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# Technological development of the train crossover drives

**Abstract:** The article includes information about the train crossover drives used in the Polish railway and their technological development. Train crossover devices are elements for the regular branching or crossing of the railway tracks. The drive of train crossover is a mechanism setting the train crossover device from one position to the other or closing it at the end position. It also transfers information about the train crossover position to the railway control room. The article characterizes drives of train crossover from different manufacturers implemented at the Polish railways in chronological order. The special emphasis was placed on their exploitation characteristics.

**Keywords**: Train crossover; Train crossover drives; Exploitation

## Introduction

In the nineteenth century, the development of rail transport has started. The century is called the age of the iron railway. Railways were the first land transport allowing fairly quick transport of goods on a large scale. In recent decades, a network of railway lines covered all the continents.

Technological development of crossover drives has been forced by rapid growth of expectations in rail transport. The first railway lines did not put excessive demands of quality and reliability for the items included in the railway road. With the development of transport volume, increase in speed of rail vehicles and increasingly urbanized infrastructure, requirements of crossover drives were significantly enlarged.

The main task of the companies of the PKP Group is to allow carriers to transport safely and reliably. To ensure safety, it is essential that each component constituting the rail route should provide appropriate standards. One of these components is a railway crossover. For the purpose of operating rail traffic, it is necessary to safely, continuously and in the shortest possible time pass the appropriate route. Crossover device is a basic element for moving the crossover.

Crossover devices are designed for:

- crossover switch,
- switch of movable cross beak of frog ,
- hold switch spires in the end positions,
- controlling the end position of spires.

In the initial phase of the development of the railway infrastructure, the use of hand-held mechanical drives was sufficient. This resulted from the occasional use of these devices. Today, when there is a much greater need for the use of crossover drives to change train road such solutions are no longer sufficient, and therefore electrical drives were implemented.

**The development of traffic control devices, depending on the control method**

Technological development of equipment controlling rail traffic can be presented chronologically, depending on changes in methods of implementation [4]:

- mechanic
  - manual (key),
  - momentum (centralized),
- electromechanic,
- electric
  - relay,
- electronic
  - hybrid,
  - computer.

Mechanical devices are those in which the process of adjustment is implemented in a mechanical way. In dependence boxes of centralized devices are installed sliders, cross, caps and other elements performing dependency, exclusion, restraints and closing switches. The switches are adjustable manually or by means of the power transmission and signalling through the electrical contacts or the power transmission (with shaped signallers).

Electromechanical devices are those in which all dependencies such as mechanical devices, remained in mechanical chest. Besides the mechanical transmission, a box with switches serving for adjusting switches and displaying allowing signals in signallers. The switches are adjustable by means of electric drives. An example of such devices is devices of VES type.

Electrical (relay) devices are those which are carried out depending on the electric path. Relays, which are executive elements, carry out various tasks in the circuits. The devices are equipped with interlocking with the geographical light plan. Over time, different varieties of relay devices were born. The most popular are devices of type E, where crossovers are individually adjustable and allowing signals appear in signallers after pressing a button by service team. The trajectory is resolved globally in a moment after passing the last crossover in the course by the rolling stock. Also popular are devices of type PB (semi-block) in which the switches are set automatically in the course of the operation by pressing the start and end buttons. Allowing signal appears in signallers automatically after "inspecting" by the device the arranged route. The road course is resolved "sectionally" after rolling stock goes out of the crossover.

Electronic devices are those which are carried out according to a suitably written computer program. We can distinguish the hybrid devices in which computer technology is used to control the external device, after delivering needed information to it. Executive elements of the hybrid devices are relays. Dependencies are very often in the relay layer. Relay-computer devices were equipped with computer monitors on which light plan is displayed. Due to the fact that production of previously used desktops was stopped, more often are used mounting so-called computer overlays on the relay devices. The solution consists in elimination of the desktop for computers with devices cooperating with the relay layer. In computing devices, external devices are controlled by the computer after providing the necessary information. In such devices, the relay falls into disuse and is used marginally [4, 5].

**Technological development of crossover drives**

The following types of crossover drives are recognized [4]:

- manual;
- switch mechanic with control or no control of spires;

- electromagnetic;
- electric;
- electrohydraulic.

