

Automated Maintenance Robot for Expressway-tunnel

Motohisa Sato * Akira Kobayasi ** Eiji Mori ***

- * Head of Facilities Section, Research Institute, Japan Highway Public Corporation, 1-4-1 Tadao Machida city Tokyo JAPAN
- ** Deputy Head of Facilities Section, Research Institute
- *** Engineer of Facilities Section, Research Institute

Abstract : This paper presents the mechanization and automation of inside tunnel maintenance works at Japan Highway Public Corporation (JH). Firstly Maintenance-Vehicles using in Kan-etu tunnel are introduced. Then automated vehicles for tunnel maintenance are proposed. There are two types of the automated vehicles. One is an all-in one type automated equipment (fig.1) and the other is a separate type automated equipment (fig.2). The all-in one type automated equipment is used in the inspection gallery in a tunnel. The separate type automated equipment is used on the side of passing lane, narrow space by the wall, in a tunnel. And this paper discusses on the field experiment of the separate type automated equipment which is currently being tested in a tunnel.

1. Introduction

The total length of the expressway network in Japan have reached 5,900Km in 1995. As the expressway use in getting more common for Japanese and becoming important in Japanese society, expressway drivers want smooth traffic at any time. For instance, traffic regulations (lane closure), which is considered indispensable to maintenance works, often cause congestion and more travel time. To solve this problem, efforts are being made as the following points.

1. Shortening time traffic regulation
2. Maintenance work without traffic regulation
3. Countermeasures for safety works

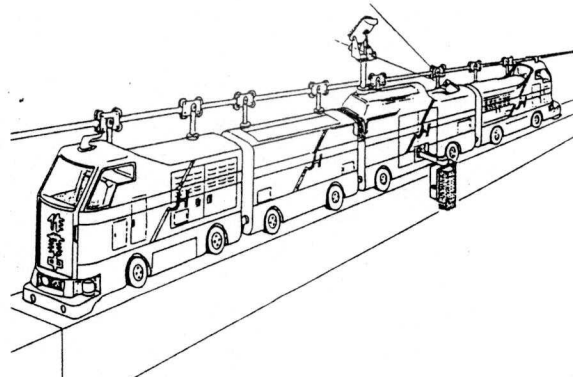


fig.1 All-in One Vehicle Type Automated Equipment

One of the answers for the question is that maintenance works should be more mechanized and automated.

2. Maintenance Works of Tunnel Facilities

2.1 Tunnel Maintenance Works

Some difficult points of tunnel maintenance works from another maintenance works on the expressway are;

- 1 .The lack of the space for maintenance works
- 2 . As a tunnel is closed to open space and traffic fume or smoke is carried into the tunnel, the sidewall and lighting luminaire easily got dirty.

This means that frequent maintenance works are required for tunnels, especial for long tunnels. Maintenance works inside a tunnel include inspection of various facilities, tunnel sidewalls cleaning and other works.

We chose next three works, which is less difficult for mechanizations, as subjects to pursue automated works.

- 1 . Tunnel sidewall cleaning.
- 2 . Tunnel luminaire cleaning
- 3 . Tunnel luminaire exchange.

2.2 The Mechanization of Maintenance Works

2.2.1 Tunnel Sidewalls and Lightings Cleaning

Tunnel sidewalls and Luminaire are washed by multi-purpose vehicle with brush attachment on the rear bed (photo.1). The vehicle has been used widely in Japan. The vehicle made the works more efficient and safer than the conventional cleaning works by men. But the shortcoming is that the works has to be performed with traffic regulations and many operators who have to work under

