PENNSYLVANIA IMPLEMENTATION OF FLASHING YELLOW ARROW

RECOMMENDED PRACTICE

LAST REVISED: MARCH 7, 2017
INTRODUCTION

The purpose of this document is to present background information and provide deployment standards and guidance for the use of Flashing Yellow Arrow (FYA) left-turn treatments in the Commonwealth of Pennsylvania. It is anticipated that the recommendations provided in this document will be folded in to a pending consolidation of Pennsylvania Department of Transportation (PennDOT) traffic signal design and guidance publications (Publication 191, Traffic Signal Manual). This Recommended Practice document is to be used in the interim until the recommended practices are formally adopted into the repurposed PennDOT Publication 191.

On May 4th, 2016, the first FYA in Pennsylvania became operational at the intersection of Rossmoyne Road (SR 2021) and U.S. Route 15 Northbound Ramps (SR 8001) in Lower Allen Township, Cumberland County. A six-month monitoring study was subsequently completed to ascertain lessons learned related to design, construction, and driver behavior. The contents of the document are reflective of these lessons learned in addition to national best practice research and Pennsylvania-centric recommendations contained within the April 28, 2016, PennDOT Implementation of Flashing Yellow Arrow Position Paper (Position Paper).

WHAT IS FLASHING YELLOW ARROW?

A FYA traffic signal head features a flashing yellow arrow indication in addition to red, yellow and green steady arrow indications. While the flashing yellow arrow indication is displayed, left-turns are permitted, but the motorist must first yield to oncoming traffic and pedestrians. Though the signal display is different from five-section heads used for protected/permissive left turn phasing, the flow of vehicles and the left-turn phasing at the intersection is the same as traditional protected/permissive signals. An animation depicting the similar left turn vehicle flow with the two different protected/permitted signal displays is available on the Flashing Yellow Arrow Resource Page of PennDOT’s Traffic Signal Portal (http://www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/FYA.html).

Exhibit 1 illustrates the difference in the typical installation position and arrangement of the FYA signal head as compared to the five-section protected/permitted signal head.

Exhibit 1: Flashing Yellow Arrow vs. Five-Section Head Illustration

The FYA was added as an optional configuration for protected/permissive and permissive left-turn signal heads in the 2009 Manual on Uniform Traffic Control Devices (MUTCD) and is currently being used in a majority of states nationwide.
HISTORY OF LEFT-TURN SIGNALS

Accommodating left-turning traffic at signalized intersections has long been an operational and safety issue. From an operational perspective, left-turning movements frequently require a dedicated phase for a portion of the cycle time. From a safety perspective, crashes involving left-turning movements are often more severe than other signalized intersection crashes because of the speed variance between the turning vehicle and the oncoming vehicle and the resulting crash frequently occurs along the side of the turning vehicle. Decades of signal enhancements have been deployed to manage these left-turn operational and safety issues.

SIGNAL HEAD CONFIGURATIONS

The configuration of a signal refers to the order and orientation of signal indications within the signal housing. Exhibit 2 depicts a timeline of the various signal head configurations used to accommodate left-turning movements since traffic signals were first installed in the United States.

Exhibit 2: Left-Turn Signal Head Configuration Timeline

SIGNAL PHASING

A signal phase is comprised of assignment of motorist right-of-way (traditionally a green indication), yellow change, and red clearance intervals in a cycle assigned to an independent traffic movement or a combination of traffic movements. For an exclusive left-turn phase, the following phasing alternatives are considered:

- **Protected/Prohibited Left-Turn Phasing**: Left-turn movements are “protected” and have the right-of-way when a green arrow is displayed, and are prohibited via the display of a red indication in the left-turn signal head at all other times.
• Protected/Permissive Left-Turn (PPLT) Phasing: Left-turn movements are “protected” and have the right-of-way when a green arrow is displayed but are then permitted to turn left upon the completion of the green arrow until a red indication is shown.

Development of PPLT phasing and corresponding signal displays to effectively and safely convey the phasing to motorists has evolved over time and there remain concerns regarding the optimal signal displays for this purpose. FYA was introduced in the 2009 MUTCD in response to these concerns. A timeline of the development of left-turn PPLT phasing, suggested signal displays, and implementation is shown in Exhibit 3.

Exhibit 3: Protected/Permissive Left-Turn Phasing Timeline

BACKGROUND

With more widespread implementation of the FYA since its inclusion in the 2009 MUTCD, the term FYA has taken on a number of meanings and is used to describe many aspects of signal operations. Specifically it has been used in the context of the following terms:

• Phasing – refers to the sequence of right-of-way, yellow change and red clearance intervals for vehicular movements at the signalized intersection. When used in the context of FYA, it typically refers to the assignment of right of way for turning movements.
• Mode – refers to possible types of turning movement phases. When used in the context of FYA it typically refers to permissive and protected/permissive turn movements or those same movements in combination with a protected-only phase.
• Display – refers to the arrangement of indications in a signal head. When used in the context of FYA, it typically refers to the four-section or three-section head FYA variations.
• Indication – refers to the particular lens in a signal display. When used in the context of FYA, it typically refers to the flashing yellow arrow lens.
• **Operation** – refers to a sequence of events. In the context of FYA, when describing the operation of the signal **display** it typically refers to the progression of illumination of lenses in the signal face. When describing the operation of a **signalized intersection**, it typically refers to the selection of phases and modes and the progression of right-of-way assignments through those phases.