**Manual mechanic crossover drives**

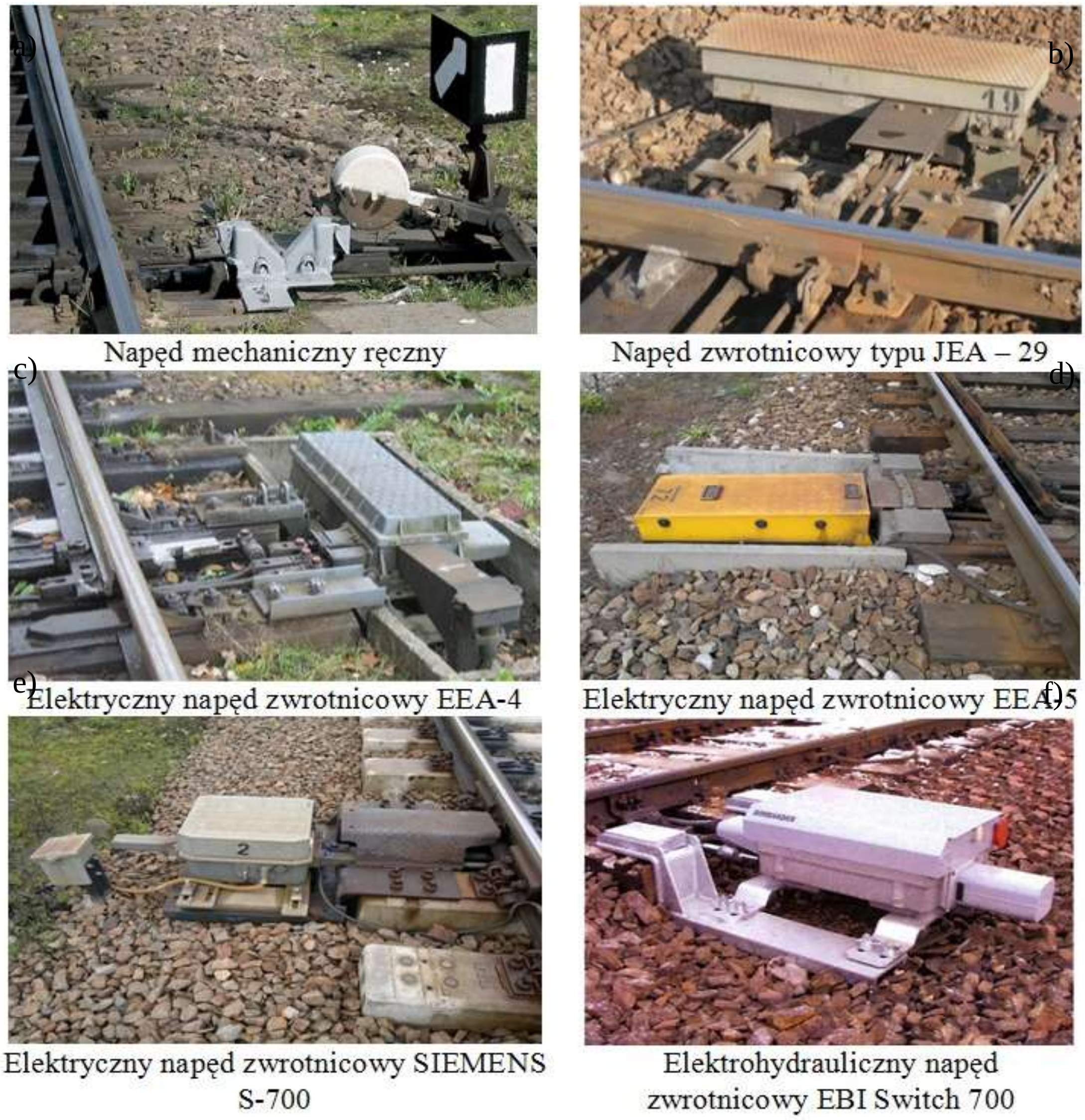
The first used in the railway rail switch drives were, occasionally found today, manual drives also called tropics (Fig. 1a). Manual drives moved by lever mechanism at the crossover are used at stations equipped with essential equipment as well as sidings and holds. Weight lever is painted in black and white, and is faced with the white half up in the basic position of the switch [5].

