

Railway Signal Aspects and Indications

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ABSTRACT

Wayside railway signaling practice in the U.S. is a nightmarish web of operating rules, signal types, aspects, aspect names, and indications, differing between the different roads and even their individual divisions and locations. Much of the “vocabulary” involved is extremely curious and counter-intuitive, a result of the long historical evolution of this field and of the industry.

This article begins with a review of the evolution of the actual “signals” themselves. Then a consistent (if tortured) thread of syntax is identified for the mainstream of current practice, and its principles and most common application are discussed at length. An appendix illustrates, with extensive charts, much of the vocabulary of a hypothetical system with explanatory notes. Other appendixes cover specialized related areas.

1 INTRODUCTION

Wayside rail signaling¹ practice in the U.S. is a nightmarish web of operating rules, signal types, aspects, aspect names, and indications, differing between the different roads and even their individual divisions and locations. Much of the protocol involved is extremely curious and often counter-intuitive, a result of the long historical evolution of this field and of the industry.

Canadian practice, although for many years generally paralleling U.S. practice, currently follows a somewhat different (and slightly more rational!) practice.

In this article, I begin with a discussion of the evolution of rail signaling and the various signal devices used in it.

Then, I describe some principles that run through most of the syntax used in the area. Next I give examples of the syntaxes used by

¹ *Wayside signaling* operates through the use of visible signals placed alongside the track which give indications intended for observation by the locomotive crew. It is distinguished from *cab signaling*, in which the indications appear inside the locomotive cab, and from various forms of *automatic train control*, in which the indications actually govern train operation (either through the engineman or directly).

illustrative signaling systems. Then I discuss various “variations” we may encounter.

There are of course numerous subtleties to the various matters I present which are beyond the scope of this paper. And I must emphasize that often what I describe for each situation is only one of many possibilities—usually the most common, and hopefully the most illustrative.

An appendix gives, in “glossary” form, illustrated, examples of signal aspects and their indications from a hypothetical system, showing how they are “composed” of the various syntactic ingredients.

Readers having need to further pursue the wide range of possibilities and the various subtleties of the field are referred to the section of the paper entitled “References”, where URLs to Web sites having an almost obscene amount of scope and detail may be found.

Finally, note that, consistent with our practice with respect to telephone signaling, we spell “signaling” that way, with one “L”. The spelling with two L’s is of course quite common and wholly proper.

2 OVERALL CONTEXT

This article (except where mentioned to the contrary) pertains to *automatic block signaling* practice and the associated *interlocking signal practice*, as widely used for many decades on most North American railroads. Nevertheless, prior doctrines, such as *manual block signaling* and even *train order* operation often used signals of essentially the same types discussed here.

Those latter two doctrines are briefly discussed in Appendix D (train order operation) and Appendix E (manual block operation).

3 DEFINITIONS

These terms will be widely used in this paper. Words in bold here have their own entries.

Signal (wayside)—A **head** or array of heads placed alongside, or over, the track that shows, at any particular time, a single visual **aspect** to the train crew.

Head—A signal element that can exhibit any one of a small number of visual messages. Called “arm” if implemented by a semaphore, and often colloquially called “arm” even if implemented with lights (out of nostalgic respect for the earlier implementation).

Aspect—The visual appearance of a **signal** at a particular time, often described verbally. Examples: “Red”, “Yellow over green over red”.

[Aspect]Name—The formal name of the **aspect**. It is essentially a short form of the **indication** conveyed by the **aspect**. Example: for the **aspect** Green, the name is often Clear. An **aspect** may be given different names in the signal systems of different railroads, and in a given system, there may be multiple alternative **aspects** that have the same name.

Indication—The operational mandate given by an **aspect**. Example, for the aspect Green, the name may be Clear, and the indication may be: “Proceed not exceeding Normal Speed”.

Rule—A numbered provision of a recognized set of operating rules (see section 4) that defines a particular **aspect**, its **name**, and the associated **indication**. Example: “NORAC Rule 282”.

4 STANDARDIZATION

4.1 Caveat

The information in this section was gathered for Issue 1 of this article, in 2002. It has not been generally updated, and so may well be out-of-date at this writing.

4.2 NORAC

Many northeastern U.S. railroads subscribe to a model set of operating rules promulgated by the Northeastern Operating Rules Advisory Committee (NORAC). The NORAC Operating Rules document covers many aspects of railway operation, including defining a set of signal aspects and indications.

4.3 GCOR

Many railroads in the western part of the United States adhere today to a set of rules known as the General Code of Operating Rules (GCOR), developed by an industry committee. Like the NORAC rules, it covers many facets of railway operation. In its initial edition (1985, substantially amended 1986), GCOR defined a set of signal aspects, names, and indications. However, as of the 1989 edition, GCOR no longer defines signal aspects, names, and indications, now leaving that up to the individual railroads.

Many railroads that follow GCOR as their overall operating rules continue to follow signal aspect and indication definitions very similar to those earlier prescribed by GCOR itself. Sometimes these are

spoken of as "GCOR aspects and indications", but in light of the current scope of GCOR, that is not fully apt.

4.4 UCOR and CCOR

At one time, many railroads followed one of three sets of standard operating rules: The NORAC Operating Rules (already mentioned), the Uniform Code of Operating Rules (UCOR), or the Consolidated Code of Operating Rules (CCOR). GCOR in effect superseded both UCOR and CCOR, in an attempt to broaden the uniformity of practices.

Both UCOR and CCOR defined sets of signal aspects, names, and indications. Reference to UCOR and CCOR aspects, names, and indications are still encountered in the literature, but these references are essentially "nostalgic".

4.5 CROR

In Canada, railroads are governed by the Canadian Rail Operating Rules (CROR). Among other things, It defines a set of signal aspects, names, and indications. That system largely evolved from the original UCOR rules.

4.6 Western U.S. Practice

Many western U.S. railroads have sets of aspects/names/indications drawn from, or evolved from, those once promulgated by GCOR. Each railroad may have a different subset of the entire GCOR repertoire, but when the same aspect appears in the list of two or more railroads, the names and indications are usually harmonious (if not identical).

4.7 Rule numbers

In the various standard sets of operating rules that define sets of signal aspects and indications, the various aspects/indications are each usually identified as a numbered "rule". Thus, it is common, in writing about one or more of these aspects, to refer to them by "rule number", as: "In such an instance, the signal shall display the aspect of Rule xxx", or even, more explicitly, "In such an instance, the signal shall display the aspect of NORAC Rule xxx".

By way of reference, the rule numbers for aspects/indications prescribed by NORAC, UCOR, CCOR, and the first issue of GCOR are all typically in the "upper 200s" and/or "300s".

In the current GCOR, Rule 9.1 states that the aspects and indications are to be found in the Special Instructions, a term used to refer to a

railroad-specific “addendum” to the railroad’s version of the GCOR.² Accordingly, railroads adhering to the GCOR as their basic set of operating rules will often number their own signal aspects/indications as “Rule 9.1.x”.

In the current CROR, the aspects/Indications are denoted as rules 405 through 439.

5 SIGNALS

5.1 Introduction

In the next sections, I will describe the important physical types of signals, discussing for each the basic historical syntactic principles pertaining to its use. These syntactic principles are largely creatures of the physical implementation, and the overall syntax developed progressively (by accretion) in parallel with the introduction of new signal implementations.

5.2 Signals shown symbolically

Because the purpose of this article is primarily to describe the syntax of railway signaling, and not necessarily the physical construction or appearance of actual signals, signals are often shown here symbolically.

5.3 Semaphore signals

5.3.1 Basic principle

Many different techniques were utilized during the earliest days of railway signaling. One which came into widespread use was the *semaphore*, a moving arm mounted on a mast, whose position conveyed information regarding the status of the track ahead.

A common arrangement was to have the semaphore arm hanging down (but not usually quite vertical) when the track ahead was clear, and to raise it to a horizontal position to indicate that the track ahead was not clear (and that therefore the train should stop). It has been suggested that this convention was evocative of a human “signalman” raising his arm to order the train to halt.

Typically the semaphore arm was square at the end, and carried a stripe of a contrasting color across its width near the end, to enhance

² Often this information will actually appear in the System Timetable (which is not a timetable at all but rather a compendium of rules)..

visibility in different “sky background” situations. Figure 1 illustrates this arrangement in fanciful style.

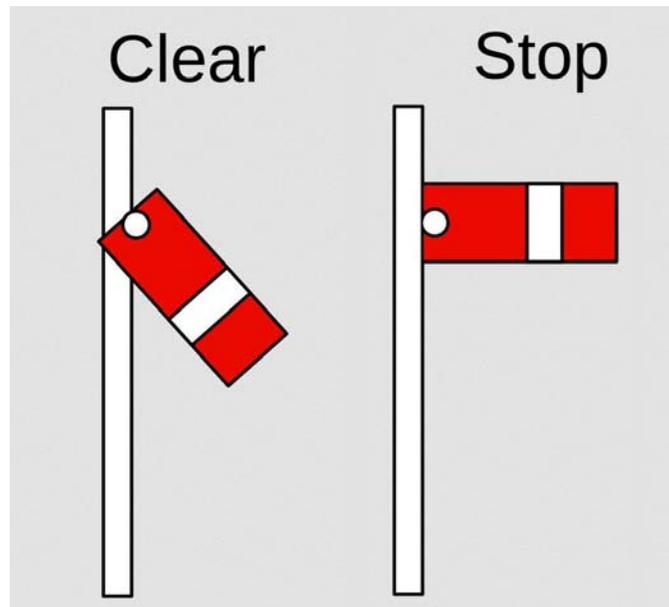


Figure 1. Early rail signal semaphore

Typically the semaphore arm was lifted (to the Stop position) by an iron wire, pulled by a lever at the base of the semaphore mast or in the station.

A common early application of a signal like this was at a small station, where the signal (set by the stationmaster) would tell the engineman whether the train should stop, as there were passengers there (or freight, or mail), in case the train did not already plan to stop there to discharge passengers (or unload freight, or mail). It could also be used to have the train stop because it was known (perhaps by telegraph communication) that another train was unexpectedly on the track ahead.

5.3.2 *Illumination*

Eventually, to allow the signal to be read at night, the “hub” of the semaphore arm was fitted with a frame³ carrying two glass lenses,⁴ behind which was placed a lamp (initially an oil lamp, later an electric lamp). The lamp was seen through a different lens for each of the two

³ The frame was colloquially called a “spectacle”, a term which is still used, even though today the frame may carry three lenses.

⁴ Formally called, today, *roundels* (pronounced “ron-DELS”), but most frequently still called “lenses” in description of signal types.

positions of the semaphore arm. Originally, the lens through which the lamp was seen with the arm down (Clear) was clear (giving a white light), and the lens through which the lamp was seen with the arm horizontal (Stop) was red.

Figure 2 shows this arrangement in, more realistic and “modern” (ca. 1990!) form.

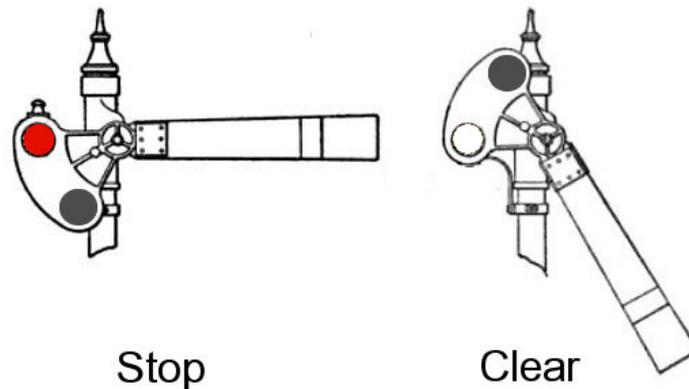


Figure 2. Early rail signal semaphore, with lights

This color convention raised the risk that, were the red lens to crack and fall out of place, with the signal at Stop a white light would be seen, erroneously indicating Clear. To avert this, the standard color of the Clear aspect was eventually changed to green, as we see in figure 3.

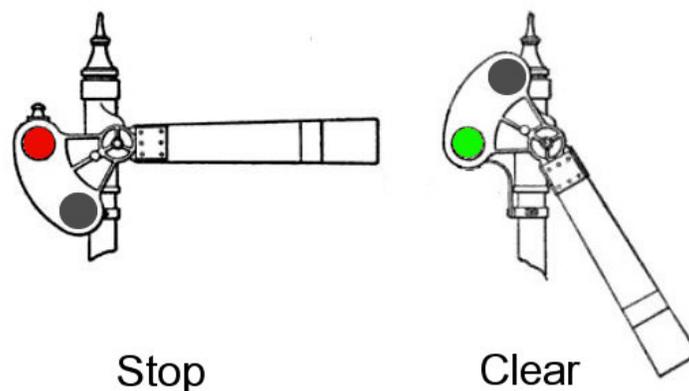


Figure 3. Lower quadrant semaphore (red-green)

5.3.3 *The continuous light spectacle*

A concern was that some obstruction might prevent the arm from being fully raised to the horizontal (Stop) position. To be sure that at night the signal could still be seen, but giving a “fail safe” message,

often the spectacle was equipped with three roundels, the middle one also being red. Figure 4 shows this scheme, which is known as a “continuous light spectacle” arrangement.

