PROBLEMY KOLEJNICTWA
RAILWAY REPORT Issue 186 (March 2020)
DOI: 10.36137/1861E
ISSN 0552-2145 (print) ISSN 2544-9451 (on-line)

Adaptation of the PKP PLK S.A. Train Light Signaling to Higher Number of Signal Aspects

Marek BARTCZAK[1]

Summary
Th e article discusses the train signaling system developed in OSŻD. Th e traffi c light signaling currently used on the net-work managed by PKP Polskie Linie Kolejowe S.A. (Polish Railway Lines) is also described. A proposal of traffi c light signals is presented, enabling the transmission of information on travel speeds on the turning tracks of turnouts operated on the PKP PLK S.A. network. Th e proposed signaling has been developed based on OSŻD (in Rus. *Организация со-трудничества железных дорог* – ОСЖД) signaling. Th e number of signals needed was obtained by introducing a second yellow light strip and optionally two diff erent fl ashing frequencies.

Keywords: railway signaling, signaling for trains, lineside signals, railway traffic control devices

1. Introduction

Ever since Poland entered the European Union, which has provided financial support to new member states for the purposes of modernizing the railway infrastructure, the railway network – PKP Polskie Linie Kolejowe S.A. – has been modernized in order to increase train speed and, at the same time, ensure the required traffic safety. The modernization of the railway infrastructure of PKP PLK S.A. encompasses the structure of the railroad surface, whose adaptation to high speeds is concerned with reinforcing the surface by using, for example, heavy rails, jointless rail track and aggregate of higher quality.

The reduction of train travel time on railway lines or their sections also requires increases in the train speed at stations. The speed of trains going through stations is limited by the type of turnouts. The speed of traveling on the turning track of a turnout (sideways) depends on the geometrical parameters of the turnout, such as track arc radius at the turnout and related turnout angle defined as the quotient 1:n. For turnouts with the angle 1:9 and arc radius 190 m, which is the most common on the PKP PLK S.A. network, the maximum permissible speed at the turning track does not exceed 40km/h. Regardless of the turnout angle, traveling on a straight track can be at the top permissible speed on the specific section of the line. An exception is a double slip junction with regard to which the maximum permissible speed on the straight track is 100 km/h.

In the last couple of years, the stations located on modernized railway lines managed by PKP PLK S.A. have increasingly adopted turnouts of lower angles and large radii, which allows trains to run on the turning track at the speeds of 80 km/h and 130 km/h. At present, they are not covered by the current train signaling. Therefore, when running on the turning track of such turnouts, a lower speed is always signaled, which substantially prolongs the train travel time through the station. A reduction of this time can be achieved by implementing train signaling which allows information to be provided on the larger number of speed levels of traveling on turnout turning tracks.

Bearing the above in mind, the article presents three block train light signaling, which allows information to be transmitted on seven levels of speed with the use of the lineside signal, based on the signaling device developed in OSŻD, which has not been implemented fully so far on the PKP PLK S.A. network due to operating conditions.

2. Train speed at turnouts

To specify the required number of travel speed levels signaled via a light semaphore, it is necessary

[1] Ph.D. Eng.; University of Technology and Humanities in Radom, Faculty of Transport, Electrical Engineering and Computer Science; e-mail: m.bartczak@uthrad.pl.

to know the train speed at turnouts in station heads and other traffic stations. The speed at turnout turning tracks – as already mentioned – depends on the turnout angle and track arc radius. Due to their angle and arc radius, turnouts can be divided into the following two groups:

1) turnouts with large angles and small arc radii, such as the ordinary turnouts Rz S49-190-1:9 and Rz S49-300-1:9,
2) turnouts with small angles and large arc radii, e.g. Rz S60-500-1:12 (Fig. 1).

Fig. 1. Ordinary turnout with the angle 1:12 and arc radius 500 m [own picture]

The turnouts with large angles and small arc radii which are adopted mostly on the PKP PLK S.A. network allow travel at high speeds but only on straight sections. The exception is the double slip junction Rkp; if at least one such turnout exists on the route, the top permissible speed on the straight track is 100 km/h.

As for turnouts with small angles and large arc radii on modernized railway lines, trains can run at high speed both straight and reverse. These turnouts are used when trains must run at high speeds in both ways [5], in particular:

- by branching of railway lines on which a large number of trains running at high speed are directed into a turning track,
- by long switch heads in the group of arrival-departure tracks of passenger stations, i.e. when the distance from the stoppage spot and high acceleration of startup allow a larger surge in speed on this road,
- on siding tracks on which trains can cross without stopping,
- on single-track bridges located on double-track lines.

