HSST-100 SYSTEM
EXPERIMENTS IN NAGOYA TEST SITE

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INTRODUCTION

HSST-100 system is currently undergoing test runs in the city of Nagoya located in central Japan. The smallest version of the HSST series, the HSST-100 system was developed for the purpose of serving urban transportation needs up to the speed of approximately 100km/h. In Aug. 1989, Chubu HSST Development Corporation was founded by Aichi Prefecture, HSST Corporation and Nagoya Railroad Co. Ltd & its subsidiary companies. Since the completion of the Nagoya Test Site in May, 1991, vehicle running tests have been conducted by Chubu-HSST and cover all elements necessary for practical utilization of the system.

1. SYSTEM GENERAL

1.1 TRACK (Fig.1)

The track is approx. 1.5km in length, which is sufficient to attain the speed of 100km/h. The track incorporates lateral and vertical curves, a switching mechanism with a branch line, and all other features that might possibly be encountered in practical operation. A standard cross section of the upper structure, shown in Fig.4, is composed of PC box girder on which a levitation and propulsion rails and a signal cable are installed. Power rails are installed on both sides of the girder.

Distance:	Total - 1566m: Main Line - 1450m; Branch Line - 80m; Maintenance Yard - 36m
Level Shape:	Minimum Curvature: 100mR (main line) 25mR (branch line)
Vertical Shape:	Minimum Curvature: 1000mR (standard) 700mR (experimental) Gradient: 6% (standard), 7% (experimental)
Rail Gauge:	1700mm

1.2 VEHICLE (Fig.2)

The car size is determined chiefly by traffic density and minimum curve radius. This vehicle has two cars (MC1 & MC2) with a peak capacity of 67 passengers per car. The design speed is 110km/h. The car body is made of aluminum alloy. A car has one entrance door(plug type) on each side; however the forward car (MC1) also has a front door for evacuation. The total weight of a car is approximately 15 tons.

Six modules which generate the levitation and propulsion forces are attached to the car body. A module has 2500kg of levitation capability. Three modules are installed respectively on the left and right sides of the vehicle. A pair of left and right modules are connected to each other with anti-roll beams and, thus, forms one stable bogie. A module contains four magnets, paired in two series, below the rail and a LIM above the rail. Secondary air suspension is located on each end of the structure. (Fig.3)

Train Formation:	2 Cars / 1 Unit
Passenger Capacity:	45 including 24 seats (standard)
	67 (peak time)
Dimensions:	8.5mL x 2.6mW x 3.3mH
Weight:	Empty: 21tons/Unit, Full: 30tons/Unit
Modules:	6 Modules/Car, 2.5m Pitch
Power Supply:	1500 VDC Trolley
Train Control:	ATO & ATS
Maximum Speed:	110 km/h
Maximum Acceleration:	4.5 km/h/s (with weight compensation)
Maximum Deceleration:	4.5 km/h/s (normal, with weight compensation)
	5.3 km/h/s (emergency)

2. LEVITATION AND GUIDANCE SYSTEM (Fig.5)

The levitation system is based mainly on the same technique as that established in HSST-05; however, there are three major differences; elimination of a stagger arrangement of the magnets, double gap sensors arrangement, and phase inverted chopping of Magnet Driver.

HSST had been adopting a staggered arrangement of the magnets so as to attain lateral stability. However, because lateral motion has no adverse effect at low speeds within 100km/h, a straight arrangement of the magnets, which is more advantageous with regards to magnet efficiency and system simplicity, has been adopted.

Because an induction type gap sensor can give an erroneous signal at the rail conjunction point, two gap sensors are installed close to each other, enabling a valid sensor signal at the rail conjunction point.

Magnet driver has two-quadrant chopping system. The carrier pulse of the upper transister is located 180 degrees opposite from that of the lower transister, so as to decrease current ripple and chopping noise.

Magnet:	4 Magnets / module (2 magnets in series)
Magnetic Gap:	8mm (standard)
Coil Turn:	304 turns
Rated Current:	29A
Attractive Force:	625kg(2500kg/module) at rated current and gap

Magnet Driver:	Two-Quadrant Transister Chopper
Power source:	280VDC
Chopping Frequency:	4kHz (PWM)
Rated Current:	35A continuous

Max. Current:	110A
Controller:	Analog Input, Digital Processing, PWM Output
Power Source:	100VDC
Processing:	PID
Gap Sensor:	Eddy Current Type
Accelerometer:	Servo Type

3. PROPULSION SYSTEM (Fig.6)

The propulsion system is also based on the same technique as the HSST-05, namely linear induction motors with instantaneous spatial vector control. The propulsion system has a capability of propelling the vehicle up to 110km/h within a specified distance. A weight adaptive compensation control is employed in powering and braking modes, and a hydraulic cooperative braking control is utilized in case of weak or failed electric braking. Thus the acceleration and deceleration rate is maintained constant as far as trolly power supply is sufficient.

