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400 GENERAL

400-1 Introduction

OMUTCD Section 1A.13 defines a Highway Traffic Signal as:

“a power-operated traffic control device by which traffic is warned or directed to take some specific action. “Highway traffic signal” does not include a power-operated sign, steadily-illuminated pavement marker, warning light, or steady burning electric lamp.”

OMUTCD Section 1A.13 defines a Traffic Control Signal (or traffic signal) as:

“any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.” [4511.01(RR), ORC].

The various types of traffic signals are discussed in OMUTCD Part 4.

The information provided in this Part of the TEM is intended to supplement the OMUTCD by presenting ODOT practices and procedures concerning the design, construction, operation and maintenance of the various traffic signal devices.

400-2 Construction Projects

Chapter 140 addresses the general application of ODOT standards, specifications and standard construction drawings in the design of construction projects. Chapter 450 provides additional construction related information specific to traffic control signals.

400-3 Force Account (ODOT Operations) Work

Districts performing force account signal work must comply with the requirements in the OMUTCD and this Manual. It is recommended that the Districts follow the provisions in the applicable signing related Standard Construction Drawings (SCDs) and Construction and Material Specifications (CMS) sections as well. It should be recognized, however, that the information in the CMS and SCDs does not necessarily provide the only method to achieve a given objective.
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401 TRAFFIC CONTROL SIGNALS - GENERAL

401-1 General

OMUTCD Chapter 4D presents information on the design, location and use of traffic control signals. Construction details are shown on the SCDs TC-81.10 through TC-85.20. Traffic signal equipment is specified in CMS Items 632 and 633, and CMS 732 and 733.

401-2 Installation of Traffic Signals on State Highways

Policy 516-002(P) documents ODOT policy regarding installation of traffic control signals and intersection control beacons on state highways. A copy has also been included in the Appendix of this manual (Chapter 15).

401-3 Periodic Review of Signals

As noted in OMUTCD Section 4B.02, changing traffic patterns may render an existing traffic signal either inefficient or no longer necessary. Therefore, the responsible agency should periodically conduct a traffic engineering study to evaluate the efficiency and necessity of traffic signals under its jurisdiction and determine if revisions may be needed. This traffic engineering study may lead to changing the signal timing, signal phasing, vehicle or pedestrian detection, roadway geometry, or the complete removal of the traffic signal.

Traffic signal installations that are not properly designed and maintained for current traffic conditions, or are no longer warranted, can result in the following conditions:

1. Excessive traffic delay.
2. Increased disobedience of the signal indications.
3. The use of less adequate routes in order to avoid such signals.
4. Increased accident frequency, especially rear-end accidents.

Some signalized intersections and/or signalized corridors may be eligible to apply for, and participate in, the Systematic Signal Timing & Phasing Program (SSTPP). See Section 1213-6 for more information about this program.

401-4 Removal of Traffic Signals Under ODOT Jurisdiction

If a traffic engineering study indicates that the traffic signal is no longer justified, the traffic signal should be removed by a uniform procedure that will consider public input, accidents, site considerations and an appropriate replacement type of traffic control device. Therefore, when ODOT determines that an existing traffic signal installation no longer meets signal warrants as contained in the OMUTCD, or is no longer the appropriate form of traffic control, the District shall proceed through the following removal process to document and determine if the signal installation should be removed:

1. To determine if the traffic signal is still needed, the District shall prepare a traffic engineering study for the signal installation documenting the following information, as appropriate:
   a. Warrant analysis summary. If reasons other than the standard warrants were used to justify the signal installation, determine if these reasons are still valid.
   b. Accident history.
   c. Site conditions, especially sight distance problems.
d. Public, business, school board or governmental complaints resulting in the original signal installation.

e. Present and future developmental growth.

f. Known reasons for change in traffic patterns or volumes.

g. Capacity analysis for the alternate traffic control scheme most likely to be installed if the signal is removed.

h. Analysis of the cost of continued signal operation versus a one-time signal removal cost.

i. Discussion of traffic volume growth needed to warrant the signal.

2. Based on the traffic engineering study, the District shall decide whether to proceed with the removal process or defer signal removal. If the removal is deferred, the District shall document the reasons for deferral. The signalized location shall be reconsidered for removal every year until a signal warrant or other determination of permanent retention is satisfied.

3. If the District decides to proceed with the removal process, the following steps shall be taken:

   a. Inform the local media, schools, governmental agencies and local emergency/safety forces of ODOT's intent to study the signalized location for removal.

   b. Remove or reduce intersection sight distance restrictions, if needed.

   c. Install the SIGNAL UNDER STUDY FOR REMOVAL (W24-H2b) sign next to the signal heads on each approach.

   d. Check the controller cabinet wiring to ensure that the color of the flashing indications will agree with the alternate traffic control scheme.

   e. Install the alternate traffic control devices, such as STOP signs and advance Warning Signs. Existing Stop Lines on the uncontrolled approaches should not be removed at this time.

   f. Place the signal in flashing operation for ninety days, in conjunction with item 3e above.