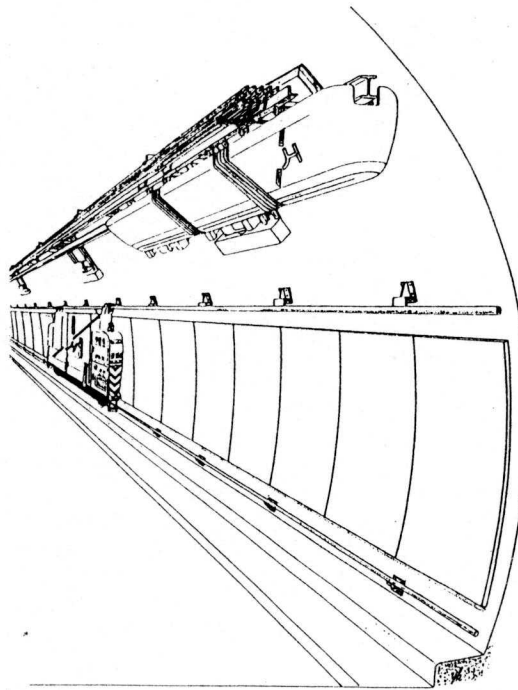


fig.2 Separate Type
Automated Equipment

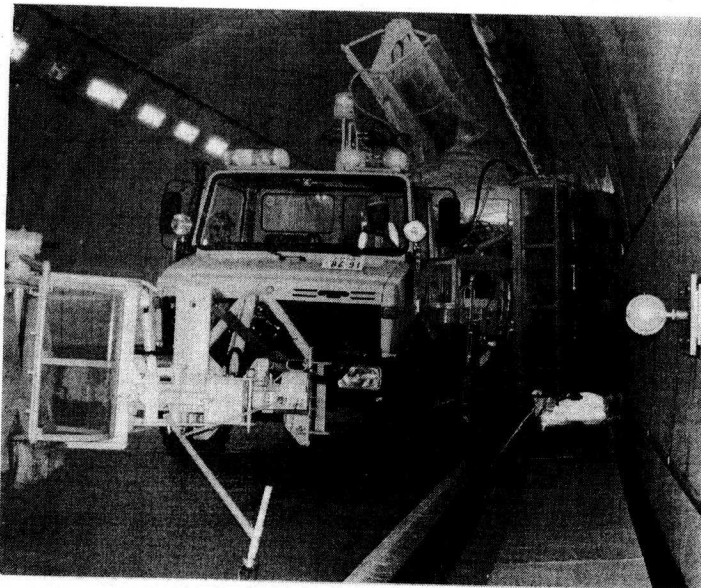


photo.1 Multi-Purpose Vehicle

dusty condition (fig.3).

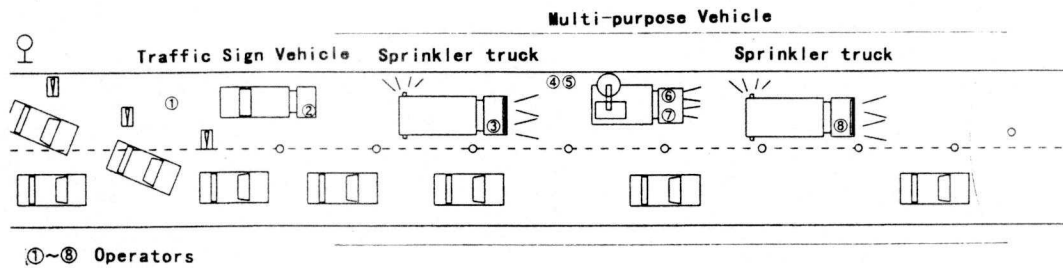


fig.3 The Formation of Tunnel Sidewall Cleaning

2.2.2 Traffic Regulation

The road work in the traffic regulated area accompanies danger, especially the works on passing laneside. It is necessary that these works be more efficient and safe. The effort has been made to mechanize the traffic regulations, and we also developed the automated cone setting vehicle for traffic regulations.

2.2.3 Kan-etu Maintenance Vehicle

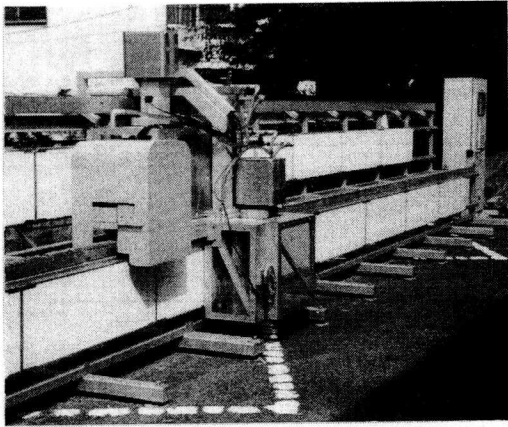
In 1985 Kan-etu tunnel maintenance vehicle (photo.2) was developed for maintenance works and inspections which were for tunnel sidewalls and luminaire cleaning in Kan-etu Tunnel. Because of the length of Kan-etu tunnel, 10,855m, an automated maintenance vehicle was specially needed. Kan-etu tunnel maintenance vehicle made the operations possible without traffic regulations, increasing a cleaning frequency in proper period, and requiring less workers. Thanks to the vehicle, the condition of the tunnel sidewalls and lightings are kept clean. With the experiences of maintenance works using the vehicle in nine years, we have found several points to be improved, listed below.