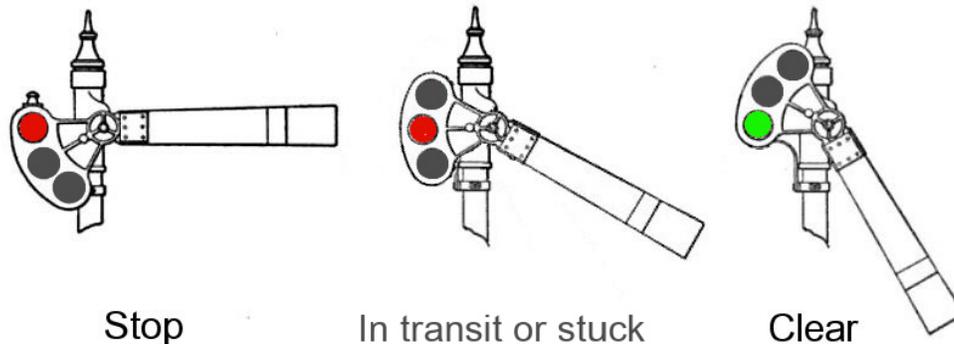


Figure 4. Lower quadrant semaphore—“continuous light” spectacle

Still, if the wire that raised the semaphore arm were to become disconnected, or rusted in two, then when the arm was supposed to be raised (Stop) it might remain in the down position, again giving an erroneous indication of Clear.

To avert this, most railroads eventually converted to “upper-quadrant operation”. Here, the Stop aspect was still with the arm horizontal⁵, but the Proceed aspect had the arm raised to an **upward** (and in fact vertical) position. Figure 5 illustrates this (in semi-realistic form).

⁵ This choice was intended to make sure that an engineman would always properly recognize the Stop aspect during a time of change of schemes.

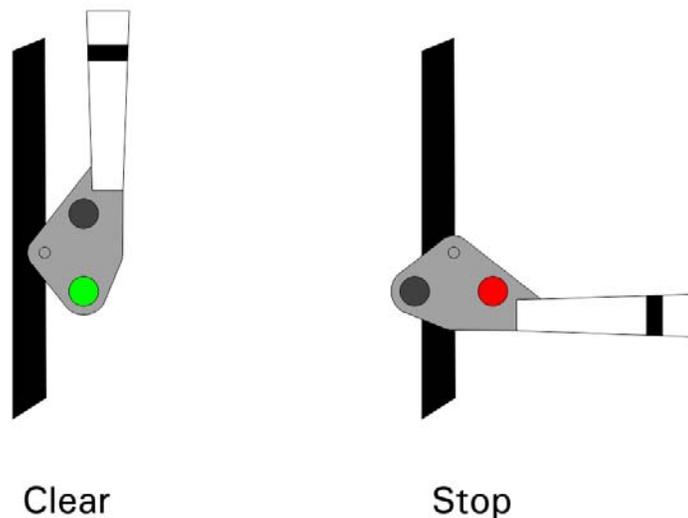


Figure 5. Upper quadrant signal semaphore

If the actuating wire were to become interrupted, the arm would (hopefully) move by gravity to the "Stop" position, a "fail safe" situation.

The original mode, then called "lower-quadrant operation", was retained for quite a while by some roads (notably Southern Pacific).

Sometimes in an upper quadrant semaphore of this type, the "continuous light spectacle" scheme was used.

5.3.4 *The distant signal*

Especially if the track were curved, the engineman might not be able to see a signal in time to bring the train to a halt at a signal that showed Stop. To deal with this, the practice was introduced of having a "distant" signal: another semaphore, following the position of the "main" semaphore but located some distance earlier in the track. The distant signal arm typically had a notched ("fishtail") end, and the stripe across the arm was replaced with a chevron (matching the contour of the arm end), allowing the nature of the signal to be recognized.

With the emergence of the *distant signal* concept, the "regular" signal at the entrance to the block was given the name *home signal*.

With the home semaphore arm for a block horizontal (Stop), the associated distant signal also had its arm horizontal, but the indication this conveyed there was not Stop but rather, "approach the upcoming signal at reduced speed, prepared to stop" (the modern indication name being just "Approach").

As the blocks controlled by signals became shorter (to provide more efficient operation), it was often practical to have a single mast carry both a home signal for the block beginning there and (beneath it) the distant signal for the next block. The two signals could be distinguished both by their relative positions on the mast and by the difference in the shapes of the arm tips and the stripe/chevron across the arm.

In the initial practice, if the block immediately ahead was occupied (or otherwise unsuited for entry) but the next block was clear, the home signal would show Stop (red) and the distant signal for the next block (on the same mast) would show Proceed (green). There was concern that in this situation the engineman might act upon this inviting apparent Proceed aspect and continue at full speed into the current block (there to collide with its occupant).

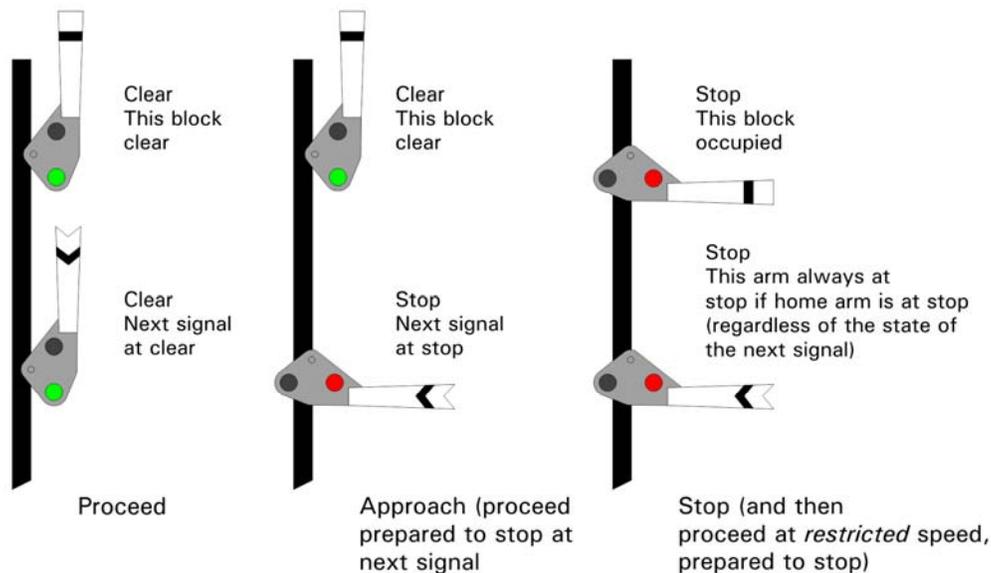


Figure 6. Home and distant semaphore signal ("slotted" operation)

To mitigate this concern, it became common to arrange the mechanism such that if the upper (home) arm showed Stop (horizontal, red) the lower (distant) arm would be forced to show horizontal/red, regardless of the position of the downline home signal that it nominally mimicked. This was called, as a result of the mechanical logic arrangement initially used to bring this about, "slotted operation". We see this complete arrangement in figure 6.

5.3.5 *Back to the lower quadrant*

Often, in lower quadrant operation with two arms (home and distant), when the lower arm is horizontal (Approach), the light shown is yellow rather than red. This is to avoid any misunderstanding that a red light

on the lower semaphore meant "stop". It is actually a back-formation from the light color arrangement described in section 5.3.6

5.3.6 *Three-aspect semaphore signals*

With "slotted operation", a set of two semaphore arms (one home, one distant) could only take on three states (as we saw in figure 6). It was realized that a single semaphore arm, with three positions ('aspects'), could convey this same repertoire. Figure 7 shows this arrangement.

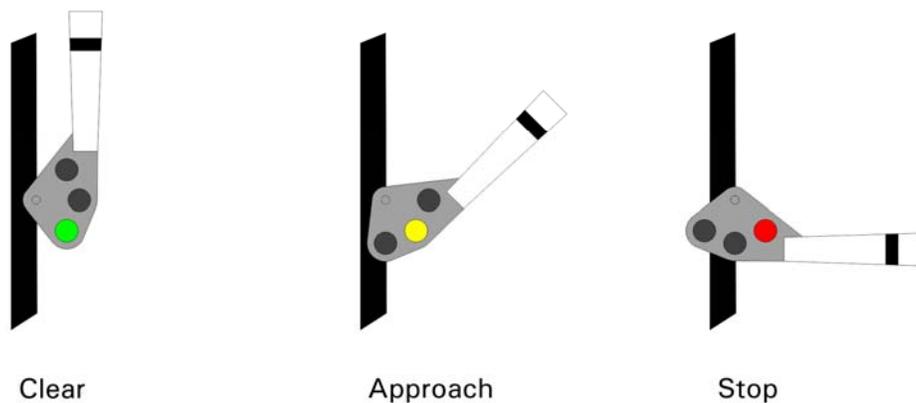


Figure 7. Three-aspect semaphore signal

This of course resulted in cost saving, since even when there was "Approach" signaling the typical signal could now still have only one arm rather than two. In modern times, with upper quadrant operation used, the use of two two-position arms for Approach signaling was rare.

The light color yellow came to be associated with the "Approach" aspect.⁶

It was almost unheard of to have three-aspect semaphore signals with lower-quadrant operation. A major reason is that the lower arm position is normally not vertical but oblique (usually at 60° or 75° to the horizontal). Then an intermediate oblique position (for Approach) might be hard to distinguish from the lower position.

⁶ At the time in which a white light meant Clear, green was often used for Approach.

5.3.7 *Names for semaphore positions*

It is common to speak of the various positions of a semaphore in terms of the corresponding light color: red, yellow, or green.

5.3.8 *Slang*

Because of the early history of the signal semaphore, in railroad slang a signal (even if given by a colored light only) is often called a “board” (“Yesterday Harry had an unexpected red board at Pistol Hill that made him late into Springfield by half an hour”).

5.3.9 *Block vs. interlocking semaphores*

Sometimes “block” and “interlocking” semaphores are distinguished by having the interlocking semaphore arms have a pointed end, rather than a square end (and a chevron, rather than a stripe, on the arm, oriented the same way as the pointed end.)

We won’t get to actually see that here, since as we get into interlocking signals, we will shift to examples using the more modern “light signals”.

5.4 **Light signals**

5.4.1 *The color light signal*

Semaphores, being overtly mechanical devices, required considerable maintenance, and were subject to problems from ice and snow. Over time, as electric lighting come into wider use, many railroads moved from the 3-aspect semaphore to a 3-aspect color light signal. In its classical form, this signal has an oval background plate (or “target”) having three lenses of different color, each with a lamp, ordinarily arranged in a vertical column.

The arrangement of the lenses is normally, from top to bottom: green, yellow, red.⁷ This matches the sequence of arm positions in the upper-quadrant 3-aspect semaphore. Only one lens is illuminated at a time. The aspects and corresponding indications are the same as for the 3-aspect semaphore. Figure 8 shows the standard arrangement, with the indications implied, in basic application, by the three aspects.

⁷ Note that this is the opposite order from that customarily used for road traffic signals. In addition, in road traffic signal work “yellow” is formally called “amber”.

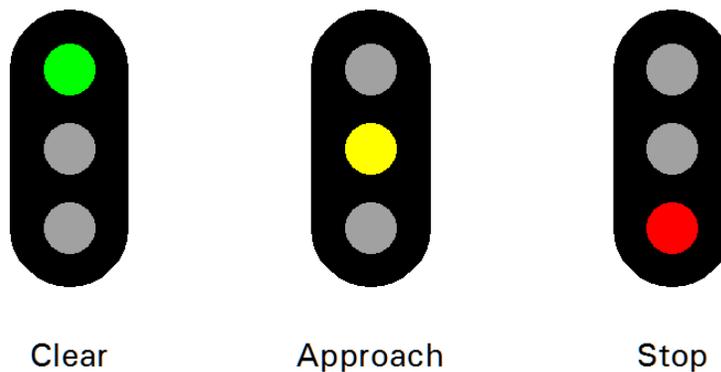


Figure 8. The basic color light signal

When one signal carries multiple “heads” of this type, some or all may not follow this standard sequence of colors (see section 21.7).

Despite being thought of as “old-fashioned”, this is in fact probably still the most commonly-used signal head type in the U.S. today. In fact some railroads, having for some while use other types of signal heads, have converted to this type.

5.4.2 *The searchlight color light signal*

A variation of the traditional 3-aspect color light signal, commonly called a “searchlight” signal, has only one lens and lamp, mounted at the center of a relatively-large circular background. In the traditional implementation, electromechanical apparatus in the signal head moves colored filters so that the light shown is either red, yellow, or green. An advantage is that it takes up less vertical space than a three-lens signal for a given lens diameter.

