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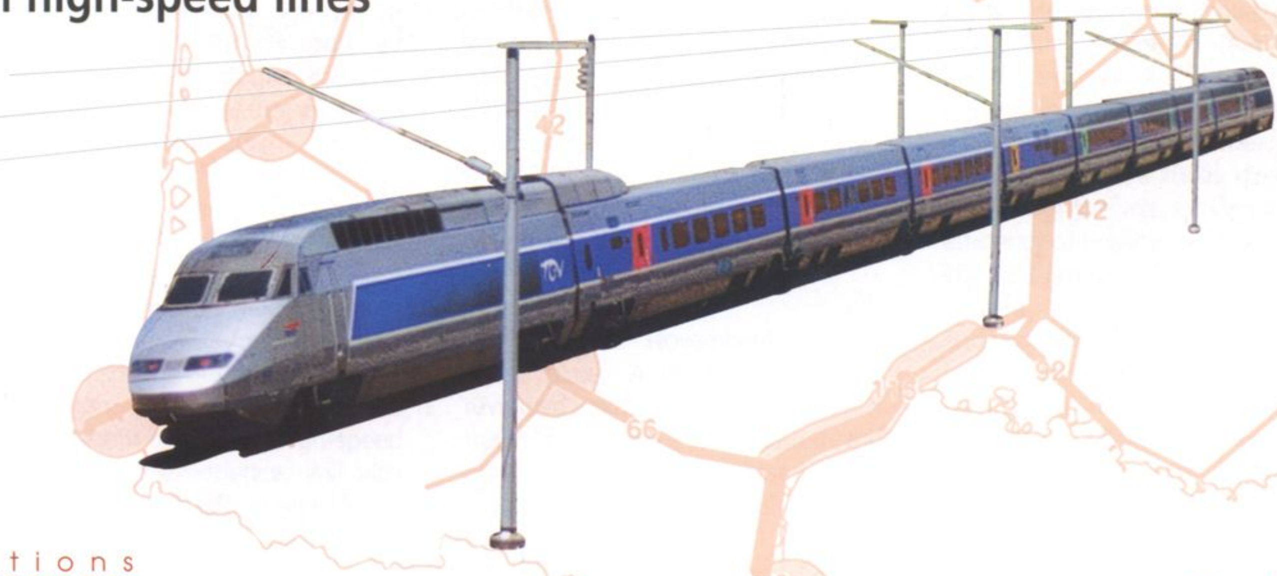
Infrastructure maintenance
on high-speed lines



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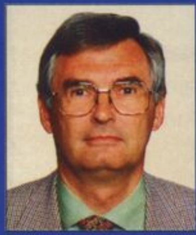

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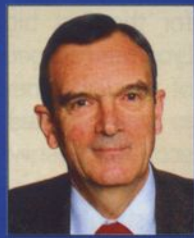

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Introduction
Jean-Pierre DERMENGHEM

Every single high-speed line project has always been seized upon as a golden opportunity to incorporate state-of-the-art technological developments into the design of railway fixed plant and its maintenance. With the recently-launched TGV-Méditerranée, which is no exception to this rule, a new forward leap has been taken particularly in the field of signalling, with the massive injection of computer-aided systems already set-in-train on the TGV North-Europe route, or again with the advent of spearhead systems such as detectors of cross-winds or earth tremors.

The OHL equipment installed on the Valence-Marseille line section also represents a quantum technological leap, having been built to ensure optimum current-collection quality at speeds of up to 350 km/h. Its design, incorporating lessons learned from 20 years' high-speed rail operating experience, will also guarantee top performance levels over the years thanks to a reduction in mechanical stresses resulting from higher voltages in the carrier and contact wire. In its April 2001 special issue dedicated to electric power supply the *Revue Générale des Chemins de Fer* (*RGCF*) had abundantly covered this new catenary design and maintenance-related developments.

However, over and above the launch of operations on the new line between Valence and Marseille, the service-commissioning of the Mediterranean TGV has also generated a large traffic increase on the Paris-Lyon segment, made possible by headways reduced from 5 to 4 minutes and revenue speeds increased from 270 to 300 km/h. These developments, on a line already 20 years old, represent a daunting challenge for maintenance staff.

In the *RGCF* November/December 1996 issue, Alain Le Bihan had reviewed experience gained with track maintenance and stated the reasons why first-time ballast renewal was necessary. The considerations that follow supplement his arguments and highlight the key developments imposed by higher traffic volumes in terms of infrastructure maintenance and track-geometry retention.

Higher traffic density also means that the least incident generally impacts upon a large number of TGV services. As a consequence of this fact, combined with customers' increased emphasis on train punctuality, SNCF has been forced into improving the reliability of the different permanent-way components. However this improvement, significant though it may be, is insufficient in itself particularly bearing in mind that a number of incidents are of external origin. Whence the extra focus directed at improving the responsiveness and efficiency of breakdown-repair teams. The text prepared by François Vilette entitled "Maintenance of Electrical and Signalling Plant on High-Speed Lines", describes the organisation set in place for the maintenance of electrical installations, as well as the measures taken to meet these different concerns.

Track maintenance: facts and developments

André LE BIHAN

(Photo SNCF/CAV P. Olivain)

Fig. 1 - A track conventional in appearance but with exceptional geometrical features

After twenty years' high-speed rail operation, the track system adopted for the first high-speed line (Paris-Lyon) and subsequently used for each of the other new lines, can be said to have passed the technical and economic test with flying colours.

It should be recalled here that the constitution of the plain track is in the final analysis fairly similar to that of any other state-of-the-art conventional line and that this ballasted-track concept, incorporating relatively flexible track panels, has proved to be extremely well suited to the dynamic loads generated by high speeds, while guaranteeing optimum transversal stability (see Figure 1). This has translated into trouble-free working at revenue speeds of 300 km/h on the TGV Atlantique route since its opening (1989) besides enabling operating speeds on the Paris-Lyon route to be raised from 270 to 300 km/h in June 2001.

All the same, various technological refinements have proved to be desirable. They were explained in detail in an earlier *RGCF* issue (November /December 1996) and are therefore summarily listed below solely for the record:

- points and crossings on concrete sleeper, with welded single-cradle switch diamond;
- cradle-free expansion mechanisms for engineering structures;
- rails made from "naturally hard" steel grades with extremely stringent geometrical features;
- ballast with extremely-enhanced mechanical characteristics.