1. Some areas of the wall cannot be cleaned.
2. It accompanied dusty condition to the operators.

We thought that these points should be improved to a future development.



photo.2 Kan-etu Maintenance Vehicle



3. The Primlinary Research

3.1 Research of Tunnel Sidewall Cleaning

As the development of compact machines, we examined on the experimental equipment (photo.3) in Research Institute, we were able to find efficient methods of cleaning.

3.2 Research on Tunnel Lighting Lamp Change

Low pressure or high pressure sodium lamps are placed for tunnel lightings. Since the lamps are used in the luminaire and are not easy for a robot to handle, we have developed "exchangeable luminaire" which is much lighter and easy to handle even for a robot. Photo4 shows the exchangeable luminaire and it is test robot to develop the luminaire(photo.5).

4 Automated Maintenance Robots produced by Research Institute

There are two types of automated equipments developed by Research Institute. One is all-in one vehicle type automated equipment (fig.1) and the other is separate type automated equipment (fig.2). All-in one vehicle type automated equipment is for inspection gallery in a tunnel. Separate type automated equipment is for the narrow space by the wall on the side of the passing lane in a tunnel.

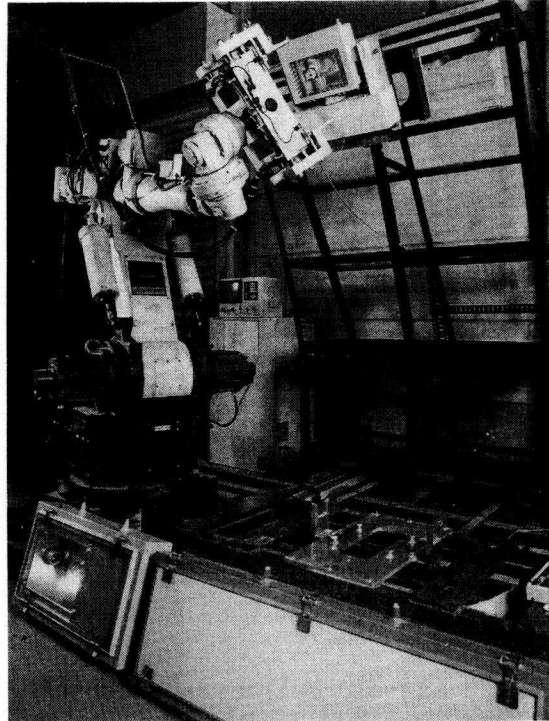


photo. 4 The Test Robot to Development The Luminaire

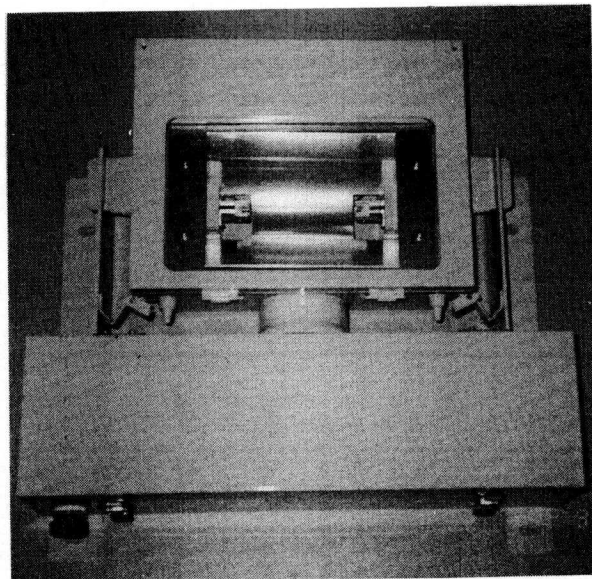


photo. 5 Development of An Exchangeable Luminaire

4.2 All-in One Vehicle Type Automated Equipment

This type is developed on the basis of Kan-etu tunnel maintenance vehicle and the preliminary research (fig.4). The equipment moves on the inspection gallery along a guide-rail with various attachments selectively connected, the equipment can be used for cleaning and inspection.

