Optical Features of German Train Control Reflect Ingenuity

System uses light source, reflector, mirror, and selenium cell to control trains automatically—Intermittent principle employed

SINCE the publication of the article entitled, "Train Control System Using Rays of Light Developed on German State Railways," in the June issue, page 228, further information, more complete technically than what was contained in the aforementioned article, has come to hand. What follows is a liberal translation of an article prepared by the "special referee for safety measures" of the Berlin district administration of the German State Railroads. The component parts of the system are each taken up separately and the inter-relationship of each unit of the system is clearly pointed out.

General Arrangement of Apparatus

The controlling influence in the optical system is light, which, with the assistance of optical apparatus between the locomotive and the signal, is sent to and from and assures the intended operation. It would be the simplest technical solution to equip every signal with a light source and transmitter, which would emit light at the stop position of the signal, and to provide every locomotive with a receiver which would be illuminated on the passing of the locomotive. But, since in Germany at the present time, it is not possible to furnish an individual light source at every signal, because the electric lighting of signals is still restricted to exceptional cases, the arrangement has been reversed, that is, the source of light and the transmitter have been arranged on the locomotive, and a reflecting device, a mirror, placed on the signal, which receives the light from the transmitter and throws it back to the receiver upon the locomotive. The mirror changes its position according to the position of the signal and at the same time its effect upon the receiver.

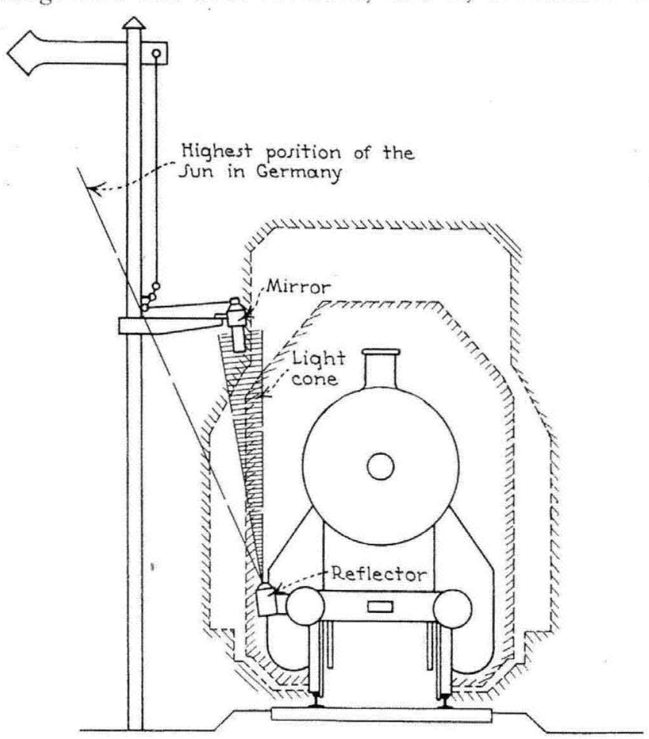
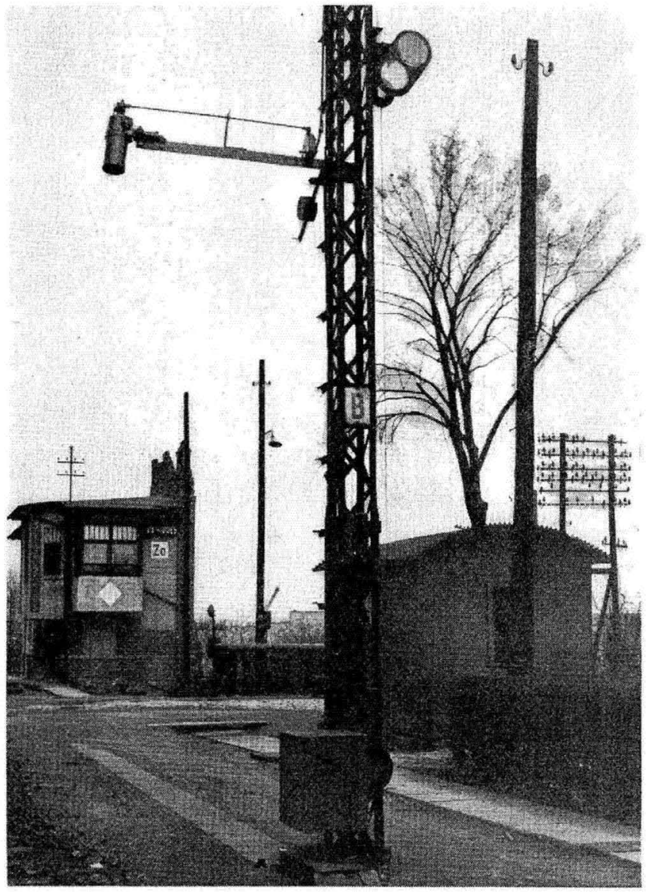


