JR East has developed a new five-year safety plan—2013 Safety Vision—that starts this fiscal year. In this plan, we will focus on two new points: “human resource development and improvement of systems related to safety” and “accident prevention through risk evaluation”. The Safety Research Laboratory formed a maintenance work study team in September 1993 and started studies on the prevention of accidents involving contact with vehicles with an aim of improving maintenance work safety. Then, in 1997, we started research on maintenance work safety in liaison with the maintenance work safety system study team formed at the head office with the 14th head office safety review in fiscal 1996. In this article, I will introduce the technical development for safe maintenance work that the Safety Research Laboratory has carried out from the beginning to actual introduction of technologies.

Many safety-related efforts have been carried out at JR East. Some major efforts include the Challenge Safety Campaign and the safety reviews since the formation of the company and the five-year safety plans that have been formulated successively since fiscal 1989.

For maintenance work safety, a maintenance work safety system study team was formed at the headquarters in February 1997 based on the results of the 14th head office safety review in 1996. After the discussions shown in Fig. 2, we have decided to proceed with studies in four working groups.

We submitted the results of working group studies to the branch office manager meeting on January 21, 1998. That meeting clearly stated details of the technical development to be addressed by the head office.

In this article, I will introduce the history for safe maintenance work that the Safety Research Laboratory has carried out from the beginning to actual introduction of technologies.
The policy of “Promoting Priority Deployment Plans for Safety Equipment”, one of the four pillars of the 2013 Safety Vision, includes systematization of track closing procedures as an issue to be continuously enhanced and expanded. That policy further specifies the development of a new train approach alarm (not using track circuits) as an issue to be dealt with.

Still, in light of collision of maintenance cars on other JR company Shinkansen lines, we have started technical development to prevent such collisions in the second half of 1999.

As an effort in maintenance work safety, we have set up a cross-group maintenance work study team in September 1993 to conduct research in prevention of accidents by contact with trains.

3.1 Maintenance Work Safety on Conventional Lines

The following are the results of the current maintenance work survey and past accident analysis that the Safety Research Laboratory obtained in research of maintenance work safety since 1997.

1) Some accidents were caused by painstaking communication and arrangements in the track closing work procedures.
2) It is painstaking to prepare a track closing request to identify the last train before closing the track in the train timetable under control of individual depots.
3) It is easy for human errors to occur in the preparation of the track closing request and the fax or telephone communication at the beginning and end of actual track closing.

We thus recommended that taking measures to reduce human errors would be effective in reducing accidents. This is done by getting away from the job pattern relying mainly on communication and arrangement, systematizing jobs from the planning stage as much as possible.

In light of those recommendations and the development items clarified in the previously mentioned branch office manager meeting, we started work on technical development to build a new track closing system in fiscal 1998.

3.2 Maintenance Work Safety for the Shinkansen

In the Shinkansen system, the running time slots for train operation and the work time slots for maintenance work are clearly separated. Still, in light of collision of maintenance cars on other JR company Shinkansen lines, we have started technical development to prevent such collisions in the second half of 1999.

The maintenance car collision prevention system has been introduced as the Shinkansen maintenance work safety system that combines wayside track closing transmitters and portable receivers for maintenance staff.

4 Building a New Track Closing System

The functions shown in Fig. 4 make up the new track closing system. In that, train operation and maintenance are separated, the work section is protected by signals, and painstaking track closing procedures for work are systematized. The functions are outlined below.

4.1 Track Closing Procedure Support Function

Request of track closing had been made with preparing the work plan which relied on human attentiveness. To prepare the work plan, train numbers and other information had to be manually extracted from the basic train timetables managed by individual depots. We thus developed a function to display the train timetable data of the IROS (Integrated Railway Operation System) that was used for purposes such as the train watch timetable and enable inputting to the system of the work plan on that display by clicking with a mouse, as shown in Fig. 5.

4.2 Function That Allows Train Operation Status to be Identified On-site

At the time, the rule was that workers on-site would make a phone call to the dispatcher to check information such as the last train before closing the track at the passing of the third-to-last train. In order to simplify the check process, we have built a system where the person in charge on-site can see from the TID information on the display of the mobile terminal information such as the number of the train currently passing. TID is line occupation information of trains displayed on the monitor of the station, for example, in which station yard or between which stations the train is located. Fig. 6 shows the display screen of the mobile terminal with this function.
4.3 Function to Prevent Entry of Trains to the Work Section
As a method to prevent entry of trains to the maintenance work section, we studied a method to make block signals display the stop aspect using remote controllers. While that was technically possible, we determined that it was not practical to add new equipment to signaling facilities that were operating stably. Instead, we concluded that adopting a new rail clamp shunt already used on some lines that didn't make the crossing warning sound would be effective.

4.4 Function to Request Work Start Approval and Report Completion
The work start approval request by phone required repetition of the request details both by the dispatcher and the person in charge of track closing. Persons involved make efforts to avoid communication errors, but there is a limit to arrangement by phone. Thus, we have developed a system where maintenance staff can make routing of the maintenance car at the mobile terminal independently instead of via the dispatcher. That is done to prevent mistakes in arrangement of routing requests and in routing.