### PERMISSIVE LEFT-TURN ISSUES

Investigation of the FYA signal head was undertaken on a national level because there were concerns with the understanding of existing signal head displays when conveying the intent of permissive and protected/permissive left-turn phasing at intersections to motorists.

### CIRCULAR GREEN FOR PERMISSIVE LEFTTurns

Motorists turning left on a permissive circular green signal indication can mistake the indication to imply they have right-of-way over opposing traffic. National studies, such as National Cooperative Highway Research Program (NCHRP) Report 493, have found that displaying a circular green signal indication in a separate signal face over or directly in line with an exclusive left-turn lane causes motorist confusion and inappropriate behavior which in turn leads to a higher crash rate and increased crash severity when compared to placing the circular green signal indication on or to the right of the lane line. This issue was partially mitigated with guidance added to Section 4D.13 of the 2009 MUTCD which recommends against locating signal heads with a circular green over or directly in line with an exclusive left-turn lane as follows:

“For new or reconstructed signal installations, on an approach with an exclusive turn lane(s) for a left-turn (or U-turn to the left) movement and with opposing vehicular traffic, signal faces that display a CIRCULAR GREEN signal indication should not be post-mounted on the far-side median or mounted overhead above the exclusive turn lane(s) or the extension of the lane(s).”
**LEFT-TURN TRAP**

The combination of a permissive left-turns with lead/lag operation creates a situation commonly called the “left-turn trap”. As a demonstration of the left-turn trap, consider the lead/lag scenario depicted in **Exhibit 4**. An animation of the lead/lag left-turn trap is also available on the [Flashing Yellow Arrow Resource Page](#).

**Exhibit 4: Lead/Lag Left-Turn Trap**

**Stage 1**: Phase 5 EBL shows a protected left-turn arrow while Phase 2 EMT shows a circular green. The opposing WB movements are stopped. *No issues during this stage; the left-turn vehicles have a protected movement.*

**Stage 2**: The EBL and WBL movements operate as permissive lefts (circular green indication). During this stage, the EBL may enter the intersection looking for gaps in the opposing traffic. Note that the EBL is actually operating as Phase 2 permissive. *At the end of this stage is when the left-turn trap occurs. Phase 2 indications will change to yellow. The EBL vehicle now has to consider how to clear the intersection and may falsely assume the opposing through is seeing a yellow indication and is about to stop. In fact, the WBT remains green since Phase 1 WBL is up next.*

**Stage 3**: Phase 1 WBL shows a green arrow (protected) operation while Phase 6 WBT remains green. *EBL motorists may assume the WBT movements is stopping and EBL motorists will either get trapped in the intersection or attempt to turn left through the intersection creating a crash situation.*

**PROTECTED/PROHIBITED OPERATION DURING LOW VOLUME PERIODS**

Protected/prohibited left-turn phasing requires all left-turning vehicles to wait for a green arrow to complete the turn. Aside from geometric considerations, the primary criteria for establishing a protected/prohibited left-turn phase is based on high volumes of left-turn traffic and/or high volumes of opposing traffic. The PennDOT threshold
used to establish the protected/prohibited left-turn phasing only needs to be met for two hours of the day, but the use of the three-section protected left-turn signal head requires the protected/prohibited phasing to operate 24-hours per day. Implementation of protected/prohibited left-turn phasing based on volume thresholds for peak hours can lead to operational inefficiencies and unnecessary delays for the remainder of the day when left-turning motorist would have adequate gaps and sight distance to safely proceed. This would occur during periods of lower opposing volumes.

**LITERATURE REVIEW**

**NCHRP 3-54 RESEARCH ON PPLT DISPLAYS**

NCHRP Project 3-54, *Evaluation of Traffic Signal Displays for Protected/Permitted Left-Turn Control*, evaluated the safety and effectiveness of different signal displays and phasing for protected/permissive left-turn control. Many agencies had sought alternatives to the circular green indication used in PPLT since the circular green can produce yellow trap situations if not used properly (i.e., lead/lag phasing schemes). NCHRP 3-54 conducted several studies of both the circular green permissive display and several other displays.

NCHRP Report 493 published the following key findings from NCHRP Project 3-54:

- The FYA indication was found to be the best overall alternative to the circular green as the display for the permissive left-turn mode.
- The FYA indication was found to have a high level of understanding and correct response by left-turn motorists, and a lower fail-critical rate than the circular green.
- Motorists had fewer crashes with flashing yellow left-turn arrows than with traditional yield-on-green signal displays.

