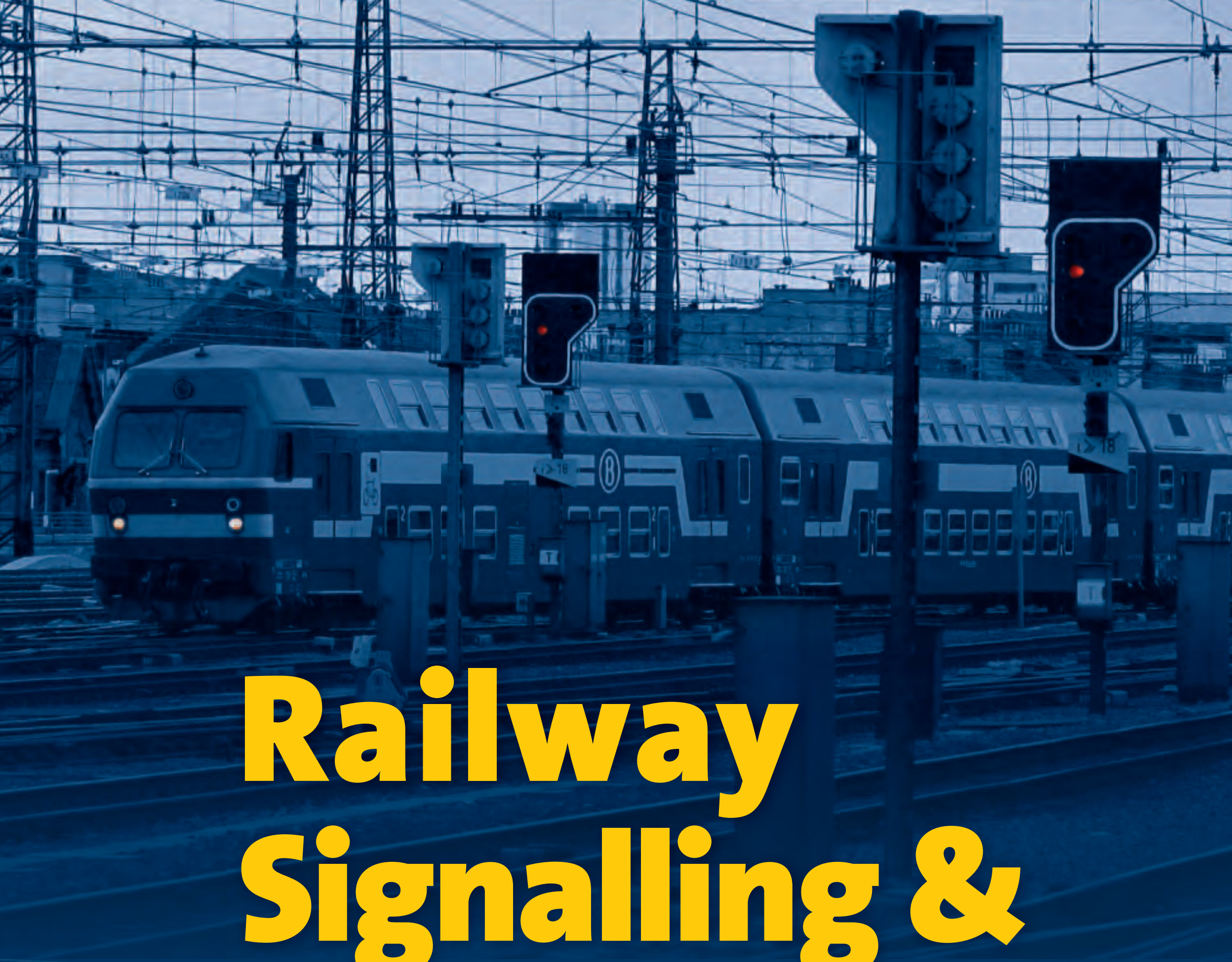

Railway Signalling & Interlocking

International Compendium

Editors: **Gregor Theeg · Sergej Vlasenko**

Eurailpress

Railway Signalling & Interlocking

International Compendium

Editors:
Dipl.-Ing. Gregor Theeg, Technische Universität Dresden
Dr. Sergej Vlasenko, Omsk State Transport University

Authors:
Dr.-Ing. Enrico Anders, Thales Rail Signalling Solutions GmbH, Technische Universität Dresden
Prof. Dr.-Ing. Thomas Berndt, Fachhochschule Erfurt
Prof. Dr. Igor Dolgij, Rostov State Transport University
Prof. Dr. Vladimir Ivančenko, Rostov State Transport University
Dr. Andrej Lykov, Petersburg State Transport University
Ing. Peter Márton, PhD., University of Žilina
Dr.-Ing. Ulrich Maschek, Technische Universität Dresden
Dott. Giorgio Mongardi, Ansaldo STS
Dr. Oleg Nasedkin, Petersburg State Transport University
Prof. Dr. Aleksandr Nikitin, Petersburg State Transport University
Prof. Dr.-Ing. Jörn Pachl, FIRSE, Technische Universität Braunschweig
Prof. Dr. Valerij Sapožnikov, Petersburg State Transport University
Prof. Dr. Vladimir Sapožnikov, Petersburg State Transport University
Dr. Andreas Schöbel, Technische Universität Wien
Dipl.-Ing. Eric Schöne, Technische Universität Dresden
Dr. Dmitrij Švalov, Rostov State Transport University
David Stratton MA CEng MIRSE, Alstom Transport
Dipl.-Ing. Gregor Theeg, Technische Universität Dresden
Dipl.-Inform. Heinz Tillmanns, Thales Rail Signalling Solutions GmbH
Prof. Dr.-Ing. Jochen Trinckauf, FIRSE, Technische Universität Dresden
Dr. Sergej Vlasenko, Omsk State Transport University
Dipl.-Ing. Carsten Weber, Technische Universität Dresden
Thomas White, Transit Safety Management