4. If the signal is put in flashing operation for ninety days in anticipation of removal, the District shall monitor accident experience during the ninety-day flashing period:

   a. If accidents of types susceptible to correction by traffic signal control have increased by more than two, the signalized location shall remain in flashing operation for an additional sixty-day period. If more than two such accidents occur in the second sixty-day period, the District should retain the signal in stop-and-go operation until the site conditions can be improved to reduce the accident frequency.

   b. If accidents of types susceptible to correction by traffic signal control have not increased by more than two, continue with the removal process.

   c. The District shall also monitor, investigate and respond to the concerns of the public during this period.

5. If the District decides to proceed with the removal process after considering the information gathered in item 4:

   a. The signal heads shall be bagged or removed, and the traffic signal turned off for a sixty
b. The accidents shall be monitored to determine if the absence of flashing traffic signals results in an increase in accidents. If accidents occur, the District may consider conversion of the traffic signal to a flashing intersection control beacon.

6. If it is decided to continue with removal of the signal, the District shall remove the signal heads, poles, foundations (1 foot below grade), pull boxes, overhead cables and controller. Underground conduit and cables may be abandoned in place. If the District wants to monitor the site for an extended period of time, the poles and cables may be left in place for one year.

7. The District shall notify all affected parties of the removal of the signal and the termination of any agreements that were in effect. If a signal permit exists for the signal removal location, the District will notify the Office of Traffic Engineering of the signal removal so that a statewide database on Village signal permits can be maintained.

401-5 Identifying Maintenance Responsibility for a Traffic Signal

Road users often have a need to know the maintaining agency of a traffic signal in order to report malfunctions or signal timing problems. Many agencies install a sign or a decal on the controller cabinet to inform the public of the responsible agency and give a telephone number to report problems.

In general, the maintaining agency of a traffic signal can be determined as follows:

1. **City/Village**: Inside the corporation limits of a City or Village, the City/Village is responsible for the traffic signal unless the signal is located at the end of an Interstate ramp in which case, ODOT may maintain the signals.

2. **ODOT**: Outside the corporation limits of a City or Village, traffic signals at intersections where at least one of the highways is a State or US Route are maintained by ODOT. ODOT is responsible for all signals at Interstate ramps.

3. **County**: Outside the corporation limits of a City or Village and the involved highways are not State or US Routes, the County will maintain the signal if at least one of the highways is a County Route.

4. **Township**: Outside the corporation limits of a City or Village and the involved highways are not State, US or County Routes, the Township will maintain the signal.

401-6 Village Signal Permit Procedures

Requests by village authorities for permission to install and operate traffic control signals on state highway extensions within villages (Form 496-8) should be substantiated by appropriate traffic studies and submitted to the District Deputy Director. If it is determined that a traffic control signal is warranted, authorization for the installation of a traffic control signal will be issued to the village authorities.

The authorization is valid for 180 days. During this time, the village shall prepare and submit to ODOT an operation plan for the proposed traffic signal installation (Form 496-9). Upon approval of this plan, the village may purchase and install the traffic control signal. The fact that the Director of Transportation is authorized to determine whether a traffic control signal is warranted does not relieve the village authorities in any way from bearing the costs of purchasing, installing and maintaining the traffic signal equipment.

As soon as the traffic control signal has been installed and put in operation, the certification at the bottom of the form shown in Form 496-9 should be filled out and returned to the District Deputy Director. The final Traffic Control Signal Permit (Form 496-10) will then be issued by the
Director of Transportation and his agent will install an identification tag (I1-H2) with the correct permit number. Table 497-9 shows the range of Village Signal Permit numbers to be used by each District.

A request for modification of the hours of operation or timing of these village traffic control signals shall be submitted to the District Deputy Director for approval using Form 496-11. However, requests for alteration of any other aspect of the operation of a traffic signal covered by permit shall be submitted using the form shown in Form 496-8.

It is the responsibility of the village authorities to periodically review their traffic signals.

401-7 Signal Agreements

401-7.1 General
Stop-and-Go Traffic Signals may be installed at driveways or roadways to private entities. For the purpose of this document "Private Entity" refers to any non-public highway access and may include: local agency, developer, school, church, company, private individual.

Signals should not be installed unless they meet the warrants as outlined in the current version of the Ohio Manual of Uniform Traffic Control Devices (OMUTCD).

Unless otherwise noted below, all design, construction, maintenance, electrical and related costs for signals, that are installed for the benefit of a private entity shall be paid by the Private Entity or their legally authorized representative.