Full details on the NCHRP Report 493 can be found on the [Flashing Yellow Arrow Resource Page](#).

**NCHRP WEB ONLY DOCUMENT 123**

NCHRP Web Only Document 123, *Evaluation of the Flashing Yellow Arrow Permissive-Only Left-Turn Indication Field Implementation*, summarized the results of a follow-up study recommended by NCHRP Project 493. The study evaluated crash data for 50 intersections nationwide. Intersections with at least one year of FYA implementation were chosen for analysis. Crash data was used as the main performance variable to evaluate the effectiveness of the FYA operation. The main findings of the follow-up study for FYA operation are summarized as follows:

- Safety was improved at intersections that operated with PPLT before the field implementation of the FYA indication and continued with PPLT operation afterwards.
- Safety was not improved at intersections that operated with protected-only left-turn phasing before the implementation of the protected and permissive operation with FYA.

Short-term analysis involved conflict rate analysis, follow-up headway, and motorist hesitation as indicators of changes in the motorist’s behavior due to FYA display for PPLT operation. For long term analyses, crash data was the main performance measure used to evaluate safety for field implementations of FYA signal displays. Motorists’ perceptions/reactions were measured under controlled conditions in a simulated environment. No naturalistic driving studies have been performed to evaluate motorists’ perceptions of FYA displays for PPLT.

Full details on the NCHRP Web Only Document 123 can be found on the [Flashing Yellow Arrow Resource Page](#).
NCHRP 17-35 RESEARCH ON SIGNALIZED INTERSECTION SAFETY

NCHRP Project 17-35, Evaluation of Safety Strategies at Signalized Intersections, evaluated the effectiveness of different strategies for improving the safety of signalized intersections. These strategies were originally identified in NCHRP Report 500, Guidance for the Implementation of the AASHTO Strategic Highway Safety Plan, Volume 12: A Guide for Reducing Collisions at Signalized Intersections. Changing various left turn phasing to FYA was among the strategies evaluated. Under the project, Highway Safety Manual (HSM) crash modification factors (CMFs) for a number of the safety strategies were developed. CMFs represent the ratio of the expected crash frequency after and before the implementation of a treatment, with CMFs less than 1.0 representing a reduction in the expected crash frequency.

NCHRP Report 705, Evaluation of Safety Strategies at Signalized Intersections published the following key findings from NCHRP Project 17-35, as summarized in Exhibit 5.

Exhibit 5: CMFs for FYA use in Permissive Left Turns

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Entire Intersection CMF</th>
<th>Left Turn CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing left turn phasing from at least one permissive approach to FYA</td>
<td>0.75</td>
<td>0.63</td>
</tr>
<tr>
<td>Changing left turn phasing from protected-permissive to FYA</td>
<td>0.92</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Full details on the NCHRP Report 705 can be found on the Flashing Yellow Arrow Resource Page.

Accepted CMFs and CRFs from the study have been published in the FHWA Crash Modification Factors Clearinghouse. These factors are acceptable for use with HSM evaluation methods.

MOTORIST COMPREHENSION OF THE FYA

National studies have shown the FYA indication is more understandable and operationally more efficient than traditional protected/permissive left-turn indications such as a five-section cluster signal head, and these results have been confirmed by agencies’ experiences. The studies are summarized below:

- To provide baseline information for future studies of the FYA permissive indication, a New England University Transportation Center 2009 report focused on driver comprehension of the solid yellow change indication that alerts drivers to the permissive or protected phase being terminated.
- A 2008 Missouri DOT report advises undertaking a public information campaign to increase familiarity with the FYA signal prior to and during the implementation process.
- In a 2008 conference paper, researchers described the results of video observation used to analyze motorist understanding of an FYA installation in St. Louis, MO, concluding that the video observation methodology is superior to questionnaires or simulation. Results indicated that more than 90% of the motorists observed understood the meaning of the FYA.
- Two 2007 Transportation Research Board (TRB) Annual Meeting papers evaluated the impact of two allowable permissive left-turn indications—the FYA and circular green—and comprehension of the solid yellow arrow resulting from exposure to the FYA permissive indication.
- The application of the FYA at specific types of intersections was evaluated in two 2006 publications.
  - In a TRB Annual Meeting paper, researchers concluded that the FYA permissive indication should be used at wide median intersections only after consideration of safety and operational issues.
  - A journal article describes the results of driving simulator evaluations that indicated the FYA is recommended for use at T-intersections where pedestrian crossings are prevalent.
• Three 2005 publications provide the results of driving simulator studies.
  o A conference paper described the tracking of eye movements to identify scan patterns among motorists completing left-turns. Researchers found that 90% of motorists first look for the PPLT signal display and then focus on opposing traffic when one is present.
  o Researchers evaluated twelve PPLT signal displays that included only the circular green and/or the FYA permissive indication to assess driver comprehension. Findings reported in a journal article indicate a high level of comprehension with no variation between the PPLT displays, which indicates that the FYA is an alternative to the circular green permissive indication.
  o A TRB Annual Meeting paper presented results of a study that compared driver comprehension of the circular green indication in a traditional five-section cluster signal configuration with a retrofit display that features the simultaneous display of the circular green with the FYA permissive indication.