In its basic use, the aspects and indications of this type of signal are the same as for the three-lens color light signal. Some searchlight heads are also equipped to produce a “lunar white” aspect (produced by a diffusing white filter), typically used to explicitly indicate *Restricted* speed.

5.4.3 *The triangular cluster light signal*

In this variation of the three-lens theme, the three lenses are arranged in a triangular pattern on a (usually) circular background, usually with yellow and green at the top (usually in that order, left-to-right) and red centered below.

“Triangular cluster light” is my name for this style—there is no consistent “official” name. It is sometimes called a “tri-light” signal (“tri” not for “three” but rather for “triangular”). It is sometimes called

a "Type G" head, based on the nomenclature for a corresponding General Railway Signal product type. Figure 9 shows the usual arrangements of the lenses in showing the three aspects of a signal of this type.



Figure 9. Triangular cluster light

5.4.4 *The position light signal*

The position light signal may be thought of as a semaphore without moving parts. It consists of a (usually) round background within which are set several lenses, all of the same color (usually yellow). For the Clear (or Proceed) aspect, three yellow lights in a vertical row are lit. For an Approach aspect, three yellow lights in a diagonal row, upward to the right, are lit. For a Stop aspect, three yellow lights in a horizontal row are lit. Often there is provision for a fourth aspect, used to indicate *Restricted* speed: three lights in a diagonal row, downward to the right. A single light serves as the center of all three patterns. Figure 10 shows the arrangement.

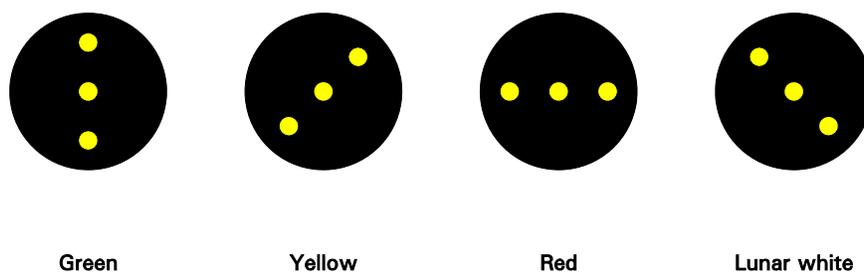


Figure 10. Position light signal

For convenience, when speaking of position light signals, we often call the four visual aspects "green", "yellow", "red", and "lunar white" (often just "lunar"), respectively, even though those colors are not actually involved. The figure is labeled this way.

5.4.5 *The color-position signal*

The color-position signal is similar to the position light signal, but the lights that are lit for the different aspects have different colors as well

as being in different positions, generally the same colors as for the corresponding aspects of the basic three-lens signal. For the Clear (or Proceed) aspect, two green lights in a vertical row are lit (there is no center light⁸). For an Approach aspect, two yellow lights in a diagonal row, upward to the right, are lit. For a Stop aspect, two red lights in a horizontal row are lit. To indicate *Restricted* speed, two "lunar white" lights in a diagonal row, downward to the right, are lit.

Figure 11 shows the arrangement.

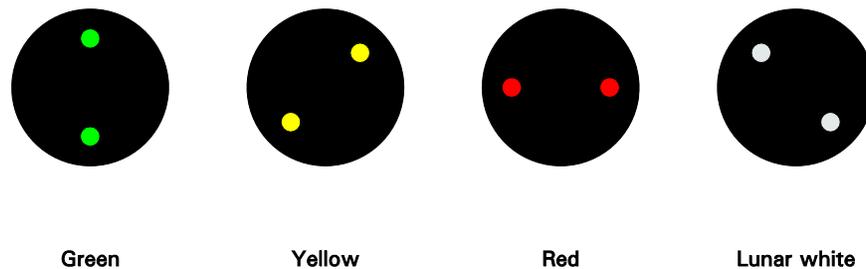


Figure 11. Color position signal

As with the position light signal, when speaking of color position signals, we often call these visual aspects simply "green", "yellow", "red", and "lunar white", respectively. The figure is labeled in those terms.

6 SIGNAL PLACEMENT

In the basic situation of a single track (for a given direction of running), signals are commonly mounted on a mast at the side of the track—typically the right side (corresponding to the engineman's side of the cab in usual U.S. practice).

When there is more than one track for a particular direction of running, rather than place signals for each on their own masts, there may be a column (usually again on the right of the track group) with a platform on the top from which arise separate short masts for each track, carrying the corresponding signals. (This is sometimes called a "bracket post" arrangement, the name coming from an earlier implementation, in which there was not a real "platform" but rather brackets extending to one or both sides of the mast itself to hold the additional signals.)

⁸ The reason that there are two, rather than three, lamps lit for each aspect is that no single light could serve as the midpoint of all three patterns, as it would have to have a different color in each.

But for greater clarity in such cases, a short gantry extending from a column at the right side of the overall roadbed may be used (called a "cantilever bridge" or just "cantilever"). The signals (on short masts arising from the gantry) are not centered over the tracks to which they pertain, but are slightly offset to the right side (as they would be if on trackside masts).

If there is no signal for one track (perhaps it is a siding), then commonly, to avoid any misunderstanding about which signal goes with which track (especially if the tracks are curved so as to distort the engineman's view of which signal is "almost over" each track), there may be in its signal mast position a small mast with no signal on it (called a "doll arm"⁹)—a "mast placeholder". Sometimes, for clarity of the situation at night, the doll arm will carry an unchanging blue or purple light.

In some cases, especially where there are several active tracks, a gantry (then called a "signal bridge") may be built over the whole set of tracks, supported by a column at each side. Again, the signals (on short masts arising from the gantry) are usually not centered over the tracks to which they pertain, but are slightly offset to the right side (somewhat as they would be if on trackside masts).¹⁰

If there is only one signaled track and one unsignaled, and a bridge or cantilever is not used, the signal may be placed on a conventional mast at the right of both tracks, with the short doll arm on a bracket off to its side (following the traditional concept of a "bracket post").

7 SIGNAL CATEGORIES

In U.S. practice, most wayside signals may be classified as either *automatic block signals* or *interlocking signals*. Their respective roles are as follows.

7.1 Automatic block signals

Basically, the purpose of automatic block signals is to prevent a train from running into the train ahead. This is done by dividing the track into a series of blocks and controlling the entrance of a train into each.

⁹ "Doll" is old British slang for a signal on a mast. The term "doll arm" for an empty mast is apparently a curious development from that. Sometimes "doll post" is used.

¹⁰ It is believed that one motivation for this was that in steam locomotive nether the enginemen nor fireman had a clear view straight ahead. In modern times, with this problem gone, some roads placed signals on gantries centered over the pertinent track

The presence of a train (or even a single errant car) in a block is usually detected by an electrical arrangement called a *track circuit*. When the track circuit determines that a block is occupied, a wayside signal at the beginning of the block gives an indication requiring the engineman to stop the train.

Stop indications given by an automatic block signal are usually *permissive*; that is, after the train has been brought to a stop, it may resume movement at a very low speed (often called the "Restricted" speed), assuming that there is adequate visibility of the track ahead. The presumption is that the engineman would be able to see the train (or other obstruction) ahead in ample time to come to a stop before hitting it. Such an indication is sometimes called "Stop and proceed". (See a further discussion of this matter in section 11.)

7.2 Interlocking signals

An *interlocking* (more completely, *interlocking plant*) is a location in which a train encounters, for example, (a) switches (turnouts), which allow the train to move onto a siding, cross from one track to another, or follow either of two routes; (b) a crossing at grade over another track; (c) a drawbridge or other such potential disruption to the continuity of the track; or (d) a situation where the train could foul another train (such as where two separate tracks are unusually close together due to space limitations).

The term *interlocking* itself comes from the fact that the controls operating the signals are mechanically or electrically interlocked among themselves, with the controls for the switches, and with track circuits detecting the presence of a train (or car) in various locations, such that a signal cannot be made to give an indication that would authorize an unsafe or infeasible movement.

Today, a location of this type is most often called a "control point" (CP) rather than an "interlocking". I will however in some cases use the term "interlocking" for continuity.

Interlocking signals are in modern times generally controlled within a concept known as Centralized Train Control (CTC). In this concept, signal operators working at control centers, which may be responsible for a rather large geographic area, control the movement of trains within that area by setting the various switches and signals, of course under the "interlocking" concept.

An *interlocking signal* is found at the entrance to an interlocking, but in fact usually also marks the beginning of, and governs, an entire block, often extending well beyond the far end of the interlocking

proper. Thus it must also perform the duties of an *automatic block signal*. Forcing both these duties on a single signal has led to some of the more curious facets of syntax.

Stop indications given by interlocking signals are usually *absolute*: the train must stop and remain stopped until the signal changes to a more favorable indication. The reason is that the conflict might be a switch setting that the train could not possibly (even cautiously) traverse, or the conflict might be "dynamic", such as the rapid approach of another train on a crossing or conflicting track. Such an indication is sometimes called "Stop and stay".

7.3 Signals for switchyard and siding operation

Special parts of the signal system described herein are often used to govern movements within switchyards or onto sidings elsewhere. They often utilize smaller signals, placed on or near the ground, known as "dwarf" signals. We will not cover this branch of signaling in this article.

7.4 Distinguishing automatic block and interlocking signals

In many cases, the implications of a particular aspect will depend on whether the signal is in an automatic block or interlocking situation, and it is thus important that the two can be distinguished.

One convention widely followed is that automatic block signals all carry on the mast a plate with the block number; no such plate will appear on interlocking signals.

Another convention sometimes used with multiple-head signals (especially with color light signals, either searchlight or vertical three-lens) is that the heads are staggered on alternating sides of the mast for automatic block signals (typically right, left, right) but are placed on the same side for interlocking signals.

8 SPEED LIMIT CATEGORIES

In our discussion of signaling, we will often make reference to various speed limits. Many present signaling systems involve the following named speeds, listed from the highest to the lowest:

Normal	Varies with railroad, perhaps also with location and/or train type
Limited	Varies, but typically 40-45 mph
Medium	Varies, but typically 30 mph
Slow	Varies, but typically 15 mph

Restricted Commonly defined as speed such that train could stop in “half the visual range”, typically not over 15-20 mph in any case

9 **APPROACH ASPECT NAMES**

As mentioned earlier, an aspect named just “Approach” means that the train should proceed (usually at some implied maximum speed), prepared to stop at the next signal.

If “Approach” is followed by a speed name (as “Approach Slow”) the train should approach and pass the next signal at not over that speed, rather than being prepared to stop there.

Sometimes, at an interlocking signal, an aspect name will include “Approach” preceded by a speed name. That speed name pertains to the speed limit applicable to movement through the switch(es) of the interlocking. If there is also a speed name after “Approach”, the implication described just above also comes into play.

10 **ADVANCE APPROACH**

Many railroads have adopted a system in which there are two types of Approach indication. The first indicates that the signal at the following block is at Stop; the second indicates that the signal at the block **after the following block** is at Stop. This system gives the engineman better information for controlling the train’s deceleration to meet the upcoming Stop signal.

The NORAC system recognizes this mode with the “Advance(d) Approach” indication. Its indication is typically to proceed at no more than *Limited* speed, prepared to stop at the **second** signal ahead (the one currently known to be at Stop). The basic aspect used is flashing yellow (on the top head if a multi-head signal).

11 **ABSOLUTE AND PERMISSIVE STOP INDICATIONS**

As I mentioned at various places, a Stop indication at an automatic block signal is usually *permissive*, and a Stop indication at an interlocking signal is usually *absolute*, although the visual aspects are identical. Thus, an engineman arriving at a signal showing a Stop aspect must be able to determine the category of signal to properly determine the indication. As mentioned above, a typical hint is that a block signal will have a block number plate, while an interlocking signal will not.

In some systems, unambiguous indication of this difference is provided. For a position light or color-position signal, a single lunar

white light below the basic head (in the Amtrak system; elsewhere, yellow or white above or below) indicates that the Stop indication is permissive. Absence of such an auxiliary light indicates that the Stop indication is absolute.

In some systems, a red aspect at an automatic block signal does not mean "stop and proceed" but rather "proceed at Restricted speed". The objectives of the two are comparable: to make certain that the train could stop in time if it encountered another train in the block being entered.

12 PRINCIPLES OF SIGNAL SYSTEM SYNTAX

12.1 Introduction

In the next several sections I will develop an understanding of the syntactic principles underlying most major American and Canadian signal systems.

12.2 Caveat

The syntactic structures of these signaling system are curious at best, and often confounding. They are often rife with arbitrary constructions, sometimes occasioned as a way of getting around conflicts, and sometimes arising from I don't-know-where. Historical evolution can beget some really amazing things.

In what follows, I have often just jumped over some of the more baffling issues, in the hopeful interest of making as clear as possible the important properties. In some cases, where I could not be certain from the available reference information exactly how something works, or why, I have made what I consider the most reasonable conjecture.

