniform contact wire height.

The main axle of the pantograph is rotated by the up-and-down movement of the pantograph corresponding to the change in the contact wire height. The dynamic height of the contact wire above the railroad surface is continuously measured by detecting the rotating angle of the main axle.

(c) Deviation of contact wire

The installation of contact wire with proper deviation is one of the requirements to maintain good current-collecting characteristics.

The same optical measuring equipment as in the case of the abrasion measurement detects deviation of contact wire.

(d) Obstacles in the way of the pantograph driving

The obstacle detector catches obstacles against the pantograph passage as well as wrongly fitted angles of the OHE fittings (steady arms, pull-off fittings).

The pan of the pantograph is equipped with an antenna with a micro-switch which gives a signal when the fitting of the contact system hits the antenna.

(e) Hard spot

In the case of the contact wire having a partially heavy part, or having some bad points, the pantograph will be jolted causing contact loss or a partial wear of the contact wire.

The hard spot detector detects acceleration in the forward-backward and upward-downward directions of the pan head through a wire strain gauge-type accelerometer on the reverse side of the pan.

2) Data processing

The data measured and processed by the electric inspection car are effectively utilized for maintenance and control of the overhead contact system to secure safety in train operation.

The electric inspection car is equipped with data processing apparatus mainly composed of a mini-computer for the purpose of immediate processing the measured data during train operation.

The processed data is output in digital & analogue. The digital data is output by two terminal devices, (1) a high speed printer (whole data output at each span) and (2) typewriter (alarming data output).

Moreover, the entire data obtained are recorded in a magnetic tape in analogue by the data recorder and are effectively utilized for time sequential control of the contact wire abrasion.

3) Measurement period

Seven electric inspection cars are stationed on conventional lines throughout Japan.

The number of measuring inspection is 4 times a year in each line.

For Shinkansen lines, inspection cars in two sets are employed on the Tokaido & Sanyo Shinkansen Lines, and also two other sets on the Tohoku & Joetsu Shinkansen. The running speed is 210 ∿ 240 km/h and the frequency of measuring inspections is about once a week.

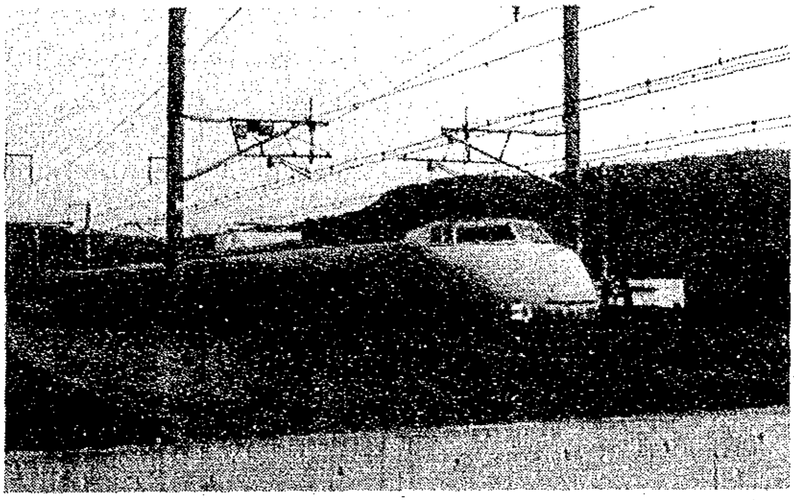


Photo 1 Electric Equipment and Track Inspection Train

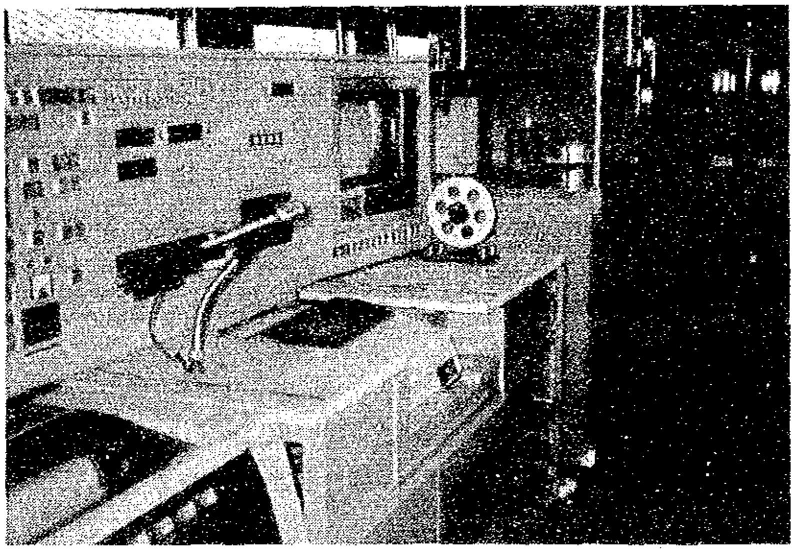


Photo 2 Measuring Equipment

7-1 Presumed Investment to be Made in the 7th 5 Year Plan by 1990 on the Section

1. Track and structure

(1) Extension of loop lines

Kanpur (up), Dankaur (up) .... (Sanctioned)

(2) Construction of loop lines

Saraibhopat and 5 other stations .... (Sanctioned)
Mandrak and 9 other stations .... (Programmed)
Balrai and 4 other stations .... (Proposed)

(3) Construction of emergency crossovers

Jalesar Road and 7 other stations .... (Sanctioned)
Balrai and 11 other stations .... (Programmed)
Jinjhak and 9 other stations .... (Proposed)

(4) Construction of hot axle sidings

Saraibhopat and 2 other stations .... (Sanctioned)
Jalesar Road and 2 other stations .... (Programmed)
Dadri and 8 other stations .... (Proposed)

(5) Track renewal work

Replacement of sleeper (P,R,C)
Dn 69.8 km .... (Proposed)
Up 81.0 km .... (Proposed)

(6) Extension of platform (to hold 25 coaches)

Kanpur
Etawah
Tundla
Aligarh
} .... (Programmed)

2. Signalling and telecommunications

(1) Construction of block huts

Samhon - Achalda and 4 other places .... (Sanctioned)

(2) Automatic signalling

Tundla ∿ Mitawali .... (Sanctioned)

Aligarh ∿ Dankhan .... (Programmed)

(3) Auxiliary warning system

Delhi ∿ Mughalsarai (part of the section) .... (Sanctioned)

(4) SHF plan

The nation wide SHF network plan is being studied by I.R.