Fig. 1—Relation between roadway mirror and engine transmitter



The roadway mirror is mounted on an arm mechanically actuated by the signal

Transmitter and Receiver

The transmitter is a reflector, which collects in a lens, the light of an incandescent lamp and projects it vertically in a small continuous light cone (Fig. 1). The mirror is so arranged at the signal that it has a fixed position with reference to the track. The light cone, at the height of the mirror, is of such breadth that it reaches the mirror, even though some depression and change of position of the rails may have taken place.

A so-called selenium cell behind a small lens serves as a receiver, which is located close to the reflector. The cell has the characteristic of changing its electrical condition under the influence of light. The weak electric current thereby generated is amplified and operates an auxiliary relay, which causes the operation desired, i.e., the automatic setting of the valves.

The selenium cell (Fig. 2) consists of a small glass plate which carries a thin coating of platinum. This is divided into two halves by a narrow fissure. A

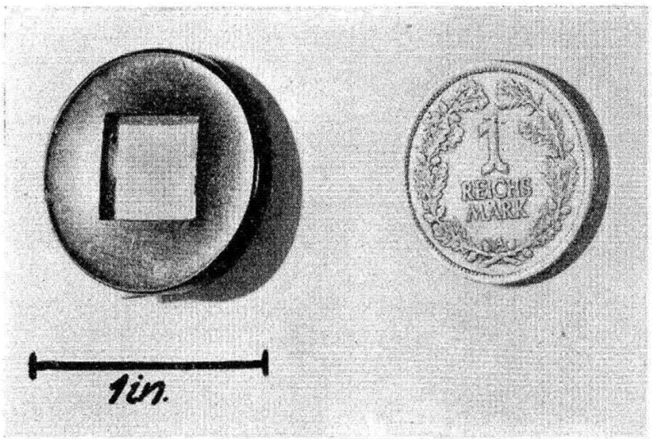


Fig. 2—The selenium cell which translates the light impulses into electric current

current lead to the amplifier is connected to one-half of the cell. The space between the two halves is filled with a thin layer of selenium.* When the cell receives light, the selenium layer becomes electrically energized. To increase the capacity of this action, the layer is arranged in comb-form (Fig. 3).

The quickness of response of the selenium cell is considerably in excess of what is required. At 120 kilometers per hour train speed, the duration of light from the mirror is around 1/30 sec. It has been determined experimentally that 1/200 sec. gives definite assurance of operation.