Prior to issuing a Right-of-Way Permit (MR509) for the installation or modification of a signal for a private entity, the District shall have a signed Maintenance Agreement which, amongst other requirements, will stipulate an annual maintenance fee due to ODOT from the private entity.

Ongoing electrical energy cost payments will be established in the agreement and in accordance with District policy.

401-7.2 Signalized Intersection Types and Costs
These signalized intersections may take a number of scenarios, of which the following describes the most common:

1. Private Drive only ("T" Intersection)
2. Private Drive across from Private Drive
3. Private Drive across from Public Road (not warranting signalization)
4. Private Drive across from Public Road (warrants signalization, but agency choosing not to signalize)
5. Private Drive across from Public Road (warranted and approved for signalization)

If another scenario arises that is not covered herein, the District should consult with the Office of Traffic Engineering.

Responsibility of costs associated with each scenario above:
1. All costs assumed by Private Entity(s). Maintenance Agreement(s) required.
2. All costs assumed by Private Entity(s). Maintenance Agreement(s) required.
3. All costs assumed by Private Entity(s). Maintenance Agreement(s) required.
5. All costs assumed by ODOT. No Maintenance agreement. Right-of-Entry Agreement may be necessary.
In each of these scenarios the private drive can be warranted or unwarranted for signalization.

In all cases, if ODOT is requiring the signal due to ODOT concerns (e.g.: safety countermeasure), all costs are assumed by ODOT. No maintenance agreement is required, but a Right-of-Entry Agreement may be necessary. If additional features (e.g.: turn phases, additional lane on driveway) above and beyond the ODOT requirements are requested by the private entity (and approved by ODOT), the installation costs shall be borne by the private entity.

401-7.3 Signal Reconstruction
If an ODOT project (e.g.: widening) requires replacement of a signal or its components, all costs to do so shall be the responsibility of ODOT.

If signal or component replacement, repair or modification is required due to private entity actions (e.g.: widening, pavement milling, relocating drive, expansion of property, significant increase in traffic generation), these costs shall be the responsibility of the private entity.

If a signal must be replaced due to age and/or deterioration of its components, all costs shall be the responsibility of ODOT.

401-7.4 Signal Maintenance Agreements
There are two types of agreements which may be necessary:

1. A Maintenance Agreement is used if fees will be required of the private entity,
2. A Right-of-Entry Agreement is used if signal appurtenances are located on the private property and require access by ODOT to maintain. The Right-of-Entry agreement may be part of the maintenance agreement or may stand alone.

Only standard agreements approved by the ODOT Chief Legal Office should be used. Standard Agreements are provided on the network O:\Traffic\Signals\Agreements\Standard Agreements. The README.doc gives a brief description of each agreement and how it should be used.

Where a standard agreement must be modified, it shall be done in consultation with the Office of Traffic Engineering and must be approved by the Chief Legal Office.

Agreements should be updated/amended when:
1. ODOT policy changes the terms of the existing agreement (e.g.: change in maintenance fees)
2. Private property changes ownership
3. Warranting conditions change affecting fee distribution (e.g.: formerly non-warranting public street becomes warranting or the classification (major/minor) of the generator changes.)

Agreements shall be memorialized in the "Miscellaneous Book" at the counties Record's Office. The district office responsible for creating the signal agreements will work with the district Real Estate Office to have the agreement recorded. Any costs for recording the Agreement should be paid for by the District. When required, the District and developer or local agency must sign and notarize the agreement prior to the agreement being recorded.

401-7.5 Agreement Distribution List
The original signed copy of the agreement will be filed by the creator with color scanned PDF format copy sent to the District Auditor/Finance Office and a scanned or paper copy to the district’s signal maintenance file.
401-7.6 Maintenance Agreement Fees
The current annual maintenance fee is $3000 per Stop-and-Go intersection that involves a private entity.

Fees for Stop-and-Go traffic signals at opposing private drives are as follows:
- Single Major Generator = $3000
- Major Generator and Major Generator = $1500 / $1500
- Major Generator and Minor Generator = $2250 / $750

A major generator is a private entity that generates sufficient traffic to warrant a Stop and Go traffic signal. A minor generator is a private entity that does not generate sufficient traffic to warrant a Stop and Go traffic signal.

If the classification of a generator changes (minor to major or major to minor) or a generator is added to the intersection, any existing signal agreements should be updated accordingly.

401-7.7 Collection of Maintenance Agreement Fees
Annual maintenance fees shall be invoiced each January in advance of the year which maintenance is to be provided by the District in which the signal is located.