3. Substation

(1) Substation construction plans

Pura and 5 other places .... (Sanctioned)

4. Rolling stock

EL	(unit)
Express train (passenger)	3
Ordinary train (freight)	6

Coach	(make-up)
Express train	3

Wagon	(make-up)
Ordinary train	6

7-2 Number of Rolling Stock to be Acquired

Type	Item	Upgrading the Section			New Corridor Construction																									Note
	Fare level (%)	—			0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	
	Period	1986/1990	1991/1995	1996/2000	1996/2000					2001/2005					2006/2010					2011/2014					2016/	2016/	2016/	2016/2022	2016/2024	
EL	L. Express	(0) 3	1	2	0	1	3	5	5	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	New EL x 2
	Ex./Mail	(5) 6	10	21	Δ34	Δ27	Δ24	Δ24	Δ24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	WAP1
	Local	(2) 2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	-	-	-	-	-	-	-	-	-	-	WAM4
	Freight fast	(0) 22	11	8	0	0	0	0	0	14	14	14	14	14	11	11	11	11	11	-	-	-	-	-	-	-	-	-	-	WAG6
	Freight ordinary	(1) 1	0	0	0	0	0	0	0	7	7	7	7	7	15	15	15	15	15	-	-	-	-	-	-	-	-	-	-	WAG5
	Total No.	(8) 34	22	31	0	1	3	5	5	21	22	23	23	23	27	28	28	29	29	0	0	2	3	3	0	0	0	7	6	
PC	L. Express	(0) 3	1	2	0	1	3	5	5	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	. Showing No. of formations
	Ex./Mail	(6) 6	10	21	Δ34	Δ27	Δ24	Δ24	Δ24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	. L. Exp. & Local: 18 coaches/formation
	Local	(2) 2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	-	-	-	-	-	-	-	-	-	-	. Exp./Mail: 19.5 coaches/formation
	Total No.	(8) 11	11	23	0	1	3	5	5	0	1	2	2	2	1	2	2	3	3	0	0	2	3	3	0	0	0	7	6	
FW	Fast	(11) 22	11	8	0	0	0	0	0	14	14	14	14	14	11	11	11	11	11	-	-	-	-	-	-	-	-	-	-	. Showing No. of formations . Fast: 56 wagons/formation
	Ordinary	(1) 1	0	0	0	0	0	0	0	7	7	7	7	7	15	15	15	15	15	-	-	-	-	-	-	-	-	-	-	. Ordinary: 28 wagons/formation
	Total No.	(12) 23	11	8	0	0	0	0	0	21	21	21	21	21	26	26	26	26	26	-	-	-	-	-	-	-	-	-	-	
EMU	Super Exp.	-	-	-	((5)) 40	((5)) 29	((5)) 19	((5)) 11	((5)) 8	7	7	5	3	2	0	8	6	4	2	0	0	7	5	3	0	0	1	9	8	. Showing No. of formations
	(ATC for L. Exp.)	-	-	-	6	7	9	11	11	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	. 16 coaches/formation

The number in parenthesis are those included in the 7th 5-year Plan.
The number in double parenthesis are those to be imported.
The number attached with triangle are those to be transferred to the other railway section.

8-1 Economic Analysis for the Delhi - Kanpur Railway Project - Case (A)

(UNIT : 1000 RS)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
INVESTMENT DIFF	58788	999109	985092	-160884	-151174	-151174	-151174	-125226	-283785	-283394	-283630	-356075
WITH	58788	999109	985092	219617	219617	219617	219617	245565	245565	245565	245565	245565
THE SECTION	53788	999109	985092	219617	219617	219617	219617	245565	245565	245565	245565	245565
ELECTRIFICATION	0	51839	51849	0	0	0	0	0	0	0	0	0
SIGNALS & TELECOM	0	393538	397850	0	0	0	0	0	0	0	0	0
CIVIL WORK	56338	144272	127934	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	2450	2000	0	0	0	0	0	0	0	0	0	0
ROLLING STOCKS	0	407460	407460	219617	219617	219617	219617	245565	245565	245565	245565	245565
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0
WITHOUT	0	0	0	380501	370791	370791	370791	370791	529350	528959	529194	601639
BUS	0	0	0	72290	39324	39324	39324	39324	54629	54394	54629	126919
TRUCK	0	0	0	308212	331467	331467	331467	331467	474720	474565	474565	474720
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0
MAINT & OPE COST DIFF	0	0	0	-52010	-315029	-578048	-841039	-1103176	-1503389	-1903293	-2303361	-2703574
FACILITY MAINT COST DIFF	0	0	0	-60555	-189118	-317682	-446245	-573990	-759349	-944602	-1129903	-1315263
WITH	0	0	0	71376	76916	82456	87996	94355	100713	107071	113429	119787
THE SECTION	0	0	0	71376	76916	82456	87996	94355	100713	107071	113429	119787
ELECTRIC FAC.	0	0	0	1786	1786	1786	1786	1786	1786	1786	1786	1786
SIGNALS & TLELCOM	0	0	0	27635	27635	27635	27635	27635	27635	27635	27635	27635
CIVIL WORK	0	0	0	12968	12968	12968	12968	12968	12968	12968	12968	12968
ROLLING STOCK	0	0	0	28987	34527	40067	45607	51965	58324	64682	71040	77398
WITHOUT	0	0	0	131931	266035	400138	534241	668344	860062	1051673	1243332	1435050
BUS	0	0	0	14643	22609	30574	38540	46506	57571	68590	79656	90722
TRUCK	0	0	0	117288	243426	369563	495701	621839	802491	983084	1163677	1344328
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
OPERATING COST DIFF	0	0	0	8545	-125911	-260366	-394794	-529186	-744039	-958690	-1173458	-1388311
WITH	0	0	0	214208	281860	349512	417192	484907	558670	632432	706195	779957
THE SECTION	0	0	0	214208	281860	349512	417192	484907	558670	632432	706195	779957
PSNL COST	0	0	0	4341	7677	11014	14378	17778	21963	26148	30332	34517
ELEC COST	0	0	0	209867	274183	338498	402814	467129	536707	606285	675862	745440
WITHOUT	0	0	0	205664	407771	609879	811986	1014094	1302709	1591122	1879653	2168268
PSNL COST	0	0	0	123254	243130	363006	482882	602758	773884	944883	1115959	1287085
BUS	0	0	0	23854	36830	49806	62782	75758	93784	111733	129759	147785
TRUCK	0	0	0	99400	206300	313200	420100	527000	680100	833150	986200	1139300
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
FUEL COST	0	0	0	82410	164641	246873	329104	411336	528825	646240	763694	881183
BUS	0	0	0	12034	18581	25127	31674	38220	47314	56370	65464	74558
TRUCK	0	0	0	70375	146060	221746	297431	373116	481511	589870	698230	806624
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
PAS TIME SAVING BENEFIT	0	0	0	94851	128098	163235	200656	240093	295910	354877	417713	484681
CASHFLOW FOR EIRR	-58788	-999109	-985092	307746	594301	892456	1192868	1468495	2083084	2541564	3004704	3544329
EIRR %	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
INVESTMENT DIFF	-566257	-347535	-370791	-212864	-386096	-385861	-529350	-601434	-568518	-511793	-513889	-2101
WITH	2251	0	0	157926	0	0	0	0	0	2251	0	345434
THE SECTION	2251	0	0	157926	0	0	0	0	0	2251	0	345434
ELECTRIFICATION	0	0	0	0	0	0	0	0	0	0	0	35140
SIGNALS & TELECOM	2251	0	0	157926	0	0	0	0	0	2251	0	310294
CIVIL WORK	0	0	0	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	0	0	0	0	0	0	0	0	0	0	0	0
ROLLING STOCKS	0	0	0	0	0	0	0	0	0	0	0	0
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0
WITHOUT	568518	347535	370791	370791	386096	385861	529350	601484	568518	514044	513889	347535
BUS	93953	39324	39324	39324	54629	54394	54629	126919	93953	39324	39324	39324
TRUCK	474565	308212	331467	331467	331467	331467	474720	474565	474565	474720	474565	308212
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0
MAINT & OPE COST DIFF	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982
FACILITY MAINT COST DIFF	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921
WITH	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787
THE SECTION	119787	119787	119787	119787	119787	119787	119737	119787	119787	119787	119787	119787
ELECTRIC FAC.	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786
SIGNALS & TLELCOM	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635
CIVIL WORK	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968
ROLLING STOCK	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398
WITHOUT	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709
BUS	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788
TRUCK	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
OPERATING COST DIFF	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061
WITH	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
THE SECTION	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
PSNL COST	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720
ELEC COST	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018
WITHOUT	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798
PSNL COST	1458162	1458162	1458162	1458162	1458162	1458162	1458152	1458162	1458162	1458162	1458162	1458162
BUS	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812
TRUCK	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
FUEL COST	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637
BUS	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653
TRUCK	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984
AIRPLANE	0	0	0	0	0	0	0	0	0	0	0	0
PAS TIME SAVING BENEFIT	555149	569453	583756	598953	614151	630242	646333	662424	680304	697289	715168	733941
CASHFLOW FOR EIRR	4231398	4026970	4064529	3921800	4110229	4126085	4285665	4373891	4358804	4319064	4339039	3846025
EIRR %	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62