Eurail press

Bibliographic information published by the Deutsche Nationalbibliothek:
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie, detailed bibliographic data are available in the Internet at http://d-nb.de

Publishing House:	DVV Media Group GmbH | Eurailpress Postbox 10 16 09 · D-20010 Hamburg Nordkanalstraße 36 · D-20097 Hamburg Telephone: +49 (0) 40 – 237 14 02 Telefax: +49 (0) 40 – 237 14 236 E-Mail: info@eurailpress.de Internet: www.dvvmedia.com, www.eurailpress.de, www.railwaygazette.com
Publishing Director:	Detlev K. Suchanek
Editorial Office:	Dr. Bettina Guiot, Ulrike Schüring
Advertisements:	Silke Härtel
Distribution and Marketing:	Riccardo di Stefano
Cover Design:	Karl-Heinz Westerholt
Layout and Production:	Axel Pfeiffer
Print:	TZ-Verlag & Print GmbH, Roßdorf
Copyright:	© 2009 by DVV Media Group GmbH | Eurailpress, Hamburg

1st Edition 2009, ISBN 978-3-7771-0394-5

Printed in Germany

A DVV Media Group publication

DVV Media Group

Eurail press

Contents

cleared by the train ahead. The principle is no more than one train, in any one block, at any one time. In a territory with lineside signals, block sections are limited by signals which govern train movements. A signal that controls entry to a block section is called a block signal.

3.2.3 Definitions of Stations and Interlocking Areas

Generally, stations are all places designated in the timetable by name. Regarding the schedule, stations are the points where time applies. On British railways, only places where trains stop for load/unload passengers or freight are referred to as stations. In North American usage, each station is designated by a station sign that designates the specific point at which an instruction using only the name of the station applies.

On European railways, station signs are mainly used at passenger stations for the purpose of passenger information. In extended and complex terminal areas, some railways place station signs at interlockings outside passenger stations to support the driver in local orientation. But this is usually only be done at places without a local interlocking station, so that the station cannot be identified by the interlocking station's ID. Some railways use the term station only for places where trains have regular stops. The term station is not necessarily associated with the term station track which is used by several railways to separate sections of main track where station rules apply from the block sections of the open line. Rules on station tracks are closely related to the interlocking rules of a specific railway.

An interlocking is an arrangement of points and signals interconnected in a way so that each movement follows another in a proper and safe sequence. Signalled routes for trains on main tracks are usually interlocked (chapter 4.3). Signals that govern train movements through an interlocking are called interlocking signals. An interlocking signal can also be a block signal. The points and signals within interlocking limits are controlled either by a local interlocking station or from a remote control centre. Local interlocking stations are called interlocking towers in North America, and signalboxes or signal cabins on railways that follow British principles. The block signals between controlled interlockings are often called intermediate block signals. In Britain, this term is used only in older systems for a block signal that is controlled from the interlocking station in rear.

Concerning interlockings and stations, the railways designated different names and limits in accordance to their individual operating practice. In particular, there is a big difference between North American railways and those elsewhere. In North America, the block system that protects train movements is not interrupted in interlocking areas. There is no station track separated from the open line. Figure 3.3 demonstrates the essential difference at the example of a track arrangement with several loop tracks. In North America, the point zones at both sides of the loop tracks would form separate small interlockings. These are limited by opposing interlocking signals in a way that each interlocking does normally not contain any consecutive interlocking signals. Station names refer to these small interlockings but not to the entire loop track layout. In Europe and on other railways outside North America, the entire loop track layout would be a station designated by name. The tracks between the outer point zones are station tracks. On station tracks, there are consecutive interlocking signals, which form station track sections. Train movements on these sections are protected by the interlocking system but not by a block system. Thus, the entire layout that may even contain more than just two point zones forms one interlocking area.