For all these constituents, stringent new specifications were drawn up, and these were subsequently recycled on several occasions into a higher-quality class as stipulated in draft European Standards, so contributing to progress in the development of industrial processes for the manufacture of track-related equipment.

Yet these technological refinements are not sufficient in themselves. The true challenge is to ensure routine "customised" maintenance guaranteeing a high standard of technical safety and comfort as cost-effectively as possible. Experience acquired, quite apart from making it possible to validate initially-defined track-maintenance policy and methodologies, has also facilitated their development (article in *RGCF* November/December 1996 issue).

In fact these developments are an ongoing process because they are the product of permanent experience feedback made easier by close interaction between the Maintenance-Development Division (of the Infrastructure Department) which is charged with framing rules and specifications, and the operational units dedicated to the maintenance of high-speed lines.

More importantly, these developments are needed if only because operating strains and constraints are becoming ever more acute commensurately with the growing commercial success of this high-speed network. The table given in Figure 2 explicitly illustrates this growth pattern.

Three examples of ongoing adaptations in the field of track maintenance are given below.

Mechanical tamping and lining

The document published in the November/December 1996 issue of *RGCF* had shown how and why mechanised track-geometry retention systems, based on deployment of state-of-the-art, medium-sized machines with high-performance characteristics in terms of functionalities and on-board computerised equipment, such as the "Level 3" tamper and multipurpose machine for high-speed lines (HSL).

These machines are primarily designed to perform lining and levelling tasks at intermittent spots or zones a few hundred metres in length, depending on short-term needs identified by local permanent way managers following monitoring

Line	1981	1982	1989	1994	2nd halfyear 2001
HSL 1 North		68	90	108	130
HSL 2 South	48	58	78	90	115
HSL 2 TC			50	55	112
HSL 3 TC				23	146
HSL 4 Satolas				18	60
HSL 5					68

Fig. 2 - Mean number of revenue runs on HSL network per day and traffic direction

or recording rounds. It was therefore quite natural for the Logistical Units serving TGV maintenance plants to acquire them.

The current fleet numbers:
• 4 HSL 3rd-level tampers;
• 6 HSL multi-purpose machines.

A new concept to have surfaced in the light of experience gained is that of maintenance optimisation through confinement of tamping only to degraded zones, with automatic calculation of any track lifting required.

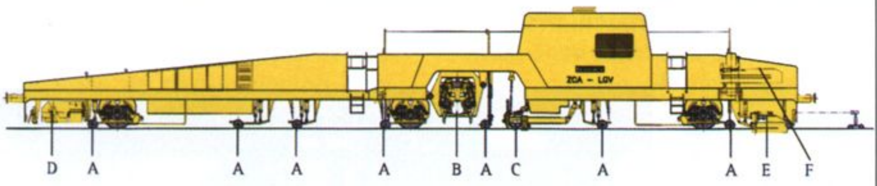
This implies:
• an initial machine pass to pre-record geometrical track parameters and screen-display the real profile;
• operator definition of the desired targeted profile;
• automatic determination of the profile to be delivered by the tamper taking into account expected sleeper pumping and ballast subsidence phenomena.

A system incorporating these features was developed by Framafer and built into a new generation of tampers (type ZC) developed by that company. A functional diagram of the ZC tamper is given in Figure 3.

Initial operations performed on the TGV-Méditerranée line in order particularly to integrate treatment of problem spots into the essential track-stabilisation phase proved to be quite convincing, hence the decision to procure one such machine for final validation as part of the HSL maintenance routine.

Anticipated benefits are not solely technical in nature. Indeed the improved ergonomics of the operator's work station and the fact that local bearing measurements in the field no longer need to be made contribute significantly towards enhanced occupational safety and work productivity.

Confinement of levelling work solely to zones requiring action, between two reference points, avoids unnecessary interference with the ballast by tamping tines and reduces maintenance costs. However there can be no question of limiting track-geometry retention to this one intervention form. More intensive tamping is needed at times and each type of tamper, including the heavy-duty model, has its particular field of pertinence. For the local permanent-way manager – with assistance from the TIMON computer-aided decision-making system – the aim is precisely to optimise the overall maintenance programme.



Tamper tools

Standard equipment

• Measuring device for recording and processing track geometry .... (A)
• Two heavy tamping units (plain line track or points and crossings) .... (B)
• Track lifting and lining unit (plain line track or points and crossings) .... (C)
• Broom .... (D)

Optional equipment

• Central ballast plough .... (E)
• Lateral track-bench profilers .... (F)

Fig. 3 - ZC tamper

Rail grinding

Rail grinding on high-speed lines first started in the early eighties, in other words even before opening of the Paris-Lyon high-speed line, the purpose of the exercise being to eliminate track-laying defects (rail-surface damage, weld imperfections, etc.). This, given the technical means then available, represented a massive challenge bearing in mind that as many as twelve grinding-train passes were required.

Quite soon after commissioning of the line, dents began to appear in the rails, caused by the crushing of ballast stones thrown onto the track with dropping ice packs in the winter time, started disturbing the track level, leading to excessive reballasting by heavy-duty mechanical tampers – levelling repairs that did not hold up well over time.

Rail grinding therefore became an absolute necessity for all track zones affected in this way. More generally speaking, the advantages of associating tamping operations with grinding operations were clearly demonstrated by a survey conducted in 1985, which showed that this method on average allowed to eliminate one tamping campaign out of two. This was to be the starting point of annual programmed grinding campaigns on the Paris-Lyon high-speed line based primarily on targeted treatment of the most affected rail sections.

In order to limit the number of ballast dent repairs made by rail surface build-up by arc-welding (a process that is proving more and more costly as daily track possession possibilities shrink), a more deliberate grinding policy was introduced in 1997, based on:

• launching a grinding campaign when the density of rail dents qualifying for repair work reached 9 per track kilometre;
• the removal of metal in the order of 3/10 mm, with complete railhead reprofiling.

The bottom line is that the number of dents needing to be repaired by welding has been appreciably reduced, and the quality of the rail/wheel contact profile has been improved.