**Centralized manual mechanic crossover drives**

In centralized mechanical devices, switches are set by control levers connected to the drive via the power transmission. The drive has inside its case bend roller of transmission and mechanism for transmitting movement to shift of the setting rod.There are a variety of mechanical drives with a control position of spires that have additional control sliders, and a control crown locking sliding of adjustment rod in the event of anomaly in traffic control sliders. In the event of damage to the drive or the power transmission, it is possible to adapt the switch to manual control by the rear lever with a weight. The use of centralized mechanical drives of switch enabled the control of multiple crossover drives from one control room. The distance between the control room and controlled drives should not exceed 350 m. Such a solution allowed (to a limited extent) to improve the compilation of railway routes for rail transport [4, 5, 6].

**Light electric crossover drives**

Light electric crossover drives with the adjustment power of 2500 N, are also called drives of type A. The common use of these drives took place after the Second World War. This was due to the development of railway routes in Poland. The construction and functionality of these drives are not developmental because of the requirements placed currently crossover drives. For this reason, they are gradually withdrawn from exploitation and replaced with heavy drives of type B [4, 5, 6].




**1.** Overview of the subsequent version of crossover drives used in the Polish railways [10]

**Heavy electric crossover drives**

Heavy electric crossover drive, also called the drive of type B consists of a single- or three-phase motor, a gear, clutch, and the control module. Usually it is also equipped with control sliders to independently control the position of spires.

Unlike light drives, these drives have a greater adjusting force (5000 N). Technological performance and improvement of drive parameters caused that they are much heavier than the drive of type A. The use of electric drives gave performers a great potential for controlling a substantial number of crossover drives from one control room. It was also avoided the effect of the extreme distance of drives from the control room, because controlling is not dependent on mechanical elements, such as the power transmission [4, 5, 6].

**Basic parameters affecting the functionality of crossover drives**

Characteristic parameters affecting the functionality of crossover drives are [1, 2, 6, 8]:

1. time of drive switch, there are distinguished the following drives:
   - high-speed, where the switch time is to 0.8 seconds,
   - normal-speed, where the switch time is to 3 seconds,
   - low-speed, where the switch time is to 7 seconds.

2. The jump of setting rod - crossover drives are carried out in systems with conventional jump of setting rod 150 mm and 220 mm. The diversity of applications and technical specificity and structural demands required from the manufacturers flexibility of offered jumps (there are feasible on request jumping from a range of even 125 ÷ 260 mm).
3. Setting force - force needed to switch spires of crossover. It is dependent upon the type of spires, impurities in lubricating and sliding saddles, temperature and other environmental conditions. It also depends on resistance arising inside the drive during adjustment. The maximum value of the setting force of electric crossover drives depends on the coupling and is checked at the locked setting slider and slipping overload clutch
4. Holding force - force with which the drive keeps the spire offset in its end position.
5. Rip force - force with which wheels of vehicle crossover exert on the setting slider, against a force holding the slider in its end position during the first phase, and against a setting force during the second phase.

Disregarding the type, crossover drives must meet the following assumptions:

- construction of the drive must be solved in order to there was no damage when the crossover is ripped,
- construction of the drive must enable, its immediate restoration to normal state, after ripping crossover,
- while adjusting the crossover, drive must enable, at any time, return the crossover to its original position,
- fixing the drive to sleepers is intended to provide a permanent connection with the crossover to shakes caused by a passing train were not transmitted to the drive,
- easy to replace,
- easy to maintain and, if necessary, manual operation during conservation,
- resistance to weather conditions and mechanical damage,
- possibility to building over on two sides of crossover without workshop modifications.

**Exploiting characteristics of crossover drives used on railway lines in Poland**

Among the typical drives used in railway network, light drive of type A is encountered sporadically and practically is out of use. Similarly, the drive of type JEA-29 (manufactured under the license from Ericsson), is gradually being phased out of service because of their age and high degree of wear. Currently, electric drives used in Polish railways are EEA-4, the EEA-5, S 700 (KM) and the EIB Switch 700.

**Crossover drive of type JEA-29**

The drive JEA-29 (Fig. 1b) is very simple in design and virtually fault tolerant. It consists of three major components:

- axial-flux engine of single-phase alternating current,
- mechanical gearbox with motor brake,
- switch assembly with friction clutch and contacts for switch-point circuits.