There will be situations where the District cannot collect the fees required by the agreement. This can be for any number of reasons including, but not limited to, the Private Entity cannot make or refuses to pay the required maintenance fees or the Owner of the property cannot be located. The District should make every attempt to locate the property owners and verify that they have not relocated or changed ownership. Districts should adhere to the following plan on delinquent invoices (providing Central Office Finance will all correspondence):

- 30 Days delinquent: Follow up letter and/or email sent to the Private Entity
- 60 Days delinquent: 2nd follow up letter and/or email sent to the Private Entity
- 90 Days delinquent: Phone call or personal visit to the Site
- 120 Days delinquent: Conference call with central Office Finance on status

During the follow up process if payment is still not satisfied (120 Days delinquent), the District will install a “Signal Under Study for Removal” sign. At the conclusion of the study the signal should be removed if it does not create an unsafe condition to the general motoring public. Should at the District’s discretion, the removal of the signal creates an unsafe condition to the general motoring public, District Finance will notify Central Office Finance and the balance of the invoice will be sent to the Ohio Attorney General’s Office for further collections. Central Office Finance will act as ODOT’s intermediary with the AG’s Office. Once an invoice is sent to the AG’s Office for collection, it shall not be counted against a District for QAR requirements. The District will continue to maintain the signal(s) in question until such a time that a decision is made to remove the signal or a resolution is provided by the AG’s Office. Any action taken with the signal or a delinquent invoice will involve District Finance, Central Office Finance and the Office of Traffic Engineering.

If the following year, a signal maintenance agreement invoice needs to be created for an invoice that is currently outstanding at the AG’s Office from previous years, the process will start over again as a new invoice.

401-7.8 Property Transfer without Agreement
The new property owner will be sent a new agreement to sign. After the new agreement is signed an invoice will be sent to the owner for the prorated maintenance fee per the agreement. A letter should also be sent and include items similar to the following.
Located at the ingress and egress at the above location there is an existing traffic signal that was installed through a previous signal agreement with the State of Ohio. According to State Law, the Ohio Department of Transportation cannot install or maintain traffic signals on public, State and US routes to private driveways unless an agreement is entered into by both parties.

The agreement is a standard agreement developed by the Departments Chief Legal Counsel that cannot be modified. This agreement must be signed and returned to this office along with the proper payment no later than 30 days from receipt of this letter.

Failure to return the signed signal agreement and payment may result in the District performing a traffic engineering study of the subject location which could lead to the removal of the existing traffic signal.

### 401-7.9 Removal of Signal / Termination of Agreement

If failure to receive payment either due to refusal or inability to pay by the private entity or inability to locate the private entity by the District the following options should be pursued:

Notify the private entity(s) of pending signal (or signal phase) removal by letter with copies to all property tenants 30 days in advance of any removal action.

Post "Signal Under Study for Removal" signs (only if complete signal is proposed for removal) for two weeks with the signal in Stop-and-Go operation. Portable Changeable Message Sign (PCMS) may also be utilized.

Place signal on flash and follow signal removal process.

### 401-8 Open Architecture Traffic Signal Controllers

An open architecture traffic signal controller is a general purpose computer that is adapted for traffic signal control with software and input/output connections. An example of this type of traffic signal controller is the Model 2070. The software can be purchased separately from the controller and installed by the user. In certain instances, this can result in an agency using only one brand of software but obtaining competitive bids on the hardware.

**ODOT** has software licenses for 2070 controllers for any District to use. The licenses include local controller, master controller and personal computer interface software. The Model 2070 controller can be used with **NEMA TS-1, NEMA TS-2 or Caltrans 332/336 cabinets.**

### 401-9 Americans with Disabilities Act (ADA) Requirements

The **ADA** requirements are issued and regulated by the **US Justice Department.** Generally, there are four major **ADA** requirements that effect traffic signal projects:

1. Accessible pedestrian signals;
2. Audible pedestrian pushbuttons (locator tones);
3. Curb ramps;
4. Truncated domes (tactile bumps on the curb ramp).
See Sections 404-3 and 440-8 for details on these requirements. Web addresses for ADA Accessibility Guidelines information are shown in Table 197-3.

401-10 Special or Off-Duty Law Enforcement Officer Operation of ODOT Traffic Signal Procedures

Before a special or off-duty law enforcement officer (LEO) can operate an ODOT traffic control signal, authorization shall be obtained from ODOT.

Applications for permission to operate an ODOT traffic control signal (Form 496-14) by a special or off-duty LEO shall be submitted to the District Deputy Director a minimum of 21 days prior to the event for which the permit is being requested. If it is determined that the operation is acceptable, a permit for the operation of the traffic control signal shall be issued (Form 496-15).

Application shall be made by the private employer hiring the special or off-duty LEO. Application by the special or off-duty LEO is unacceptable.

The operation of the traffic control signal by the special or off-duty LEO shall conform to the Ohio Manual of Traffic Control Devices (OMUTCD).