That all having been said, let's get started.

13 BASIC ASPECTS AND INDICATIONS

13.1 Introduction

These aspects are given by a single-head signal, a situation most often found for a basic block signal. They are listed by visual aspect "description". The customary aspect name is given underlined, followed by the indication.

Note that these are all consistent with the more fundamental aspects of a speed signaling or route signaling system.

13.2 Green

Clear—proceed at *Normal* speed.

13.3 Yellow

Approach—reduce speed to *Medium* and approach next signal preparing to stop.

13.4 Red

13.4.1 *At an automatic block signal*

Stop—stop, then proceed at *Restricted* speed, prepared to stop (as when a train is seen ahead).

But in some practices, the rule is to proceed (without stopping) at *Restricted* speed, prepared to stop.

13.4.2 *At an interlocking signal* (although such are rarely single-head)

Stop—stop (and stay).

14 MULTIPLE-HEAD SIGNALS

14.1 Introduction

Signals providing for more extensive "glossaries" of aspects (whether block or interlocking) typically have two or three heads arranged vertically.

It is perhaps easiest when visualizing this type of signal to think of the heads being of the searchlight color light type, although most of the aspects can be presented equally well on other types (sometimes with some special considerations). When we illustrate the various aspects with figures, they will be based on the searchlight signal form.

14.2 "Promotion" of lights

In "speed" signaling systems, the position of certain lights (on the 2nd vs. 3rd head) indicates the speed limit that applies to a certain movement. In order to expand the repertoire of separate speeds that can be indicated, in many cases a light at a certain position may be either steady or flashing. The flashing situation designates a speed "one notch" higher than that indicated by a steady light in that position. This is often spoken of as the flashing "promoting" the indicated speed.

In other cases, the flashing of a light "promotes" the basic indication given by a certain light in a certain position, not implying a speed limit, to a "less restrictive" one.

14.3 The unique nature of red lights

Almost invariably, If all (lit) heads on a multi-head signal show red lights, the indication is **Stop (Stop and stay or Stop and proceed**, as appropriate to the type of signal).

If, however, some but not all of the lit heads show red lights, in most cases the red lights do not mean Stop, nor do they directly mean anything at all. They are merely placeholders.

A cute phrase used to remind us of this is, "If it isn't all red, it isn't red at all".

14.4 The "verb" color

Generally, the presence of a **yellow** light indicates that the basic nature of the indication is Approach; the presence of a **green** light may indicate that the basic nature of the indication is Clear. I will sometimes refer to this color as the "verb" color of the aspect.

14.5 About "standing orders"

In many situations, the specific speed limit that pertains is not explicitly given by the signal but rather is given by what I will call (for consistency) the "standing orders". This means it is given, in some cases as a "default", by some official railroad publication (almost never actually entitled "Standing Orders").

Sometimes this is entitled the "Rule Book". In other cases it may be entitled the "System Timetable" or "Employee Timetable". These latter odd names go back to the days before railway signaling, when the movements of trains were governed by a strict, very detailed time plan, devised so that trains would not run into one another (hopefully).

This plan, updated periodically, was given in what was (understandably) called the "System Timetable" or (more often) "Employee Timetable." This document also typically gave the speed limits applicable to each kind of movement, in many cases at individual locations, and usually many other operating rules.

This was as distinguished from the "passenger timetable" which of course told at what time and on what days did trains leave Erie for Cleveland, and what time were they expected to arrive at Cleveland.

As railway signaling came fully into use, the concept of a detailed timing plan to govern train movements declined, and eventually, actual "timetable" information disappeared from the "Employee Timetable", which still survived (under that name) to present detailed speed limits and other such details of operating discipline.

But, for consistency, I will speak of "default" speed limits and such as coming from the "standing orders".

15 SPEED AND ROUTE SIGNALING

15.1 Route and speed signaling systems

Most of the signaling systems of interest can be classified as being either of the *route signaling* or *speed signaling* types.

15.2 Route signaling systems

In an enroute setting (outside of an interlocking), pure route signaling systems confine themselves as showing the basic indications: Clear, Approach, or Stop.

At an interlocking, these signaling systems still present these indications but, in the case of a Clear or Approach indication, additionally show whether the interlocking is set for a through or diverging route.

The speeds at which the train is allowed to operate are determined by standing rules applicable to the general situation or perhaps to a specific location. The signaling system does not contribute to that (other than of course indicating whether the interlocking is set for a through or diverging route, which might, under the rules, put different speed limits into effect).

Pure route signaling systems are rarely found in practice.

15.3 Speed signaling systems

Speed signaling systems, for openers, present the familiar basic indications: Clear, Approach, or Stop. But they may augment these with indications of applicable speed limits for certain parts of the movement. By definition, at an interlocking, they **do not** give an indication as to whether the route set is through or diverging.

Oddly enough, in most of the familiar speed signaling systems, signals cannot instruct the engineman at what speed to "proceed" outside an interlocking. For example, if the basic indication for an oncoming block is Clear, where the "standing orders" speed limit is Normal, the speed signaling system cannot tell the engineman, in this case, to proceed at

only Limited speed. Rather, "speed" signaling systems can in general only instruct the speed to be used in these situations:

- At an interlocking: the speed that is to be used passing through the interlocking. This might be different depending on the route set through the interlocking; the safe speed for a train to traverse the interlocking when a *through* (straight ahead) route is set is typically greater than when a *diverging* route is set.
- When the basic indication is "Approach". The ordinary Approach indication instructs that the train must approach the next signal prepared to stop at it (meaning prepared to stop at it if it shows Stop, which in fact it does at the time the engineman sees the Approach signal).

But, with a speed signaling system available, the Approach indication is enlarged to include alternative indications that the engineman need not approach the next signal prepared to stop at it but nevertheless must approach and prepare to pass it at a certain speed less than Normal.

This typically occurs when, at the present time, the next signal is not showing Stop, but perhaps is showing Approach or, if at an interlocking, is showing a reduced speed limit for transit through the interlocking.

The reason for stating "prepare to pass" rather than "pass" is that, even though this should not occur, if that signal unexpectedly showed Stop when the train arrived, then it must of course stop.

This is most often said, in signaling system documents, as only "approach next signal at <speed>", or in rare cases, "approach and pass next signal at <speed>".

But the complete and precise description is the more cumbersome "approach and prepare to pass the next signal at <speed>". As I will often need to refer to that description, for conciseness I will use "APP" to mean "Approach and Prepare to Pass".

15.4 "Weak" route signaling systems

Often the route signaling system I described above is spoken of as a "weak route signaling" system. One rationale for this is that these systems generally can't describe the upcoming route other than with two possibilities (through vs. diverging), while there might be three or even more route possibilities at the interlocking.

15.5 Classification of important signaling systems

The NORAC signaling system, and the CROR (Canadian) signaling system, are strictly of the speed signaling variety. The signaling system formerly specified by GCOR combines both route and speed signaling features (as for most railroad systems based on GCOR).

16 SPEED SIGNALING SYNTAX

16.1 Introduction.

A three-head signal is assumed.

This gives generalized syntax rules. It would be rare for all the possible combinations to be included in a given system.

Heads not assigned a color by these rules will show red (as placeholders).

A system will very likely include aspects not covered by these rules.

16.2 Stop

- All red.

16.3 Clear family

- Has a green (verb color) and never a yellow.
- Position of green (verb color) tells speed limit through the interlocking.
 - Green on top: proceed at Normal speed.
 - Flashing Green on 2nd head Limited speed.
 - Green on 2nd head: Medium speed.
 - Green on 3rd head: Slow speed).

16.4 Approach family

- Has a yellow (verb color) and maybe a green (non-verb color).
- Position of yellow (verb color) tells speed limit through the interlocking.
 - Yellow on top: Normal speed.
 - Flashing Yellow on 2nd head: Limited speed.
 - Yellow on 2nd head: Medium speed.

- Position of green (non-verb color) tells speed to approach and prepare to pass next signal at
 - No green: approach next signal at Medium speed prepared to stop at it.
 - Flashing green on 2nd head (only possible with yellow on top): APP¹¹ next signal at Limited speed.
 - Green on 2nd head (only possible with yellow on top): APP next signal at Medium speed.
 - Green on 3rd head: APP next signal at Slow speed).

16.5 A pragmatic compromise

If the yellow is on the 2nd head to indicate Medium speed through the interlocking, and the approach speed is also Medium, we cannot have the green on the 2nd head to indicate that, so the green is placed on the 3rd head instead. In this situation, green on the 3rd head is interpreted "as APP the next signal at Medium speed", not "at Slow speed".

Of course, having adopted this, we cannot have Approach indications in which the speed through the interchange is Medium and but the situation for the next signal is APP Slow.

17 ROUTE SIGNALING SYNTAX

17.1 Introduction

A two-head signal is assumed.

This is for a "pure" route signaling system (no speed implications). This is rare in practice. In any case, there may well be speed limits for transiting the interlocking imposed by the standing rules.

a Head not assigned a color by these rules will show red (as a placeholder).

A system will very likely include aspects not covered by these rules.

17.2 Stop

- All red.

¹¹ "Approach and Prepare to Pass"

17.3 Through route indicated

- Not red on top.
 - Green on top: Clear (proceed at Normal speed).
 - Yellow on top: Approach (proceed at Normal speed, prepared to stop at next signal).

17.4 Diverging route indicated

These aspects can only appear on interlocking signals.

- Red on top
 - Green on 2nd head: Clear (proceed at prescribed speed through interlocking, then continue at Normal speed).
 - Yellow on 2nd head: Approach (proceed at prescribed speed through interlocking, then continue at Normal speed, prepared to stop at next signal).

18 HYBRID SYSTEM SYNTAX

18.1 Introduction

Many actual systems combine features of the speed signaling and route signaling systems. The "ideal" concept is typically as follows.

18.2 The route indication

If the top head does not show red, the route set is *through*. If the top head shows red, the route set is *diverging*.

18.3 Through route indication aspects

With regard to speed indications, this portion of the syntax generally follows that of the speed signaling system. If there is no speed limit prescribed for transit through the interlocking, the top head would carry green (Clear) or yellow (Approach), with the secondary meaning that the through route is set, as is accurate in this system.

But, under the strict speed signaling system, when there is a speed limit through the interlocking, the "verb" color would be on a lower head (to indicate that speed) and the top head would be red, in this situation spoiling the "through vs. diverging" distinction.

To prevent that, in this system, in this situation, the verb color is "repeated" on the top head, indicating that the through route is set.

18.4 Diverging route indication aspects

Here, the top head always carries red, the cue that a diverging route is set. Speed indications are then carried by the 2nd and 3rd heads.

Of course, these two heads cannot support the full speed signaling syntax used in the speed signaling system, so various accommodations are made in systems of this type. For example, we cannot have the "verb" color on the top head to indicate transit through the interlocking at Normal speed. But that is not usually a problem, since it is rare to prescribe Normal speed for transit through the interlocking.

18.5 A pragmatic compromise again

The compromise described in section 16.5 applies here as well.

18.6 Examples

The aspects and indications in Appendix A are for a hypothetical system of this kind, with both speed and route indicating features.

19 ADVANCE(D) APPROACH

Many systems include provision for what is called the "Advance(d) Approach" indication. This tells the train crew that the next signal is Clear but the following signal is at Approach (and thus the third signal is at Stop). This allows more refined planning of the train's speed profile to be able to pass the second signal in a way as to be able to stop at the third signal.

The common aspect for this indication is flashing yellow on the top (or only) head. We can think of the flashing here as "promoting" "proceed, prepared to stop at the next signal" to the more liberal "proceed, prepared to stop at the second signal) (although that is a bit of a stretch).

There is often a requirement in the standing rules to make a certain speed reduction when passing a signal at Advance(d) Approach.

20 THE CANADIAN RAIL OPERATING RULES (CROR) SYSTEM

20.1 Introduction

The Canadian Rail Operating Rules (CROR) System is essentially universally followed by railroads in Canada. It is a speed signaling system.

20.2 Red lights

As in most American systems, except in the case where all heads show red (meaning Stop), a red light is of no actual significance, just a placeholder.

20.3 Block vs. interlocking signals.

For multi-head signals, block signals can be distinguished from interlocking signals in that for block signals, the heads are on alternating sides of the mast, typically left-right(-left).

But, more potently, all aspects on a interlocking signal have red on the top head.

Most commonly, block signals have two heads, and interlocking signals, three.

20.4 Terminology

The CROR system uses a different approach than most American systems for the naming of the various aspects-indications. The term "approach" is never used. Rather, the aspects typically have names such as "Medium to Slow". That means that the speed limit to proceed is Medium but that the next signal must be approached at Slow speed. Thus we recognize this as an "Approach" family aspect.

But the term "Clear" is used in the position of the "proceed" limit to mean that the signal does not of itself impose a speed limit to proceed. Rather, the usual running speed limit for this location, as stated in the standing rules, applies.