To ensure that this policy would deliver high productivity levels, the Infrastructure Division in 1998, jointly with Speno, developed a single-pass grinding method, using two modern grinding trains with 40 grinding wheels working together (see Figures 4 and 5), at an operating speed of 5700 metres per hour, while complying with quality specifications concerning micro-roughness values, absence of grinding-wheel streaks and longitudinal and transverse profile tolerances.

These developments have made it possible to double the number of grinding campaigns at no extra cost.

A new focus area is the fight against a disturbing contact-fatigue defect involving the fillet between web and head, first observed on conventional lines but which is now an emerging phenomenon on the rails of high-speed lines, in particular the Paris-Lyon line: the "head-checking" defect illustrated in Figure 6. Increased grinding, which is designed to clean up the strain-hardened steel layer, is in this regard just as beneficial.

For all the reasons mentioned, the immediate objective of SNCF is to grind at least one third of the total length of high-speed lines every year.

Track condition monitoring

From the very outset high-speed line monitoring has been based on quite conventional concepts, with of course periodicities adapted to this new intervention field. However the sharp growth in traffic volumes has had the dual effect of increasing track loads – and therefore the need for condition monitoring – and reducing opportunities for conducting these line inspections.

This situation applies equally to line recording runs using dedicated inspection cars and to foot inspections on track.

In fact conventional recording cars can only operate at maximum speeds of 160 or 200 km/h, this restriction being imposed by the very design of the Mauzin track examination coaches and the presence of a third bogie under the car body.

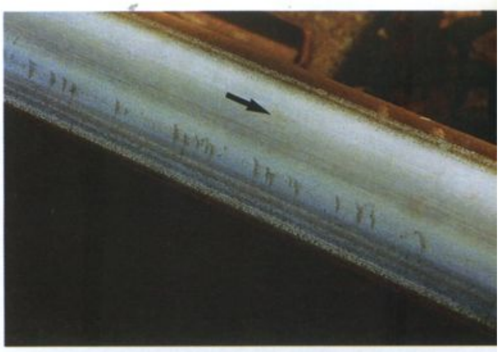


Fig. 6 - Illustration of "Head Checking" type track defects. The arrow denotes the main traffic direction

Such speed constraints are incompatible with the increasing density of revenue slots at 300 km/h, with the result that these line inspections might soon have to be conducted during track-possession periods earmarked for line maintenance, in which case they would have major adverse effects on production times.

The solution therefore consists in developing a vehicle to perform at maximum line speed and so blend into the commercial traffic pattern while conducting measurements of the features of the different sub-systems

Fig. 4 - Speno rail grinding train

Fig. 5 - Track grinding operation

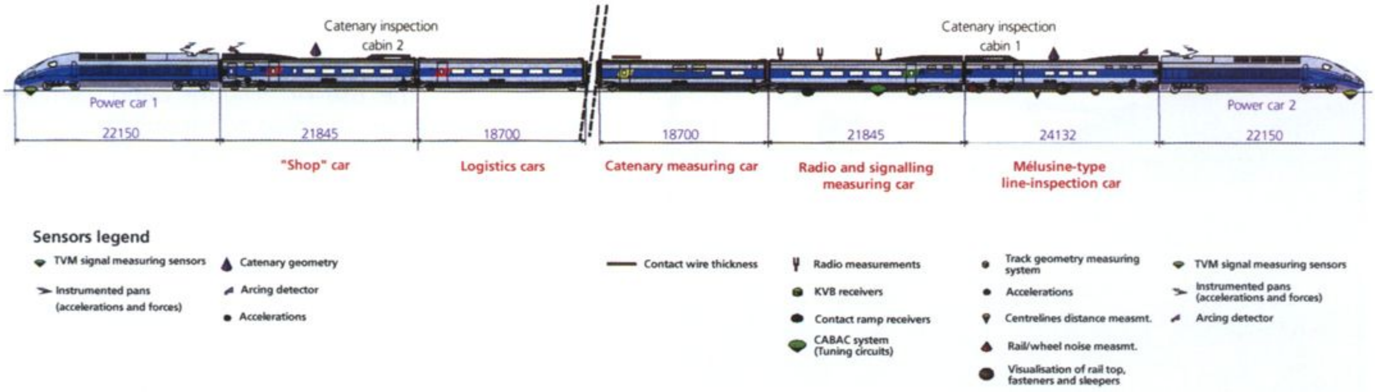


Fig. 7 - Concept of multi-current (25 kV, 50 Hz – 1.5 kV d.c. – 3 kV d.c.) high-speed measuring train

(track, OHL equipment, signalling,...). An outline diagram of this future vehicle is given in Figure 7.

This highly ambitious project, codenamed "MGV" (for "high-speed measuring", as in TGV) is currently under assessment with the launch in 2002 of an assessment and validation exercise on some measuring systems. The target is for this vehicle to be ready in time for 2006 coinciding with the opening of the future East-European high-speed line, when its importance will become even more obvious.

Where line inspections by foot patrols are concerned, two distinct scenarios have been identified:

• inspections of switches and crossings, which require excellent three-dimensional view of complex parts and assemblies (detection of early signs of dysfunctioning, incipient cracks, etc.). Daytime inspection must therefore be the preferred option, which means maintaining "windows" for periods of up to one hour's duration is an absolute necessity. However the development of remote-surveillance systems will probably enable the frequency of these inspections to be curtailed in the medium term;

• daytime inspections on plain track are proving increasingly difficult to organise within the limited time window that remains or will remain available. Other options are therefore under consideration:

- track inspection by express railcar unit with automatic capture of the characteristics of components (status of sleepers, position of fastenings, ballast profile, etc.). These in no way must be construed as "video recordings" – the viewing of which would be both fastidious and unproductive – but rather as high-performance image analyses, an application of which is already operational in the field of rail-surface defects. The "Ivoire" system, mounted on Melusine car, is designed to examine rail surfaces and perform digitised defect measurements at speeds of 300kmh (see detailed presentation in the October 2000 *RGCF* issue);

- two different prototypes of these new machine designs have been ordered and will be validated in 2002 on the conventional rail network. They could also prove pertinent in the context of the overall high-speed line monitoring process;

- line inspections using dedicated motolorries with powerful lighting equipment. Each such machine would enable a two-person team to conduct night-time inspections of track components under optimum conditions at a speed of some 4 km/h. This motolorry design also incorporates a mechanism to protect staff from traffic on adjacent track, which means the motolorry can stop at any point on the line for a localised track inspection to be carried out safety. A prototype of this machine design (see Figure 8) has been developed for testing under "real-life" conditions during 2002 with a view to its validation.