5.1 Sections Protected by Stop Signals
We developed the routing function learning from the maintenance work management system of COSMOS (COmputerized Safety, Maintenance, and Operation systems of Shinkansen). In that system, maintenance staff can make routing of the maintenance car independently using the mobile terminal (handy terminal) within the work time slot separated from the train operation time. Thus, we have limited the scope of the routing that maintenance staff is allowed to set to within an area between multiple stations protected stop signals (system work time slot).

5.2 Connection to the CTC Central Unit
In order to make routing of maintenance cars using mobile terminals, we developed a function in this system to connect the maintenance control server for routing to the CTC (Centralized Traffic Control) central unit and operate turnouts with mobile terminals on-site. This system even prevents starting the work unless the track closing levers in the work area are activated to protect the work section by stop signals. It further has the function to forcibly disconnect the hardware on the routing function side in case of incidents such as mechanical failure of those. That way, train operation will not be obstructed.

5.3 Visual Routing Input
Routing of maintenance cars is made by operating route levers on the mobile terminals. Thus routing is limited in this system also to the routes under control of the dispatcher. This system displays the yard track layout on the maintenance terminal to be used for routing. In that situation, we developed a system where maintenance staff can make routing of the maintenance car at the mobile terminal. That way, train operation will not be obstructed.

5. Development of a Routing Function
We conducted field tests on the Chuo East and Shinonoi lines of the Nagano branch office for the above-mentioned functions which make up the new track closing system as a track closing procedure support system. Then, that system was put into actual use at the end of fiscal 2004 after trial use from the end of fiscal 2001.

Arrangements by phone were eliminated from start and finish of work with track closing during the trial period. But, when using a maintenance car, the painstaking procedure still remained where the dispatcher had to make routing for each route the car traveled. In light of that situation, we developed a system where maintenance staff can make routing of the maintenance car at the mobile terminal independently instead of via the dispatcher. That is done to prevent mistakes in arrangement of routing requests and in routing.
5.4 Route Conflict Check Function

Since this system operates route levers for routing, it has a route conflict check function in addition to the existing work location and time conflict check function. The system checks for route conflict on route sections from the current route section to the second route ahead to ensure the availability of the planned route of the maintenance car. It also has a function to display a warning in the dispatcher’s office in case a set-off device is used before approval of use. This function uses short circuit information of track circuits.

6 Introduction and Deployment of the New Track Closing System

We developed the track closing procedures support system (with maintenance car routing function) as the total system to achieve the aforementioned new track closing system. That system was being tested on the Shinonoi line from February 2005 and put into actual use in April 2006. With an aim of deploying that system to line sections under CTC, we have organized briefings in fiscal 2008 with branch offices along with the department in charge of at the head office. In the future, we will address technical development and actual introduction of that. Such development and introduction subjects include the safety system for work sections on double track lines that have more incidences of work done and the safety system for cases where track closing between stations is temporarily cancelled while a maintenance car is waiting on the common passing track of a station.

7 Development of the Shinkansen Maintenance Work Safety System

Since opening of the lines, maintenance cars for Tohoku and Joetsu Shinkansen have been equipped with a maintenance car approach alarm to prevent collision. But, as that alarm is activated when it receives signals of other maintenance cars, it would not work at a constant distance. Operators of maintenance cars thus distrusted the alarm. In light of such a situation, we developed a new collision prevention system. That system checks the positions of maintenance cars and gives an alarm when the interval between maintenance cars becomes shorter than a specified distance according to the running speed. It further automatically operates emergency brakes to prevent a collision if the operator does not apply the brakes within a certain time even after the alarm and the running speed of the cars does not decrease.

7.1 Achievement of a Train Position Detection Function

The essential position detection method of this system is, as shown in Fig. 8, a method of combining position correction with speed pulse and ground coils. This system is used in the automatic operation system of the new confirmation cars that the Safety Research Laboratory developed.

7.2 Development of a Trailing-Point Movement Prevention Function

The collision prevention function we developed has been introduced to all Shinkansen maintenance cars by fiscal 2003. However, checking the direction in which turnouts are open in in-station shunting work still relies on human attention, so the possibility of trailing-point movement leading to derailment remains. We thus started development since fiscal 2005 of a Shinkansen maintenance safety system (with the trailing-point movement prevention function) that prevents trailing point movement to further increase safety.

The system imports routing information from handy terminals of COSMOS, and it determines how far the maintenance car can proceed based on the line database including turnout positions and kilometerage. If a maintenance car attempts to enter a non-approved area, the system outputs an alarm and braking signal to stop the car. As shown in Fig. 9, the area that can be entered in the yard track layout is displayed on the cab monitor.

Visually displaying on the cab monitor creates a man-machine interface based on the concept that increasing visual information for the operator prevents human errors. That is the same as the concept of the track closing procedure support system.

The system with point movement prevention function added has been introduced to all Shinkansen maintenance cars at the end of fiscal 2006.

8 Future Issues

As a future effort for achieving maintenance work safety, we will assess the latest technical trends while making full use of component technologies and man-machine interfaces that we already developed as the core of various systems. We will also make efforts in research and technical development such as...

- Development of a train approach alarm for sections without track circuits
- Development of a track closing procedures support system for double track lines
- Development of a new track closer for the Shinkansen maintenance safety system