LIM:	3 Phases, 8 Poles, 3S2P/car
Core Dimension:	1800L x 220W x 50mmH
Pole Pitch:	202.5mm
Coil Turns:	120 turns/phase
Air Gap:	12mm nominal
Rated Thrust:	3280N
Inverter:	ISVEC PWM with Reverse Conductive GTO Thyristers
Trolley Voltage:	1500VDC
Output:	1130V, 800A max. 0-90Hz max.
Slip Frequency:	12Hz const. (adjustable)
Thrust Control:	Weight Compensated Constant Current (see above), 3 Notches/Powering, 6 Notches/Braking

4. SWITCHING SYSTEM (Fig.7)

The switching system is that of a segment type. There are three straight segments; the Main Beam is driven by electric motor and the Slave Beams are moved by the Main Beam. Each joint provides 2.3 degrees of attack angle, thus a total of 6.9 degrees can be obtained by this system. Each joint has transitional rail, which reduces rail attack angle by half. Adaptive beams at both ends ensure beam alignment against heat expansion or other disturbances.

Switching System:	Three Segmental High Speed Switch
Total Length:	31.7m
Switchig Time:	15 seconds total
Driving Device:	Induction Motor 220VAC/7.4kW equipped with Manual Override System
Crank Arm Radius:	1203mm
Locking Device:	Electric Cylinder (Main Beam and Flap Rail)

5. RESULTS OF TEST RUN

The construction of the test track was completed in May 1991 and test runs were conducted subsequently. The entire system's performance was confirmed in Sept. 1991 including full load tests. The MC2 car is designed to facilitate experimental data aquisition on which main test items are conducted. The following information is samples of the data aquired from the test runs.

5.1. Levitation Gap and Current (Fig.8)

The magnet followability and rail irregularity are so designed to ensure 100km/h cruising with gap fluctuation of less than ±4mm. The mechanical allowance is ±6mm, of which ±2mm are considered as required for various irregularity provisions. Fig.7 illustrates gap and current fluctuation during 100km/h cruising with a full cabin load. As indicated in the figure, the gap fluctuation is maintained within 4mm and its RMS average within 1mm. Magnet current is measured between 20A and 50A, higher with leading magnets and lower with trailing magnets. The gap fluctuation was also related to the rail irregularity and valuable data was aquired regarding their mutual correspondance.

5.2. Propulsion and Braking Behaviour (Fig.9)

Fig.9 displays propulsion related parameters measured from start to stop with a max. speed of 100km/h on an empty load. In normal operation, the acceleration becomes nearly 5km/h/s(0.14G, notch 3) soon after starting, and begins to decrease at 50km/h on account of voltage saturation. The vehicle speed reaches 100km/h at the 500m point. The deceleration rate was maintained at 4.8km/h/s(0.14G, notch 5, from regenerative to negative phase) in this case and the total travel of the vehicle was 900m. Hydraulic brake pressure rises just before stopping and is maintained during parking. At approximately 400m from the start, where the track proceeds downhill, the on-board accelerometer maintains constant acceleration while the velocity derivative calculation indicates a sharp increase.

BIBLIOGRAPHY

All articles listed below are contained in "11TH INTERNATIONAL CONFERENCE, MAGLEV '89"

(1) A.Ohishi: HSST-05 System General and Operational Outline at YES '89
(2) M.Iwaya: Dynamic Behaviour of the Module & Suspension system on HSST-05
(3) K.Nagata et al: Levitation Magnet Driver for HSST - by SI Thyrister
(4) I.Miyashita et al: New Modulation Method for VVVF Inverter for HSST-05