The above examples clearly show that track maintenance on high-speed lines must constantly be adapted in order to keep pace with changing needs and working conditions. The new approach, consistent with past practice in this field, is driven as ever by the constant need to uphold quality standards and ensure optimum cost-effectiveness, by capitalising on the significant technological advances made and on vital experience feedback. Ongoing projects look extremely promising and augur well for the future in this field.

Maintenance of electrical and signalling plant on high-speed lines

François VILETTE

Electrical and signalling installations on high-speed lines have experienced significant technological enhancements over the past twenty years. Indeed, recent generations of railway automatic systems boast a massive injection of computerisation, this applying to operating systems and maintenance systems alike. In the case of high-speed lines, bearing in mind their operating characteristics, the accompanying

Fig. 8 - Motolorry track inspection motor car

regularity and safety requirements and the technologies deployed to this effect, it follows that the infrastructure maintenance concept set in place must provide for optimal availability of the fixed plant at all times.

Optimal organisation of maintenance services

For each new high-speed line, the territorial (sectoral) coverage of the maintenance organisation is carefully set out to ensure that problems can be attended to quickly, since time-to-attend is an important factor in the duration of incidents.

To this end a preliminary study is conducted, factoring-in all the physical features of the particular high-speed line, such as site topography, access to/positioning of installations, and also incorporating more complex parameters such as the occurrence of incidents according to their nature, to the times of day at which they can happen, and to the deployment availability of maintenance staff during and outside their daily duty roster.

Experience gained in this field with the first few high-speed lines has been a major contributory factor in the development of an optimal solution.

In the context of the TGV-Mediterranean project, the Maintenance Development Division of the Infrastructure Department introduced for the first time simulation methods based on application of stochastic Petri networks to check the effectiveness of the different signalling-maintenance procedures along the entire Lyon-Marseille high-speed line.

The approach adopted centred on:

- describing line typologically (Figure 9);
- analysing experience feedback and determining the operational reliability levels for the different systems requiring maintenance, with characterisation of the occurrence of different possible statuses for a family of specific equipment items housed in an instrumentation centre or signal box (Figure 10);
- defining organisational scenarios and modelling them in order to characterise different situations for the benefit of maintenance teams (Figure 11);
- quantifying each option through the use of "Monte Carlo" simulations, leading to identification of a sufficient number of random events derived from previous inputs, in order to obtain results that offer an acceptable confidence interval;
- analysing results obtained (Figure 12).

This study confirmed the appropriateness of the options taken for earlier HSLs, and culminated in adoption of an organisation based on "sectors" 100km in length (maximum), with each "sector" assigned to a team positioned midpoint along the "sector" and split into two half teams sharing the workload on a geographical basis. However, the regularity targets required the introduction of remote-surveillance and monitoring systems.

Plant condition monitoring

Among the different types of maintenance-related operations, condition monitoring is playing a decisive role and becoming a more expert activity. Over and above human surveillance – which is and will always remain a key component

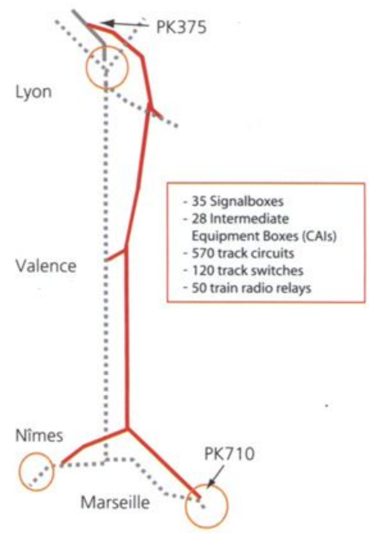
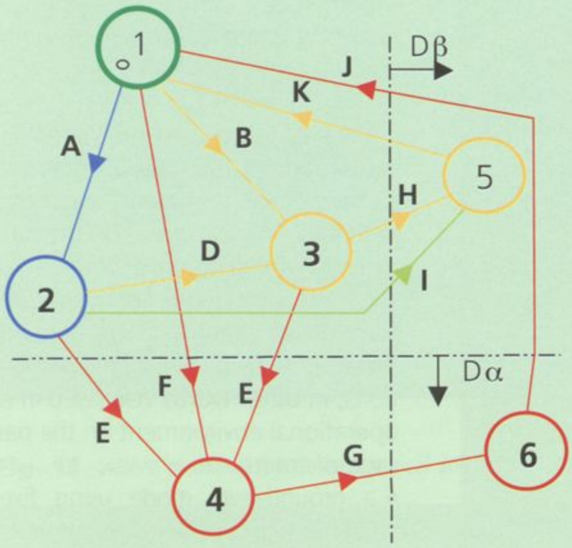


Fig. 9 - General typology of Lyon-Marseille high-speed line



With the following statuses

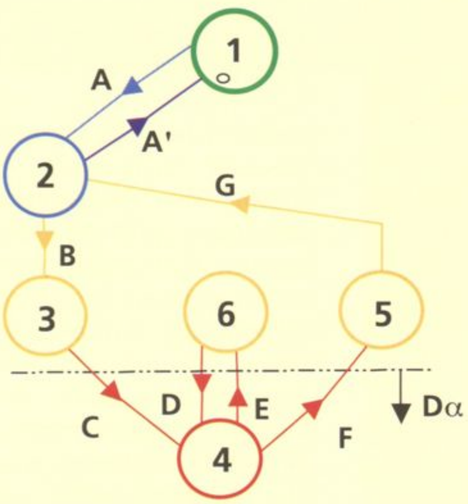
1 Nominal working status of installation ;
2 Working status of installation presenting a latent defect non-detectable by surveillance systems
3 Working status of installation presenting a defect detected by surveillance systems
4 Failure status of installation (incident)
5 Installation in preventive, conditional or systematic maintenance mode
6 Installation and post-incident corrective maintenance

and the following transitions :