97	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
94	-283630	-356075	-536257	-347535	-370791	-212864	-386096	-385861	-529350	-601484	-568518	-511793	-513889
65	245565	245565	2251	0	0	157925	0	0	0	0	0	2251	0
65	245565	245565	2251	0	0	157925	0	0	0	0	0	2251	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2251	0	0	157925	0	0	0	0	0	2251	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	245565	245565	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	529194	601639	568518	347535	370791	370791	386096	385861	529350	601484	568518	514044	513889
94	54629	126919	93953	39324	39324	39324	54629	54394	54629	126919	93953	39324	39324
65	474565	474720	474565	308212	331467	331467	331467	331467	474720	474565	474565	474720	474565
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	-2303361	-2703574	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982
02	-1129903	-1315263	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921
71	113429	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787
71	113429	119787	119787	119787	119787	119787	119787	119787	119737	119787	119787	119787	119787
36	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786
35	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635
58	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968
32	71040	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398
3	1243332	1435050	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709
0	79656	90722	101788	101788	101788	101788	101788	101788	101783	101788	101788	101788	101788
4	1163677	1344328	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	-1173458	-1388311	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061
2	706195	779957	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
2	706195	779957	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
3	30332	34517	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720
5	675862	745440	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018
2	1879653	2168268	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798
3	1115959	1287085	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162
3	129759	147785	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812
0	986200	1139300	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	763694	881183	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637
0	65464	74558	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653
0	698230	806624	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984
0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	417713	484681	555149	569453	583756	598953	614151	630242	646333	662424	680304	697289	715168
4	3004704	3544329	4231398	4026970	4064529	3921800	4110229	4126085	4285665	4373891	4358804	4319064	4339039
2	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
-2101	-386096	-385861	-386096	-300460	-568673	-513889	-511638	-514044	-529194	671931	-166479	-221725	-263738
345434	0	0	0	157925	0	0	2251	0	0	1034535	219617	236661	-1304661
345434	0	0	0	157925	0	0	2251	0	0	1034535	219617	236661	-1304661
35140	0	0	0	0	0	0	0	0	0	0	0	0	0
310294	0	0	0	157925	0	0	2251	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	17044	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1034535	219617	219617	219617
0	0	0	0	0	0	0	0	0	0	0	0	0	2024278
347535	386096	385861	386096	458386	568673	513889	513889	514044	529194	362605	386096	458386	-1540924
39324	54629	54394	54629	126919	93953	39324	39324	39324	54629	54394	54629	126919	93953
308212	331467	331467	331467	331467	474720	474565	474565	474720	474565	308212	331467	331467	331467
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1966343
-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982	-3109982
-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921	-1506921
119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787
119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787	119787
1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786	1786
27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635	27635
12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968	12968
77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398	77398
1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709	1626709
101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788	101788
1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921	1524921
0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061	-1603061
853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738	853738
38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720	38720
815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018	815018
2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798	2456798
1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162	1458162
165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812	165812
1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350	1292350
0	0	0	0	0	0	0	0	0	0	0	0	0	0
998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637	998637
83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653	83653
914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984	914984
0	0	0	0	0	0	0	0	0	0	0	0	0	0
733941	752714	771487	791155	811716	832277	853732	876081	898430	921673	944916	969947	994977	1020008
3846025	4248793	4267330	4287233	4222158	4510932	4477603	4497701	4522456	4560849	3382967	4246408	4326684	4393728
42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62	42.62

8-2 Financial Analysis for the Delhi - Kanpur Railway Project - Case (A)