Wayside Mirror

On the passing of an operative mirror by a locomotive, the reflected light falls upon the selenium

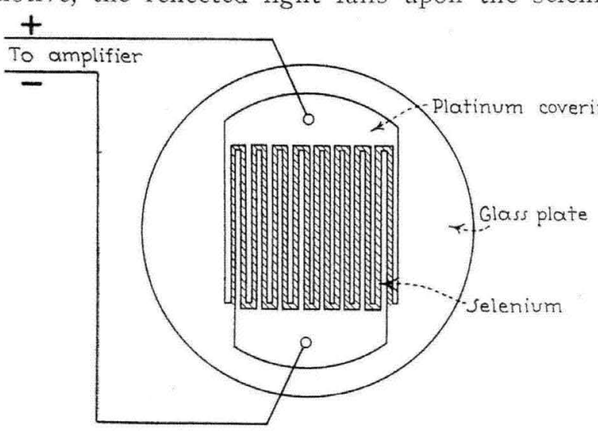


Fig. 3—A comb-like arrangement increases the capacity of the selenium cell

cell. Slight changes of the rails, or of the mirror, rolling of the locomotive and high-speed operation must not affect the correct functioning of the cell. With an ordinary mirror, this condition cannot be fulfilled, but it can be fulfilled by using the triple mirror which Professor-Doctor Straubel, manager of the Leiss Works, has invented. If three reflecting planes are placed together at angles of about 90 deg., as on the corner of a cube, this optical system has the peculiar characteristic of throwing back in its original direction, the light falling on the inside. A source of light on the locomotive is reflected in this way as soon as it strikes such a mirror. It makes no difference at what point of the light cone the mirror is located so long as it receives the light at all. Always, the light is thrown back to the transmitter. All angular variations of the mirror in the light cone and even considerable displacements of the light stream itself are without effect upon the direction of the reflected light point. The movement of the locomotive may be very uneven, but the selenium cell will always act with certainty. The conditions here

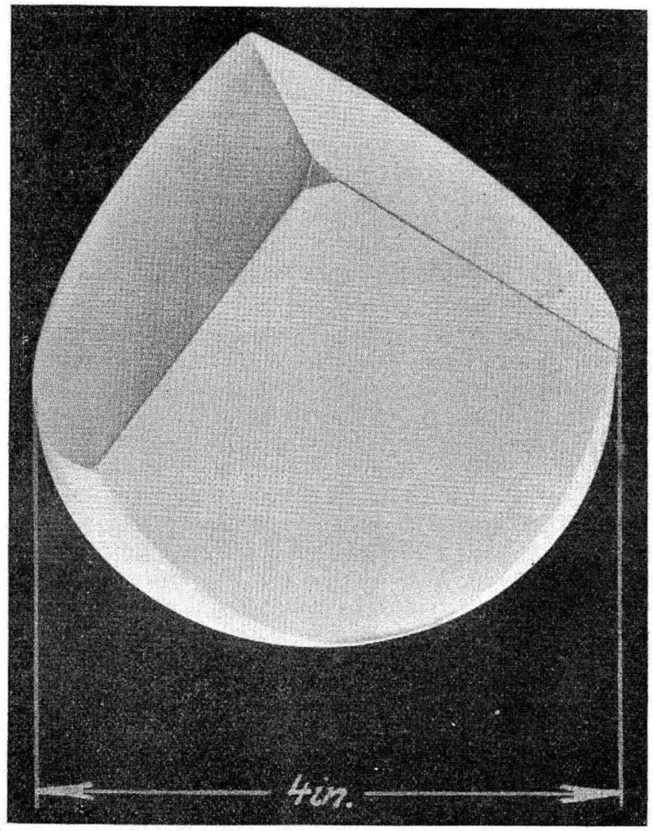


Fig. 4—The wayside mirror is a three-sided glass pyramid, each reflecting plane is at 90 deg. to the other two planes

correspond to those in the angular mirrors used by surveyors and in the sextant. The only change in the direction of the reflected light point occurs when the mirror is turned upon the entering ray of light itself as an axis. Then the outgoing ray, and with it the point of light, changes in a circle around the light outlet.

Recently the outside mirror has been constructed as a three-sided glass pyramid of which the side planes stand at an angle of about 90 deg. to each other (Fig. 4). It accomplishes total reflection and therefore its operation can neither change nor weaken in the course of time.