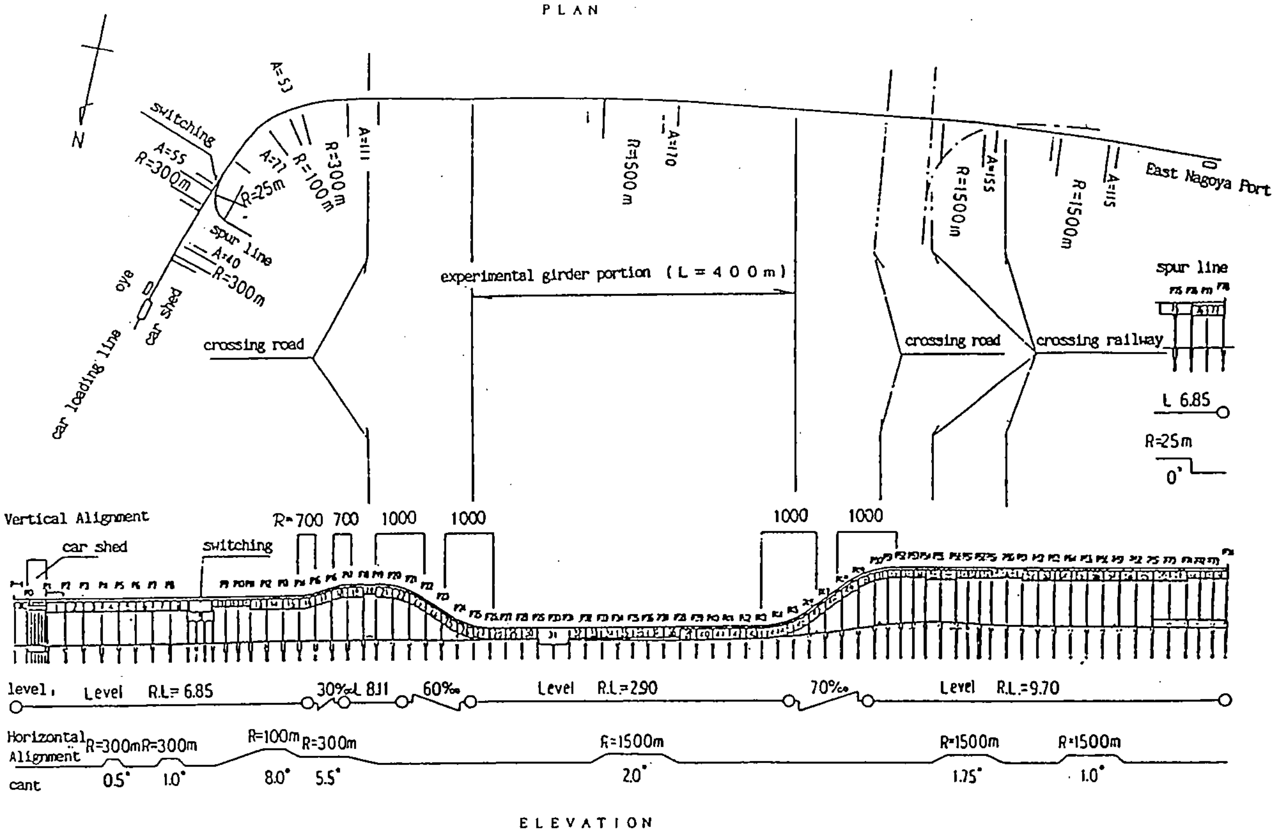

Fig.1 Test Track Profile

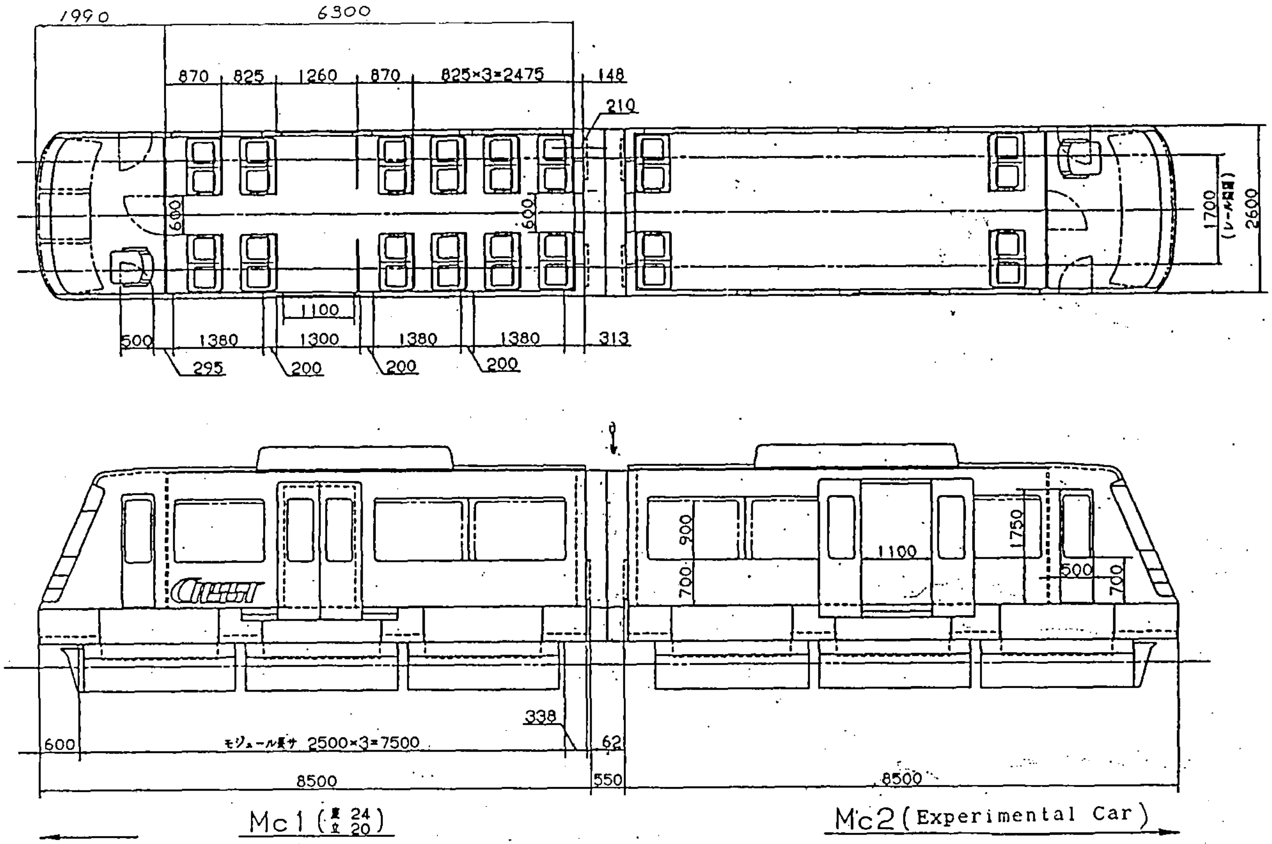