(UNIT : 1000 RS)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
OPERATING PROFIT	0	0	0	44992	274265	503537	732770	959865	1301762	1643660	1985557	2327454	2687360	2687360
OPERATING REVENUE	0	0	0	329295	611929	894563	1177197	1459831	1861422	2263013	2664604	3066195	3467786	3467786
THE SECTION														
PASSENGER	0	0	0	134394	207407	280419	353432	426444	527902	629360	730818	832276	933734	933734
FREIGHT	0	0	0	194901	404523	614144	823765	1033387	1333520	1633653	1933786	2233920	2534053	2534053
TOTAL	0	0	0	329295	611929	894563	1177197	1459831	1861422	2263013	2664604	3066195	3467786	3467786
OPERATING EXPENSE	0	0	0	284303	337664	391026	444427	499966	559660	619353	679047	738741	780426	780426
THE SECTION	0	0	0	284303	337664	391026	444427	499966	559660	619353	679047	738741	780426	780426
WORKING COST	0	0	0	193515	237799	282083	326407	371796	421339	470883	520427	569970	611656	611656
MAINTENANCE COST	0	0	0	95907	102777	109647	116517	124401	132285	140169	148053	155938	155938	155938
PERSONNEL COST	0	0	0	6056	10700	15344	20028	24763	30588	36414	42239	48065	53916	53916
ELEC COST	0	0	0	91551	124321	157092	189862	222632	258466	294300	330134	365968	401802	401802
DEPRECIATION	0	0	0	90788	99865	108943	118020	128170	138320	148470	158620	168770	168770	168770
INVESTMENT	69530	1351945	1336871	272325	272325	272325	272325	304500	304500	304500	304500	304500	3336	0
FOREIGN TOTAL	0	149250	149850	0	0	0	0	0	0	0	0	0	600	0
LOCAL TOTAL	69530	1202695	1187021	272325	272325	272325	272325	304500	304500	304500	304500	304500	2736	0
ELECTRIFICATION	0	75888	75898	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	16260	16260	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	59628	59638	0	0	0	0	0	0	0	0	0	0	0
SIGNALS & TELECOM	0	597897	603503	0	0	0	0	0	0	0	0	0	3336	0
FOREIGN CURRENCY	0	132990	133590	0	0	0	0	0	0	0	0	0	600	0
LOCAL CURRENCY	0	464907	469913	0	0	0	0	0	0	0	0	0	2736	0
CIVIL WORK	67080	170910	152220	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	67080	170910	152220	0	0	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	2450	2000	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	2450	2000	0	0	0	0	0	0	0	0	0	0	0	0
ROLLING STOCK	0	505250	505250	272325	272325	272325	272325	304500	304500	304500	304500	304500	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	505250	505250	272325	272325	272325	272325	304500	304500	304500	304500	304500	0	0
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INT. DURING CONST.	4734	91778	212239	0	0	0	0	0	0	0	0	0	0	0
FINANCE PROGRAM														
FINANCE TOTAL														
BORROWING	74264	1443723	1549110	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	15484
BALANCE	74264	1517987	3067097	3067097	3067097	3067097	3067097	3067097	3067097	3067097	3067097	3067097	3067097	3051613
INTEREST	4734	91778	212239	242897	242897	242897	242897	242897	242897	242897	242897	242897	242897	242577
FINANCE IN FOREIGN CCY														
BORROWING	0	152393	157285	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	15484
BALANCE	0	152393	309678	309678	309678	309678	309678	309678	309678	309678	309678	309678	309678	294194
INTEREST	0	3143	7435	8516	8516	8516	8516	8516	8516	8516	8516	8516	8516	8197
FINANCE IN LOCAL CCY														
BORROWING	74264	1291330	1391825	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	74264	1365594	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419
INTEREST	4734	88635	204804	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381
NET CASHFLOW	0	0	0	-379442	-141092	97258	335569	540638	892686	1244733	1596780	1948828	2609898	2598069
CUM NET CASHFLOW	0	0	0	-379442	-520533	-423275	-87706	452932	1345618	2590351	4187132	6135960	8745858	11343927
CASH IN	74264	1443723	1549110	135780	374130	612480	850790	1088035	1440083	1792130	2144177	2496225	2856131	2856131
OPERATING PROFIT	0	0	0	44992	274265	503537	732770	959865	1301762	1643660	1985557	2327454	2687360	2687360
DEPRECIATION	0	0	0	90788	99865	108943	118020	128170	138320	148470	158620	168770	168770	168770
BORROWING	74264	1443723	1549110	0	0	0	0	0	0	0	0	0	0	0
CASH OUT	74264	1443723	1549110	515222	515222	515222	515222	547397	547397	547397	547397	547397	246233	258061
INVESTMENT	69530	1351945	1336871	272325	272325	272325	272325	304500	304500	304500	304500	304500	3336	0
INT. DURING CONST.	4734	91778	212239	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	15484
INTEREST	0	0	0	242897	242897	242897	242897	242897	242897	242897	242897	242897	242897	242577
CF FOR FIRR	-69530	-1351945	-1336871	-136545	101805	340155	578465	783535	1135583	1487630	1839677	2191725	2852795	2856131
FIRR %	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
OPERATING PROFIT	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360
OPERATING REVENUE	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786
THE SECTION														
PASSENGER	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734
FREIGHT	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053
TOTAL	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786
OPERATING EXPENSE	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426
THE SECTION	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426
WORKING COST	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656
MAINTENANCE COST	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938
PERSONNEL COST	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916
ELEC COST	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802
DEPRECIATION	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770
INVESTMENT	0	182855	0	0	0	0	0	3336	0	608436	0	0	0	182855
FOREIGN TOTAL	0	1210	0	0	0	0	0	600	0	192830	0	0	0	1210
LOCAL TOTAL	0	181645	0	0	0	0	0	2736	0	415606	0	0	0	181645
ELECTRIFICATION	0	0	0	0	0	0	0	0	0	78115	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	32520	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	45595	0	0	0	0
SIGNALS & TELECOM	0	182855	0	0	0	0	0	3336	0	532321	0	0	0	182855
FOREIGN CURRENCY	0	1210	0	0	0	0	0	600	0	160310	0	0	0	1210
LOCAL CURRENCY	0	181645	0	0	0	0	0	2736	0	372011	0	0	0	181645