The mirrors used in the optical system of train control have the special peculiarity that one of the three reflecting faces is set a little "out of angle." This has the effect of throwing back the reflected light not quite parallel to the direction in which it enters, but at a small angle with it. Since this angle

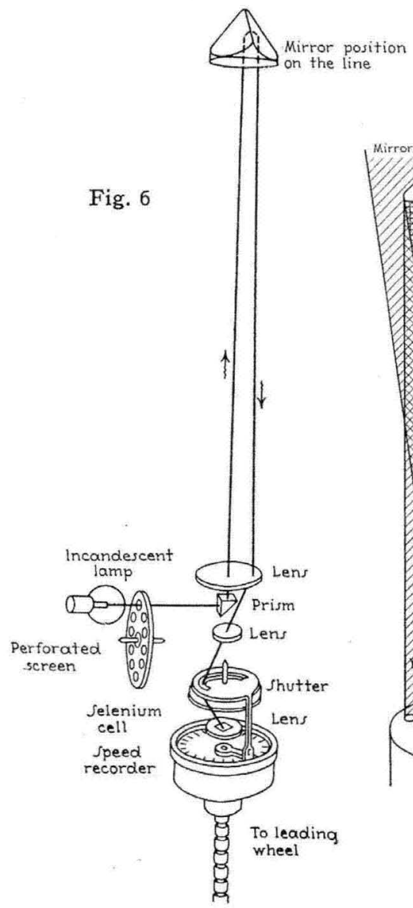
*Chemical element, somewhat similar to sulphur. In its crystalline form it has the peculiar characteristic of greatly increasing its electrical energy under the influence of light.

can be controlled at will, it is possible to spread the reflected light stream in greater circles around the source of light (as with a circle of light) and secure thereby the possibility of lighting up a considerable number of selenium cells placed near each other. Every selenium cell would then correspond to a definite turning position of the mirror and control a definite and different effect upon the locomotive.

Mirror Is Also a Condensing Lens

What in the foregoing has been called a light ray is actually a bundle of rays. The underside of the body of the glass mirror is ground in spherical form and therefore operates as a condensing lens. All the light falling upon the mirror is therefore brought together to a focal point, forming an image of the light source, which image falls upon the selenium cell. Besides, for optical reasons, the mirror provides this image always in duplicate and on diamet-

Fig. 6



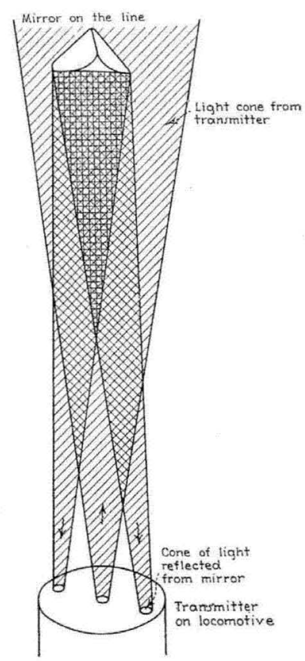


Fig. 5

Fig. 5 (Right) Optical relationship between roadway mirror, engine transmitter and selenium cells arranged in pairs on diametrically opposite sides of the transmitted light cone

Fig. 6 (Left) Optical and mechanical arrangement for obtaining and translating the pulsating light stream (600 flashes per sec.)

rically opposite sides of the source of light, so that in certain cases it is useful for the reinforcement of its functioning to arrange the selenium cells in pairs and operate them in parallel (Fig. 5).

Protection Against Foreign Light

Since the selenium cell might respond to the action of foreign sources of light, for example, to the change of light in passing through bridges and tunnels, to bright cloud reflections, etc., it is necessary to take precautions against this.