AGENCY USE OF FYA

There were 19 state departments of transportation and 46 additional agencies (cities, counties, territories, etc.) that received interim approval for the use of the FYA prior to inclusion of the FYA in the 2009 MUTCD. The number of additional states implementing the FYA since the 2009 MUTCD was adopted has not been tracked. Exhibit 6 shows the agencies (by state) that were using the FYA under interim approval.
The states that border Pennsylvania include New York, New Jersey, Delaware, Maryland, West Virginia, and Ohio. Exhibit 7 summarizes each state’s usage of FYA as of April, 2016.

### Exhibit 7: Status of FYA use in States Bordering Pennsylvania

<table>
<thead>
<tr>
<th>Bordering State</th>
<th>Using FYA?</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>Yes</td>
<td>The New York State Department of Transportation (NYSDOT) began implementation in 2011 in select DOT regions with the emphasis on replacing protect/prohibited signals where protection wasn’t needed on a 24-hour basis. Since then, NYSDOT has implemented the use of FYA statewide for protected/permissive signals as well.</td>
</tr>
<tr>
<td>New Jersey</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Delaware</td>
<td>Pending</td>
<td>The Delaware Department of Transportation (DelDOT) currently uses Flashing Red Arrow (FRA) and has since the 1970s. Motorists are required to stop before turning left at a FRA. DelDOT began using FRA as a solution to provide flexibility in left turn signal control. Rather than use protected/prohibited at certain locations, the FRA acts as protected/semi-permissive. As of April 2016, DelDOT is actively pursuing the transition to FYA.</td>
</tr>
<tr>
<td>Maryland</td>
<td>No</td>
<td>The Maryland State Highway Administration (SHA) started to use FRA instead of FYA in 2011 for known reasons.</td>
</tr>
<tr>
<td>West Virginia</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Ohio</td>
<td>Yes</td>
<td>The Ohio Department of Transportation (ODOT) began statewide implementation in 2012.</td>
</tr>
</tbody>
</table>

### ADVANTAGES OF FYA

- Direct replacement for a PPLT phase
- The FHWA study found the FYA was better understood by motorists
- Provides similar safety benefits while providing more flexibility in how it operates
- Best overall alternative to circular green
- More versatility in field operation
- Lead/lag and left-turn re-service
- Time of day flexibility to run protected-only, PPLT, or permissive-only.
- Eliminates left-turn trap when implemented correctly
- Allows permissive left-turns when the adjacent through phase is red and opposing through phase is green

### ELIMINATION OF THE LEFT-TURN TRAP

Exhibit 8 illustrates how FYA eliminates both left-turn and “soft-trap” conditions. The soft-trap occurs when opposing through movements have different clearance times and permissive lefts are allowed. In this case, one direction sees the circular yellow indication while the opposing through is still green. As with the left-turn trap, the left-turn that sees the yellow indications assumes the opposing through sees the yellow at the same time. This is not as critical as a full left-turn trap, yet it can be problematic. As noted, the FYA eliminates this situation since the FYA indication is tied to the opposing through phase.
Exhibit 8: Elimination of Left-Turn Trap using FYA

**Stage 1:** During this stage, normal leading protected and opposing left-turn phases operate. This is the typical operation even with a traditional five-section signal. At the end of this stage, Phase 1 clears the intersection with a solid yellow arrow.

**Stage 2:** During this stage Phase 2 begins green as Phase 5 continues green in normal operation. The opposing left-turn is operated as a FYA. In a traditional five-section operation, the opposing left-turn would be red.

**Stage 3:** In this stage, Phase 2 and 6 through movements receive a circular green indication. The opposing lefts are operated as an FYA overlap with the opposing through movements. This will ensure that the left-turning movements clear and the movements terminate with the through movements, thus eliminating the left-turn trap.

**DISADVANTAGES OF FYA**

There are a few issues disadvantages regarding the use of the FYA. One of them is the “disco effect.” In an urban environment with traffic signals every block (or even more), all the arrows flashing at different rates adds visual clutter.

The second disadvantage is the “perceived yellow trap.” If a motorist was looking down and then looks up and sees the FYA indication when it is illuminated at the same time the other approach signals show yellow, the motorist may incorrectly assume the left-turn phase is terminating as well. The perceived yellow trap is not as problematic as the left-turn trap because the motorist usually quickly determines that the left-turn movement is still permissive.
A third disadvantage is that while research shows enhanced motorist understanding, some motorists may not understand the meaning of the FYA. There are anecdotal reports of situations where the driver thought the FYA indication meant they had the right of way. In these cases, LEFT TURN YIELD ON FLASHING YELLOW ARROW signs were used as an interim treatment to educate motorists.