The advantage of this drive is its simplicity and reliability. From the motor side, the drive is provided a hole, through which it is possible to control manually the drive (by cranking). The main disadvantage is its high weight and the lack of connection between the crank of manual control and the crossover circuit. When cranking there is a possibility to over control electrically the drive and in consequence, there is a risk of throwing off the crank from hand [6].

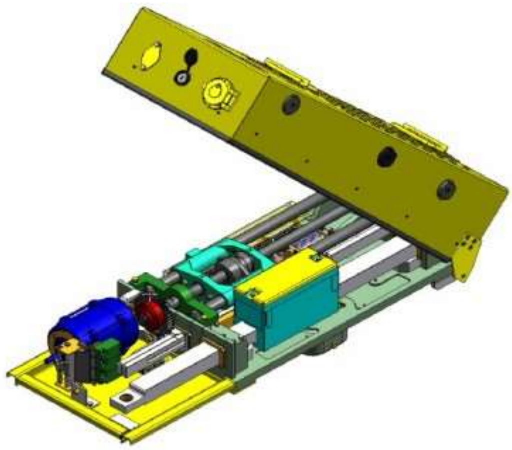
**Crossover drive of type EEA-4**

Crossover drive EEA-4 (Fig. 1b) is a lighter and more modern successor to the drive JEA, produced since 1975. In the early twenty-first century it has been discontinued as an obsolete design. However, the demand and the need for spare parts have decided to return the drive to the offer of Bombardier Transportation (ZWUS) Poland.

The construction of the drive is very similar to its predecessor, but its disadvantages were eliminated by the designers. It is produced in various forms and configurations depending on the needs. The drive is a bit more complicated, but praised by installers because of its reliability. With a proper maintenance, the drive virtually does not crash. The elements on which greater attention should be paid, e.g. during periodic maintenance, are safety switches running during the manual handling of the crossover and the mechanical part of the drive system [1].

**Crossover drive of type EEA-5**

The Drive of type EEA-5 produced since the late nineties of the last century is a product of Bombardier Transportation (ZWUS) Poland. It is characterized by a modular construction (Fig. 1d, Fig. 2).



**2**. Electrical crossover drive EEA-5 [2]

The crossover drive EEA-5 consists of the following modules:
- system of base plate,
- locking module,
- steering-control module,
- clutch of gripping force with the setting slider,
- switch of crank module,
- sliding module,
- motor module,
- system of control sliders,
- lower engine cover,
- cover drive.

The electric drives of type EEA-5 are made in ripping and non-ripping versions. When ripping the crossover, the shaft of worm gear in the drive is often deformed and destroyed. The shaft extends almost across the entire length of the drive, so it is quite long and bendable. The cranking is difficult and tedious and consequently a longer time of drive job (compared to EEA-4). There is no possibility of using the drive on top timing gear, where a fast shift of the crossover is required when carriages are sliding down a hill [2, 7].

**Crossover drive of type SIEMENS S-700 (KM)**

Crossover drive of type S-700 (KM) of SIEMENS Company is one of the most technologically advanced, most expensive and less common drives in the PKP PLK network. This device is similar in construction to the drive EEA-5. It is based on a similar principle to transfer the crossover and adapted for use in railway lines with a speed of 350 km/h. However, S700 KM crossover drive is a more modern version of the S700 K. It has improved technical parameters and operational characteristics, as well as favourable solution for mounting the drive in a crossover. The drive is more compact and thus is of smaller size. Its significant advantage is the presence of drain water hole, which prevents electrical components against moisture and its freezing, which increases the safety and reliability of operation [7].

**3**. Modules of crossover drive of the type S700 KM [10]

In the basic module, in a cast iron casing with lockable steel (galvanized) cover are built into the following functional modules:

- motor unit,
- electrical wiring module with switches,
- drive module,
- module of drive screw with the adjusting clutch,
- setting module with holding clutch,
- module of control sliders.

The basic module includes a safety switch, switch lock, locking slider, cover and the lock of hand crank. Across the entire length of the drive is running screw shaft, wherein the guide with attached slider moves mechanically. These drives are functioning properly [7, 8].