Fig.2 Vehicle Configuration

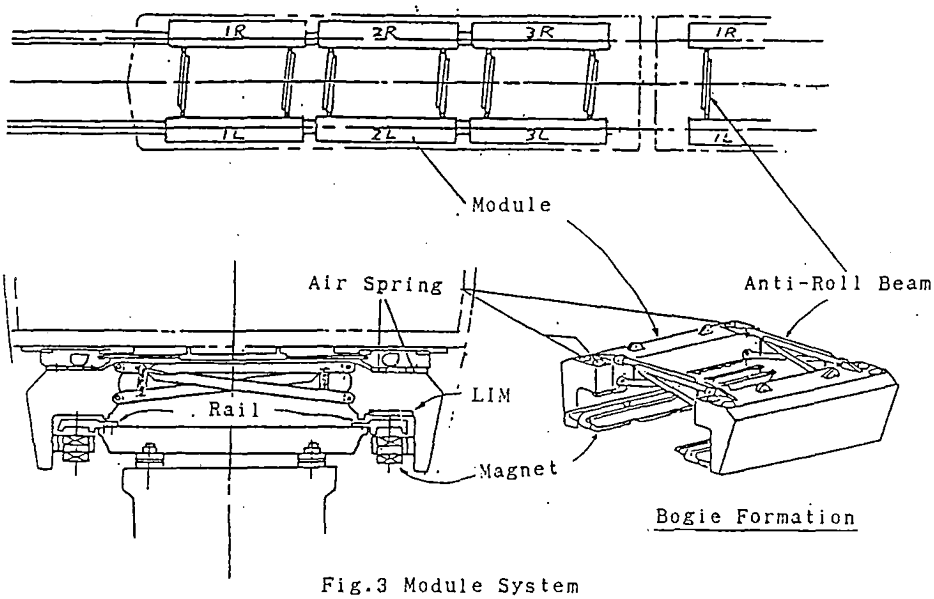

Fig.3 Module System

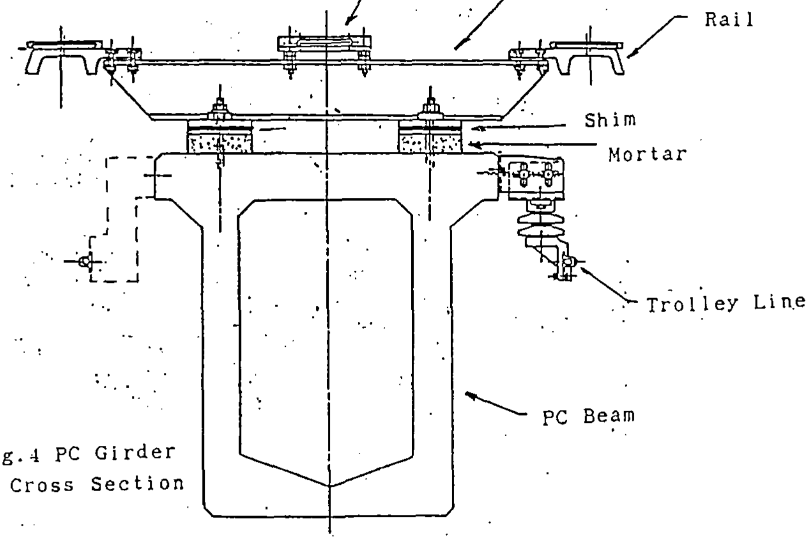