A Occurrence of defect not perceptible with fixed surveillance systems [λ_{defect}*(1- P $_{DETECTED}$)]
B Occurrence of failure visible with mobile surveillance systems (maintenance run) [λ_{defect}*(1- P $_{DETECTED}$)]
C Occurrence of failure visible by operator ($\lambda_{failure}$ with $\lambda_{TOTAL} = \lambda_{failure} + \lambda_{defect}$)
D Occurrence of defect detection with a mobile surveillance system (maintenance run)
E Occurrence of failure following second defect or failure ($\lambda_{TOTAL} = \lambda_{failure} + \lambda_{defect}$)
F Failure occurrence [λ] ;
G Occurrence of arrival of a staff member to undertake corrective maintenance repair (depending on call, on staff workbase or domicile, on place of accident/incident)
H Occurrence of arrival of maintenance staff on conditional maintenance site ($\tau' = \tau_{trajet}$)
I Occurrence of arrival of cyclical-maintenance staff (annual work plan)
J Occurrence of end of corrective maintenance operation
K Occurrence of end of preventive maintenance at end of half-day concerned

Dα – Equipment state impacting on traffic
Dβ – Equipment state requiring maintenance-interception

Fig. 10 - Modelling of possible operational states of an installation



1 Team unavailable (outside daily duty roster)
2 Team available for duty rostering on the sector's maintenance platform. Preparation of the day's maintenance operations based on surveillance Information and annual work plan
3 Team on Sector - Worksite run
4 Team on work site (preventive maintenance)
5 Team on Worksite - Sector run to complete job at Sector base
6 Team during halfday break

and the following transitions

A&A' Occurrences of start and end of daily duty roster (excluding holidays and weekends)
B Occurrence of end of preparation at Sector base
C Occurrence of team arrival at preventive-maintenance base
D&E Occurrences at start and end of midday break
F Occurrence of end of preventive maintenance operation compatible with return to Sector base at end of daily duty roster
G Occurrence of team return to maintenance base

Dα – Team effectively at the side doing preventive maintenance

Fig. 11 - Modelling of the statuses of maintenance teams

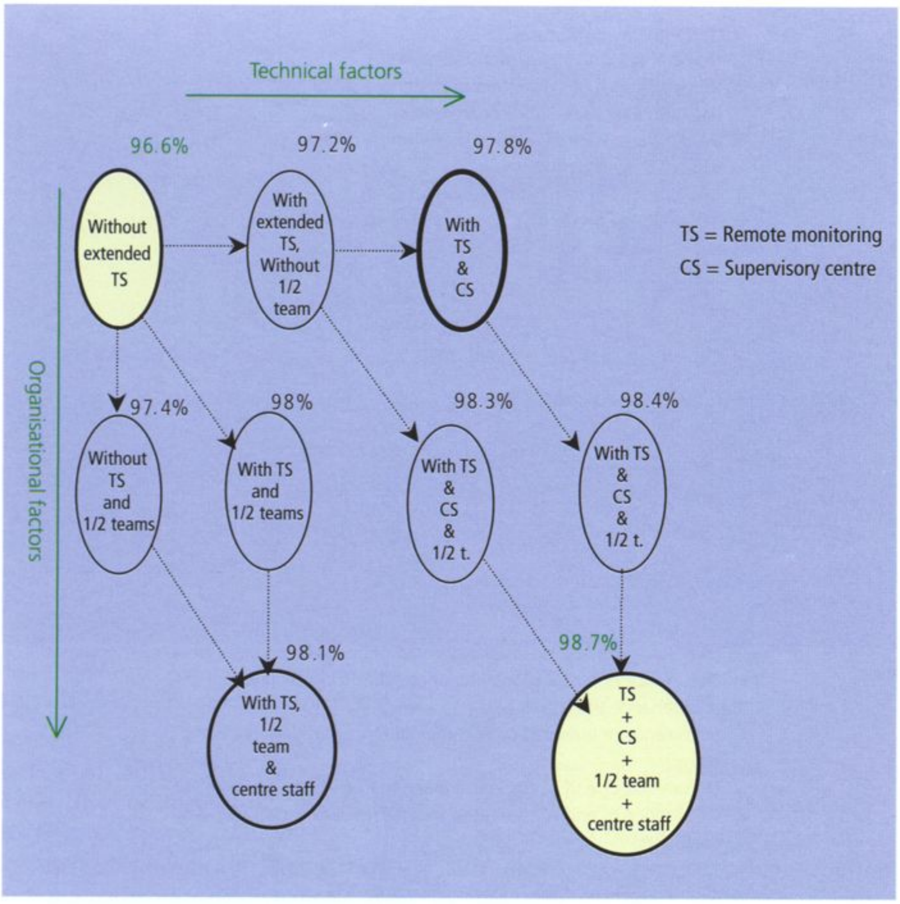


Fig. 12 - Theoretical regularity rate obtained for incidents ascribable to the infrastructure

Maintenance typologies

Maintenance must be tailored to each specific type of installations: it is influenced by the technologies implemented, failure modes and experience gained. It is designed to deliver sustainable quality standards (safety, availability, comfort,..) as demanded by the operator and customers alike.

Preventive maintenance, tailored to failures characterised by slow, gradual and detectable development, is structured around the following two types of operations:
- surveillance, whether human or automatic, involves observations and checks (working tests, measurements, etc.) ;
- programmed interventions based in particular on the outcome of surveillance, includes maintenance operations, readjustments, reconditioning work and preventive replacement of degraded or obsolete equipment.

These operations are:
- systematic when triggered according to a pre-ordained calendar ;
- conditional when triggered as from attainment of thresholds, modifications in status, or changes in climatic conditions ;
- predictive when they derive from an analysis of parameters representing degradation phenomena, depending on their development over time.

Corrective maintenance is frequently better adapted to so-called "catalectic" (catastrophic) failures that occur in a totally-unforeseeable manner.

of the maintenance process – automatic monitoring is a fast-developing activity. It is structured around measurement of significant parameters, combined with an analytical phase which is increasingly tending to be automated.

Where Electrical and Signalling Installations (IES) are concerned, surveillance is triggered – each time technology so permits – on the basis of two complementary modes :
- a train-based mode using specialist measuring vehicles to provide dynamic surveillance of the installations, in other words visualised in an operational environment on the passage of trains;
- a ground-level mode using fixed equipment or specific instrumentation. This type of surveillance is more appropriate to the measurement of static characteristics.