The direct contact of sunlight is prevented by the high position of the mirror and the upwardly directed mounting of the reflector. In the southern part of Germany there are points, as shown in Fig. 1, where the sun's rays on June 21, even at the greatest superelevation of the rails on curves are always at an angle several degrees lower than that formed by the edge of the rays of the reflector.

To protect against other sources of foreign light, the optical system of train control uses a special light such as does not occur naturally. The most suitable is a pulsating light stream of about 600 flashes per second. This is accomplished in this

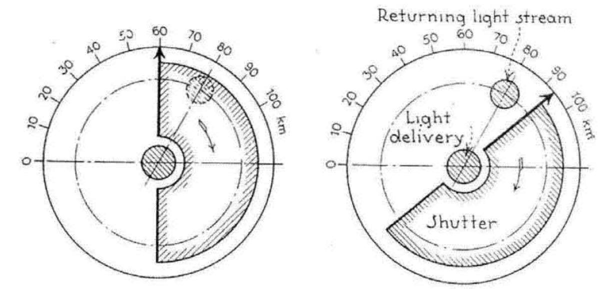


Fig. 7—Rotating shutter mechanism for translating the pulsating light stream before this light reaches the selenium cell

way: There is interposed close behind the incandescent lamp a rapidly revolving perforated screen in the path of the light. The perforated screen cuts off, by its imperforated parts, a portion of the radiated light, but the excitation of the selenium cell corresponds, even under the most unfavorable circumstances, with a 10 to 20 factor of safety.

Closed Circuit Principle

The equipment upon the locomotive is electrically operated and designed upon the principle of closed circuit control. Every failure is shown immediately to the engineman, and, if this is not at once detected, causes a setting of the brakes not later than in a few seconds. The operating current is taken from a 24-volt direct-current turbo-dynamo, which is mounted upon the locomotive and which also serves for lighting. The reinforcing pipes are of ordinary commercial material and should last for years. The vibration of the locomotive has, up to the present time, had no injurious effect on the pipes. The reflector lamp is of special manufacture with a concentrated filament. All auxiliary apparatus (reinforcing pipes, relays, brake magnet, etc.,) are grouped in a case on the wall of the cab.

Influence of Weather

The influence of the weather in no way disturbs the operation of the apparatus. The mirrors are protected by a long covering tube of papier-mache and a celluloid peak over the body of the glass. They have withstood the last uncommonly severe winter without failure. Blurring of the mirror by frost has not occurred. Fog formation weakens the force of the light only inconsiderably as the course of the light is only two or three meters. Locomotive smoke does not interfere, as the locomotive smoke-stack is higher than the mirror and the light producer is situated at the farthest forward corner of the locomotive, at least it is forward of the smoke-stack. The locomotive reflector can be kept free from snow and ice by heating it with electricity or steam.

The change of position of the mirror corresponding to the change of the signal is effected either mechanically from the signal, or from the operating wire, or, in special cases, by means of an electrical impulse. Since the mirrors in their housings rest in ball-shaped seats, and are fully enclosed, their resistance to movement is very small. For this reason, their movement may be controlled from the signal or from the signal-operating wire.

Continuous Control of the Mirror

A special advantage of the optical system is that the roadway mirrors, during all their preparation for service, can be supervised. On the installation of the signal, the mirror is so turned that its reflected light falls upon a specific control cell on the locomotive. This causes an indication on the locomotive which gives the engineman the possibility of control, and by which the engineman can also be informed, under bad weather conditions, that he is to pass an expected signal in the running position. At the distant signal this same operation takes place, but with a certain retardation in time, in order that the attention of the engineman to the track and the signals shall not be distracted. Every train exercises this control over all the mirrors on every trip over the equipped line.