Figure 3.4 gives a more detailed example of how interlocking limits are established on North American railways. At each track that leads into interlocking limits, there is a signal that may authorise train movements, even at tracks that are not used for regular train movements (this

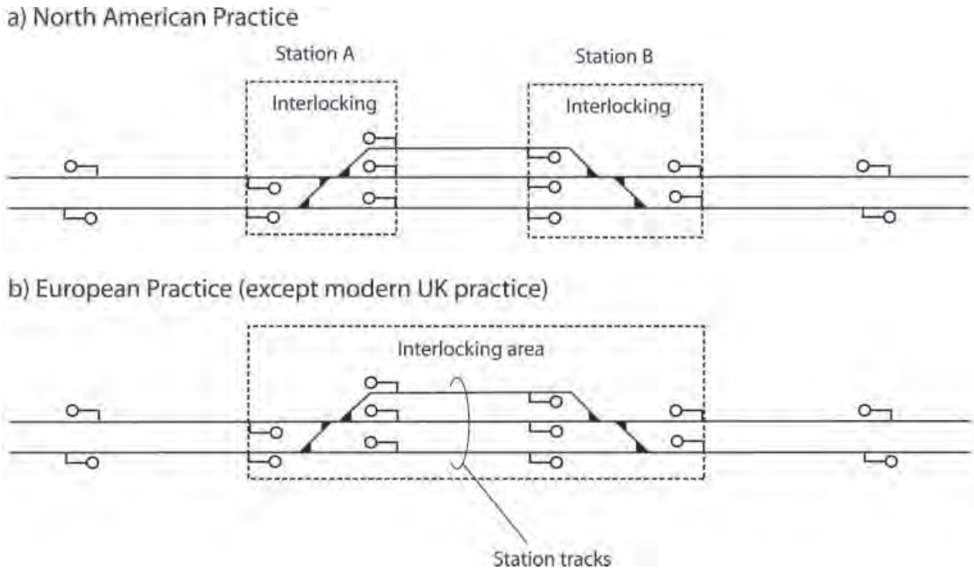

Figure 3.3: Different principles of assigning interlocking and station names to a track layout on North American and European railways

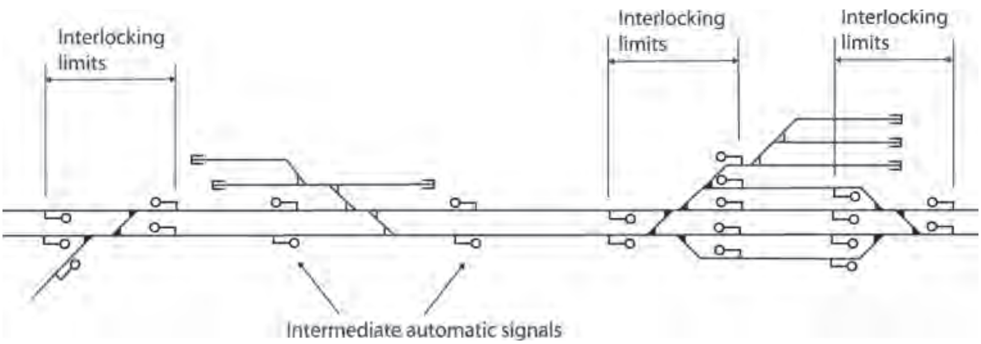

Figure 3.4: Interlocking limits (North American practice)

is an essential difference from European signalling). These signals are called home signals. A speed indication at an interlocking signal applies until the train has passed the first opposing interlocking signal, which is called the exit signal of that interlocking.

On European railways, there is still a difference between the traditional British practice and the continental railways that followed more the German principles. In traditional British interlocking systems, there are designated 'station limits'. Station limits are the tracks between the home signal and the last main signal of the same direction (the section, or starting signal), controlled from the same signalbox (interlocking station). The section signal permits trains to leave the station limits and enter the next block section. There are different station limits for each direction. In most British installations, this signal is placed behind the last points of the interlocking (then also called an advance signal or formerly an advanced starter signal), thus usually requiring additional interlocking signals before the points (figure 3.5).

4.3.7 Route Elements in the Start Zone

In some cases, movable track elements which are situated in rear of the route entrance signal in the start zone have to be included into the route functions (figure 4.29). In particular, this occurs with station exit routes in situations where the train starts the route from a scheduled stop, with the previous route of this train already released (chapter 4.3.3.6). Many railways try to avoid such situations in track layout planning by not placing movable track elements in tracks where trains will stop regularly. But particularly in areas with a restricted availability of space, these situations cannot always be avoided.

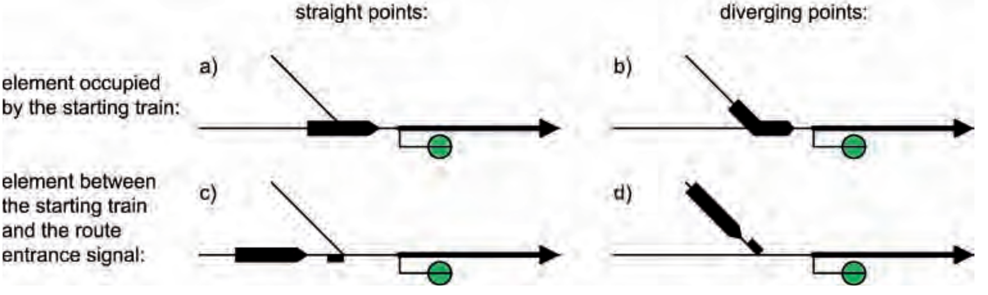

Figure 4.29: Examples of route elements in the start zone

In cases where the movable track element is already occupied by the starting train (figure 29 a and b), locking functions are already fulfilled by the track occupation: However, depending on the interlocking system, additional locking of this element in the route can be applied. In cases where the element can be situated between the train front end position and the route entrance signal (figure 4.29, c and d), this element must always be included in the route locking functions. Additional special requirements in interlocking logic can occur to determine the exact position of the starting train in this context, and in the case of converging tracks to determine the track from which the train starts. The solutions are particular for the interlocking systems and are not be discussed in detail here.