Examples of events requiring a permit are church services, football or basketball games, midnight madness sales, farm science reviews and county fairs.
400 TRAFFIC SIGNALS

402 TRAFFIC CONTROL SIGNAL NEEDS STUDIES

402-1 General

All new or reconstructed signalized intersections shall be warranted based on OMUTCD Chapter 4C; however, for roadway projects that have a minor impact on the existing signals, signal warrants may not be necessary. An example is a pavement planing and resurfacing project which will destroy and replace loop detectors.

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Considerations such as geometrics and lack of sight distance generally have not been accepted in lieu of satisfying signal warrants. These considerations may allow an otherwise unwarranted traffic signal to be retained at 100 percent local cost.

402-2 Traffic Volumes

In addition to proper signal warrant analysis, good signal design requires recent volume data. Therefore, for existing intersections, actual turning movement counts should be used for signal warranting purposes. The traffic counts shall not be over three years old and should, at a minimum, include the 8 hours that contain the greatest percentage of daily traffic.

If the actual turning movement counts fail to satisfy a signal warrant, it may be acceptable to use traffic volumes projected to the second year after project completion. The Office of Modeling and Forecasting should provide the projected traffic volumes. Twenty-year design ADT or DHV (Design Hourly Volumes) shall not be used for signal warrants. Seasonal Adjustment Factors should be applied to the actual traffic counts.

When actual side street volumes do not exist, such as at a proposed development or new road, an eighth highest hour factor may be used with the ADT for warrant purposes. This factor is obtained from the Office of Modeling and Forecasting, and usually ranges from 0.054 to 0.050 of the ADT. Hourly distribution factors should not be used to develop 8 hours of warrant data from the ADT as hourly distribution factors vary greatly depending on the type of development surrounding an intersection.

Consideration should be given to operating a signal, which was warranted based on project traffic, as a flasher until actual traffic volumes satisfy signal warrants and make signalization appropriate.

402-3 Signal Warrant Practices and Procedures

402-3.1 General

As noted above, the warrants used to evaluate the need for a traffic control signal at a particular location are described in OMUTCD Chapter 4C.

PC Warrants should be used for all ODOT Signal Warrant analysis.

402-3.2 Warrant Numbers 1, 2, and 3 (Volumes)

For determining the number of approach lanes, a short left-turn lane is not usually considered an approach lane (OMUTCD Section 4). Usually, the number of approach lanes refers to through lanes. An exception might be where a through lane develops into an exclusive turn lane or high-turning volumes require double turning lanes.

For new ODOT signals, warrant numbers 1, 2, and 3 shall be based on the 100 percent
values (OMUTCD Chapter 4) and right turn reduction factors.

For new ODOT signals, warrant numbers 1, 2 and 3 can be based on the 70 percent values (OMUTCD Chapter 4) combined with engineering judgment, Warrant 7 (Crash Experience) and right turn reduction factors.

For retention of existing ODOT Signals, warrant numbers 1, 2 and 3 can be based on the 70 percent values (OMUTCD Chapter 4) and engineering judgment.

Signals installed under Warrant No. 3 should be traffic-actuated.

402-3.3 Warrant No. 4 (Pedestrian Volume)

Intersections approved under this warrant shall utilize pedestrian signal heads. Signals based only on Warrant No. 4 or Warrant No. 5 should also control the minor street or driveway.

If installed at a non-intersection crossing the traffic control signal shall be pedestrian-actuated.

402.3.4 Warrant No. 5 (School Crossings)

Intersections approved under this warrant shall utilize pedestrian signal heads. Signals based only on Warrant No. 4 or Warrant No. 5 should also control the minor street or driveway.

The designer shall show that the intersection is used as a school crossing. This may include:

1. School route plan developed by the school system.
2. Count of pedestrians during the study period. OMUTCD Section 4C.06 requires a minimum of 20 students during the highest crossing hour.
3. Presence of school crossing guards.
4. Map showing the location of the school relative to the intersection.

In order to show that there is less than one acceptable gap per minute, the designer shall present the following:

1. Street crossing time based on width and crossing speed.
2. The number of gaps in the traffic stream that exceed the minimum crossing time during the study period. These gaps may be measured in the field or approximated using two different equations to find the probability of a gap greater than the crossing time.

\[ t = \text{required gap time (seconds)} \]
\[ t = 3 \text{seconds} + \left( \frac{\text{Width of crossing (ft)}}{3.5 \text{(ft./sec.)}} \right) \]
\[ T = \text{length of time period for which the volume V applies (seconds)} \]
\[ V = \text{two way vehicular volume across the crossing path in time period T} \]
\[ e = \text{base of the natural system of logarithms, having an approximate value of 2.718} \]

The expected number of gaps per hour which are equal to or greater than t will be:

\[ Ve^{-V/t} \]

The expected number of t-second intervals per hour which are free of cars will be:

\[ (T/t)e^{-V/t} \]
402-3.5 Warrant No. 6 (Coordinated Signal System)

Warrant No. 6 shall not be used as the sole warrant in an ODOT signal warrant analysis.