**LAWS AND REGULATIONS**

**STATUTE (TITLE 75) [VEHICLE CODE]**

Part III of the Pennsylvania Vehicle Code (Title 75 of the Pennsylvania Consolidated Statutes, 75 Pa.C.S.) contains all statutes relating to the operation of vehicles in Pennsylvania. Statutes are officials laws of the Commonwealth voted on by the General Assembly and approved by the Governor. Title 75 can be viewed at: http://www.dmv.state.pa.us/vehicle_code/index.shtml

On January 14, 2015, PennDOT’s Office of Chief Counsel determined that flashing yellow arrows are permissible under 75 Pa.C.S. §3114(a)(2) since arrows are a type of signal and §3114 is not limited to solid circular signals. Therefore, no statutory changes were made relating to the use of FYA in Pennsylvania.

**REGULATION (TITLE 67) [67 PA. CODE]**


Commonwealth agencies, including PennDOT, have the authority, discretion, and, to the extent necessary, the responsibility to promulgate regulations pursuant to their respective enabling statutes. Regulations can be adopted to implement legislation, comply with federal and state regulations or statutes, comply with a decision of a state or federal court, or clarify an existing regulation. Procedures for adoption of regulations are governed by statute. Once a regulation has been approved and published in the Pennsylvania Bulletin, it has the full force and effect of law.

Since Chapter 212, Subchapter D does not contain regulations pertaining to vehicular signal displays, no modifications to Title 67 of the Pennsylvania Code were necessary to use FYA in Pennsylvania.

**STANDARDS AND GUIDANCE**

The following section outlines pertinent application, design, construction, asset management and public awareness standards and guidance to promote consistency in the application of FYA throughout Pennsylvania.

**APPLICATION**

The determination to signalize left turn movements should be guided by the criteria set forth in Chapter 3 of PennDOT Publication 149, *Traffic Signal Design Handbook*, supplemented with the guidance provided in Chapter 4 or PennDOT Publication 46, *Traffic Engineering Manual*. The decision making process to provide left turn signalization is independent of the use of the FYA signal display. The FYA is an alternate means to convey left-turn traffic control; however, the FYA signal display allows for lead-lag left turn operations without incurring the left turn trap. It also allows for time-of-day (TOD) operations; operating the left turn as a protected turn for part of the day and as a protected/permitted left turn for other parts of the day.

**The use of FYA signal displays for right-turn applications have not been evaluated for use in Pennsylvania and shall not be used.**
Four-section FYA signal displays shall be used for all new and candidate retrofit signal installations with exclusive left-turn lanes and either protected/prohibited or protected/permissive left-turn phasing. Considerations when reviewing candidate retrofit locations include the type of cabinet, controller, vehicle detection, mast arm orientation and length, availability of a post mounted alternative if needed, structure integrity of the existing signal support and mast arm, vertical clearance constraints, and the presence of conflicting left-turn paths. Engineering judgement should be exercised in determining candidate retrofit installations. The District Traffic Engineer (DTE) should be consulted for all retrofit installations.

Candidate retrofit locations should be prioritized based on the following:

- Corridors where changing to lead/lag rather than lead/lead left-turn phasing would improve progression but implementation without FYA would result in a yellow-trap situation.
- Locations where left-turn demand is low during off-peak periods and variable modes of left-turn phasing would be beneficial.
- Locations where crash patterns involve left-turning vehicles and could be attributed to driver misunderstanding of shared signal indications.
- Locations with frequent railroad or emergency vehicle preemption which currently results in a left-turn trap.
- Locations undergoing signal upgrades.

The four-section FYA signal display is not required for new or retrofit signal installations with an exclusive left-turn lane and no associated left-turn phase (permissive-only left-turns). If a FYA signal is desirable for a permissive-only exclusive left-turn lane condition, it is strongly recommended that the four-section FYA signal display be used so that the appropriate mast arm length and signal hardware/wiring is installed should the left-turn movement require a left-turn phase in the future. If the four-section FYA signal display is installed for permissive-only left-turn lane conditions, the steady green arrow lens is not illuminated. The three-section variation of the FYA head configuration may be used in place of the four-section FYA for permissive-only left-turn lane conditions per the MUTCD, however PennDOT prefers the four-section FYA be utilized in these circumstances. The three-section FYA excludes a steady green arrow lens.

The decision as to whether or not to install FYA at a single intersection within a corridor or for the entire corridor should be based on the circumstances/constraints of the project, practicality, and engineering judgement. The District Traffic Engineer (DTE) should be consulted when determining whether a single intersection or an entire corridor should be outfitted with FYA. The consistent use of FYA along a corridor is encouraged, when practical, so that motorists encounter the same type of left-turn signal display rather than a combination of various left-turn displays.