The maximum permissible speed on the turning track of a turnout can be expressed through the following equation:

$$V = 3,6\sqrt{0,65 \cdot R}\,,$$

where:

V – maximum permissible speed on the turnout turning track [km/h],
R – arc radius in turnout [m].

For example, the maximum permissible speed, calculated on the basis of the aforesaid equation, on a turnout turning track with an arc radius of 190 m is 40.01 km/h, and on a turnout turning track with an arc radius of 760, it is 80.01 km/h.

The maximum permissible speeds on turnout turning tracks used on the PKP PLK S.A. network are specified in Table 1 [7]. We can easily notice that the number of speed levels is 5. Considering the speed of 0 km/h (signal "Halt") and top permissible speed, the minimum number of speed levels indicated by means of the light semaphore, referring to the first road, located directly behind the semaphore, should be 7. This means that an increase in the number of signal indications in the current light signaling for trains can be achieved in a simple way, economically and without a need to use speed increase indicators W21, and it is understandable to engine drivers operating rail vehicles.

Table 1

Maximum permissible train speeds on turnout turning tracks [7]

Permissible speed on the turnout turning track [km/h]	Turnout angle	Arc radius of the turnout turning track [m]
≤ **40**	1:9	190–300
≤ **60**	1:12	500
≤ **80**	1:14	760
≤ **100**	1:18,5	1200
≤ **130**	1:26,5	2500

3. Train light signaling

3.1. Six-level three block signaling

The train light signaling currently used on the network managed by PKP PLK S.A. is a simplified variant

of the light signaling developed in the 1960s in OSŻD (in Russ. *Организация сотрудничества железных дорог* – ОСЖД) in order to satisfy railway needs in the foreseeable future.

The light signaling for trains developed in OSŻD [1, 2, 4, 6] is a six-level three block signaling. It allows information to be transmitted about six speed levels with the use of the lineside signal, referring to two section intervals located behind the specific semaphore. To provide information, the following light colors are used: red, yellow, green and matte white (white) as well as green and yellow light strips. The amount of information transmitted is raised by the adoption of two frequencies of light flashing:

- slow flash – flashing frequency is about 50 flashes a minute,
- fast flash – flashing frequency is about 100 flashes a minute.

OSŻD train light signaling informs about the following six travel speed levels:

1) first level – travel speed is 0 km/h ("Halt" signal),
2) second level – travel speed must not exceed 40 km/h,
3) third level – travel speed must not exceed 60 km/h,
4) fourth level – travel speed must not exceed 90 km/h,
5) fifth level – travel speed must not exceed 120 km/h,
6) sixth level – top travel speed permissible for a specific railway line section, that is 160 km/h.

With respect to the fourth and fifth levels, this signaling can be used with a tolerance of ±10 km/h.

The station's six-level three block light semaphore is presented in Figure 2. This semaphore has a five-chamber signal head under which three light strips can be found: outermost green and central yellow.

Fig. 2. Three block light semaphore for signaling six travel speed levels [own elaboration]

The intended use of particular light chambers of this semaphore is as follows:

1) two upper chambers of green and yellow light inform about speed levels referring to the second route in relation to the semaphore in question, indicated by another semaphore,
2) two lower red and yellow chambers and three light strips, the central one of which is yellow and two outermost green, provide information about speed levels for the first route which is located directly behind the specific semaphore,
3) the bottom chamber of white light serves to give a substitute signal. This chamber is also used to provide signal authorizing for shunting if such a signal is to be sent on the semaphore (sign and exit semaphores).

In OSŻD signaling, information concerning travel speed levels is provided according to the following principles:

- information is provided with one or two lights in the semaphore head or two lights in the head with one or two light strips,
- as for providing information with two lights, the upper light may flash only.

The six-level light semaphore can provide the following information for the first route located directly behind the semaphore:

- red light – travel speed is 0 km/h,
- lower yellow light and one of six types of upper lights – travel speed does not exceed 40 km/h,
- lower yellow light and yellow light strip and one of six types of upper lights – travel speed does not exceed 60 km/h,
- lower yellow light and green light strip and one of six types of upper lights – travel speed does not exceed 90 km/h,
- lower yellow light and two green light strips and one of six types of upper lights – travel speed does not exceed 120 km/h,
- no lower light and only one of six types of upper lights glows – maximum speed does not exceed 160 km/h.