Train-based monitoring

Measuring vehicles are used for periodically recording track, signalling or other equipment parameters.

Where signalling equipment is concerned, for example, track/machine transmission measurements clearly demonstrate the relevance of this surveillance routine and of its potentialities.

The TVM 300 system (Track-Machine Transmission – Version 3.0.0), like the subsequently-developed TVM 430 model, are systems that utilise the UIC 71C track circuit as carrier for signalling information transmitted to TGV trains. The quality of transmission can only be sustained if track-circuit components perform correctly. Any drift of their characteristics can precipitate either interference between two track circuits on the same track or create crosstalk (influence of a track circuit on another circuit in adjacent track) which can become safety critical. It can also cause unduly

Fig. 13 - Hélène recording vehicle for electrical and signalling installations (IES)

Fig. 14 - Operator room inside Hélène vehicle

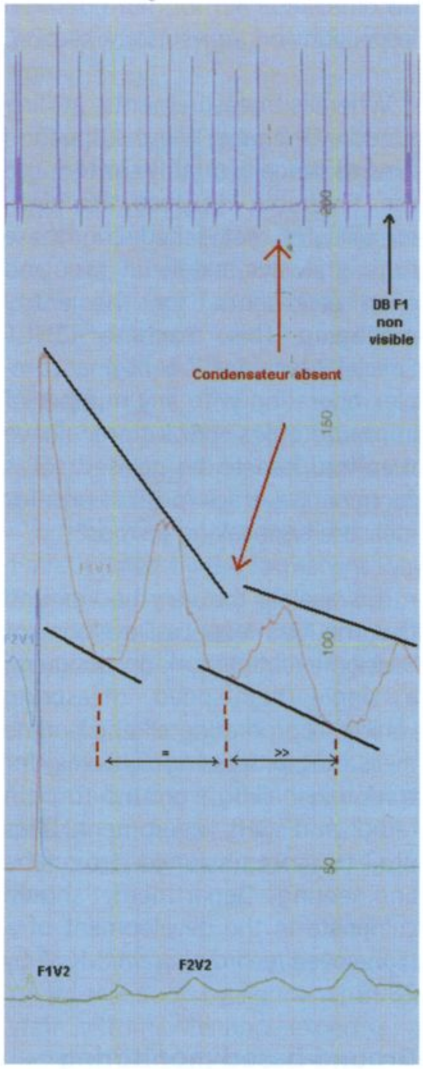


Fig. 15 - Example of graphic recording of TVM 430 field measurement

sudden dampening of the signal in track, so inducing inadequate reception by trains and leading to fast-worsening consequences for traffic regularity.

Measuring vehicles (Figures 13 and 14) are therefore fitted with similar sensors as those found on trains in revenue service, and record track-transmitted TVM signal levels.

The expertise and know-how acquired on high-speed lines over the past twenty years or so mean that these recordings can now be analysed in finer detail. As a result defects or significant changes in the transmission parameters can be detected from the shape of the measured signal (Figure 15). Their early detection made possible by the measurements taken, followed by on-site inspection, translates into accurate location of the failed component and its replacement.

Digital capture of the measurements and introduction of computerised techniques mean that it will soon be possible to think in terms of automated classification of typical defects, so facilitating data analysis and speeding up decision-making.

Likewise, progress achieved over the past few years with the measurement of OHL-equipment parameters – whether for measurement of contact-wire height, stagger or thickness at high speed, or for quality-of-collection assessment – by providing the maintainer with an increasingly large set of data correlatively justifies development of appropriate capacities to process this data.

The use of graphic charts as traditional medium for recordings thus becomes reserved for more detailed inspections on a given track section.

Whereas measurements at line speed will enable these inspection runs to be comfortably slotted into the timetable diagram for high-speed lines, yet scheduling these runs is always a difficult task and even represents, for the entity managing this machine (SNCF Special Machines Agency) a complex operation with any number of imponderables. Solutions have therefore had to be devised so as to minimise track possessions for measurement-taking purposes.

It is against this very background that the Maintenance Development Division initiated work on designing a single high-speed measuring vehicle incorporating all appropriate measuring/processing systems for track, signalling, ground-to-train radio and OHL equipment. This project, commissioned from the Engineering Department, should culminate in the development of a high-speed recording train (MGV) by 2005.

Ground-based monitoring

Signalling is unquestionably the area where the technological and innovative impact of systems is the most remarkable.

First computerised applications in the command-control systems of high-speed line signalboxes were launched in 1993 coinciding with the opening of the TGV-North high-speed line. A further milestone was reached in 2001 with the massive injection of computerisation into the safety systems of high-speed line interlockings.

Today fifteen signalboxes and twelve SEI (Integrated Interlocking Systems & Signalling) centres perform safety-related tasks over the 250 km of new line opened to revenue service in June 2001. This generation of signalboxes represents a further technological advance following-on the MCKT-type boxes integrated with the TVM 430 system installed on the TGV-North high-speed line.

The Marseille state-of-the-art traffic control centre, which not only performs signalbox tasks for the Marseille platform but also ensures centralised train control over most of the TGV line, is one of Europe's busiest, covering as many as 1180 routes. To ensure that this box was ergonomically designed to serve its catchment area, and to compensate for the obsolescence of the first high-tech command-control systems, boxes now incorporate computer-aided Alarm-Transmission and Signalling Modules (MISTRAL). The technical originality of these modules resides primarily in the management of the different computerised sub-systems (Standard Computer-Aided Command System, Standard Computer-Aided Programming System, Monitoring System, Integrated Alarm System,...) using 25 industrial-type PCs operating under Windows NT and connected via a duplicated local IT network, so providing interfaces with the PRCI, MCKT and SEI interlocking modules. This technical configuration, in which the "interlocking" stage is markedly different from the "command-control" stage, offers the operator a complex Man/Machine Interface tailored to the working environment, which presents all relevant command-control functionalities in a coherent form while providing the possibility of modulating the configuration of work stations. Lastly, innovative solutions accommodating the risks linked to cross winds and seismic phenomena have been implemented.

The launch of the TGV-Mediterranean high-speed line thus marks yet another stage in the development of signalling-related technologies, in that it has accelerated the move away from the "all-relay" era and into the "all-computer" era.

However a technological development of this magnitude is not neutral in terms of its consequences for the operator or maintainer.