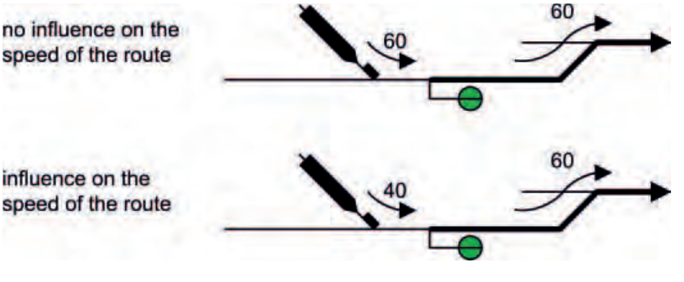

Figure 4.30: Points of the start zone influencing the route speed

A controversial problem of speed signalling occurs if the train uses an element in the start zone in the diverging track (figure 4.29, b and d) and the speed permitted by this element is lower than the speed the route would permit without this element (figure 4.30). The solutions depend on the regulations about the local validity of the speed indication of the signal in rear and which speed has been signalled there (chapter 4.3.2.3). The case that the speed signalled at the station home signal is valid through the whole station (figure 4.9, case 1) is the simpler case in this context. In case of separate speed restrictions for each route (figure 4.9, cases 2a-e), particular attention has to be paid to the element of the start zone concerning speed regulation:

These technologies are mainly applied to detect occupancy of level crossings by road users (chapter 13.4.4.4) and in other cases with increased probability of objects other than rail vehicles occurring, e.g. at platform tracks, particularly in automatic metropolitan railways.

In other applications, systems of this type are also suitable for indirect detection of occupancy by trains. An example is the disruption of a ray with sender and receiver on opposite sides of the track by each wagon of a train. The evaluation principle is similar to that for axle counters, but wagons are counted instead of axles. This principle is applicable mainly to metropolitan railways (Barwell 1983).

By using the Doppler effect, the speed of trains and, calculated from speed and occupation time of a certain position, the train length can be measured (Fenner/Naumann/Trinckauf 2003).

5.2.4.2 Mechanical Technologies

Mechanical supervision of the limiting areas of the clearance profile is applied by some railways. A net of wires or a single horizontal wire stretches outside the limits of the clearance profile and carries a low voltage current (figure 5.14). If an object of not too small extension breaks through this area with a certain minimum force, the wires break, disrupting the current. This disruption of current is evaluated by the interlocking or block system which can hold signals at red in this case. As repair works are necessary after such events, this technology is only useful to detect occurrences which seldom occur. Examples are:

- Detection of avalanches and earthslides in mountainous areas.
- Detection of road vehicles fallen from a bridge above a railway line, as applied on French high speed lines.
- In situations where a railway is situated in proximity of an airport, to protect against an aircraft overshooting the runway and obstructing or destroying the railway line.

Figure 5.14: Example of an installation to detect avalanches mechanically (France)

Another mechanical technology is contact mats placed on and beside the track to detect the presence of persons, vehicles or other objects by their weight. This technology is applied on some automatic metropolitan railways, e.g. in Vancouver.

5.2.4.3 Magnetic Inductive Loops

Such detectors consist of a resonant circuit with the inductivity situated in the track (figure 5.15). When a rail vehicle passes over the loop, the inductivity L changes due to the iron mass of the vehicle. According to the formula of the resonant circuit $(2\pi \cdot f)^2 = \frac{1}{L \cdot C}$ (with f being the

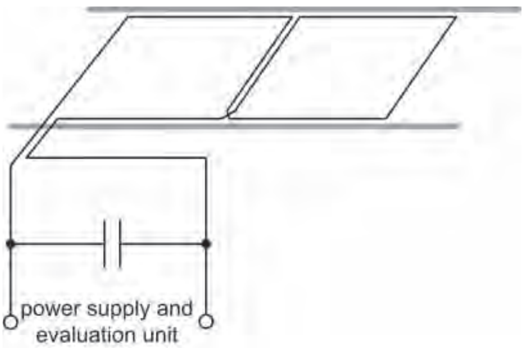

Figure 5.15: Inductive loop for vehicle detection

frequency, L the inductance of the coil and C the capacity of the capacitor), this changes the frequency of the resonant circuit. This shift of frequency is evaluated to detect the vehicle.

To compensate inductive effects of traction return currents in the rails, symmetrical double loops are normally used (figure 5.15).

By this technology, directions cannot be distinguished (unless using two double loops) and axles cannot be counted. It is applied for initiating the opening and closing of level crossings in some systems. It can also be used to detect road vehicles on level crossings, with the disadvantage that due to lack of iron mass, pedestrians and animals are not detected and cyclists rarely. In road traffic management, such loops are widely used.