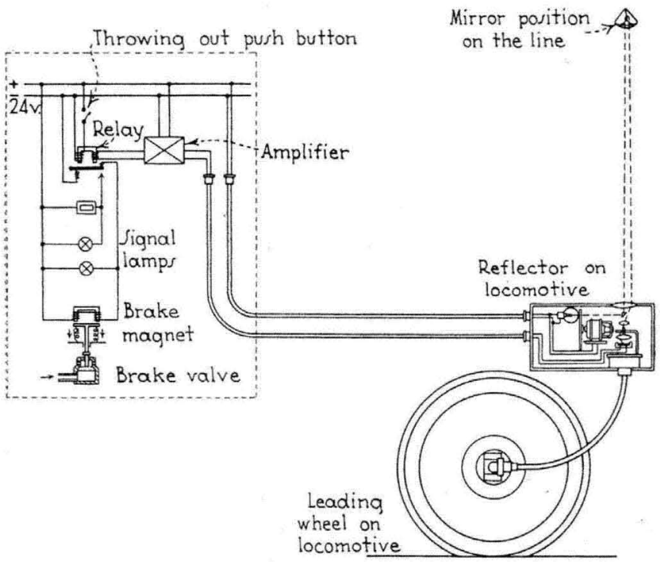


Fig. 8—Diagram of electrical and pneumatic apparatus for effecting control of the train brakes

Fundamentals of Control Scheme

The optical system of train control incorporates all of the established fundamentals of train control; the principle of acknowledgment and of speed control. With the principle of acknowledgment the first point of control is the advance signal. If this stands at "caution," which means the home signal is at "stop," the train receives an indication that, at the expiration of five seconds, operates automatically upon the brake system to reduce the speed, provided the engineman has not taken proper action before that time. If he has received the caution signal properly, and wishes to avoid setting the brakes, he must, within these five seconds, make use of an acknowledging lever, by which means he puts the automatic control out of operation and again secures the full control of the train. In order to control the further systematic speed reduction, between the advance and home signals, after the expiration of a certain time (say 15 sec.), a speed-control device operates, which remains in force up to the home signal and compels the engineman, even in the case of intervening signals, to maintain this reduced speed. But, if he should again speed up the train, the brake-setting operation ensues. This speed control must extend over a stretch of from 80 to about 45 kilometers for passenger trains. A certain over-running of stop signals cannot, in this way, always be avoided.

At the home signal another operation is provided for, which effects an absolute block and causes the setting of the brakes, if the engineman improperly over-runs a signal in the stop position. This operation cannot be nullified by the engineman alone. But, if the over-running of a stop signal is necessary, on account of interruptions, or in switching, it is, in Germany, done only upon special order. There is a provision for this case, but the fireman must take an active part. For this purpose, he must make use of a key and hold it in a designated position until the train has passed the stop signal. Upon release, the key returns automatically to its permanent position.

Advantages of Optical Control

Following are the advantages of the optical system of train control briefly summarized. The same apparatus accomplishes a variety of functions and, therefore, permits variations in control.

(A) By the system of acknowledgment levers:

1. An absolutely forced stop at the home signal, without special and expensive measures is readily and positively effected.

2. The train control points are at the signals (advance and home signals), thereby eliminating cable transmission and saving expense.

3. There are no electrical parts upon the roadway; only maintenance of simple apparatus is necessary.

(B) By the system of speed control:

1. Reduction of over-running of a signal to any desired amount is effected, thereby avoiding the expense and delay of backing trains.

2. Does away with the use of acknowledgment levers.

3. Eliminates sliding action of wheels on rails, thereby relieving the wear and tear on the track structure.

(C) Further advantages, not only from the acknowledgment system, but also from the system of speed limitations are:

1. Operation of the mirror is checked in running position, thus constantly testing the efficiency of service.

2. There is no part of the apparatus on the track or under the locomotive, therefore it is easy to maintain and is not in danger of being struck.

(D) Various uses:

1. Protection of slow-running points, danger points, curves and "head-houses."

2. Warning of trains at unclosed barriers or crossings, where signal plants are not provided for country service.

3. Cheap construction for three-indication advance signals.

4. Possibility of extending the system later to include any number of new signals.