Integration of maintenance into the design process

Investigation methods adopted and resources deployed for railway signalling installations must be tailored to the technology of the systems used, which means that new maintenance tools – that necessarily involve setting-in-place new work practices and rules – had to be developed concurrently with the systems themselves, so as to provide the maintenance manager with practical and high-performance implements.

Perception of the proper working – or not – of the installation, which previously was based on visual observation of the relays or on direct measurement of electrical values, is now supplemented by consultation of computerised terminals in order to facilitate dialogue analysis or reading of data files. State-of-the-art systems, as part of their design features, henceforth incorporate maintenance interfaces and software packages to record and present the different work statuses to the maintainer, also to notify him of defective elements identified.

This means that the maintainer now applies a more functional approach to the system maintained, so enabling action to be focused more rapidly on locating failed sub-assemblies and their replacement. In other words the maintenance process is gradually evolving towards "maintenance-by-level".

The modularity and redundant nature of the new systems allow for interventions that are not only swift but also increasingly transparent for the train operator.

Computer-aided maintenance systems

These systems have evolved technologically with each new generation of high-speed line. Initially confined to the TVM with the Maintenance Aid System (SAM) on the TGV Paris-Lyon route, the SIAM 430 on the Paris-North route and the Lyon bypass, they are now used in all computerised systems.

In fact with the advent of the Local Computer-Aided Maintenance System (SILAM) and Central Computer-Aided Maintenance System (SICAM) for the SEI (see article herein on the Integrated Interlocking and Signalling System), and of the Maintenance and Records Modules, not only for MISTRAL but also for the Seismic Detection Network (RDS), the Cross-Wind Warning System (DVL) and the Hotbox Detectors (DBC), they henceforth play a decisive role in all HSL infrastructure maintenance.

In order to ensure optimum maintenance efficiency and reduce infrastructure down-times, computers and data networks have moreover served to develop in recent years a powerful remote monitoring and surveillance system: the 2nd generation SIAM-ST, for signalling and telecoms plant, deployed inter alia on all South-

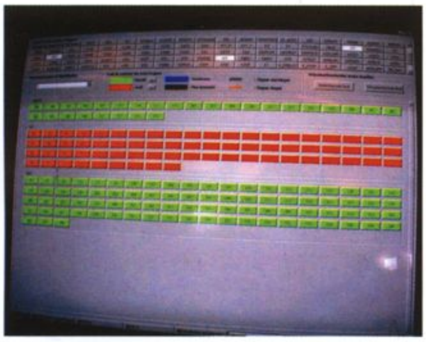


Fig. 16 - Mistral maintenance terminal

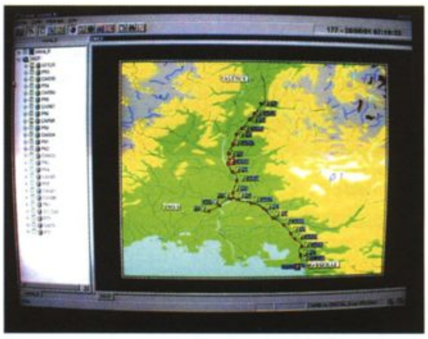


Fig. 17 - Image of technical terminal of thermal detection network

East high-speed lines in 2001. With the SIAM-ST, maintenance staff can now readily access a whole range of data about items of plant all along the route. The scene is clearly set for introducing predictive maintenance sooner or later. Remote surveillance, when combined with the computer-aided maintenance tools described earlier, provides maintenance staff with alarm and warning tools for critical installations – primarily points and crossings, track circuits, power supply and computer modules – under their responsibility (Figure 18).

Monitoring of installations

To complement the process and so ensure that the maintenance teams can fully control every single aspect of their work, it was important for them to be immediately informed about the occurrence of any anomaly or incident. Whence the concept of centralising at a single venue the tools needed to operate remote-surveillance systems on a permanent basis, which materialised with the opening of a Lyon-based remote-surveillance centre to manage the entire Paris-Marseille high-speed route and its conventional-line extensions – including the Marseille zone in the first phase – coinciding with the opening to revenue service of the TGV-Méditerranée high-speed line.

This Centre (Figure 19) incorporates several high-performance systems including:

• computer screens to visualise the status of installations within its catchment area through consultation of the different remote-surveillance or computer-aided maintenance systems;

• software packages to manage the lists of maintenance-staff calls via Intranet, the purpose being to identify – on the basis of a centralised database updated by the Permanent Way Division – particulars of team members to be contacted through direct location of the incident site on graphic chart;

• an electronic register to keep trace of incidents processed and e-mail initial information to the departments directly concerned in real-time;

• appropriate communication facilities.

The monitoring centre, manned round-the-clock by Permanent Way staff with maintenance expertise, is designed to trigger interventions in response to inspecting infrastructure incidents. As such it receives real-time alarm signals from all remote-surveillance systems and/or indications coming from the operator. It also conducts initial cause analyses of incidents and contacts the maintenance teams involved as speedily as possible. This means that it performs a task previously handled by the operator himself, contributing added-value through its expert know-how and the tools placed at its disposal.

In fact for the first time ever, maintenance teams are suitably equipped to monitor installations on a permanent basis and to step in as and when necessary.

This model of maintenance organisation means sharply-reduced repair times at the call-