402-3.6 Warrant No. 7 (Crash Experience)

Warrant No. 7 should only be used to warrant a signal if the 70 percent volume warrants are met.

Any traffic signal installed solely on this warrant should be semi-traffic-actuated with control devices which provide proper coordination if installed at an intersection within a coordinated system and normally should be fully traffic-actuated if installed at an isolated intersection.

The following types of accidents are susceptible to correction by traffic signal control:

1. Those involving substantially right-angle collisions or conflicts, such as occur between vehicles on intersecting streets.
2. Those involving conflicts between straight-moving vehicles and crossing pedestrians.
3. Those between straight-moving and left-turning vehicles approaching from opposite directions, if an independent time interval is allowed during the signal cycle for the left-turn movement.
4. Those involving excessive speed, in cases where signal coordination will restrict speed to a reasonable rate.

Traffic control signals cannot be expected to reduce the following types of accidents:

1. Rear-end collisions, which often increase after signalization.
2. Accidents involving pedestrians and turning vehicles when both move during the same interval.
3. Other types of pedestrian accidents, if pedestrians or drivers do not obey the signals.
4. Collisions between vehicles proceeding in the same or opposite directions, one of which makes a turn across the path of the other. This is particularly true if no independent signal interval is provided for these turn movements.

402-3.7 Warrant No. 8 (Roadway Network)

Warrant No. 8 shall not be used as the sole warrant in a ODOT signal warrant analysis.

402-3.8 Warrant No. 9 (Intersection Near Highway-Rail Grade Crossing)

The purpose of Warrant No. 9 is to provide a warrant for a traffic signal where a highway-rail grade crossing is in close proximity to an intersection and a traffic signal is not warranted under any of the other traffic signal warrants. This is especially beneficial where the clear storage distance (see Part 8) is less than a design vehicle length and gaps are infrequent on the road parallel to the track(s).

Signals installed based on Warrant No. 9 shall have minor street actuation, train preemption, and flashing-light grade crossing signals, and should also have automatic gates.
402-4 Unwarranted Existing Signalized Intersections

Every effort should be made to encourage removal of an existing unwarranted signal installation. The designer should realize that all existing unwarranted signals cannot always be removed, most often because of public or political pressures on the maintaining agency. If the removal of signals and the placement of STOP signs is agreed to, the work should be at normal project participation.

If the local agency insists that a large number of unwarranted signals be retained, the State should reevaluate if the project should continue. Reasons for retention of existing unwarranted signals shall be documented.

If an existing unwarranted signalized intersection is retained, the following applies:

1. All work and equipment at the intersection shall be at 100 percent local cost. Written confirmation is required from the local agency.

2. If within a system, signal control equipment shall be upgraded to be compatible with the system (same manufacturer for all controller software).

3. If within an area approved for special design considerations (such as mast arms, aesthetically designed poles, etc.), the unwarranted intersection shall be upgraded to these standards.

4. If it is not necessary to upgrade equipment except for the controller, the existing intersection signals, signs and pavement markings shall be in conformance with the **OMUTCD**. Deficiencies may be corrected by the project (at 100 percent local cost) or by the local maintaining agency. The intersection shall conform to the **OMUTCD** by the final inspection of the construction project.

402-5 Removing Right-Turn Vehicles from Signal Warrant Analysis

At intersections under **ODOT's** jurisdiction, the following procedure should be used to determine how much, if any, right-turning traffic from the minor street to remove from the signal warrant analysis. This does not apply to traffic signal warrant analyses on state route extensions in villages or on projects within local jurisdictions that require **ODOT** oversight.

From the “Minor Street Analysis Parameters” *(see Tables 497-7 and 497-8)* select the closest minor-leg lane configuration. Enter the configuration number under the MINOR STREET column on the “Right Turn Factorization Sheet” *(see Forms 496-12 and 496-13)*. If both minor legs are being studied and have different configurations, include both and note next to the hour which leg or direction is being selected.

Note the number of lanes on the critical mainline approach. The critical mainline approach is the major-street leg whose through movement is in conflict with the right turn from the minor leg. Turn lanes on the major street are not usually considered a lane in this instance because a turn lane on the major route does not conflict with a right-turning vehicle from the minor leg.

Calculate the Critical Mainline Approach Volume per Lane. This is the hourly through volume of the critical mainline approach divided by the number of through lanes on the approach plus the hourly right-turning volume if it is not served by an exclusive right-turn lane on the mainline. Record this number in the Mainline Approach Volume per Lane column on the “Right Turn Factorization Sheet.”