CIVIL WORK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROLLING STOCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INT. DURING CONST.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FINANCE PROGRAM														
FINANCE TOTAL														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484
BALANCE	3036130	3020646	3005162	2989678	2974194	2958710	2943226	2927742	2912258	2896775	2881291	2865807	2850323	2834839
INTEREST	242152	241726	241300	240874	240448	240023	239597	239171	238745	238319	237894	237468	237042	236616
FINANCE IN FOREIGN CCY														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484
BALANCE	278710	263226	247742	232258	216775	201291	185807	170323	154839	139355	123871	108387	92903	77419
INTEREST	7771	7345	6919	6494	6068	5642	5216	4790	4365	3939	3513	3087	2661	2235
FINANCE IN LOCAL CCY														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419
INTEREST	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381
NET CASHFLOW	2598495	2416066	2599347	2599773	2600199	2600624	2601050	2598140	2601902	1993892	2602753	2603179	2603605	2421176
CUM NET CASHFLOW	13942423	16358489	18957836	21557609	24157807	26758431	29359482	31957622	34559523	36553415	39156168	41759348	44362952	46784128
CASH IN	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131
OPERATING PROFIT	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360
DEPRECIATION	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASH OUT	257636	440064	256784	256358	255932	255506	255081	257991	254229	862239	253377	252952	252526	434955
INVESTMENT	0	182855	0	0	0	0	0	3336	0	608436	0	0	0	182855
INT. DURING CONST.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484
INTEREST	242152	241726	241300	240874	240448	240023	239597	239171	238745	238319	237894	237468	237042	236616
CF FOR FIRR	2856131	2673276	2856131	2856131	2856131	2856131	2856131	2852795	2856131	2247695	2856131	2856131	2856131	2673276
FIRR %	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360
3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786
933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734	933734
2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053	2534053
3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786	3467786
780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426
780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426	780426
611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656	611656
155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938	155938
53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916	53916
401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802	401802
168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770
3336	0	0	182855	0	0	0	0	0	3336	0	608436	0	0	0	182855	0	0	3336	0	0	1282825	272325	292255	272325
600	0	0	1210	0	0	0	0	0	600	0	192830	0	0	0	1210	0	0	600	0	0	0	0	0	0
2736	0	0	181645	0	0	0	0	0	2736	0	415606	0	0	0	181645	0	0	2736	0	0	1282825	272325	292255	272325
0	0	0	0	0	0	0	0	0	0	0	76115	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	32520	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	43595	0	0	0	0	0	0	0	0	0	0	0	0	0
3336	0	0	182855	0	0	0	0	0	3336	0	532321	0	0	0	182855	0	0	3336	0	0	0	0	0	0
600	0	0	1210	0	0	0	0	0	600	0	160310	0	0	0	1210	0	0	600	0	0	0	0	0	0
2736	0	0	181645	0	0	0	0	0	2736	0	372011	0	0	0	181645	0	0	2736	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19930	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19930	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1282825	272325	272325	272325
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1282825	272325	272325	272325
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2862845
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	0	0	0	0
3067097	3051613	3036130	3020646	3005162	2989678	2974194	2958710	2943226	2927742	2912258	2896775	2881291	2865807	2850323	2834839	2819355	2803871	2788387	2772903	2757419	2757419	2757419	2757419	2757419
242897	242577	242152	241726	241300	240874	240448	240023	239597	239171	238745	238319	237894	237468	237042	236616	236190	235765	235339	234913	234487	234381	234381	234381	234381
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	0	0	0	0
309678	294194	278710	263226	247742	232258	216775	201291	185807	170323	154839	139355	123871	108387	92903	77419	61936	46452	30968	15484	0	0	0	0	0
8516	8197	7771	7345	6919	6494	6068	5642	5216	4790	4365	3939	3513	3087	2661	2235	1810	1384	958	532	106	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419	2757419
234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381	234381
2609898	2598069	2598495	2416066	2599347	2599773	2600199	2600624	2601050	2598140	2601902	1993892	2602753	2603179	2603605	2421176	2604457	2604882	2601972	2605734	2606160	1338925	2349425	2329405	5012070
8745858	11343927	13942423	16358489	18957836	21557609	24157807	26758431	29359482	31957622	34559523	36553415	39156168	41759348	44362952	46784129	49388585	51993468	54595440	57201174	59807334	61146259	63495684	65825179	70837249
2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131	2856131
2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360	2687360
168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770	168770
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
246233	258061	257636	440084	256784	256358	255932	255506	255081	257991	254229	862239	253377	252952	252526	434955	251674	251248	254159	250397	249971	1517206	506706	526636	-2155940
3336	0	0	182855	0	0	0	0	0	3336	0	608436	0	0	0	182855	0	0	3336	0	0	1282825	272325	292255	-2390320
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	15484	0	0	0	0
242897	242577	242152	241726	241300	240874	240448	240023	239597	239171	238745	238319	237894	237468	237042	236616	236190	235765	235339	234913	234487	234381	234381	234381	234381
2852795	2856131	2856131	2873276	2856131	2856131	2856131	2856131	2856131	2852795	2856131	2247695	2856131	2856131	2856131	2873276	2856131	2856131	2852795	2856131	2856131	1573306	2583806	2563876	5246451
25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79	25.79