5.2.5 Three-Dimensional Detection

5.2.5.1 Visual Observation

The simplest and historically oldest form of detection is visual observation of the respective track by staff. The ability of human to also evaluate unexpected observations is the main advantage over all technical systems. Disadvantages are the relatively high probability of human error and the high costs of staffing. Therefore, the usage of visual observation is decreasing, especially in highly developed countries.

Another version is remote visual observation via camera and monitor (figure 5.16). The number of people required for observation can be much reduced by this method. It is used especially in situations where not only rail vehicles have to be detected. Examples are the conflicting areas of level crossings with roads, the tracks in platform areas, but also passenger areas for security purposes.

Figure 5.16: Remote visual supervision of a level crossing

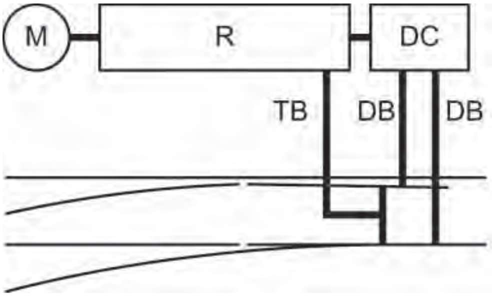

Figure 6.14: EPM block diagram (R is a mechanical gear in electro-mechanical and a hydraulic gear in electro-hydraulic point machine)

The generalised block diagram is shown in figure 6.14:

- In an electro-mechanical point machine, electric power is transformed into mechanical by means of an AC or DC electric motor M. The motor rotation is spread on to the reduction gear R meant to strengthen the angular momentum and to reduce the rotary speed of the motor. The motor is connected with reduction gear via branch sleeve which allows an insignificant radial displacement of shafts while retaining a parallel position of their axes. To protect the motor from overloads, e. g. if the blades do not reach their end position due to an obstacle, and to ensure the braking of the revolving parts of the EPM after the end of switching the points, a friction gear is inserted into the gear. The rotating movement is transferred into the progressive motion of the **throw bar** TB in the last cascade of the reduction gear.
- In an electro-hydraulic point machine, the electric motor M rotates the pump of the hydraulic gear R. This pump pumps oil from one cylinder into another and causes a relative movement between the cylinder and a piston. Either the cylinder or the piston is mechanically connected with the **throw bar** TB, the other is fixed.

In both forms, the throw bar impacts upon the blades of the points through the point drive rod. The **detection contacts** DC provide checking of point positions and commutate the electric controlling circuits. Obtaining the checking signal about of point end position is only possible if the position of the **detection bars** DB conforms to that of the throw bar.

An important factor for exchangeability of EPM's of different manufacturers is compatibility of two kinds:

- Electrical compatibility of the EPM in the operation and supervision circuitry. An example for a standard is the German four-wire point circuitry (chapter 6.6.3.1).
- Mechanical compatibility at the interface between EPM and point drawbar, regarding mechanical connections, switching length and others.

Often compatibility is provided in one country, but not internationally.

For degraded mode operation and for maintenance, EPM shall enable the possibility of switching the points by the hand crank. During hand cranking, electrical movement must be prevented for safety.

The EPM influences directly the safety of train movements, since is checks the actual position of a set of points. The idea of supervision of point position is to verifiy the conformity between the detection bars and the throw bar. In order to check point position, one checking drawbar is attached to each blade. These drawbars are connected with the detection bars which move inside the EPM.

6.4.3 Supervision of Point Position on the Example of SP-6

To illustrate the principle of proving the point position, let us examine the checking block of the Russian EPM SP-6 (Reznikov 1985, Sapožnikov et al. 2008). According to the classification given in chapters 6.4.1 and 6.4.2, this EPM is electro-mechanical with possibility of using