For the second route behind the specific semaphore, the following indications can be communicated:

- upper yellow light (constant) – next semaphore shows a speed of 0 km/h,
- upper yellow light (slow flash) – next semaphore shows a speed of max. 40 km/h,
- upper yellow light (fast flash) – next semaphore shows a speed of max. 60 km/h,
- upper green light (slow flash) – next semaphore shows a speed of max. 90 km/h,

- upper green light (fast flash) – next semaphore shows a speed of max. 120 km/h,
- upper green light (constant) – next semaphore shows max. speed, not more than 160 km/h.

All possible indications of the six-level three block light semaphore for the first and second route are compiled in Table 2. The total number of indications is 31.

3.2. Five-level three block signaling

As already mentioned – the train light signaling used on the PKP PLK S.A. network is a simplified variant of light signaling developed in OSŻD because previous turnouts allowed traveling on the turning track with a speed reduced to 40 km/h or 60 km/h. This signaling allows information to be transmitted on five travel speed levels for the first route located directly behind the semaphore [1–4, 6]:

- first level – travel speed is 0 km/h,
- second level – travel speed must not exceed 40 km/h.
- third level – travel speed must not exceed 60 km/h,
- fourth level – travel speed must not exceed 100 km/h,
- fifth level – top travel speed permissible on the specific railway line section, that is 160 km/h.

Figure 3 presents the station's five-level three block light semaphore used on the PKP PLK S.A. network. Under the head of this semaphore are only two light strips: upper green and lower yellow.

Fig. 3. Three block light semaphore for indicating five travel speed levels [own elaboration]

Table 2

Six-level three block light signaling

Speed by first semaphore [km/h]	Speed by second semaphore [km/h]					
	0	40	60	90	120	160 (*V*max)
0						
40						
60						
90						
120						
160 (*V*max)						

Legend:  – 50 flashes/min,  –100 flashes/min,  – 50 flashes/min, – 100 flashes/min [own elaboration]

The five-level three block light semaphore can provide the following indications for the first route behind the semaphore:

- red light – travel speed is 0 km/h,
- lower yellow light and one of six types of upper lights – travel speed does not exceed 40 km/h,
- lower yellow light and yellow light strip and one of six types of upper lights – travel speed does not exceed 60 km/h,
- lower yellow light and green light strip and one of six types of upper lights – travel speed does not exceed 100 km/h,
- no lower light and only one of six types of upper lights glows – maximum speed of not more than 160 km/h.

As for the second route behind the specific semaphore, four indications can be communicated:

- upper yellow light (constant) – next semaphore shows a speed of 0 km/h,
- upper yellow light (flash) – next semaphore shows a speed of max. 40 km/h or 60 km/h,
- upper green light (flash) – next semaphore shows a speed of max. 100 km/h,
- upper green light (constant) – next semaphore shows maximum speed, not more than 160 km/h.

The signal indications of the five-level three block light semaphore for the first and second route are presented in Table 3. In this case, the total number of indications is 17 because the flashing yellow light is used to signal two speeds concerning the second route behind the semaphore (40 km/h and 60 km/h). Irrespective of its color, the flashing light is always a slow-flashing light.

3.3. Seven-level three block light signaling

The train light signaling suggested by the author is seven-level three block signaling. This signaling is aimed at raising the number of signal indications on signal lights on the PKP PLK S.A. network as arises from the potential travel at turnout turning tracks at the speed of 80 km/h and 130 km/h. When compared to OSŻD signaling, the seven-level unit is equipped with a second additional yellow light strip. The seven-level three block signaling also informs about speeds of 80 km/h and 130 km/h. The seven-level signaling can be used in full or simplified forms.

The station's seven-level three block light semaphore is presented in Figure 4.

As opposed to the six-level three block semaphore shown in Figure 2, there are four light strips under the head of this semaphore: two green and two yellow. Light strips are situated alternately so that they are divided by a dark strip when displayed at the same time, similar to signaling with two lights. The upper light strip is green.

Table 3

Five-level three block light signaling

Speed by first semaphore [km/h]	Speed by second semaphore [km/h]			
	0	40/60	100	160 (*V*max)
0				
40				
60				
100				
160 (*V*max)				

Legend:  – 50 flashes/min,  – 50 flashes/min [own elaboration]

Fig. 4. Three block light semaphore for indicating seven travel speed levels [own elaboration]

The indications of the seven-level three block light semaphore referring to the first and second route are demonstrated in Table 3. As shown in the table, strips of the same color are used to provide indications with light strips. The information on the travel speeds of 0 km/h, 40 km/h, 60 km/h and 100 km/h as well as the maximum speed is provided just like in the currently adopted signaling. The signals informing about these

speeds are framed in Table 4 with a thick line. The speeds of 80 km/h and 130 km/h for the first route behind the specific semaphore are signaled with the lower yellow light and two light strips (yellow and green), and for the second route with the upper fast-flashing light: yellow and green. The number of indications is higher than in OSŻD signaling, namely 37.