Fig.4 PC Girder Cross Section

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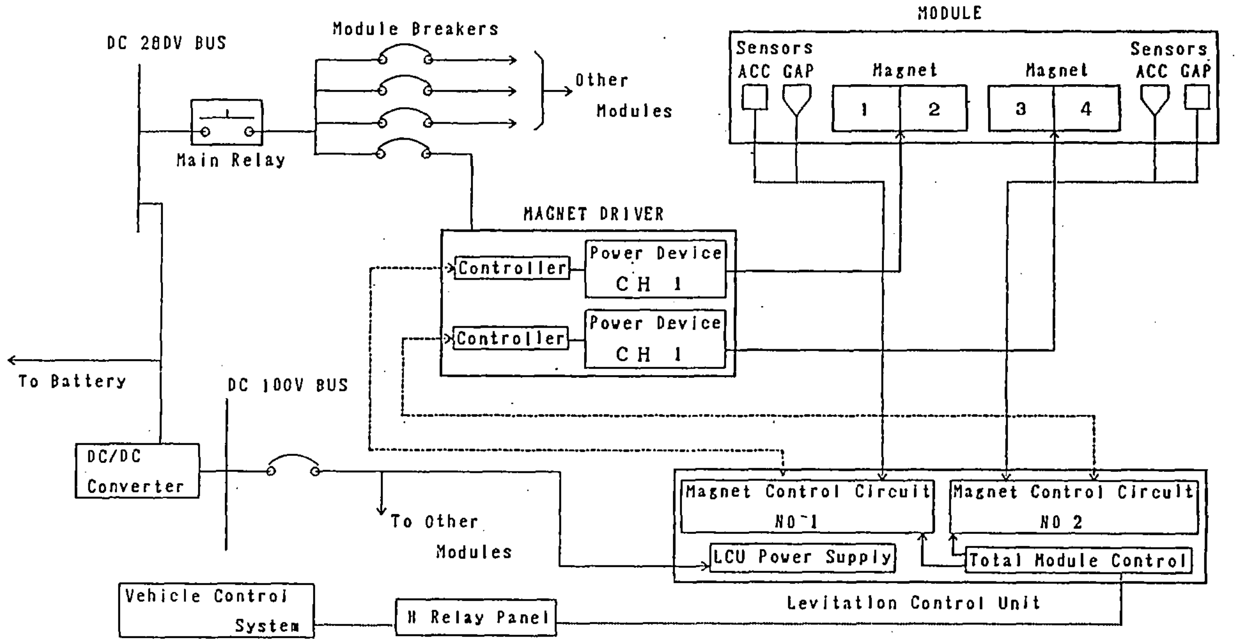