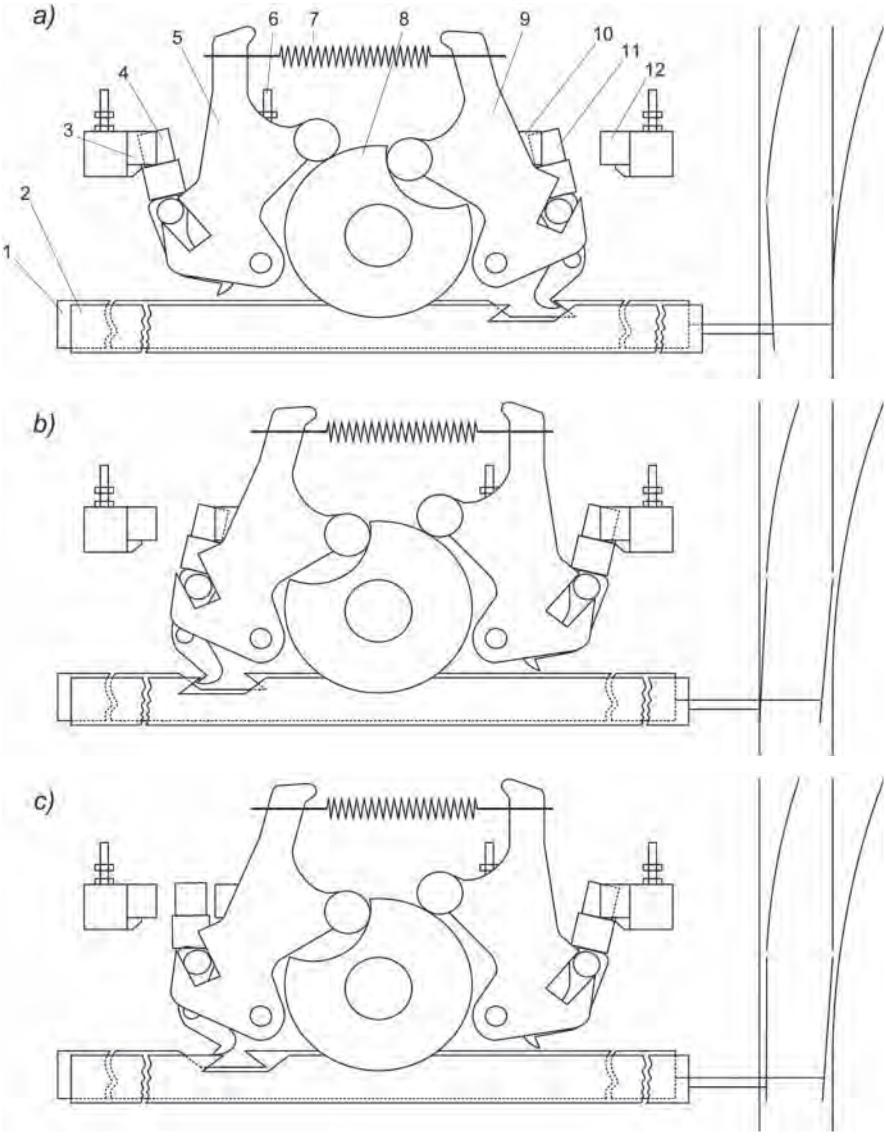

Figure 6.15: Checking of point position in SP-6

either AC or DC motors, with electrical supervision using mechanical contacts. The tooth gear transmission is designed to be not trailable with internal locking. EPM is designed to be installed on one side of the track.

The movements of the throw bar for the fixed distance and confirmation that the detection bars are in this position are verified by the switching levers 5 and 9, and jointly with them connecting levers 4 and 11 (figure 6.15). When the throw bar is located in its end position, the roller of one of the switching levers sinks down into a notch of the collar 8 mounted upon the main drive shaft of the reduction gear. The checking scheme is commutated with the detection contacts 6, 10. These contacts are closed by the connecting levers. The closing is possible if the beak-shaped end of the connecting lever is dropped into in the superimposed notches of the detection bars 1 and 2.

Figure 6.15a shows the state of details of an EPM checking mechanism when the blades are located in their end position, with the right blade fitted to the stock rail and the left blade free. Herewith the operational contacts 3 (controlling a control circuit of an EPM) are connected with the connecting lever 4, while the checking contacts 10 – with the connecting lever 11.

When the points are switched to the opposite position, the main drive shaft of the reduction gear rotates in a clockwise direction. Firstly, the roller of the switching lever 9 rolls onto the surface of the collar 8. That results in the following successive movements: the connecting lever 11 moves aside, disconnecting the checking contacts 10, and the operational contacts 12 become connected. Henceforth the throw bar begins moving and the blades of the points do the same together with it. This, consequently, provokes the movements of the detection bars 1 and 2. At the moment of the final movement of the throw bar, the notch of the collar of the main drive shaft becomes positioned under the roller of the switching lever 5, which causes it to move to the right under the influence of the spring 7. That results in the connecting lever 4 disconnecting the work contacts 3. If all elements of the EPM and the points are in working order, and therefore the blades and detection bars have moved to their end positions, the beak-shaped end of the connecting lever 4 drops into the superimposed notches of the detection bars. Owning to that, the checking contacts 6 (figure 6.15b) become connected.

They will not be connected, however, if at least one of the detection bars does not move for the specified distance, e.g. as a result of a breakage. In this case its notch will not be positioned under the beak-shaped end of the connecting lever and it will be propped against the surface of the detection bar (figure 6.15c). Neither the contacts 4 nor 6 will be connected.

In case of trailing of the points, the collar 8 and the main drive shaft do not revolve, but the detection bars do move. The beak-shaped end of the connecting lever is pushed to the surface of the detection bar by the splayed edge of the notch of this bar. In that case the connecting lever occupies an intermediate position disconnecting the checking contacts. At that time, the connecting and switching levers of the other blade do not change their position, and the operational contacts remains to be connected.

6.5 Point Locking Mechanisms

Under dynamic impact from passing rail vehicles, blades should be locked. As was already pointed out earlier, their locking can be external or internal. Besides, locking of the blades in the end position can be either form fitted (not trailable) or force fitted (trailable). In the following, some examples for locking mechanisms are described.