8-3 Economic Analysis for the Delhi - Kanpur Railway Project - Case (B)

(UNIT : 1000 RS)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INVESTMENT DIFF	1444816	3243891	4318122	5485036	2194270	-3280301	-630891	-630891	-630891	-630891	-610478
WITH	1444816	3243891	4318122	5485036	2194270	155371	155371	155371	155371	155371	175548
NEW CORRIDOR	1444816	3243891	4318122	5485036	2194270	155371	155371	155371	155371	155371	175548
ELECTRIFICATION	0	355665	590085	574952	230721	0	0	0	0	0	0
SIGNALS & TELECOM	0	798975	798975	798975	266325	0	0	0	0	0	0
CIVIL WORK	1289776	1872331	1872331	2002198	403402	0	0	0	0	0	0
LAND ACQ & COMP	155040	216920	165240	0	0	0	0	0	0	0	0
ROLLING STOCKS	0	0,	891492	2108911	1293823	155371	155371	155371	155371	155371	175548
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0
WITHOUT	0	0	0	0	0	3435672	786262	786262	786262	786262	786026
BUS	0	0	0	0	0	815672	82179	82179	82179	82179	81944
TRUCK	0	0	0	0	0	0	376582	376582	376582	376582	376582
AIRPLANE	0	0	0	0	0	2620000	327500	327500	327500	327500	327500
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0
MAINT & OPE COST DIFF	0	0	0	0	0	-655144	-1137927	-1620709	-2103492	-2586275	-3068115
FACILITY MAINT COST DIFF	0	0	0	0	0	127172	-42725	-212622	-382519	-552415	-721558
WITH	0	0	0	0	0	414893	420261	425629	430997	436365	442440
NEW CORRIDOR	0	0	0	0	0	414893	420261	425629	430997	436365	442440
ELECTRIC FAC.	0	0	0	0	0	29841	29841	29841	29841	29841	29841
SIGNALS & TLELCOM	0	0	0	0	0	83587	83587	83587	83587	83587	83587
CIVIL WORK	0	0	0	0	0	138637	138637	138637	138637	138637	138637
ROLLING STOCK	0	0	0	0	0	162828	168196	173564	178932	184300	190375
WITHOUT	0	0	0	0	0	287722	462987	638251	813516	988781	1163998
BUS	0	0	0	0	0	165226	181872	198519	215166	231812	248411
TRUCK	0	0	0	0	0	0	143306	286612	429918	573225	716531
AIRPLANE	0	0	0	0	0	122496	137808	153120	168432	183744	199056
OPERATING COST DIFF	0	0	0	0	0	-782316	-1095201	-1408087	-1720973	-2033859	-2346557
WITH	0	0	0	0	0	203288	211220	219152	227083	235015	243018
NEW CORRIDOR	0	0	0	0	0	203288	211220	219152	227083	235015	243018
PSNL COST	0	0	0	0	0	69282	70469	71657	72844	74032	75291
ELEC COST	0	0	0	0	0	134007	140751	147495	154239	160983	167727
WITHOUT	0	0	0	0	0	985604	1306422	1627239	1948057	2268874	2589575
PSNL COST	0	0	0	0	0	270743	419509	568275	717042	865808	1014496
BUS	0	0	0	0	0	269153	296270	323387	350505	377622	404662
TRUCK	0	0	0	0	0	0	121450	242900	364350	485800	607250
AIRPLANE	0	0	0	0	0	1590	1789	1988	2187	2386	2584
FUEL COST	0	0	0	0	0	714861	886912	1058964	1231015	1403066	1575079
BUS	0	0	0	0	0	135789	149470	163150	176831	190512	204154
TRUCK	0	0	0	0	0	0	85987	171973	257960	343946	429933
AIRPLANE	0	0	0	0	0	579072	651456	723840	796224	868608	940992
PAS TIME SAVING BENEFIT	0	0	0	0	0	1588773	1760846	1939508	2127933	2323358	2529371
CASHFLOW FOR EIRR	-1444816	-3243891	-4318122	-5485036	-2194270	5524217	3529664	4191108	4862316	5540524	6207964
EIRR %	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	:
INVESTMENT DIFF	-703094	-702859	-1518766	361133	-3911618	-786262	-786262	-786026	-797093	-796858	-1694314	-960586	18:
WITH	175548	175548	175548	1321719	0	0	0	0	0	0	0	0	114(
NEW CORRIDOR	175548	175548	175548	1321719	0	0	0	0	0	0	0	0	114(
ELECTRIFICATION	0	0	0	0	0	0	0	0	0	0	0	0	
SIGNALS & TELECOM	0	0	0	1146171	0	0	0	0	0	0	0	0	114(
CIVIL WORK	0	0	0	0	0	0	0	0	0	0	0	0	
LAND ACQ & COMP	0	0	0	0	0	0	0	0	0	0	0	0	
ROLLING STOCKS	175548	175548	175548	175548	0	0	0	0	0	0	0	0	
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	
WITHOUT	878642	878407	1694314	960586	3911618	786262	786262	786026	797093	796858	1694314	960586	96
BUS	93011	92776	908083	174955	178487	82179	82179	81944	93011	92776	908083	174955	17
TRUCK	458131	458131	458131	458131	458131	376582	376582	376582	376582	376582	458131	458131	45
AIRPLANE	327500	327500	327500	327500	3275000	327500	327500	327500	327500	327500	327500	327500	32
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	
MAINT & OPE COST DIFF	-3633288	-4198296	-4763469	-5328477	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-598
FACILITY MAINT COST DIFF	-923976	-1126346	-1328763	-1531133	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-175
WITH	448514	454588	460662	466737	466737	466737	466737	466737	466737	466737	466737	466737	46
NEW CORRIDOR	448514	454588	460662	466737	466737	466737	466737	466737	466737	466737	466737	466737	46
ELECTRIC FAC.	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	2
SIGNALS & TLELCOM	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	8
CIVIL WORK	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	13
ROLLING STOCK	196449	202523	208597	214672	214672	214672	214672	214672	214672	214672	214672	214672	21
WITHOUT	1372490	1580934	1789426	1997870	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	222
BUS	267252	286045	304886	323679	343187	343187	343187	343187	343187	343187	343187	343187	34
TRUCK	890870	1065209	1239548	1413887	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	158
AIRPLANE	214368	229680	244992	260304	290928	290928	290928	290928	290928	290928	290928	290928	29
OPERATING COST DIFF	-2709312	-3071950	-3434706	-3797344	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-423
WITH	251378	259738	268098	276458	284890	284890	284890	284890	284890	284890	284890	284890	28
NEW CORRIDOR	251378	259738	268098	276458	284890	284890	284890	284890	284890	284890	284890	284890	28
PSNL COST	76460	77630	78800	79970	81211	81211	81211	81211	81211	81211	81211	81211	8
ELEC COST	174917	182108	189298	196488	203679	203679	203679	203679	203679	203679	203679	203679	20