Determine the Base Right Turn Reduction Percentage or Base Reduction. After determining which lane configuration best represents the leg that is being studied and based on the movements for each hour, calculate the percent reduction “R” or Base Reduction for each hour and record in the Base Reduction column on the “Right Turn Factorization Sheet.” Transfer this same number to the Base Right-Turn Reduction % column on the same sheet.
Calculate the Mainline Congestion Factor. This is a reduction of the Base Right-Turn Reduction. Its purpose is to allow for the vehicles which are unable to turn right during exceedingly high volume on the major street. This reduction is five percent for mainline approach volumes of 400 vehicles per hour per lane and is increased by five percent for every 100 vehicles per hour per lane. The Mainline Congestion Factors for Limiting Right-Turn Reductions are shown at the bottom of the “Minor Street Analysis Parameters” sheet. Select the appropriate reduction based on the mainline volume per lane and record the reduction in the Mainline Congestion Factor % column on the “Right Turn Factorization Sheet.”

Calculate the Adjusted Right-Turn Reduction. This is the Base Right-Turn Reduction minus the Mainline Congestion Factor. If less than 0, then the Adjusted Right-Turn Reduction equals 0%. Record this number in the Adjusted Right-Turn Reduction % column for each hour.

Calculate the Adjusted Right Turns. This is (1 - % Adjusted Right-Turn Reduction) multiplied by the Right-Turn Volume from the selected minor leg. Record this number in the Adjusted Right Turns column.

Determine the new Adjusted Minor-Street Volume by adding the Adjusted Right Turns to the through and left-turn volumes for each hour. Record this number in Adjusted Minor-Street Volumes column on the “Right Turn Factorization Sheet” for each hour. This number shall be used in the signal warrant analysis.
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403 TRAFFIC CONTROL SIGNAL FEATURES AND OPERATION

403-1 General

OMUTCD Chapter 4D presents information on the design, location and use of traffic control signals. Construction details are shown on SCDS TC-81.10 through TC-85.20. Traffic signal equipment is specified in CMS Items 632 and 633, and CMS 732 and 733.

403-2 Yellow Change and Red Clearance Intervals

The vehicle change interval (or phase change interval) described in OMUTCD Section 4D.26 consists of the yellow change interval and the red clearance interval. A yellow signal indication shall be displayed following every CIRCULAR GREEN or GREEN ARROW signal indication. The function of the yellow change interval (Y) is to warn traffic of an impending change in the right-of-way assignment. For ODOT-maintained signals, the yellow change interval should be followed by a red clearance interval (AR) of sufficient duration to permit traffic to clear the intersection before conflicting traffic movements are released. For more efficient operations, start-up time for the conflicting movements may be considered when setting the length of the red clearance interval. The durations of the yellow change interval and the red clearance interval shall be predetermined.

The length of the phase change interval can be determined using the following equation, in which 
\[ t + V/(2a + 64.4g) \] represents the yellow change interval in English units and 
\[ (W + L)/V \] represents the red interval:

\[
Y + AR = t + V/(2a + 64.4g) + [(W + L)/V] \quad \text{(for English units)}
\]

- \( t \) = perception/reaction time of driver, (typically assumed to be 1 second)
- \( V \) = approach speed, ft/s, (Posted Speed Limit or the 85th-Percentile Speed)
- \( a \) = deceleration rate, ft/s\(^2\), (typically assumed to be 10 ft/s\(^2\))
- \( W \) = width of intersection, ft, (measured from the near side Stop Line to the far edge of the conflicting traffic lane, along the actual vehicular path)
- \( L \) = length of vehicle, ft, (typically assumed to be 20 feet)
- \( g \) = approach grade, percent of grade divided by 100, (plus for upgrade, minus for downgrade)

Yellow change intervals typically are in the range of three to six seconds, and the red clearance interval should have a duration not exceeding six seconds.

403-3 Off-Peak Flashing Operation of Traffic Control Signals

Using a flashing operation at a signalized intersection during off-peak or low-volume periods may increase the efficiency of the intersection. It also reduces fuel consumption by the traveling public because of the fewer starts and stops, and helps to improve the environment by reducing air and noise pollution. The signal head itself consumes a significantly lower amount of power during flashing operation as compared to regular signal operation. Flashing operation at a signalized intersection during off-peak hours is cost effective and should be considered at those intersections where safety would not be compromised. Actuated signals should not flash during off-peak hours. However, each intersection considered for flashing operation should be carefully analyzed, since recent research also indicates that accident rates may increase, especially at night.
The following considerations should be taken into account when making a decision to use off-peak flashing operation at a signalized intersection:

1. Flashing operation may be appropriate at simple, four-legged or three-legged intersections where the minor street drivers have an unrestricted view of approaching main street traffic and the traffic volume meets the criteria in item 2 below.