So the aspect "Clear to Slow" means "Proceed at usual running speed for this situation, but approach next signal at Slow speed.". And the aspect "Clear to Stop" means "Proceed at usual running speed for this situation, but approach next prepared to stop." The latter is in fact what, in most American systems, would be a basic Approach aspect.

The aspect named just "Clear" means "Proceed at usual running speed for this situation", just as for the American aspect of that same name.

20.5 Syntax—Block signals

All red: Stop. At a block signal this is permissive: Stop and then proceed at Restricted speed. Other than for Stop, no aspect at a block signal has red on the top head.

Green on top: Clear. There is no implication as to the next signal. Thus this is equivalent to the American "Clear". The actual speed limit is as

defined by the standing orders. No light (other of course for red placeholders) appears on the lower head(s).

Yellow on top: Clear to <speed name>. This is equivalent to the American "Approach" family. The train may proceed, initially at the speed prescribed for normal running, but must approach the next signal at the indicated speed (one possibility for which is "prepared to stop", in which case the aspect corresponds to the American basic "Approach". The proceed speed is as defined by the standing orders.

With yellow on top, the speed to approach the next signal is given by a green or yellow light on the 2nd head:

- Nothing: Prepared to stop (making this equivalent to the American "Approach")
- Green: Medium
- Flashing green: Limited
- Flashing Yellow: Slow

20.6 Syntax—Interlocking signals

All red: Stop. At in interlocking signal this is absolute: Stop and Stay.

Other aspects: Red on the top head. No meaning *per se*.

The color on the 2nd head indicates the speed limit through the interlocking.

- Flashing Green: Limited
- Green: Medium (but see below)
- Flashing yellow: Slow

The color on the 3rd head indicates the speed limit at which to approach the following signal.

- Flashing green: Limited.
- Green: Medium.
- Flashing yellow: Slow.
- Red: no meaning *per se* (as if there were no 3rd head). But:
 - If the 2nd head shows green or flashing green, then there is no speed limit associated with the next signal, and the train can adopt Normal speed after the interlocking.
 - If the 2nd head shows flashing yellow, then the speed limit to approach the next switch is "prepared to stop".

These two situations are much like the American "Clear" and "Approach", respectively, except for the imposition of a speed limit for passing through the interlocking.

But there are some irregularities that permit those two rules to work.

- In the aspect Limited to Stop, the speed through the interlocking (Limited) by rights should be shown as flashing green on the 2nd head, but to make the above work the second head shows flashing yellow (which by rights should make the speed through the interlocking "Slow").
- In the actual aspect Slow to Stop, the Slow speed through the interlocking is indicated by flashing yellow on the 3rd head (to make a difference with the implementation of the aspect Limited to Stop).
- In the aspect Medium to Stop, the speed through the interlocking (Medium) by rights should be shown as green on the 2nd head, but to make the above work the second head shows yellow.

Of course, trainmen do not "parse" the aspects but rather recognize them by *gestalt*, so they just learn what these ones mean just like all the others.

21 HEAD VARIATIONS

21.1 Introduction

Now that we have seen the kinds of aspects that a signal may be called upon to display, we are in a position to understand the context within which some variations in signal construction emerge.

21.2 Approach lighting

In some cases, so as to conserve energy, at a block signal the entire signal is dark until an approaching train occupies the preceding block. The term "approach" used in this connection is not at all related to an Approach aspect.

21.3 Dark heads

If for a certain aspect on a two-head signal the lowest head (or the two lowest heads on a three-head) would show red (which would of itself be meaningless), those heads may actually be dark. (They contribute nothing to the aspect.)

Thus for example (in a typical syntax) a Clear aspect would appear to an approaching train as just a single green light (just as if the signal were of the single-head type).

This is done in the interest of saving energy and, to some extent, for visual clarity.

This does not contribute to any dangerous ambiguity in the even of a lamp failure in one or more heads; if the only thing showing on a signal is red, or if the entire signal is dark, this is to be interpreted as Stop.

Nevertheless, when the “dark head” plan is used, it is sometimes not followed for the Stop aspect, which then still shows red on all heads.

21.4 Hybrid position-family signals

In some systems (including one flavor of the NORAC system) a two-head position-family signal may use one scheme on the top head and the other on the lower head. Quite common is to use the color position scheme on the top head and the position light scheme on the bottom head. I am not in a position to explain the rationale for this.

21.5 Narrow background heads

Very often, on a position-family signal with two heads, the background of the lower head is cut back on the sides, leaving a sort-of oval shape. This helps to visually distinguish the lower head from the upper one.

This is often done in combination with the “hybrid” scheme described just above.

We see this first in figure 12, which shows (in schematic form) three possible implementations of NORAC Rule 288. Slow Approach. The visual aspect for all of these implementations can be spoken of as “red over yellow”.¹² The lower head in each case has a narrow background.

¹² Oddly enough, implementation of this rule with color light or searchlight signals usually uses three heads, the visual aspect being red over red over flashing yellow.

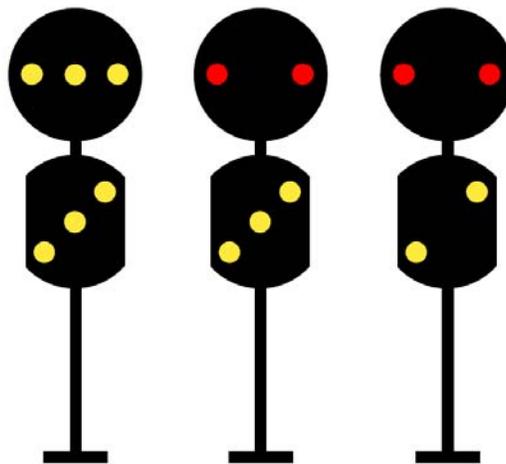


Figure 12. Narrow background 2nd head—NORAC Rule 288

- In the leftmost example, both heads use the position light scheme. The upper head visual aspect is “red” (horizontal); the lower head visual aspect is “yellow” (diagonal upward to the right).
- In the center example, the upper head uses the color-position scheme, and the lower head the position light scheme.
- In the rightmost example, both heads use the color-position scheme.

As we can imagine from these figures, a “narrow” lower head of either style cannot exhibit the “red” visual aspect (which would have the lights in a horizontal row). But red on the lower head would mean, of itself, “not significant” (see section 14.3), and so here in such cases the lower head is just dark.

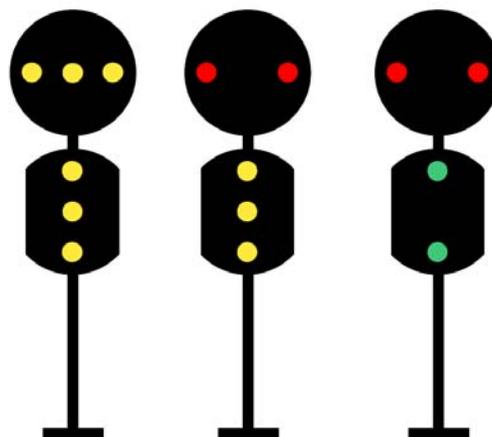


Figure 13. Narrow background 2nd head—NORAC Rule 283

We get further insight into how this works from Figure 13, which shows three implementations of NORAC Rule 283, Medium Clear, using “position family” heads.

In this case, the visual aspect for all of these implementations can be spoken of as “red over green”¹³.

For the top head, the leftmost example uses the position light scheme; the center and rightmost use the color position scheme. For the bottom head, the leftmost and center examples use the position light scheme; the rightmost uses the color position scheme.

As we can imagine from these figures, a “narrow” lower head of either style cannot exhibit the “red” visual aspect (which would have the lights in a horizontal row). But red on the lower head would mean, of itself, “not significant” (see section 14.3), and so here in such cases the lower head is just left dark, as if it were not even there.

We see an example in figure, 14 for position light and color position signals showing NORAC Rule 281, “Proceed”.

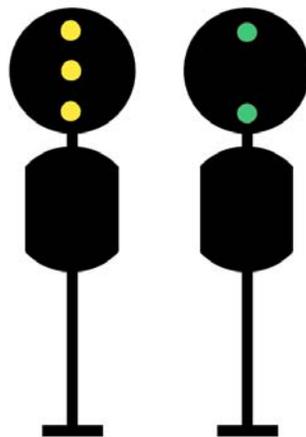


Figure 14. Narrow background 2nd head—NORAC Rule 281

21.6 Limited aspect heads

21.6.1 Semaphore signals

For a semaphore signal, if a head always exhibits one visual aspect, that arm will not even be equipped with a motor mechanism, and there will be only one lens in the spectacle.

¹³ And in fact here, implementation with color light or searchlight signals can use two heads, the visual aspect being red over green.

21.6.2 *Light signals*

If the repertoire of aspects to be given does not ever utilize all possible colors on a certain head, that head may have only one or two (sets of) lenses. In some such cases, for a position light or color position signal, the background is usually cut back to a shape that only embraces the light pattern(s) that are used. This gives an additional visual cue to the state of that head.

Figure 15 shows a nice example of that on a color position signal on the former Norfolk and Western Railway (N&W).



Figure 15. Color position signal with “yellow only” lower head

Photograph by Larry Evans
Used under the doctrine of “fair use”

Here, the lower head can only exhibit the color position aspect “yellow”. For overall signal aspects where, on other signal types, the lower head would show red for “not significant”, this head will be dark.

Note that the lower head has a center light, not needed for its (only) color position aspect (see figure 11). This is a red light, and it is the only light lit on the lower head in one of the more odd aspects in the N&W syntax: “red over little red” (Stop and Stay).

21.7 Implementation on vertical three-lens heads

In a two- or three-head signal using vertical three-lens color light heads, the position sequence of colors in the 2nd and 3rd heads is not necessarily the same as in the upper head, and the upper head may itself not follow the normal arrangement. Two arrangements used are (shown for three-head signals):

G	R
Y	Y
R	G
Y	Y
G	G
R	R
R	R
Y	Y
G	G

These arrangements are intended to improve the ability of an engineman to visually recognize certain aspects in the repertoire. I am not prepared to further discuss the rationale for this.

21.8 LED-based heads

Today, it is common for heads of various layouts to be implemented with LEDs rather than incandescent lamps. This of itself usually has no affect on the syntax that is employed, but might affect some of the details that are based on the conservation of energy or lamp life.

22 SOME SERIOUS CONTROL POINTS

I mentioned earlier that a control point (which might even comprise just a single switch) is often also the beginning of a signal block, perhaps of typical “enroute” length. But often, at a major “yard” or approaching a large terminal, we may have a series of control points immediately adjacent, such that the “blocks” are very short—comprising just the control point proper.

Figure 16 shows the Amtrak trackwork just south of Chicago Union Station (looking north, toward the terminal).¹⁴

¹⁴ Note that this photo is seemingly taken from a substantial distance and thus the apparent distances between objects is greatly “compressed”. For example, the nearby switchwork is not nearly as “acute” as it appears in the photo; the whole control point is actually about 800 feet long. What we see here actually represents about 0.30 miles along the trackwork altogether.



Figure 16. Control points approaching Chicago Union Station

In the foreground we see most of CP (control point) Roosevelt. It comprises complex switchwork mainly devoted to allowing an inbound or outbound train to move from one track to another among the six main tracks.

At the nearest of the two signal bridges the next control point, CP Taylor, begins. Its switchwork allows movement of trains from certain of those six tracks to three other tracks off to both sides.

On that signal bridge we see the signals for the six main tracks that enter CP Taylor. As usual, they are placed slightly to the right of the tracks they govern.

What can we conclude from this picture?

- Most of the signal heads are of the “triangle cluster” type.
- The leftmost and rightmost signals also include a third head. It is believed that this is a searchlight head. These three-head signals are on tracks for which there is an upcoming switch. The three heads provide for the preferred Amtrak syntax providing indication of a possible diverging route ahead.

23 APPENDIXES

Appendix A gives two tables showing a number of aspects of a hypothetical signal system in graphic form along with the corresponding aspect name, indication, perhaps an explanation of how the aspect is constructed and interpreted.

Appendix B describes the unique B&O Railroad color-position light signaling scheme.

Appendix C describes a semaphore type that operates in both lower- and upper quadrants (the “Mozier scheme” semaphore).

Appendix D describes *train order operation*, a method of control of train movements largely used prior to the introduction of block signaling, but which has its own signaling practice.

Appendix E gives a brief introduction to manual block operation, a mode that was the precursor to automatic block operation.

24 ACKNOWLEDGEMENTS

The detailed information in this paper comes mostly from a collection of over 300 pages of wondrous, encyclopedic reference documents found on the Web. These documents reflect the great love of railway signaling and its history by the respective authors as well as their extraordinary patience, diligence, and attention to detail. Without in any way slighting the many other contributors to this body of work, I would like to particularly recognize the following:

Mark A. Bej, M.D., of the Department of Neurology, Cleveland Clinic, Cleveland, Ohio (one of the world’s finest hospitals, by the way). Mark’s special interest is the Pennsylvania Railroad, but his collection of works on signaling overall is wondrous.