Fig.5 Levitation System Schematic Diagram

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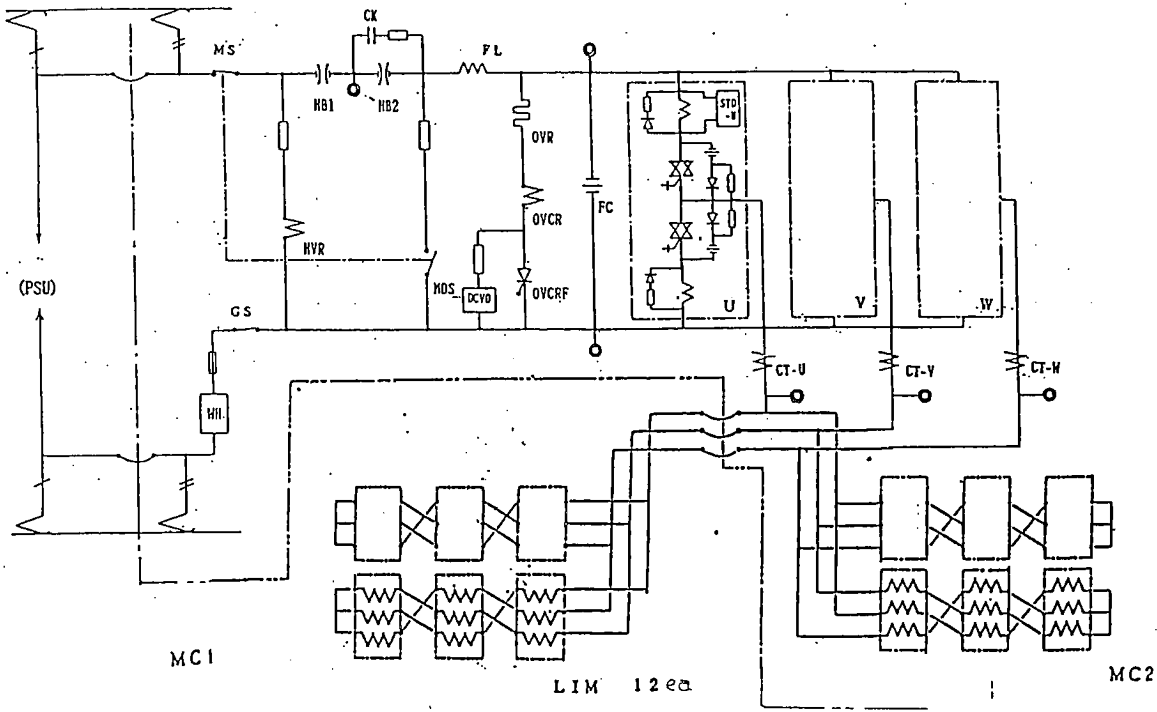