DESIGN

REGULATION

FYA for permissive left-turns is governed by relevant provisions in the 2009 MUTCD. These provisions are found in the following sections of Chapter 4D, Traffic Control Signal Features:

- Section 4D.05: Application of Steady Signal Indications, allows the use of a FYA indication before a steady yellow arrow.
- Section 4D.09, Positions of Signal Indications Within a Vertical Signal Face, specifies the proper location of flashing yellow and flashing red indications, including:
The flashing yellow indication cannot be placed in the same vertical position as the signal section that displays a steady yellow signal indication.

The flashing yellow indication shall be placed below the steady yellow signal indication.

- Section 4D.17, Signal Indications for Left-Turn Movements—General, begins the discussion of signal indications for left-turn movements.
- Section 4D.20, Signal Indications for Protected/Permissive Mode Left-Turn Movements, Paragraph 03 provides the requirements associated with use of the FYA using a separate left-turn signal face in a PPLT mode.

Figures from the 2009 MUTCD related to the position and arrangement of FYA signal displays:

- Figure 4D-7, Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Permissive Only Mode Left Turns.
- Figure 4D-12, Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Protected/Permissive Mode and Protected Only Mode Left Turns.
- Figure 4D-20, Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 2 of 3).
- Figure 4D-20, Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 3 of 3).

All other regulations of the MUTCD pertaining to traffic control signals, to include those supplemented by PennDOT Publication 212, Official Traffic Control Devices, are to be adhered to as appropriate and necessary.

MEANING OF DISPLAY INDICATIONS

The FYA head is a signal that uses a flashing yellow arrow indication for permissive left-turns instead of using a circular green indication. The 2009 MUTCD, Section 4D.04, includes language on the use of the flashing yellow arrow which states:

“Vehicular traffic, on an approach to an intersection, facing a flashing YELLOW ARROW signal indication, displayed alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or other such movement as is permitted by other signal indications displayed at the same time.

Such vehicular traffic, including vehicles turning right or left or making a U-turn, shall yield the right-of-way to:

   a) Pedestrians lawfully within an associated crosswalk, and
   b) Other vehicles lawfully within the intersection.

In addition, vehicular traffic turning left or making a U-turn to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.”

HEAD CONFIGURATION

With the use of the four-section FYA signal display, the FYA signal head indications can adapt in response to the three left-turn modes of operation (permissive-only, protected/permissive and protected/prohibited), providing additional operational flexibility. This flexibility is indicated in Exhibit 9.
Exhibit 9: FYA Indications Used with Various Operational Modes

<table>
<thead>
<tr>
<th>Four Section FYA Head and Indications</th>
<th>Permissive-Only Mode</th>
<th>Protected/Permissive Mode</th>
<th>Protected/Prohibited Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady Red Arrow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady Yellow Arrow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flashing Yellow Arrow</td>
<td></td>
<td></td>
<td>Not Illuminated</td>
</tr>
<tr>
<td>Steady Green Arrow</td>
<td>Either Not Illuminated or Not Included</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The use of three-section FYA signal displays with a bi-modal lens that displays both the steady yellow arrow and flashing yellow arrow indications in the middle section is not approved for use in Pennsylvania.

HEAD PLACEMENT

In accordance with Section 4D.13 of the 2009 MUTCD, the FYA signal display for a left-turn movement shall not be positioned any further to the right than the extension of the right-hand edge of the exclusive turn lane or any further to the left than the extension of the left-hand edge of the exclusive turn lane.

The FYA signal display should be placed in line with the center of the exclusive left turn lane.

Exhibit 10 includes Figure 4D-7 from the MUTCD, depicting the typical position and arrangement of separate signal faces using FYA for permissive-only left-turns (PennDOT recommends installing a four-section FYA head in lieu of the three-section FYA head depicted), and Figure 4D-12 from the MUTCD, depicting the typical arrangement of separate signal faces for FYA for protected/permissive mode and protected-only mode left-turns.
When replacing a five-section head with a FYA, a second through-movement three-section signal head may be required in addition to the installation of the FYA head to ensure the minimum required two signal heads for the through movement are provided per 2009 MUTCD, Section 4D.11. Additionally the replacement three-section through movement head should correspondingly be shifted to the right to be aligned over the center of the adjacent through lane so the green ball is no longer near the left-turn lane (and a minimum of 8-feet away from the FYA head). This will likely result in the need to relocate all signal heads for the approach since all heads must be 8-feet minimum /12-feet preferred apart in typical installations. Clearly account for and communicate the resultant signal head placements within the design documents.

The FYA display may be pedestal-mounted within the median if existing overhead supports are inadequate to ensure the proper alignment between the FYA and the associated turn lane. Consider a supplementary signal head especially for pedestal mounted FYA installations since they are located centered on the left-turn lane and are mounted at a height that is obscured by large vehicles as vehicles progress towards the signal.