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James P. G. Sterbenz of GTE Laboratories, Waltham, Massachusetts, author of a large body of (large) Web pages covering signaling practice around the world. As you might expect, his range of interests is quite extensive, and covers many forms of transportation beyond rail.

Special thanks to Dave White, retired locomotive engineman with the Disneyland Railroad, for his insight into common western signaling practice”, and to Dennis Yachechak of the Federal Railway Administration for his help on the evolution of the General Code of Operating Rules.

Thanks to Larry Evans for his nice photo used as figure 15.

25 REFERENCES

For those interested in a much larger and deeper look at the extensive landscape of railway signaling (and other railway technical matters as well), I suggest the following Web sites as starting points (the links are all seemingly operative as of February, 2018):

Railway Technical Web Pages—Home Page and Index
<http://www.railway-technical.com>

Railway Signalling and Operations FAQ (the starting point for access to Mark Bej's monumental work in this field):
<http://broadway.pennsyrr.com/Rail/Signal/index.html>

This link takes one to a wonderful interactive graphic signaling simulator (Java) developed by Henry J. Sundermeyer:
<http://raildata.railfan.net/java/DivRte/NORAC.htm>

It is predicated on the NORAC rules, and includes the use of the "Approach Limited" aspect to provide the "advance approach" function.

His home page on matters related to New Jersey railroads can be reached at:
<http://raildata.railfan.net>

Click on any railroad logo at the left and you will go to a page listing many items about all these railroads, in many cases including detailed signaling information (often with Java-based interactive displays). The New York Central area has an especially nice graphic table of signal aspects and indications, directly accessible at:
http://raildata.railfan.net/nyc/signals/nyc_signals.html

A very nice resource on U.S. signaling practice is provided by, of all things, a Danish rail signal engineer, Carsten S. Lundsten, accessible here:
http://www.lundsten.dk/us_signaling

From the North East Rails site; includes a nice summary of signal aspects and indications:
http://www.northeast.railfan.net/pro_faq1.html

Joseph Hoebet has prepared very nice charts concisely showing the aspects, names, and indications for many railroad practices in a consistent format. They are indexed here:
<http://signals.jovet.net/rules>

26 ISSUE RECORD

Issue 10, October 20, 2019 (this issue). In Appendix D, enlarged discussion of fail-safe mechanism of three-position train order semaphore signal. Improved illustrations of lower-quadrant semaphore signals. Various editorial improvements.

Issue 9, October 17, 2019. Changed title to "railway" from "rail". Added discussion of centering signals on gantries. Changed illustration of triangular cluster signal to symbolic form. Substantial revision to various sections. Substantial revisions to Appendix A. Numerous editorial corrections and improvements.

Issue 8, February 1, 2019. The material on a complex control point, deleted in issue 6, was restored (now in section 22). The material formerly in Appendix C was divided between Appendix C and Appendix D and substantially revised. Appendix E was added. Substantial additional material was added in the description of semaphore signals.

Issue 7, January 13, 2019. Added Appendix C with a discussion of the "Mozier" semaphore scheme and train order signaling. Minor editorial changes.

Issue 6, January 16, 2018. The detailed description of the Union Pacific signal syntax is removed and the discussion of a generic syntax expanded. The signal chart for The Full Bucket line is removed. The photo of a complex control point and the ensuing discussion is removed. Additional figures are added, especially in the section on narrow lower heads for position-family signals.

Issue 5. This issue primarily adds further information on absolute vs. permissive Stop aspects and some related matters. The signal chart for a imaginary/virtual railroad, the Full Bucket Line, is added in an Appendix. The photo of a complex control point is added, with some discussion. Figure captions have been added to conform to our editorial style. A number of editorial adjustments have been made.

Issue 4, February 10, 2018. This issue adds a number of figures, especially in the section on semaphore signaling. The description of multi-head signaling (in sections 14 and 15) has been completely rewritten, hopefully for greater clarity, now revolving around the example of the Union Pacific Railroad (UPRR) system. The list of external references has been updated. Many editorial adjustments have been made.

Issue 1, June 10, 2002. Initial issue (Engineering Monograph format).

Appendix A

Illustrative Aspects and Indications

The tables that follow list a number of signal aspects and associated indications for a hypothetical system incorporating both route and speed features.. It is principally intended to illustrate how various syntactic elements typically found in American systems combine. Many of the illustrative aspects may not exactly appear in any of the recognized systems.

I point out that it is rare among actual systems to find such an extensive combination of route and speed signaling features as this appendix suggests.

The names given to these illustrative aspects are mine, intended to be clearly descriptive of the significance of the aspect. Nevertheless, as discussed in the notes, I will follow a widely-used convention for the speed control implications of aspect names.

In these tables, the aspects are shown as if implemented with searchlight heads. In some railroads an aspect may be implemented with other types of heads. But the equivalence with the searchlight implementation is usually direct and obvious.

For automatic block signals, I show schematically both a number plate and the convention of "staggered heads".

Keep in mind the following about heads showing red: only if all heads show red is the indication "Stop". When not all heads show red, the heads showing red have no significance—they are merely placeholders. (This is noted in the table where practical.)

Block signal aspects are illustrated with only the number of heads required to convey that aspect. On an actual signal, there will be the number of heads needed to show all aspects the signal may be expected to show. When an aspect shown in the table with a certain number of heads is shown by a signal with more heads, the additional heads (below) will usually show red (as placeholders). However, in some practices those heads may be dark.

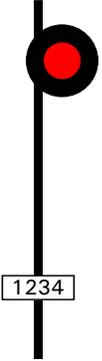
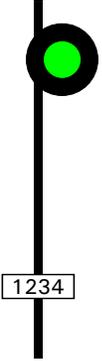
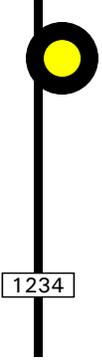
All interlocking signal aspects are shown as they would be implemented on three-head signals.

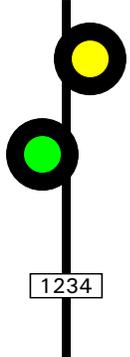
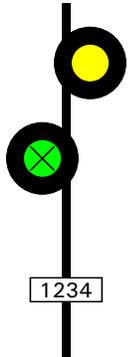
Many systems include some "irregular" aspects, not formed in the expected way from the syntactic ingredients. I do not show any such here.

Table A-1 – Automatic block signal aspects

The aspects are shown with the number of heads required to display it. If the signal has more heads, the remaining ones usually show red.

A cross across the light symbol denotes "flashing".

Aspect	<u>Aspect name</u> Indication	Explanation
Basic indications		
	<u>Stop (permissive)</u> "Stop and proceed" Stop; then proceed if appropriate at Restricted speed.	The stop is permissive since this is an automatic block signal (number plate present).
	<u>Clear</u> Proceed at Normal speed.	Basic clear indication.
	<u>Approach</u> Proceed at Medium speed and approach next signal at that speed, prepared to stop at it.	Basic approach indication. It is assumed that the next signal will be at Stop. The proceed and approach at Medium speed is inherent in the unqualified Approach indication.

Approach indications with approach speed limits (In aspect name, approach speed limit stated after "approach") APP: "Approach and Prepare to Pass"		
	<p><u>Approach Medium</u></p> <p>Proceed at Medium speed and APP the next signal at Medium speed.</p>	<p>Yellow: Approach;, the default proceed speed for Approach is Normal,</p> <p>No significance to green color; it is used arbitrarily, just to differ from the yellow light, for clarity.</p> <p>Green on 2nd head: approach speed Medium.</p>
	<p><u>Approach Limited</u></p> <p>Proceed at Limited speed and APP¹⁵ the next signal at Limited speed.</p>	<p>Same as above, but flashing of the green light "promotes" the approach speed from Medium to Limited.</p> <p>Since the APP next signal speed is Limited, the default Medium speed for proceed on an Approach indication is promoted to "Limited" also.</p>

¹⁵ Approach and Prepare to Pass

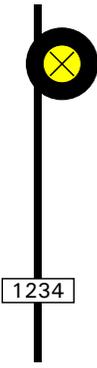
	<p><u>Approach Slow</u></p> <p>Proceed at Medium speed and APP the next signal at Slow speed.</p>	<p>Yellow present: approach</p> <p>Green (arbitrary color) on 3rd head: approach speed Slow.</p> <p>The default proceed speed for an Approach indication, Medium, applies.</p> <p>The red is a placeholder.</p>
	<p><u>Advance(d) Approach</u></p> <p>Proceed at Medium speed prepared to stop at the second following signal.</p> <p>(Speed rule details vary greatly between railroads.)</p>	<p>The flashing of the yellow light promotes its indication from "prepare to stop at the following signal" to the less-restrictive "prepare to stop at the second following signal".</p> <p>It is assumed that the second following signal is at stop.</p>

Table A-2—Interlocking signals

Three head signal form shown. Aspects shown with red on the bottom head(s) may be utilized on one- or two-head signals.

A cross across the light symbol denotes "flashing".

Aspect	<u>Aspect name</u> Indication	Explanation
	<u>Stop (absolute)</u> "Stop and stay." Stop and remain stopped.	Basic stop indication— "It's red because its all red". The stop is absolute since this is an automatic block signal (heads in line, no number plate present).
Through route set; no speed limits indicated		
	<u>Clear</u> The through route is set. Proceed at Normal speed.	Non-red color on top head: through route set. Green present (no yellow): clear.

Through route set; approach indications without speed limit indications APP: "Approach and Prepare to Pass"		
	<p><u>Approach</u></p> <p>The through route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and approach next signal prepared to stop.</p>	<p>Non-red color on top head: through route set.</p> <p>Yellow present: Approach.</p> <p>Approach (with no speed limits indicated) implies Medium speed through interlocking, proceed at Medium speed, and approach next signal prepared to stop.</p>
	<p><u>Advance(d) Approach</u></p> <p>The through route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and approach second following signal prepared to stop.</p>	<p>The flashing of the yellow light promotes its indication from "prepare to stop at the following signal" to the less-restrictive "prepare to stop at the second following signal".</p> <p>It is assumed that the second following signal is at stop.</p>

<p>Through route set; speed limits indicated. In the name, interlocking speed stated before "approach" or "clear", APP next signal speed stated after "approach". Approach speed "prepared to stop" is the "default".</p>		
	<p><u>Approach Medium</u></p> <p>The through route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and APP next signal at Medium speed.</p>	<p>Non-red color on top head: through route set.</p> <p>Presence of yellow: Approach.</p> <p>Yellow (verb color) on top head: no speed through interlocking indicated (but default is Medium).</p> <p>Proceed speed Medium is inherent for Approach.</p> <p>Green (not verb color) on 2nd head: APP next signal at Medium speed.</p>
	<p><u>Approach Limited</u></p> <p>The through route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and APP next signal at Limited speed.</p>	<p>Same as above except:</p> <p>Flashing Green (not verb color) on 2nd head: APP next signal at Limited speed.</p>

	<p><u>Approach Slow</u></p> <p>The through route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and APP next signal at Slow.</p>	<p>Non-red color on top head: through route set.</p> <p>Presence of yellow: Approach.</p> <p>Yellow ("verb" color) on 2nd head: Medium speed through interlocking.</p> <p>Proceed speed Medium is inherent for Approach.</p> <p>Yellow (again) on top head to make this a "through route" indication.</p>
<p>Diverging route set; speed limits indicated.</p>		
	<p><u>Diverging Medium Clear</u></p> <p>A diverging route is set.</p> <p>Medium speed through interlocking, proceed at Normal speed.</p>	<p>Red on top head (but not all heads): diverging route set.</p> <p>Green present, no yellow: Clear.</p> <p>Green (verb color) on 2nd head: Medium speed through interlocking.</p> <p>Proceed speed Normal is inherent for Clear.</p>

	<p><u>Diverging Limited Clear</u></p> <p>A diverging route is set.</p> <p>Limited speed through interlocking], proceed at Normal speed.</p>	<p>Same as above, except:</p> <p>Flashing green (verb color) on 2nd head: Limited speed through interlocking.</p> <p>Proceed speed Normal is inherent for Clear.</p>
	<p><u>Diverging Slow Clear</u></p> <p>A diverging route is set.</p> <p>Slow speed through interlocking, proceed at Normal speed.</p>	<p>Red on top head (but not all heads): diverging route set.</p> <p>Green present, no yellow: Clear.</p> <p>Green (verb color) on 3rd head: Slow speed through interlocking.</p> <p>Proceed speed Normal is inherent for Clear.</p>
	<p><u>Diverging Medium Approach</u></p> <p>A diverging route is set.</p> <p>Medium speed through interlocking, proceed at Medium speed, and approach next signal prepared to stop.</p>	<p>Red on top head (but not all heads): diverging route set.</p> <p>Yellow present: approach.</p> <p>Yellow (verb color) on 2nd head: Medium speed through interlocking.</p> <p>Proceed speed Medium is inherent for Approach.</p> <p>Approach next signal prepared to stop is the default for Approach.</p>