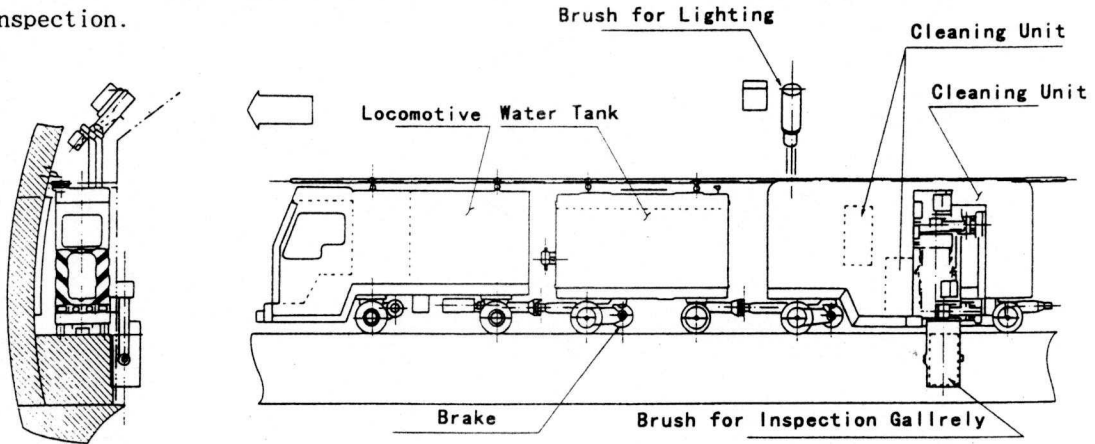


fig.4 All-in One Vehicle Type Automated Equipment

4.3 Separate Type Automated Equipment

This type have been developed for the narrow working space, as a automated robots (fig.5), separated into two parts as the kind of the work. One is for the upper part, the automated robot for tunnel luminaire exchange and cleaning. The other is for lower part, the automated robot for tunnel sidewall cleaning. We are making field experiment of the equipment.

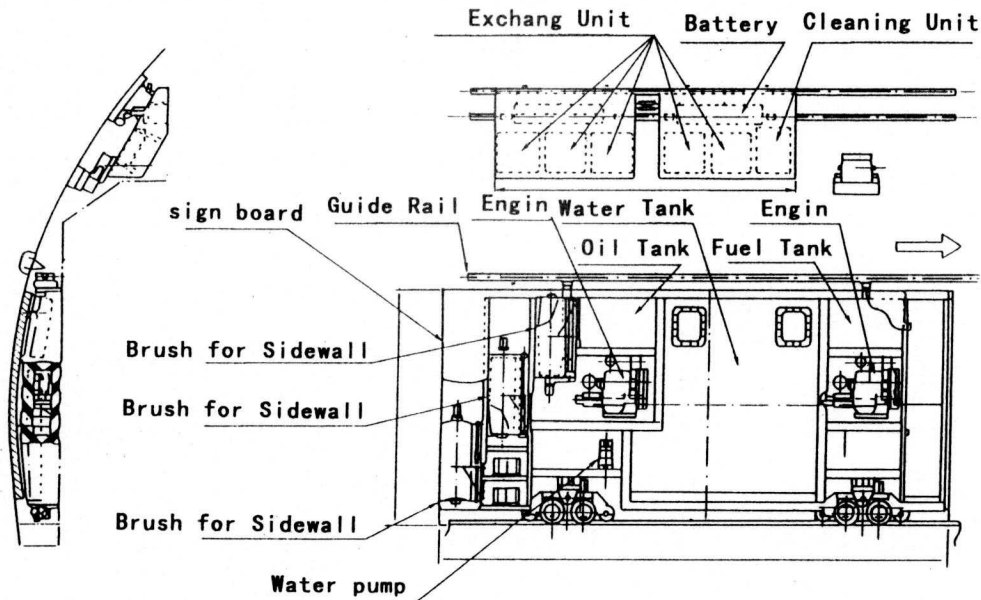


fig.5 Separate Type Automated Equipment

5 Field Test of The Separate Type Automated Equipment

5.1 Purpose of The Test

Installation of the guide rail, like the distance between the rail and the lighting luminaire, has to be very precise, because the error of the installment many cause some trouble changing the luminaries for the robot.