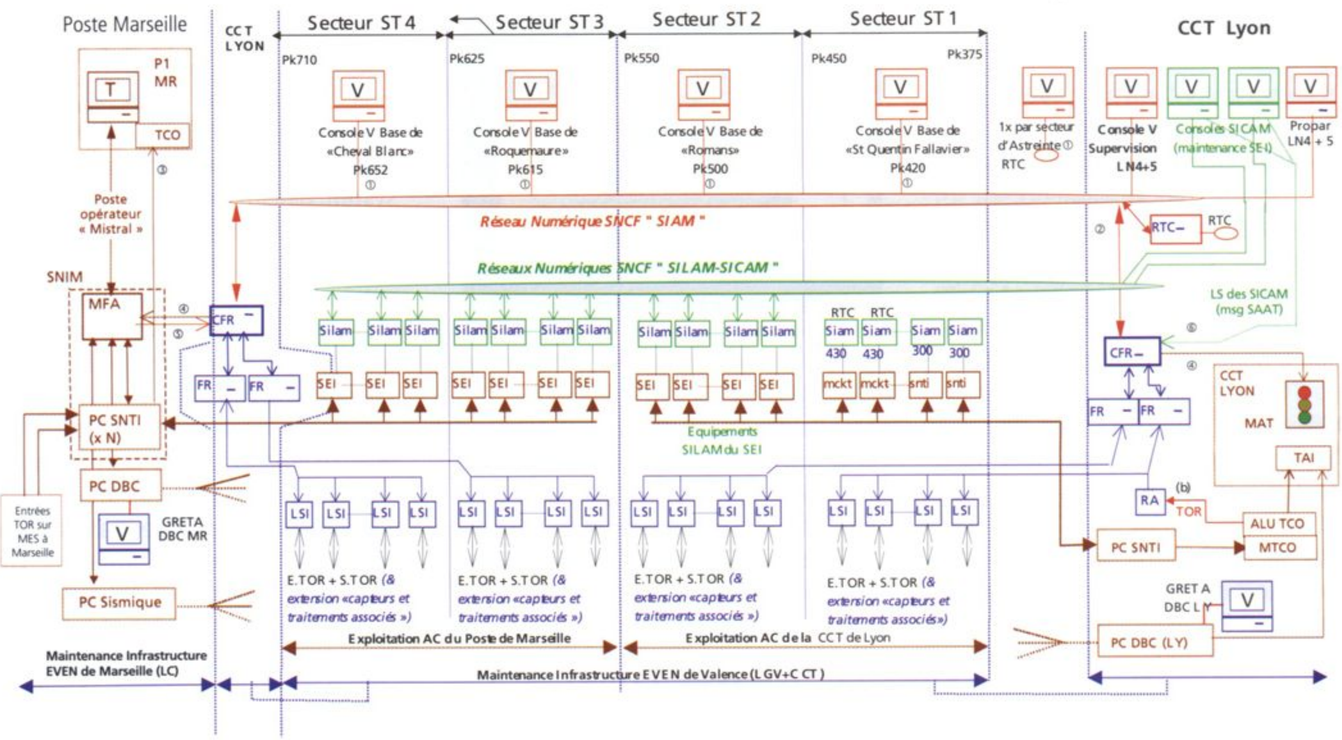


Fig. 18 - Principle of the architecture of data transmission systems used for TGV-Mediterranean high-speed line equipment maintenance

for-assistance, movement to the site or actual intervention stage, which consequently translates into speedier return of the infrastructure to the operator and an earlier resumption of full service.

The logistical aid procured by maintenance staff from the new entity, plus the reduction in constraints which hitherto burdened the operator when trying to contact maintenance staff at the same time as having to focus on managing the particular incident from the "traffic" standpoint, are factors that contribute towards improving the quality of service offered to our customers.

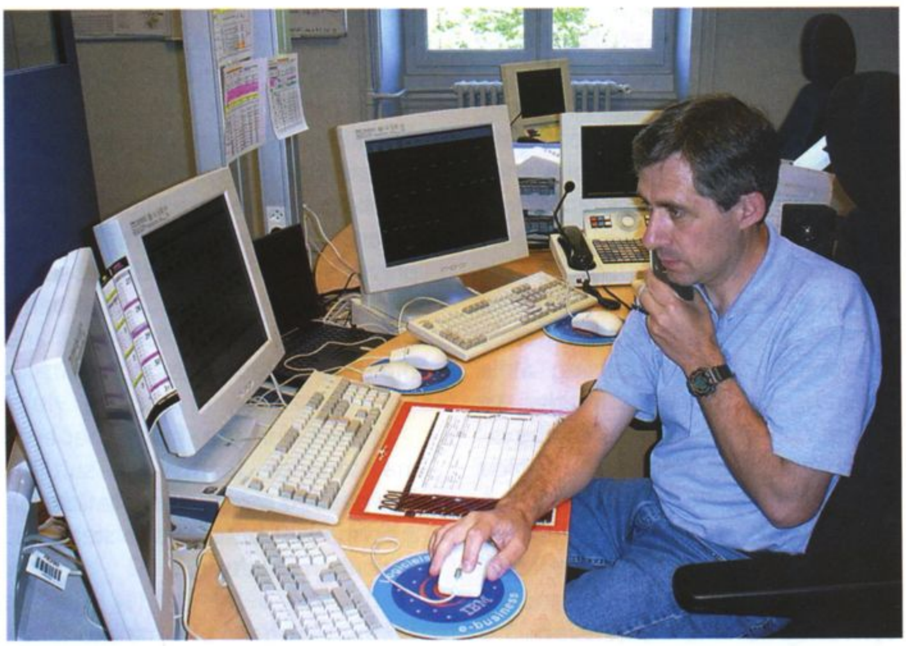


Fig. 19 - Monitoring centre

Next developments

The increasingly large volume of quality data thus made available to the maintenance manager in respect of installations in his care, broadens his information base in such a way that in some cases he already can detect transient anomalies and remedy them before the actual occurrence of serious failure.

Tomorrow, in the fairly near future, the maintenance manager – thanks more particularly to remote-surveillance and complex sensors currently being designed – will be afforded access to a wider range of more complex systems better suited to the surveillance of installations that must guarantee maximum availability levels. It follows that the automatic surveillance of sensitive components of rail infrastructure (such as traction sub-stations, OHL equipment, signalling systems and points and crossings), by virtue of the priceless information it provides on the actual status of these installations, has today become a priority field for applied research given the underlying interests at stake.

Conclusion

Experience built-up over more than twenty years of operating high-speed lines clearly shows that the integration of maintenance into product or system design is vital to achieving availability levels compatible with performance specifications. This integration is made possible by close and fruitful collaboration between design and maintenance engineers, also between the different maintenance units, from prescriber to operator.

In other respects the operating mode and technologies adopted have been instrumental in the development of expert systems capable of ensuring detailed surveillance over operating systems while providing increasingly accurate information to the maintenance teams. These systems, by paving the way for the development of conditional and predictive maintenance, contribute towards greater equipment reliability and to faster incident responsiveness.

It can thus be stated that maintenance policy in the field of electrical installations has successfully kept pace with the sharp traffic growth recorded on high-speed lines, while guaranteeing ever-improving quality standards.