	<p><u>Diverging Slow Approach</u></p> <p>A diverging route is set.</p> <p>Slow speed through interlocking, proceed at Medium speed, and approach next signal prepared to stop.</p>	<p>Red on top head (but not all heads): diverging route set.</p> <p>Yellow present): Approach.</p> <p>Yellow (verb color) on 3rd head: Slow speed through interlocking.</p> <p>Proceed speed Medium is inherent for Approach.</p> <p>Approach next signal prepared to stop is the default for Approach.</p>
	<p><u>Diverging Medium Approach Medium</u></p> <p>A diverging route is set</p> <p>Medium speed through interlocking, proceed at Medium speed, then APP next signal at Medium speed.</p>	<p>Red on top head (but not all heads): diverging route set.</p> <p>Yellow present): Approach.</p> <p>Yellow (verb color) on 2nd head: Medium speed through interlocking.</p> <p>Green (non-verb color) on 3rd head: would normally mean APP next signal at Slow speed, but here means (arbitrarily) APP next signal at Medium speed (since green cannot be put on 2nd head to indicate that).</p>

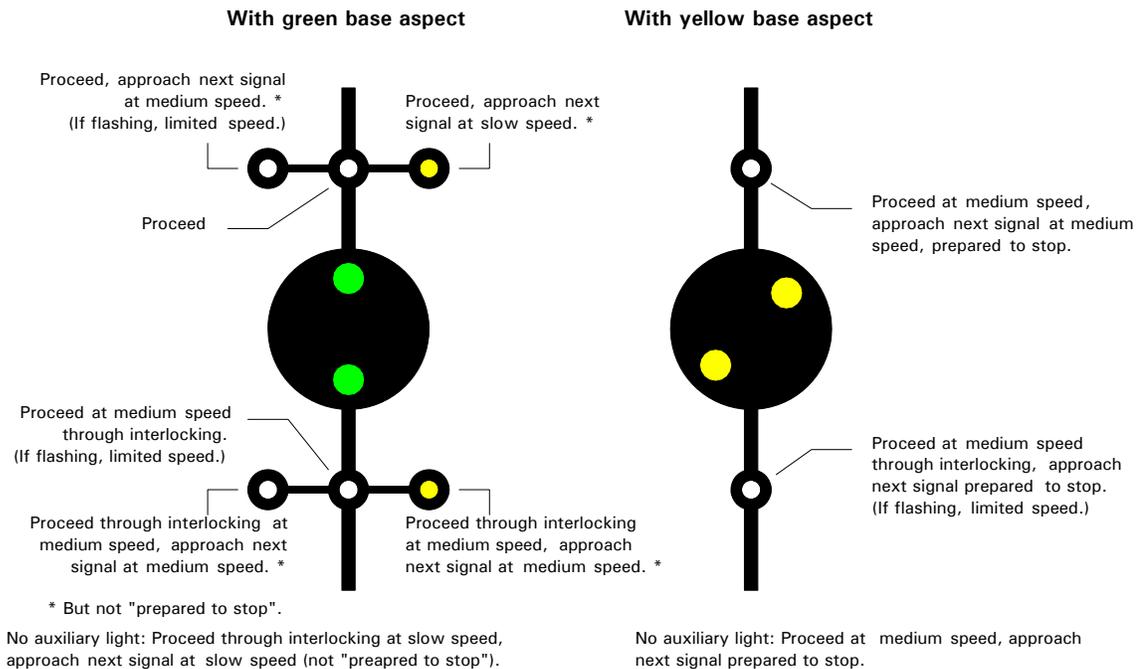
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Appendix B B&O Color-position signal conventions

Introduction

The former B&O railroad widely utilized an interesting convention based on a single color-position head accompanied by auxiliary lights (on individual circular backgrounds) above and/or below the head proper. Although this practice has largely been superseded, it is fascinating, and so I describe it here.

The syntax is quite direct. The signal layout and the basics of the syntax are shown in this chart:



Auxiliary light syntax

There are three auxiliary light positions above the color-position head proper and three below. Only one auxiliary light is illuminated for any aspect (a few involve no auxiliary light).

An auxiliary light above denotes a signal of the automatic block type (or one that is functionally equivalent); one below denotes an interlocking signal.

The center lights in either group essentially denote the "basic" form of the indication given by the aspect of the head proper. The left and

right lights, used mainly in connection with a green base aspect, indicate that the indication is of the speed-Limited approach type (that is, not "prepared to stop" at the next signal), and indicate the speed limit for approach.

Green base aspect

With a green base aspect:

An auxiliary light above indicates that this is an automatic block signal, and

- A left light indicates proceed and approach to the next signal be at *Medium* speed.
- A flashing left light indicates proceed and approach the next signal at *Limited* speed.
- A right light (yellow) indicates proceed and approach the next signal at *Slow* speed.
- A center light indicates proceed.

An auxiliary light below indicates that this is an interlocking signal, and

- A left light indicates proceed at *Medium* speed and approach the next signal at *Medium* speed.
- A right light (yellow) indicates proceed at *Medium* speed and approach the next signal at *Slow* speed.
- A center light indicates proceed through the interlocking at Medium speed and proceed at Normal speed.
- A flashing center light indicates proceed through the interlocking at *Limited* speed and the proceed at *Normal* speed.

Yellow base aspect

With a yellow base aspect:

- A light above at the center indicates that this is an automatic block signal: proceed at *Medium* speed and approach the next signal prepared to stop.
- A light below at the center indicates that this is an interlocking signal: proceed through the interlocking at *Medium* speed and approach the next signal prepared to stop.

- A light below at the center indicates that this is an interlocking signal: is proceed through the interlocking at *Limited* speed and approach the next signal prepared to stop.

Red base aspect

A red base aspect indicates Stop ("and stay), unless one of the following conditions obtains, in which case it indicates Stop and Proceed:

- There is a block number plate on the mast (denoting an automatic block signal)
- The center auxiliary light, above or below, is illuminated.

Lunar white aspect

A lunar white aspect (there will be no auxiliary light) indicates proceed at *Restricted* speed.

Alternative to flashing

For any of the aspects that involve a flashing auxiliary light, an alternative is to have the light steady and a triangular yellow plate in the lower right auxiliary light position. (The plate essentially indicates, "Limited speed".)

Flashing green aspect

A flashing green base aspect (there will be no auxiliary light) indicates *Slow* speed through the interlocking, then proceed at *Normal* speed. (This is an irregular construction.)

No auxiliary light

With no auxiliary light, the indication is highly restrictive (a "fail-safe default" situation). With a green base aspect, the indication calls for Slow speed through the interlocking (if applicable) and approach to the next signal at Slow speed. With a yellow base aspect, the indication calls for Slow speed through the interlocking (if applicable) and approach to the next signal prepared to stop.

As already mentioned, with a red base aspect and no auxiliary light, the Stop indication is absolute ("Stop and Stay") unless a number plate is present (denoting that the signal is of the automatic block type), in which case the indication is Stop and Proceed.

Appendix C

The “three-phase” (“Mozier”) semaphore scheme

C.1 Introduction

When lower quadrant operation of semaphore signals was common, a single semaphore arm could usually only give two aspects: one (“Clear”) with the arm downward, perhaps at an angle of 45°-75° to the horizontal, and one (“Stop”) with the arm horizontal (see figure 1).

In a few cases, a third aspect (“Caution” or “Approach”, the latter typically meaning that a further signal was at Stop) was provided with the arm at an intermediate angle. But the fairly similar positions for the three aspects meant that the signal could readily be misunderstood. Thus the three-position, lower quadrant semaphore never came into wide use.

Of course, after upper quadrant semaphore operation came into use, it became common to have three different aspects by way of three easily-distinguished arm positions (see figure 7).

But, in the general context of lower quadrant semaphore signaling, A. M. Mozier of the Erie Railroad developed a semaphore in which the arm operates in both lower and upper quadrants. The scheme was also used in the “Style D” semaphore made by Union Switch & Signal Company (US&S), which they described as a “three-phase” semaphore.

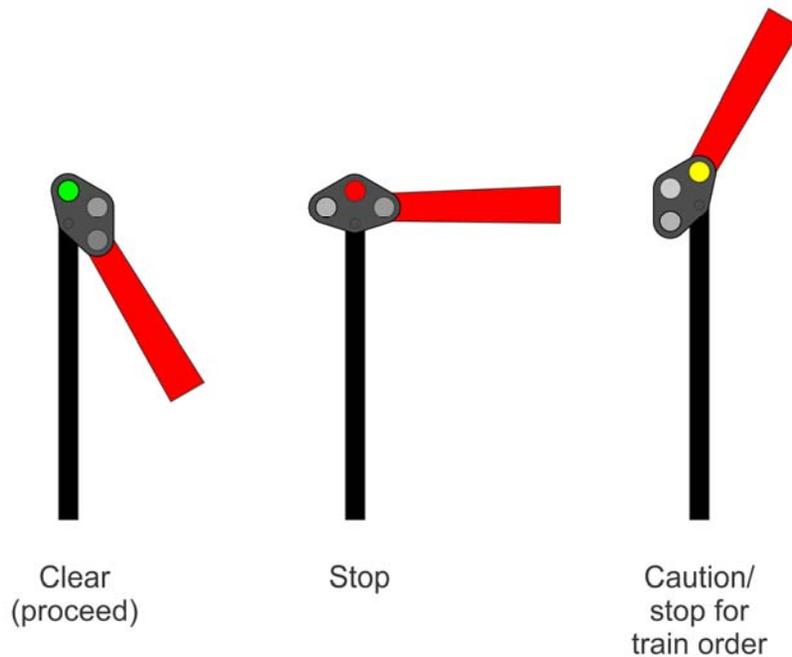


Figure 17. "Mozier" semaphore scheme

Figure 17 shows the scheme, which, regardless of the mechanism design used, is often called the "Mozier" scheme.

The drawing is evocative of the design of the US&S Style D signal.

It is essentially an extension of the classical lower-quadrant scheme, with a third position added, having the arm above the horizontal at an angle of typically 60° (the lower position then being at an angle of 60° below the horizontal). In the modern signal light color scheme, a yellow roundel is illuminated in this position.

C.2 Spectacle and lamp arrangement

In the US&S Style D semaphore the spectacle was arranged for the lamp to be atop the post (rather than on a bracket to the side, as was common for other semaphore designs). This way, when there were two semaphores on the same post, one facing each direction (common for train order signals), the same lamp (with a lens on both sides) could work for both.

C.3 Example

A lovely example of a US&S Style D Mozier scheme semaphore signal is seen in figure 18 in Appendix D.

C.4 Earlier color system

At one time, a white light on a lower quadrant semaphore meant Clear and a red one meant Stop. Then, in "Mozier-scheme" semaphores, for the "arm up" aspect (Caution/Approach), a green light was often used.

C.5 "Fail safe" operation

Both the actual Mozier design and the US&S Style D design used (different) ingenious counterweight schemes to assure that the signal arm went to horizontal (the Stop indication) in case the chains or pipe operating the signal arm were to break or become disconnected.

The operation of this scheme for the US&S Style D signal is described in connection with figure 20 in Appendix D.

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Appendix D

Train order operation

D.1 Train order operation

D.1.1 Introduction

Early railroad operation depended on “timetable” operation. There, the movement of trains was governed by a timetable (not the kind used by patrons to choose a train for their travel) that prescribed when a train is permitted to leave each station (or perhaps a way point where the train was required to wait). This system, when it worked properly, avoided (or at least reduced) the possibility that train movements could conflict.

After the use of the telegraph became widespread, timetable operation was augmented by a system of reports of train movement, carried by telegraph, the results of which were to give a train instructions (by way of “train orders”) as to departure from stations and in other respects (perhaps, with two-directional single-track running, it might direct the train, at a certain upcoming point, to enter the siding there and wait for a train in the other direction to pass). This led to improved efficiency and reduced chance for inadvertence. The protocols for doing this were of course very elaborate, intended to avert any misunderstandings that could have tragic consequences (and to assure accountability by all persons in the loop).

Certain types of train order had to be signed for by both the engineman and the conductor (who, rather than the engineman, is actually the “captain” of the train). Drawing upon the terminology used by the practices of one of the early railroads to adopt this scheme, these were often described as “Form 31” train orders.

D.1.2 Pick up of orders “on the fly”

Another type of train order (“Form 19”) did not require a signature by the train crew. To minimize the delay at an intermediate station for the pickup of an order of that type, the practice came into effect of passing these kinds of orders to the train crew “on the fly”.