5.2 Out Line of The Field Test (fig. 6)

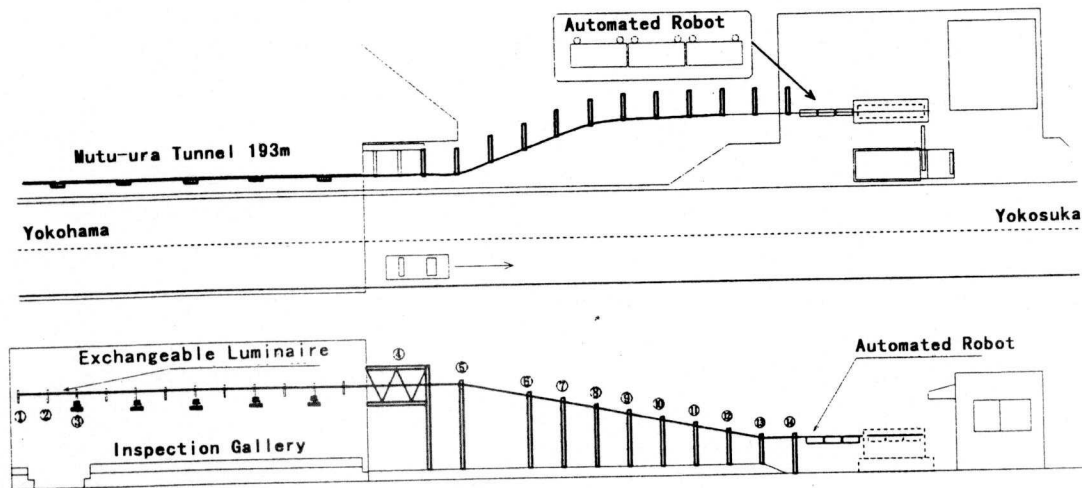


fig. 6 Out Line of The Field Test

5.3 Guide Rail

For automated maintenance robots, the guide rail is very important in terms of precise installation and cost. As a result, the tie using type guide rail (photo.6) is used as the following reasons.

1. The luminaires are placed quite precisely
2. It is easier to install in the existing tunnels.
3. It is less expensive because it is used in many other fields.

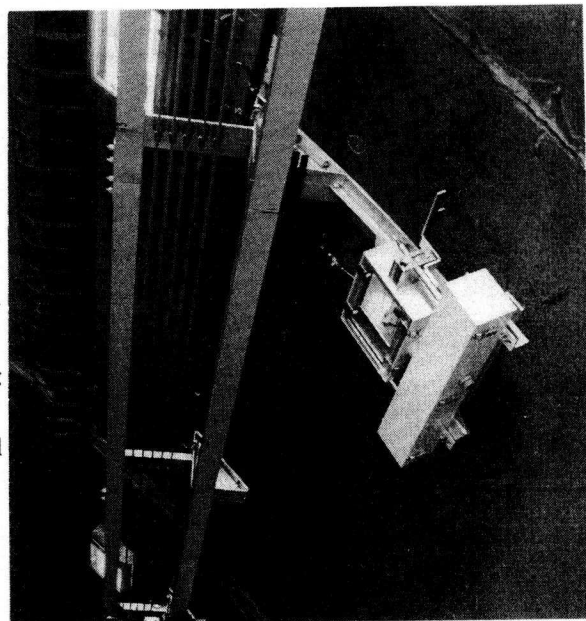


photo. 6 The Tie Using type Guide Rail

5.4 Power (photo.7)

The power supply to the robot has to be carefully chosen because of the cost and importance to the robot system reliability. The trolley system is considered to be reliable, compact, and suitable for remote control.