**SIGNING**

A supplemental R10-12A (LEFT TURN YIELD ON FLASHING YELLOW ARROW) sign shall be used when a left-turning movement on an approach is permitted by the display of a left FYA for all new or retrofit installations. The R10-12A sign should be placed approximately 1-foot to the right of the traffic signal which displays the left FYA. No variations to the R10-12A sign to include the use of symbols is allowable. See Exhibit 11 for the R10-12A sign specification.
WIRING

A traditional signal head for the protected/permissive left-turn mode contains five indications with the three circular indications running off the output for the adjacent through phase and the two arrow indications running off the output for the left turn phase. The steady red arrow, steady yellow arrow, and steady green arrow in a FYA display can be wired the same as a traditional three-section protected/prohibited display, however must not utilize ‘daisy chained’ signal wires. The FYA signal head introduces the requirement for a fourth output, a flashing indication, which cannot be run from the output for a steady indication and thus introduces the requirement to output and monitor an additional signal indication.
In order for the conflict monitor to prohibit conflicting indications in accordance with Section 4D.05 of the 2009 MUTCD, the flashing yellow arrow indication should be wired so it is monitored by a separate channel from the steady red arrow, steady yellow arrow and steady green arrow indications in the FYA head. Typically the FYA indication is wired to an overlap or the unused third output of a pedestrian load switch.

If an existing five-section protected/permissive signal head is replaced with a four-section FYA signal head, the existing wiring between the signal head and cabinet can be reused with connection to different outputs. Re-use of the existing wire assumes the signal head wiring was not ‘daisy chained’ with adjacent heads.

**POSITIVE OFFSET FOR PERMISSIVE LEFT-TURN OPERATION**

Consideration of lateral offset for left-turning vehicles is important with the widespread installation of FYA, or any permissive left-turn movement, to ensure vehicles waiting in the opposite left-turn lane do not restrict sight distance to oncoming through traffic. A positive left-turn lane lateral offset helps FYA permissive operation in terms of safety and efficiency.

**DETECTION**

In most cases, existing detection within the exclusive left-turn lane used for protected left-turn phases will be adequate for the protected period of operation with the FYA head. The detector within the exclusive left-turn lane can also be programmed to extend the permissive period of operation with the FYA head, which is typically run as an overlap of the opposing through phase in the controller.

**CHANGE AND CLEARANCE INTERVALS**

When used for permissive left-turn phasing, the FYA signal display shall be tied to the opposing through green indication/display.

Steady yellow arrow time for clearing the green arrow for leading or lagging left-turns should be the same as the current yellow change interval for protected left-turn operation.

Steady yellow arrow time for clearing the FYA should be the same as the opposing through circular yellow change interval, as the FYA is driven by an overlap with the opposing through phase.

All new and retrofit FYA installation shall include an all-red interval, with a steady red arrow shown, when transitioning from a protected left-turn to a permissive left-turn in protected/permissive operations. The all-red interval shall be calculated in accordance with Publication 149 as a protected left-turn phase.

**VARYING TIME-OF-DAY OPERATIONS**

PennDOT Publication 149, Traffic Signal Design Handbook, provides design criteria for establishing left-turn phasing, with the primary criteria being the “conflict factor”. The conflict factor is the product of the left-turn volume and the opposing through traffic volume for any one-hour period on a normal weekday. Depending on the traffic demand of a left-turning movement and the opposing traffic volumes, protected/prohibited phasing is warranted when two or more separate one-hour periods in a day meet the conflict criteria established in Publication 149. As a result, protected/prohibited phasing may be installed for the traffic demands of a couple hours of a day whereas the remainder of the day doesn’t need a protect/prohibited phase.
With a four-section FYA head, the mode of operation for the left-turn phase is flexible and can vary between permissive-only, protected/permissive, and protected/prohibited on a time-of-day basis with the following considerations:

- Each signal approach will need to be analyzed individually to determine the time-of-day FYA operation by considering the conflict factor during each hour of the day.
- Where protected/prohibited phasing is necessary due to the geometric considerations in Publication 46, the FYA head shall not be used and the left-turn shall operate with protected/prohibited phasing at all times.

The geometric considerations for establishing a protected/prohibited left-turn phase are identified in PennDOT Publication 46, *Traffic Engineering Manual*. Publication 46 indicates protected/prohibited left-turn phasing should be considered if any of the following conditions exist:

- Dual left-turn lanes.
- Three or more opposing through lanes.
- Multi-legged intersections with more than four approaches.
- Approaches with significant non-correctable, sight distance deficiencies, including deficiencies created by stopped opposing left-turn vehicles.

**EMERGENCY VEHICLE PREEMPTION**

With traditional five-section, protected/permissive operation, there are cases where an emergency vehicle preemption (EVP) can create a left-turn trap. This occurs when an EVP detection brings up a left-turn arrow in the direction when the opposing through is currently green. The EVP detection will require the opposing through to terminate causing the trap. Additional information on how the FYA can eliminate this trap can be found in a separate document on the *Flashing Yellow Arrow Resource Page*.

**RAILROAD PREEMPTION OPERATION**

The FYA four-section head helps railroad preemption operations with the flexibility to operate in either protected/prohibited, protected/permissive, or permissive-only modes with no concern of a left-turn trap issue. It might be possible to run the left-turn as a FYA unless railroad preemption occurs (in which case it would run in protected-only operation). This issue is currently under development and more information is forthcoming.