6.5.1 External Locking Mechanism: Clamp Lock

In these countries which use external locking mechanisms, there is a large variety of locks. However, the by far most widely used solution is the clamp lock. The clamp lock (figure 6.16) is trailable. Besides the clamp lock, in recent years modern optimised external locking mechanisms have been developed by different manufacturers, which are optimised for low friction and are therefore used for points which shall be switched very frequently. On high speed lines, a problem of trailable points can be the danger of unintended switching by dynamic impact. Therefore, special locks are often applied.

The drive rod is fixed to the point machine via the throwbar, but not to the blades. Instead, the blades are mounted to special lock arms. When the blade is unlocked (right blade in figure

The basic type of *Siemens* is Simis, out of which different variants have been developed. Simis firstly went into operation in the 1980s. The currently most important version on the international market is Simis W, with different adaptations for different national requirements.

Thales offers basically two systems: the older system L90 (Locktrac 6111), used in Germany and other countries, and the newer L90 5 (LockTrac 6151), used in different countries mainly outside Germany. L90 firstly went into operation in 1989 in Neufahrn i.NB. Also here, different adaptations have been developed for different national requirements and operational situation.

Figure 9.42: Part of Simis interlocking (Żywiec, Poland)

9.4.6.2 System Structure

In L90 and L90 5, the modules are divided by the functional levels (figure 9.34) into Interlocking Module (IM) and Field Element Controllers (FEC) (figure 9.43). In Simis (example: Simis-W, figure 9.41), in contrast, the hardware distribution is different: IIC/OMC (figure 9.42) and ACC are responsible for the interlocking functions cooperatively, with IIC/OMC being comparable with the central switching sets of a topological relay interlocking (chapter 9.3.5.2).

The territorial structure is that of high centralisation: A central interlocking station (including IIC/OMC in Simis and IM in L90) can be responsible for a portion of single or double line of about 50 to 100 km, whereas the area of a local interlocking station is approximately the size of a medium size station.

If in Germany the electronic interlocking is included into an operation control centre, (chapter 11.5.2), the central interlocking station is called the 'sub-centre', with the CTC even one level above.

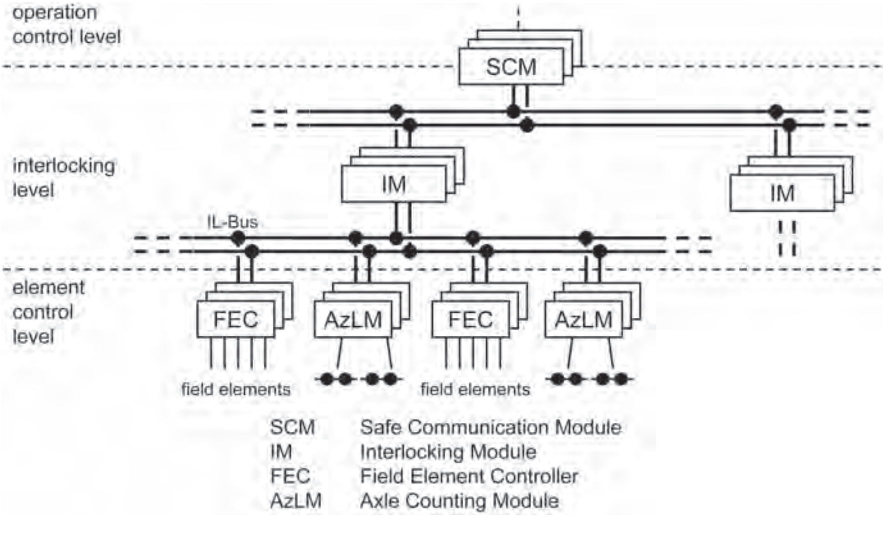

Figure 9.43: System structure of L90 5

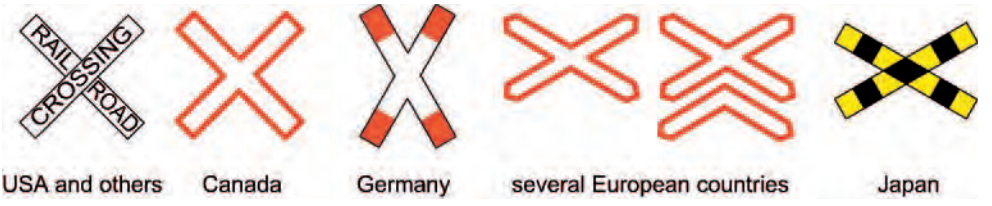

Figure 13.1: Forms of St. Andrew's cross on level crossings (not in scale)

In addition to the St. Andrew's cross, in many cases other signals such as text boards are installed immediately in front of the level crossing to warn the road users and give instructions.

In many countries, warnings of the approach to level crossings are given by road signs few hundred metres (usually 50 to 250 m, depending on local situation) in advance to give the road user the ability to prepare. In some cases, these signs distinguish between active and passive level crossings or between level crossings with and without barriers. A frequently used form is a triangular road sign with red rim and a steam locomotive or a modern train inside. In the USA, it is a circular sign with a black rim and a black X inside. Frequently the distance between the warning sign and the level crossing is measured by countdown markers with three stripes, two and then one. An example is given in figure 13.2.