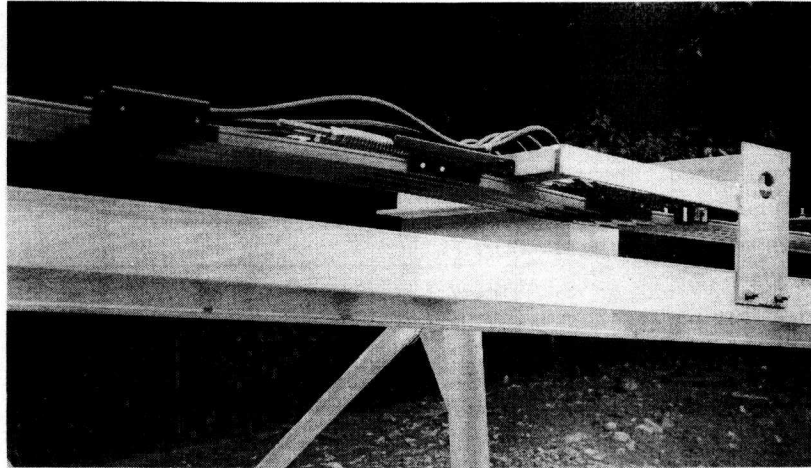


Photo. 7 Trolley

5.5 Automated Luminaire Exchange Robots (photo.8,9)

The composition of automated equipments is made up of one electric locomotive and two luminaire exchange robots. The compactness is an important factor since the available space for the robot is very limited (the clearance of a tunnel is determined by the Road Structure Ordinance).

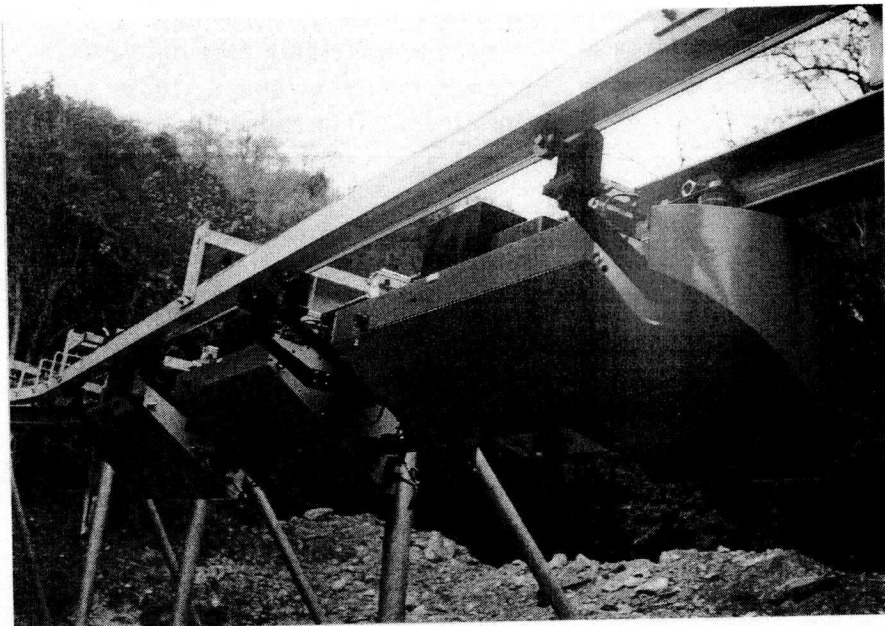


Photo. 8 Automated Lightings Exchange Robot

5.6 Results of The Field Test

It was confirmed that the tie using type guide rail showed good result for the precise measurement and construction. But the devices on these equipments may need a countermeasure to the vibration, when the speed is increased more (90m/min for field test). However it is necessary to confirm how much the error will be as it is used. We must make further effort to the guide rail and the trolley in terms of cost, then decide the standard design. The cleaning robot for luminaire, which composes another robot of the formation, will be tested in-site next year.

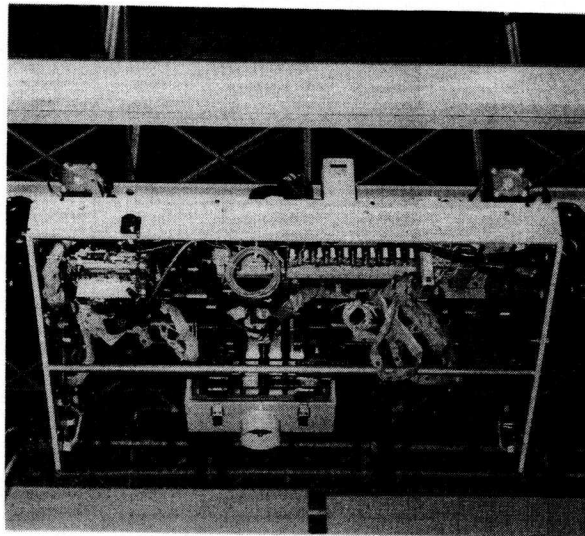


Photo. 9 Exchange Unit

6. Conclusion

We have introduced our recent development in robot in the field of expressway tunnel maintenance. The number of tunnels are expected to increase continuously and the importance of the automation will become much more. The research and development has to be continued to answer the needs.