**Crossover drive of type EBI Switch 700**

Electrohydraulic crossover drive EIB Switch 700 (Fig. 1f) is the latest drive of Bombardier Transportation (ZWUS) Poland and is designed for adjusting switches with external setting locks. It consists of the following components:

- electric motor;
- axial piston pump;
- control block;
- hydraulic system.

The drive EIB Switch 700 is equipped with two safety systems, i.e. the basic system responsible for moving the spire and its locking in the desired position and the reserve system, which is an emergency option in the case of malfunction of the basic system.

The drive is compatible with all types of crossovers, with any setting jumps of closures and any track gauge. It is produced in ripped and non-ripped version. It is built on special mounts with adjusting rod and control rods designed to control the position of the spires [9].

**Research opportunities of laboratories at the University of Technology and Humanities in Radom for controlling rail traffic**

Department of Control Systems in Transport at the Faculty of Transport and Electrical Engineering (WTiE) UTH Radom with cooperation with Bombardier Transportation (ZWUS) Poland SA Katowice, Automation Plants KOMBUD SA Radom and Scheidt & Bachmann Poland Sp. with o.o. in Luboń extended its research infrastructures with modern and unique in European scale laboratories for testing technical and functional systems and devices controlling rail traffic.

In WTiE, are currently working three laboratories equipped with modern technical solutions for control of rail traffic:

- Laboratory of Components and Devices SRK, e.g. Z.A. KOMBUD SA, Bombardier Transportation (ZWUS) Poland SA,
- Laboratory of Systems SRK (Bombardier Transportation ZWUS Poland SA),
- Laboratory of Automation Railway Systems (Scheidt & Bachmann Poland Sp. O.o.).

In these laboratories, are collected models of basic systems and railway traffic control devices currently manufactured by the specified companies and used on the upgraded railway lines. All laboratory positions correspond to real systems controlling traffic on Polish railways [3].

The SRK Systems Laboratory (Bombardier Transportation ZWUS) has the model of crossover drive of the type EEA-5 (Fig. 4b), while in the Laboratory Components and Devices SRK there is the older model drive JEA-29, on which can carry out different kinds of experimental research.

Based on the laboratories controlling rail traffic at the Department of Transport and Electrical Engineering University of Technology and Humanities in Radom are conducted studies and research, including project under the Programme for Applied Research "System for collection of operating data and analysis of reliability and safety systems of railway automation" PBS3/A6/29/2015 (IDz47180).


**4**. Selected laboratory positions for testing systems and railway traffic control devices from different manufacturers used in Polish railway [own elaboration]:
- Bombardier Transportation (ZWUS) Poland: a) self-crossing signaller of type SPA-5; b) crossover drive of type EEA-5;
- Plant Automation KOMBUD: c) meter system for controlling non-occupancy of type SKZR; d) self-crossing signaller of type RASP-4ft;
- Scheidt & Bachmann Company Poland: e) crossing signaller of type Buesa in 2000; f) panel containing management and diagnostic modules.

**Conclusions**

Manufacturers of crossover drives largely unified their technical solutions maintaining varied performances. This is due, among other things by:

- diversity of requirements for functionality drives,
- availability of service and spare parts to these drives.

Regardless the manufacturer, crossover drives are characterized by a simple construction, which prevents them against harmful atmospheric agents. Their construction is based on the electric motor, the transfer element of motor torque (e.g. by mechanical gear or hydraulic actuator) and system for switching crossover. Solutions of executive blocks in particular types of switch drives are different, but their basic characteristics remain the same.

Among the functional advantages of switch drives the following design features can be listed:

- construction of the crossover drive must protect it from damage in the case of ripping crossover,
- construction of the crossover drive must enable quick restoring it to the normal operation after ripping crossover,
- construction of the crossover drive must allow in every phase of setting the crossover its back to the original position,
- mounting the crossover drive, regardless of its type, must guarantee to shakes arising in the crossover do not bear on its elements,
- construction of the crossover drive should allow it to be mounted either on its right or the left side without necessity to make workshop modifications.

The current works on the modern solutions of switch drives are mainly focused on the use of electrical and electronic components. The use of electronic components gives manufacturers a possibility of using them for the purpose of increasing the safety of traffic.

Despite the many differences between the presented electric crossover drives, their functional purpose and high reliability remain valid.

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**Source materials**

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