Besides road signs, the warning of level crossings is often supported by pavement design.

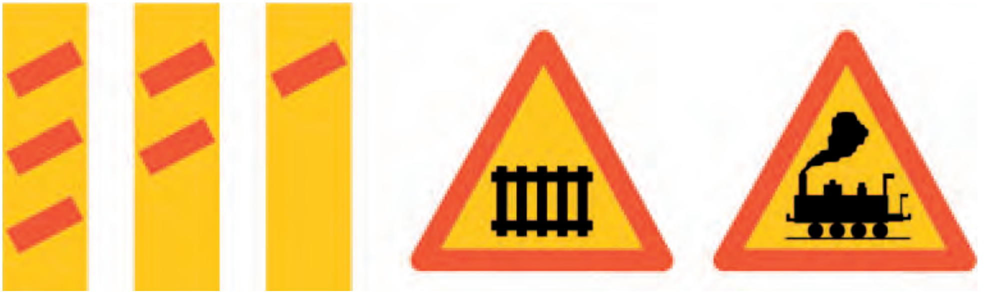

Figure 13.2: Road sided warning signs and countdown markers (Sweden as example)

13.3 Passive Level Crossings

In passive level crossings, the road user is responsible for observing the railway line and recognising an approaching train directly. The most important measure to ensure the perception of the train is to keep the approach sight triangle clear of obstacles. The approach sight triangle is formed as follows, primarily described for the case that the road user is allowed to pass a clear level crossing without stopping or slowing down:

As described in chapter 13.1, the road user, when arriving at the permitted speed, must be able to stop at the level crossing when recognising an approaching train. Or, if stopping is not possible because he is already within the stopping distance from the level crossing, he must be able to pass the level crossing safely. The necessary sighting point A (figure 13.3) is the latest point where the road user must decide whether to stop in front of or to pass over the level crossing. It is determined by the stopping distance of the road user, which varies with the initial speed, the braking deceleration and the reaction time of the driver and the vehicle. The necessary sighting distance from the sighting point A to the stopping point, which is usually at the St. Andrew's cross, can be calculated as follows:

$$l_A = t_r \cdot v_v + l_b$$

and the complete clearing length as follows:

$$l_C = t_r \cdot v_v + l_b + l_{lc} + l_v$$

with:
l_b: braking distance of the road vehicle (speed-dependent)
l_{lc}: length from the stop position to the end of the conflicting area of the level crossing
l_v: length of the road vehicle
t_r: reaction time of driver and vehicle
v_v: speed of the road vehicle

Accordingly, the clearing time can be calculated as follows:

$$t_C = t_r + \frac{l_b + l_{lc} + l_v}{v_v}$$

The minimum approach time to avoid conflict is:

$$t_a = t_C + S$$

with
S: safety margin [s]

The approach length l_B of the train is therefore as follows:

$$l_B = v_t \cdot t_a = v_t \cdot \left(t_r + \frac{l_b + l_{lc} + l_v}{v_v} + S \right)$$

with:
v_t: speed of the train

Typical value ranges of variables are shown in table 13.2.

Variable	Typical value range
l_b	5 to 100 m (depending on vehicle speed and brake deceleration)
l_{lc}	5 to 20 m (depending on number of tracks and crossing angle)
l_v	up to 25 m (depending on national upper limit for vehicle length)
t_r	1 to 3 s
v_v	1 to 30 m/s (depending on general or local speed restriction)
S	2 to 5 s

Table 13.2: Value ranges of variables

In some national cases or where special regulations apply, stopping is obligatory even if no train is approaching. In this case, t_r and l_b can be set zero, which means that the sighting point A is the stopping point (the position of the St. Andrew’s cross). In this case the clearing time t_c must be higher because the acceleration of the road vehicle (starting up) must be considered. Therefore the approach length l_B can also be longer.

For a real level crossing, particularly where stopping in front of the level crossing is not mandatory if no train is approaching, the differing speeds of road users have to be considered: Whereas the sighting distance l_A increases with increasing speed of the road user, for the ap-

Railway signalling is one of the few technical fields which are still mainly oriented nationally. However, the international aspect becomes more and more important. The purpose of this book is to give a summary and comparison of railway signalling and interlocking methods at the international level.

The contents cover the whole range of signalling equipment and methodology. They include:

- basics of safety
- operational basics of signalling
- principles of interlocking
- technical interlocking and block systems
- systems for centralised operational control
- shunting control systems
- movable track elements such as points
- detection
- signals
- train protection systems
- level crossings
- hazard alert systems

The book follows a generic approach and sets out the basic principles, giving the reader a better understanding of the solutions applied in different countries. It is intended for experienced railway signalling experts and railway operators, as well as for students who want to extend their signalling knowledge to an international level. More than 20 authors from universities and practitioners from various countries have contributed, and much literature has been used to gain the information.

The authors have also discussed the topics of the book widely, to develop an international understanding. The result is a book which records the principles and the present situation on railway signalling throughout the world.

ISBN 978-3-7771-0394-5

9 783777 103945