WITHOUT	2960690	3331688	3702804	4073802	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	451
PSNL COST	1193136	1371699	1550339	1728902	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	190
BUS	435353	465967	496658	527272	559052	559052	559052	559052	559052	559052	559052	559052	55
TRUCK	755000	902750	1050500	1198250	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	134
AIRPLANE	2783	2982	3181	3380	3777	3777	3777	3777	3777	3777	3777	3777	3
FUEL COST	1767554	1959989	2152464	2344900	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	261
BUS	219638	235082	250566	266011	282044	282044	282044	282044	282044	282044	282044	282044	28
TRUCK	534540	639147	743754	848361	952968	952968	952968	952968	952968	952968	952968	952968	95
AIRPLANE	1013376	1085760	1158144	1230528	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	137
PAS TIME SAVING BENEFIT	2761896	3002784	3260603	3523198	3876624	3978385	4080147	4181908	4288515	4399968	4511421	4627720	474
CASHFLOW FOR EIRR	7098278	7903939	9542838	8490542	13778094	10754499	10856260	10957786	11075461	11186678	12195587	11578158	1055
EIRR %	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
30891	-610478	-703094	-702859	-1518766	361133	-3911618	-786262	-786262	-786026	-797093	-796858	-1694314	-960586	182053	-867811	1772312	-644397	-655464	-655229	-4974017
55371	175548	175548	175548	175548	1321719	0	0	0	0	0	0	0	0	1146171	0	5587623	141629	141629	141629	-9163152
55371	175548	175548	175548	175548	1321719	0	0	0	0	0	0	0	0	1146171	0	5587623	141629	141629	141629	-9163152
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	586048	0	0	0	0
0	0	0	0	0	1146171	0	0	0	0	0	0	0	0	1146171	0	697000	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55371	175548	175548	175548	175548	175548	0	0	0	0	0	0	0	0	0	0	4304484	141629	141629	141629	141629
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9304781
86262	786026	878642	878407	1694314	960586	3911618	786262	786262	786026	797093	796858	1694314	960586	984118	867811	3815311	786026	797093	796858	-4189135
82179	81944	93011	92776	908683	174955	178487	82179	82179	81944	93011	92776	908683	174955	178487	82179	82179	81944	93011	92776	908683
76582	376582	458131	458131	458131	458131	458131	376582	376582	376582	376582	376582	458131	458131	458131	458131	458131	376582	376582	376582	376582
27500	327500	327500	327500	327500	327500	3275000	327500	327500	327500	327500	327500	327500	327500	327500	327500	3275000	327500	327500	327500	327500
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5801900
86275	-3068115	-3633288	-4198296	-4763469	-5328477	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852	-5989852-
52415	-721558	-923976	-1126346	-1328763	-1531133	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605	-1755605
36365	442440	448514	454588	460662	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737
36365	442440	448514	454588	460662	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737	466737
29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841	29841
83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587	83587
38637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637	138637
84300	190375	196449	202523	208597	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672	214672
88781	1163098	1372490	1580934	1789426	1997870	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341	2222341
31812	248411	267252	286045	304886	323679	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187	343187
73225	716531	890870	1065209	1239548	1413887	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226	1588226
33744	199056	214368	229680	244992	260304	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928	290928
33859	-2346557	-2709312	-3071950	-3434706	-3797344	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247	-4234247
35015	243018	251378	259738	268098	276458	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890
35015	243018	251378	259738	268098	276458	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890	284890
74032	75291	76460	77630	78800	79970	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211	81211
0983	167727	174917	182108	189298	196488	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679	203679
8874	2589575	2960690	3331688	3702804	4073802	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137	4519137
5808	1014496	1193136	1371699	1550339	1728902	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829	1908829
7622	404662	435353	465967	496658	527272	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052	559052
5800	607250	755000	902750	1050500	1198250	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000	1346000
2386	2584	2783	2982	3181	3380	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777	3777
3066	1575079	1767554	1959989	2152464	2344900	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308	2610308
0512	204154	219638	235082	250566	266011	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044	282044
3946	429933	534540	639147	743754	848361	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968	952968
3608	940992	1013376	1085760	1158144	1230528	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296	1375296
3358	2529371	2761896	3002784	3260803	3523198	3876624	3978385	4080147	4181908	4288515	4399968	4511421	4627720	4748864	4870009	4995999	5121989	5257671	5393353	5529035
9524	6207964	7098278	7903939	9542838	8490542	13778094	10754499	10856260	10957786	11075461	11186678	12195587	11578158	10556864	11727672	9213539	11756239	11902988	12038434	16492903
.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09	24.09