Fig.6 Propulsion Main Circuit Schematic Diagram

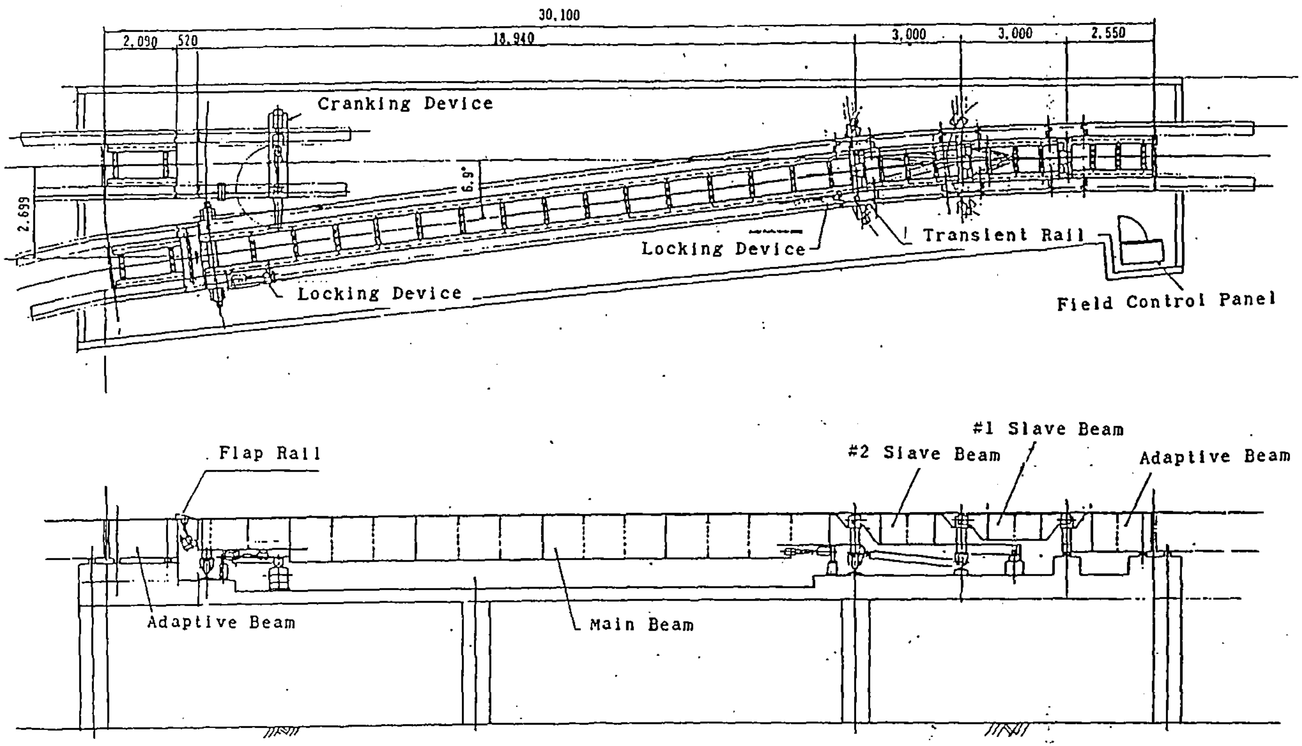

Fig.7 Switching System

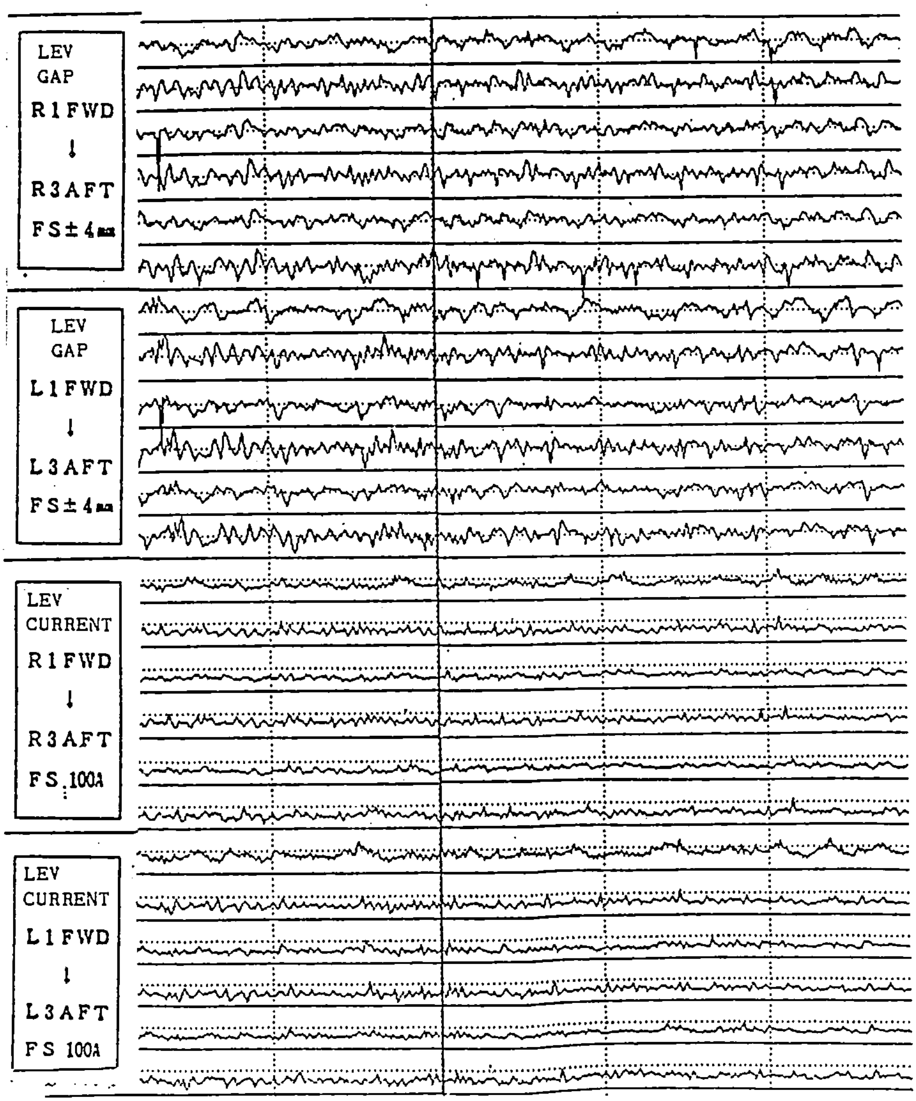