Typically, then the order was placed in a clip on a cane or bamboo hoop (usually with a straight “handle”), which was then held up by the station agent, or placed in a clip on a post. The engineman was alerted to the need to pick up a train order in that fashion in various ways, sometimes by what was a “yellow” indication of a signal at the station.

The train would slow down but continue through the station. The engineman or fireman would snag the hoop with his arm, promptly pull the train order out of the clip, and toss the hoop onto the ground, from where it would later be recovered by the station agent or one of his subordinates.

Later, a fork on a long handle was used to hold (in a triangular pattern) a loop of twine into which the rolled-up train order was tied. The trainman would put his arm through the loop, which came out of the fork. The trainman would then untie the twine from the train order and discard the twine.

The protocol here often required delivery of the "Form 19" train order to both the engineman and the conductor (whose office was in the caboose). Then there would be separate hoops (or forks) for the two copies.

D.1.3 Signaling

An attractive mode of operation at a station where train orders were issued involved three position wayside signals (typically a separate one for each direction of operation, usually mounted on the same mast). These were often semaphore signals.

The aspect that indicated Proceed (we can think of this as the green aspect) meant that the train should proceed through the station in the normal way. The aspect that indicated Stop (red) meant that the train should stop, perhaps to pick up a "Form 31" train order (which had to be signed for), or perhaps (for a passenger train) to pick up passengers.

The aspect that usually indicates Caution or Approach (yellow) meant that the train should slow down and prepare to pick up a "Form 19" train order "on the fly".

Often, when lower quadrant signaling was the norm for block signaling on the railroad, a Mozier scheme semaphore (see Appendix C) was used as the train order signal.

D.1.4 Fail-safe operation

Typically, the protocol prescribed at the signal at a station be normally kept at Stop. When the station agent (or signalman) saw an approaching train, and there were no train orders for it, he would put the signal to Clear until the train had passed, then put it back to Stop.

D.2 Example

D.2.1 Introduction

Figure 18 shows a lovely example of a manually-operated two-directional US&S Style D “Mozier scheme” semaphore used as a train order signal, at the restored depot at Columbus, N.M., three miles north of the border with Mexico. The depot went out of use in 1959, when the railroad line was dismantled. The building, originally built in 1902 (some authorities say 1906), now houses the town historical museum.



Figure 18. Columbus, N.M. restored railway depot

At the far left of the picture we see the train order mast, with clips at various heights to hold the train order hoops. (There is a small stairway for access.)

D.2.2 Personal inspection of the signal

In January, 2019, my wife Carla and I visited Columbus (it was the take-off point for a weekend trip into Mexico—Columbus is only three miles from the border with Mexico), and we had a chance to examine this signal. From our examination, it appears that this signal had originally been a classical Mozier-scheme signal, with three positions.

But subsequently it has been converted to a two-position lower-quadrant signal.

We found that the third spectacle position (which would have been for the arm up position and would normally carry a yellow roundel) now actually has a blank metal plate. Additionally, the semaphore operating levers inside the station, which appear to originally have had three positions, had each been fitted with a piece that blocked their motion to the third position (which again would have corresponded to the arm up position).

D.2.3 Evolution

This signal was probably originally installed when this line was operated by the El Paso and Southwestern Railroad, the original builder of the line. Very likely that line used a three-position train order signaling plan. The line was eventually leased and later bought by Southern Pacific. That line used strictly two-position lower-quadrant semaphore signals, including for train order signaling. We presume that the conversion of the signals at Columbus from three-position to two-position was done when the line was under Southern Pacific control.

With only two signal arm positions, how would it be indicated that the train should slow and prepare to receive a Form 19 train order? Noted rail signal expert J. B. Calvert describes one scheme used by Southern Pacific. As the train approached, the station agent would twice briefly put the arm to Clear (described as a "wink"). That signified that the train could proceed but must slow and prepare to receive a Form 19 train order.

Figure 19 shows Carla at the base of the train order signal mast, with her hand on the end of the bellcrank that, through a vertical "pipe", operated the arm of the westbound signal. (The horizontal pipes from the levers in the station to the two bellcranks have been removed to allow visitors to traverse the sidewalk we see to our right to reach the building entrance.)



Figure 19. The author's wife Carla considers putting the westbound train order signal to Clear

D.2.4 Details of the signal head

Figure 20 shows the signal heads, annotated to support the discussion of fail-safe operation.

We see the spectacle hub and the counterweight arm hub (neither labeled) on a common shaft, retained by a cotter pin.

The lamp (bidirectional) is atop the post, between the two spectacles, behind the red roundel we see in the picture.

We can see the metal disk in the third (now unused) spectacle positions.

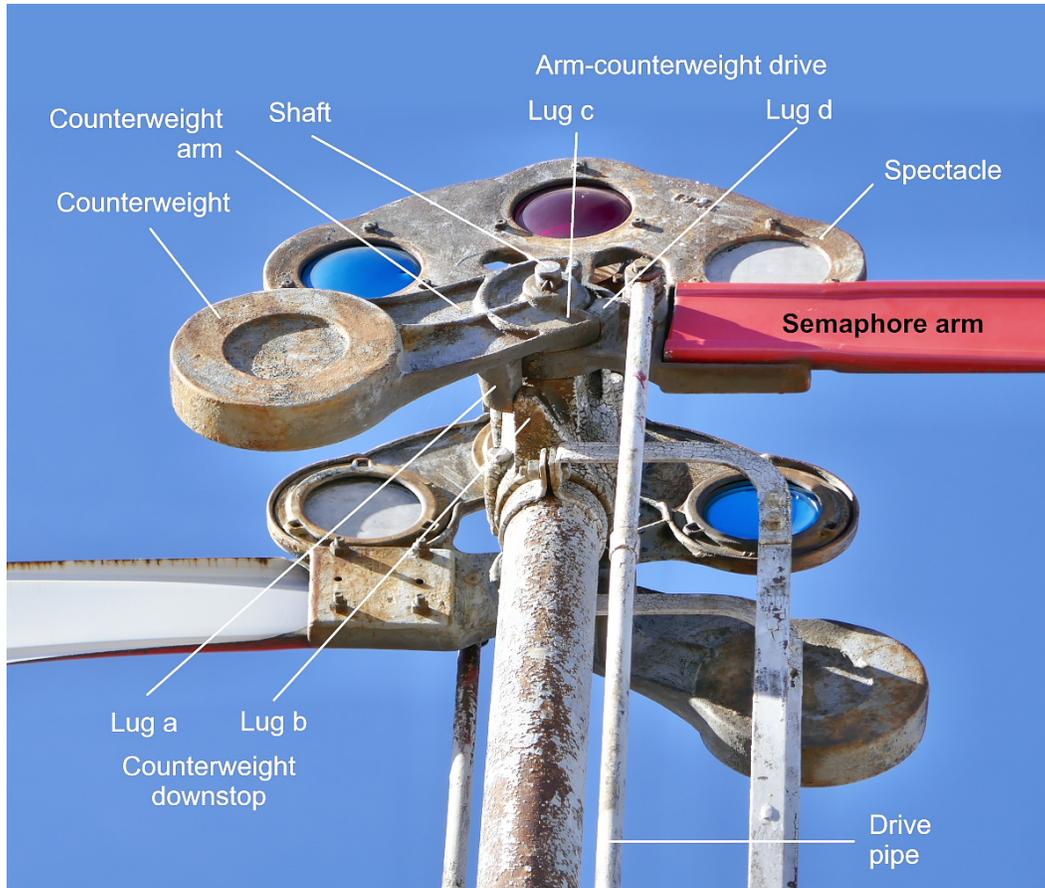


Figure 20. Train order signal heads

D.2.5 Fail-safe mechanism

D.2.5.1 Introduction

This discussion is predicated on the signal being used in its original three-position mode.

The objective of the fail-safe mechanism is that if the operating pipe should break or become disconnected, the signal arm will automatically take the horizontal ("Stop") position.

In the following discussion, when I say just "arm" I mean the *semaphore arm*, rather than the *counterweight arm* (which I will always call that).

D.2.5.2 Preparatory exercise

To understand its operation, we will first do an exercise. We will start with the (semaphore) arm horizontal (as seen in the picture). In this state, the counterweight arm is at the lower limit of its travel, because in the counterweight downstop, lug **a** (on the counterweight arm hub) is in contact with lug **b** (on the mechanism frame). And, in what I call

the "arm-counterweight drive", lug **d** (on the spectacle hub) is in contact with lug **c** (on the counterweight arm hub).

(What I call "lug" **c** is actually the end of an open region in the periphery of the counterweight arm hub.)

Now, we will lower the arm. Lug **d** will press on lug **c** and rotate the counterweight arm hub, lifting the counterweight arm as the arm goes down to the lower limit of its travel.

Next I will raise the arm. As it begins to rise, the counterweight will go down. But when the arm reaches the horizontal position, lug **a** will hit lug **b**, and the counterweight cannot fall any more.

But I can continue to raise the arm, now above the horizontal. As I do, lug **d** moves away from lug **c** (that is, the limitation in further motion of the counterweight arm does not impede further movement of the arm). I can continue to raise the arm to the upward limit of its motion.

D.2.5.3 *Actual failure scenarios*

Now, let's consider the actual failure of the operating pipe. First, imagine that before the failure, the arm was in the down ("Clear") position. With the arm now free to move (because of the broken operating pipe), the pressure of lug **c** on lug **d** (from the weight of the counterweight) rotates the arm hub, raising the arm. (The counterweight is heavy enough to overcome the weight of the arm.)

When the arm reaches horizontal, lug **a** contacts lug **b**, stopping the rotation of the counterweight arm. With its motivation halted, the rising of the arm stops, with the arm horizontal ("Stop").

Suppose the failure in the operating pipe system is a disconnection at the bell crank (or even at the operating lever). Then as the weight of the counterweight raises the arm, it must also lift the operating pipe. So, yes, the counterweight is heavy enough to do that.

Next we consider the scenario when the operating pipe fails with the arm above horizontal ("Train Order"). Free to move under its own weight, the arm falls. But when it reaches horizontal, lug **d** contacts lug **c**, and further descent of the arm would lift the counterweight. But, as we noted earlier, the weight of the counterweight is such that this can't happen. Thus the arm comes to rest in a horizontal position ("Stop").

D.3 Possible alternate use

It is very possible that at some point in the history of this signal, it was used for manual block operation (see Appendix E) rather than as a train order signal.

D.4 Many years earlier

Figure 21 is a photo of the Columbus depot and surrounding facilities, likely taken in about 1914. Here we are looking east.

There were two tracks passing this station, with a substantial separation between them. We see the second track passing a water tower and coaling station. We assume that this track was a siding, used for watering and coaling, and probably as well to allow the passing of opposing trains.



Figure 21. Columbus, N.M. rail depot (perhaps ca. 1914)

We note that the train order signal is apparently of a different type that we have discussed earlier. It may in fact have not been illuminated.

D.5 A curiosity

We recently encountered another photograph (figure 22), taken in 1962, after the train line had gone out of use but before the rails were taken up. Here we are looking west.



Figure 22. Columbus, N.M. depot, line abandoned, 1962

Photo by Tom Otoski
used under doctrine of fair use

It shows a train order post with access stairs (almost certainly the very one we see in figure 18, now related to in front of the station) located on the far side of the second track. This was perhaps intended for use by westbound trains using the siding.

Note that no similar post is shown on the near side (as we see in figure 18).

That would mean that at the time, for trains using the "near" track, the train orders would have been handed up with a hoop or fork held by the station agent.

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Appendix E

Manual block operation

Manual block operation was, in a way, a refinement of train order operation and was often intertwined with it for a period. It was an important step along the path to automatic block signal operation.

In this scheme the route was divided into blocks, often quite lengthy and always having a station (or an intermediate signal cabin) at the boundary between blocks. At each such point there were wayside signals (often using semaphore signals). The signals were operated by signalmen (of course at a small station, the station agent might also be the signalman).

The signal control points were interconnected by telegraph (or later by telephone). (The signalman was often the telegraph operator, especially at smaller stations, and certainly at signal huts).

Following an elaborate and strict protocol, in the simplest case our signalman would set the signal to Stop after a train had passed (and was thus in the block). When the train has completely exited the block (at the following station or signal hut), that fact was reported by the signalman there to our signalman, who would then put the signal to Clear, allowing a subsequent train to enter the block.

But because of the great length of the block, the ideal result (a train never entering a block where there was already a train with which it might collide) would seriously limit the traffic capacity of the line.

Thus, compromises were built into the scheme. Simplistically, even if there was a train still in the block ahead, a following train would be permitted to enter the block after a certain time period. This of course did not protect against the possibility that the first train might unexpectedly stop in the block due to mechanical trouble, and that the following train might then collide with it.

Often, this concept was more liberally applied to freight trains than passenger trains. I suppose it was considered that a collision involving only freight trains was more "acceptable" than one involving a passenger train.

A common situation was that the signals at a station used for train order operation were then repurposed for manual block operation (and again, sometimes the mode was a very complex hybrid of the two).