**PEDESTRIAN OMIT**

It is possible to omit the permissive FYA indication during phases when a pedestrian actuation results in a conflicting pedestrian phase. Since motorists are required to yield to pedestrians when conducting a permissive left-turn pedestrian omit is not required, but could provide an extra factor of safety if desired.

**PERMISSIVE OPERATION DELAY**

Some agencies have experimented with a FYA permissive operation delay. In cases where a left-turn FYA leads the protected green arrow, as may be implemented for a lagging left-turn phase, the onset of the FYA is delayed to allow the opposing through to start. In this case, the opposing through starts to move seconds before the FYA, allowing the through to occupy the intersection thus minimizing confusion for the left-turning motorist. A FYA permissive operation delay is not the normal operation recommended and will require DTE approval for implementation.
CABINET AND CONTROLLER

In general, the following steps are required to setup FYA operation in the cabinet and controller:

- Program the channel assignments
- Program the appropriate overlaps
- Map Flashing Yellow Arrow Output to Unused Pedestrian Load Switch Input
- Program preemption (if applicable)
- Review/Modify Detector Vehicle Parameters
- Review/Modify Phase Call, Inhibit, Redirect
- Program the Malfunction Management Unit (MMU) i.e. Conflict Monitor
- Make the appropriate cabinet modifications

Installation of the FYA can present issues with older controller equipment. Chapter 5 of NCHRP Web Document 123 includes a list of successful FYA installations by controller type. This document is available on the Flashing Yellow Arrow Resource Page. The amount of effort and necessary steps will vary greatly depending on the type of equipment used.

NEMA STANDARDS

In order to provide consistency in vendor specification to be capable of handling the FYA, NEMA has developed standards on the FYA. The NEMA Standards Publication TS 2-2003, Traffic Controller Assemblies with NTCIP Requirements, were developed as a design guide for traffic signaling equipment and is available on the Flashing Yellow Arrow Resource Page.

PLAN PRESENTATION

An example permit plan and construction plan depicting the retrofit of an existing traffic signal with a FYA signal display is provided on the PennDOT Traffic Signal Portal. The examples depict one retrofit scenario but they may be helpful for first reference to identify preferred ways to incorporate FYA in to design documents.

CONSTRUCTION

Test the FYA signal display(s) and timings at the controller cabinet to confirm proper wiring and controller configuration to minimize troubleshooting and disrupting traffic during signal head installation.

When deploying FYA for the first time in a new area, where the determination of a new area should be determined during design, portable dynamic message sign(s) (DMS) should be used along the approaches to each FYA signal for a period of seven (7) days starting on the day in which the FYA is turned on. The preferred DMS message to display is Phase 1: NEW; SIGNAL; DISPLAY and Phase 2: FLASHING; YELLOW; ARROW.

During the day in which the FYA will be turned on, consider location specific traffic characteristics when determining a turn on time. Avoid turning it on just prior to or during the heaviest left-turn volume period(s).

ASSET MANAGEMENT

In order to track statewide installations of FYA, the traffic signal owner, for local led projects, or the local Engineering District, for Department led projects, should create a traffic signal record in the PennDOT Traffic Signal Management System (TSAMS) for new construction projects or update the existing traffic signal record in TSAMS for retrofit projects to reflect FYA installations.
When entering a FYA signal display in TSAMS, the user shall include two yellow arrow lenses within the associated signal housing record for four-section FYA signals and enter the text “Flashing Yellow Arrow” in the associated signal housing record comment field regardless of three-section or four-section FYA.

**PUBLIC AWARENESS**

Provide abbreviated public awareness campaigns for areas receiving their first FYA. A local PennDOT Engineering District prepared press release that references the Flashing Yellow Arrow Resource Page on the PennDOT Traffic Signal Portal should suffice.

Available public awareness/education resources on the Flashing Yellow Arrow Resource Page of the PennDOT Traffic Signal Portal:

- Pennsylvania Educational Video: Animated and narrated video to explain how motorists are to negotiate a FYA
- Pennsylvania FYA Fact Sheet: A flier that covers the benefits of FYA and provides graphics related to the meaning of its indications and the difference between a FYA and a five-section signal
- Listing of Past FYA Installation Press Releases: For reference when preparing new press releases
- National Research: Relevant national studies that may be of interest to the general public
- Other Videos and Animations: Educational animations to demonstrate the difference between the FYA and the five-section head, what is the left-turn trap, and the benefits of the FYA

Based on experience to date with FYA installations in Pennsylvania, anticipate a three month learning curve for motorists to become accustomed to the FYA especially when first installed in a new area.

Chapter 2, Signals, Signs and Pavement Markings, of PennDOT Publication 95, *Pennsylvania Driver’s Manual*, includes information for drivers to interpret and negotiate the FYA.