Fig.8 Magnet Gap & Current Fluctuation - 100km/h, Full Load

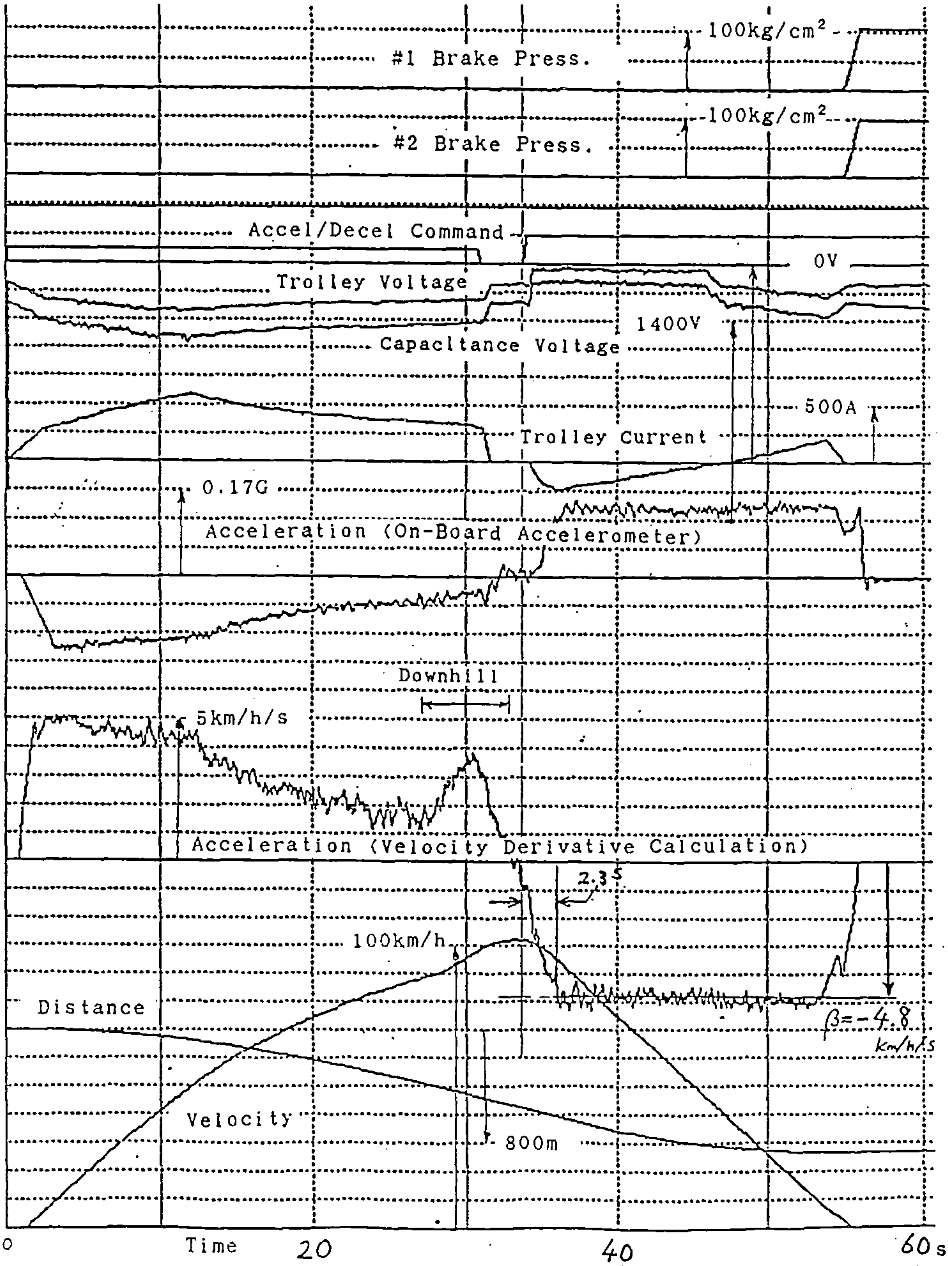

Fig.9 Propulsion & Braking Behaviour - 100km/h, Empty Load