In the simplified seven-level three block signaling, the station's seven-level three block semaphore can provide the same indications for the first and second route as is the case in the full version, however, two additional indications can be communicated for the second route:

- upper fast-flashing yellow light – next semaphore shows a speed of max. 80 km/h,
- upper slow-flashing green light – next semaphore shows a speed of max. 100 km/h or 130 km/h.

The indications on the seven-level three block light semaphore referring to the first and second route are demonstrated in Table 5. For the second route, the fast-flashing light is used solely to transmit information on the speed of 80 km/h, while other speeds (40/60 km/h and 100/130 km/h) are signaled with the use of slow-flashing lights. In this case, the number of indications is 31 because flashing lights – yellow and green – are used for two indications, referring to the second route.

When the yellow and green flashing light is used for several indications, it is possible to use only one flashing frequency (Table 6).

4. Conclusion

The seven-level three block train light signaling in question has been developed on the basis of the OSŻD train light signaling. The seven-level signaling allows information to be transmitted on the speed of travel on turnout turning tracks used on the PKP PLK S.A.

Table 4

Seven-level three block light signaling version 1 full

Speed by first semaphore [km/h]	Speed by second semaphore [km/h]					
	0	40/60	100	160 (*V*max)	80	130
0						
40						
60						
100						
160 (*V*max)						
80						
130						

Legend: – 50 flashes/min, –100 flashes/min, – 50 flashes/min, – 100 flashes/min [own elaboration]

Table 5

Simplified seven-level three block light signaling, version 2

Speed by first semaphore [km/h]	Speed by second semaphore [km/h]				
	0	40/60	80	100/130	160 (*V*max)
0					
40					
60					
80					
100					
130					
160 (*V*max)					

Table 6

Simplified seven-level three block light signaling, version 3

Speed by first semaphore [km/h]	Speed by second semaphore [km/h]			
	0	40/60	80/100/130	160 (*V*max)
0				
40				
60				
80				
100				
130				
160 (*V*max)				

Legend: – 50 flashes/min, –100 flashes/min, – 50 flashes/min [own elaboration]

network. The signals on the signal lights are transmitted via a suitable system and colors of lights and two additional frequencies of light flashing. It is not difficult to generate various frequencies of light flashing. In computerized devices intended to control the railway traffic, for example, it is possible to use a time-counter system located inside the micro-controller which is part of the signal controller.

Similarly to the currently used five-level signaling, in the seven-level variant the semaphore, distance signal and repeating signaling device do not differ because signals transmitted via lights on the specific signaling device inform simultaneously about signals on the next signaling device.

The seven-level signaling in question guarantees a simple readout and is easy to remember, while the information it communicates is unambiguous. It adopts all signal images used in five-level signaling. Besides this, particular signal images can be assigned various values of speed for the first and second route. Another strong point is the low implementation cost because it does not require any new signaling devices (e.g. higher speed indicators W21).

Literature

1. Dąbrowa-Bajon M.: *Podstawy sterowania ruchem kolejowym. Funkcje, wymagania, zarys techniki* [Basics of railway traffic control. Functions, requirements, outline of technique], Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2014.
2. Dąbrowa-Bajon M., Apuniewicz S., Sobolewski J.: *Automatyzacja sterowania ruchem kolejowym*

[Automation of railway traffic control], Tom 1, Elementy i układy, Wydawnictwa Politechniki Warszawskiej, Warszawa, 1983.
3. Instrukcja sygnalizacji Ie-1 (E-1) [Signaling instructions], PKP Polskie Linie Kolejowe S.A., Warszawa, 2016.
4. Karaś S.: *Elementy i układy sterowania ruchem kolejowym* [Elements and systems of railway traffic control], Wydawnictwa Politechniki Warszawskiej, Warszawa, 1981.
5. Przystosowanie kolei do zwiększonych szybkości i dużych przewozów [Adaptation of railway to higher speeds and large transports], Wydawnictwa Komunikacji i Łączności, Warszawa, 1969.
6. Sterowanie ruchem kolejowym [Railway traffic control], Wydawnictwa Komunikacji I Łączności, Warszawa 1970.
7. Tory, rozjazdy, skrzyżowania torów, Poradnik dla Komisji Kolejowych, Kultura bezpieczeństwa w transporcie kolejowym [Tracks, turnouts, crossings], Guideline for railway commissions, Safety in rail transport, Urząd Transportu Kolejowego, Warszawa 2017.