8-4 Financial Analysis for the Delhi - Kanpur Railway Project - Case (B)

(UNIT : 1000 RS)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
OPERATING PROFIT	0	0	0	0	0	1534077	1670011	1805946	1941880	2077815	2211521	2379287	2547053	2714819
OPERATING REVENUE	0	0	0	0	0	3426767	3603594	3780422	3957249	4134076	4310903	4523312	4735721	4948129
NEW CORRIDOR														
SUPER EXPRESS	0	0	0	0	0	2998796	3157029	3317263	3477497	3637731	3797964	3985099	4172235	4359370
LONG EXPRESS	0	0	0	0	0	420971	446565	463158	479752	496345	512939	538213	563486	588760
TOTAL	0	0	0	0	0	3426767	3603594	3780422	3957249	4134076	4310903	4523312	4735721	4948129
OPERATING EXPENSE	0	0	0	0	0	1892690	1933583	1974476	2015368	2056261	2099382	2144025	2188667	2233310
NEW CORRIDOR	0	0	0	0	0	1892690	1933583	1974476	2015368	2056261	2099382	2144025	2188667	2233310
WORKING COST	0	0	0	0	0	1127710	1159254	1190797	1222341	1253885	1286406	1320449	1354491	1388534
MAINTENANCE COST	0	0	0	0	0	575599	582255	588912	595568	602224	609756	617288	624820	632352
PERSONNEL COST	0	0	0	0	0	98309	99971	101633	103296	104958	106722	108361	110000	111638
ELEC COST	0	0	0	0	0	453802	477027	500252	523477	546702	569927	594799	619671	644543
DEPRECIATION	0	0	0	0	0	764980	774329	783678	793027	802376	812976	823576	834176	844776
INVESTMENT	1695620	4144906	6122981	7604521	2820692	192660	192660	192660	192660	192660	217680	217680	217680	217680
FOREIGN TOTAL	0	393240	1098340	1098340	170880	0	0	0	0	0	0	0	0	0
LOCAL TOTAL	1695620	3751666	5024641	6506181	2649812	192660	192660	192660	192660	192660	217680	217680	217680	217680
ELECTRIFICATION	0	414140	769240	751340	309630	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	79600	79600	39800	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	414140	689640	671740	269830	0	0	0	0	0	0	0	0	0
SIGNALS & TELECOM	0	1279716	1279716	1279716	426572	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	393240	393240	393240	131080	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	886476	886476	886476	295492	0	0	0	0	0	0	0	0	0
CIVIL WORK	1540580	2234130	2234130	2389210	480150	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	1540580	2234130	2234130	2389210	480150	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	155040	216920	165240	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	155040	216920	165240	0	0	0	0	0	0	0	0	0	0	0
ROLLING STOCK	0	0	1674655	3184255	1604340	192660	192660	192660	192660	192660	217680	217680	217680	217680
FOREIGN CURRENCY	0	0	625500	625500	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	1049155	2558755	1604340	192660	192660	192660	192660	192660	217680	217680	217680	217680
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INT. DURING CONST.	115456	428159	919685	1588919	2068428	0	0	0	0	0	0	0	0	0
FINANCE PROGRAM														
FINANCE TOTAL														
BORROWING	1811076	4573065	7042666	9193440	4889120	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	1811076	6384141	13426807	22620246	27509366	27509366	27509366	27509366	27509366	27509366	27509366	27509366	27509366	27509366
INTEREST	115456	428159	919685	1588919	2068428	2168724	2168724	2168724	2168724	2168724	2168724	2168724	2168724	2168724
FINANCE IN FOREIGN CCY														
BORROWING	0	401521	1132745	1164551	250259	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	0	401521	1534266	2698817	2949076	2949076	2949076	2949076	2949076	2949076	2949076	2949076	2949076	2949076
INTEREST	0	8281	34405	66211	79379	81100	81100	81100	81100	81100	81100	81100	81100	81100
FINANCE IN LOCAL CCY														
BORROWING	1811076	4171543	5909921	8028889	4638861	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	1811076	5982619	11892541	19921429	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290
INTEREST	115456	419877	885280	1522708	1989049	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625
NET CASHFLOW	0	0	0	0	0	-62327	82956	228240	373523	518807	638093	816459	994825	1173191
CUM NET CASHFLOW	0	0	0	0	0	-62327	20629	248869	622392	1141199	1779292	2595751	3590576	4763768
CASH IN	1811076	4573065	7042666	9193440	4889120	2299057	2444340	2589024	2734908	2880191	3024497	3202863	3381230	3559596
OPERATING PROFIT	0	0	0	0	0	1534077	1670011	1805946	1941880	2077815	2211521	2379287	2547053	2714819
DEPRECIATION	0	0	0	0	0	764980	774329	783678	793027	802376	812976	823576	834176	844776
BORROWING	1811076	4573065	7042666	9193440	4889120	0	0	0	0	0	0	0	0	0
CASH OUT	1811076	4573065	7042666	9193440	4889120	2361384	2361384	2361384	2361384	2361384	2386404	2386404	2386404	2386404
INVESTMENT	1695620	4144906	6122981	7604521	2820692	192660	192660	192660	192660	192660	217680	217680	217680	217680
INT. DURING CONST.	115456	428159	919685	1588919	2068428	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	2168724	2168724	2168724	2168724	2168724	2168724	2168724	2168724	2168724
CF FOR FIRR	-1695620	-4144906	-6122981	-7604521	-2820692	2106397	2251680	2396964	2542248	2687531	2806817	2985183	3163550	3341916
FIRR %	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
OPERATING PROFIT	2882586	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973
OPERATING REVENUE	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538
NEW CORRIDOR														
SUPER EXPRESS	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505
LONG EXPRESS	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034
TOTAL	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538
OPERATING EXPENSE	2277953	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565
NEW CORRIDOR	2277953	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565
WORKING COST	1422576	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189
MAINTENANCE COST	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884
PERSONNEL COST	113277	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018
ELEC COST	669415	694287	694287	694287	694287	694287	694287	694287	694287	694287	694287	694287	694287	694287
DEPRECIATION	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376
INVESTMENT	2021925	0	0	0	0	0	0	0	0	1804245	0	8595120	175620	175620
FOREIGN TOTAL	544300	0	0	0	0	0	0	0	0	544300	0	1894000	0	
LOCAL TOTAL	1477625	0	0	0	0	0	0	0	0	1259945	0	6701120	175620	175620
ELECTRIFICATION	0	0	0	0	0	0	0	0	0	0	0	887750	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	199000	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	688750	0	0
SIGNALS & TELECOM	1804245	0	0	0	0	0	0	0	0	1804245	0	1231400	0	0
FOREIGN CURRENCY	544300	0	0	0	0	0	0	0	0	544300	0	444000	0	0
LOCAL CURRENCY	1259945	0	0	0	0	0	0	0	0	1259945	0	787400	0	0
CIVIL WORK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LAND ACQ & COMP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOCAL CURRENCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROLLING STOCK	217680	0	0	0	0	0	0	0	0	0	0	6475970	175620	175620
FOREIGN CURRENCY	0	0	0	0	0	0	0	0	0	0	0	1251000	0	0
LOCAL CURRENCY	217680	0	0	0	0	0	0	0	0	0	0	5224970	175620	175620
-SALVAGE VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INT. DURING CONST.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FINANCE PROGRAM														
FINANCE TOTAL														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454
BALANCE	27509366	27361913	27214459	27067005	26919551	26772097	26624643	26477190	26329736	26182282	26034828	25887374	25739921	25592467
INTEREST	2168724	2165683	2161628	2157573	2153518	2149463	2145408	2141353	2137298	2133243	2129188	2125133	2121078	2117023
FINANCE IN FOREIGN CCY														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454
BALANCE	2949076	2801623	2654169	2506715	2359261	2211807	2064353	1916900	1769446	1621992	1474538	1327084	1179631	1032177
INTEREST	81100	78058	74003	69948	65893	61838	57783	53728	49674	45619	41564	37509	33454	29399
FINANCE IN LOCAL CCY														
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BALANCE	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290	24560290
INTEREST	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625	2087625
NET CASHFLOW	-452687	1398213	1402268	1406323	1410378	1414433	1418487	1422542	1426597	-373593	1434707	-7156358	1267197	1271252
CUM NET CASHFLOW	4311080	5709293	7111560	8517883	9928261	11342693	12761181	14183723	15610320	15236728	16671435	9515078	10782275	12053527
CASH IN	3737962	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349
OPERATING PROFIT	2882586	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973
DEPRECIATION	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376	855376
BORROWING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASH OUT	4190649	2313137	2309082	2305027	2300972	2296917	2292862	2288807	2284752	4084942	2276642	10867707	2444152	2440097
INVESTMENT	2021925	0	0	0	0	0	0	0	0	1804245	0	8595120	175620	175620
INT. DURING CONST.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REPAYMENT	0	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454	147454
INTEREST	2168724	2165683	2161628	2157573	2153518	2149463	2145408	2141353	2137298	2133243	2129188	2125133	2121078	2117023
CF FOR FIRR	1716037	3711349	3711349	3711349	3711349	3711349	3711349	3711349	3711349	1907104	3711349	-4883771	3535729	3535729
FIRR %	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
2547053	2714819	2882586	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973	2855973
4735721	4948129	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538
4172235	4359370	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505	4546505
563486	588760	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034	614034
4735721	4948129	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538	5160538
2188667	2233310	2277953	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565
2188667	2233310	2277953	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565	2304565
1354491	1388534	1422576	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189	1449189
624820	632352	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884	639884
110000	111638	113277	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018	115018
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