2. The two-way main-street volume should not exceed 200 vehicles per hour (vph). However, if the two-way main street volume is greater than 200 vph and the ratio of main street volume to minor street volume is greater than 3, flashing operation may be appropriate.

3. In areas where night establishments are located and driving while under the influence of alcohol may occur, flashing operation should not begin until one hour after these establishments close.

4. A "speedway" effect can be avoided and uniform speeds can be achieved by maintaining enough regularly operating signals at appropriate spacing to provide signal progression at the desired speed.

5. When a traffic control signal is put on flashing operation, a yellow indication is normally used for the major street and red indications are used for all other approaches. The MUTCD stipulates that yellow indications shall not be used for all approaches. MUTCD Sections 4D.11 and 4D.12 list requirements for flashing operations.

6. After off-peak flashing operation has been implemented, the accident pattern should be monitored. The signal should be changed to regular operation if the accident pattern and/or severity increases. The following guidelines should be used:
   a. A short-term rate of three right-angle accidents in one year.
   b. A long-term rate of two right-angle accidents per million vehicles entering during the flashing operation, if the rate is based on three to five observed right-angle accidents.
   c. A long-term rate of 1.6 right-angle accidents per million vehicles entering during the flashing operation, if the rate is based on six or more observed right-angle accidents.

7. When a traffic control signal is interconnected with an adjacent highway-rail grade crossing, night or off-duty flashing operation should not be used.

403-4 Approach Monitoring

All ODOT-maintained traffic signals shall be designed to use an approach monitoring concept. Approach monitoring makes use of the dual indication monitoring capabilities of the NEMA plus or NEMA extended monitor. The approach monitoring concept will not function if the “plus” features in the monitor are disabled or not available. Intersections designed for approach monitoring permit the “plus” monitor to detect total loss of a signal color indication on an approach basis rather than a per phase basis. With approach monitoring, the loss of all green, yellow or red indications on an approach place the intersection into flash. ODOT’s primary intent however is to catch the red out.

To detect a “no load” signal condition, a basic signal design is necessary. The approach monitoring design requires each approach to be wired separately. Each has its own load switch and its own monitor channel. The final equipment requirement is a NEMA plus monitor programmed to accommodate the approach monitor design.

403-5 Traffic Law Photo Monitoring

Substitute House Bill Number 30, passed by the 127th General Assembly, took effect September 12, 2008. This law imposes certain responsibilities on local authorities who choose to use traffic law photo monitoring devices. Section 201-14 addresses the local authority’s duties, which include assuring that the yellow change interval exceeds by 1 second the yellow change
interval determined in accordance with Section 403-2.

As noted in Section 201-14, no traffic law photo monitoring device shall be installed at any intersection or on any highway maintained by ODOT.

403-6 Emergency-Vehicle Preemption Control Systems

403-6.1 General

As noted in OMUTCD Section 4D.27, preemption systems are used to give certain vehicles control over traffic signals. These systems use devices located on an approaching vehicle to preempt the normal operation of signalized intersections. This Section provides a consistent method for funding traffic control signal preemption systems if needed.

Over the years, several methods of providing priority control of traffic signals have been developed. The first method, which is not covered by this Section, involves a hard-wired signal system. For example, personnel in the fire station can activate one or more circuits by pushbutton to preempt a series of signalized intersections. This system is usually not proprietary and is localized to the main arterial intersections near the fire station.

The intent of this Section is to cover a second method of priority control which involves equipping the vehicle with a preemption emitter and equipping the signalized intersection with preemption receivers. These systems tend to use proprietary equipment, and once a local governmental agency installs the equipment, the agency is restricted to the same brand and type of preemption equipment in order to have emitters and receivers work together.

Vehicle-activated systems can use light (optics), sound or radio signals (includes GPS systems) to activate a receiver at the intersection. Optical and sound-activated systems are extensively used in Ohio. The optical system uses a strobe-type light emitter mounted on the vehicle and sound-activated systems use the siren from the vehicle. Each system has benefits inherent in the type of signal used.

The decision to install and maintain a preemption control system shall be made by the maintaining agency.

The cost for the installation and maintenance of a preemption control system at ODOT signals shall be assumed by the requesting agency.

403-6.2 Procedures

For new preemption systems, ODOT will participate at the normal project participation rate in the acquisition and installation of a generic preemption system as determined by the lowest contract bid price. In addition to obtaining generic bids, a local governmental agency may request alternate bids if they desire a specific brand of preemption equipment and agree to pay any extra cost above the generic bid price. A Plan Note specifying three different preemption systems by manufacturer and model is equivalent to a generic bid item.

When a municipality adds intersections to its existing preempt system, it can obtain the same type of equipment by either the use of alternate bids or, if justified, proprietary bids.

For proprietary bids to be considered justified, the existing preempt system must control an appreciable part of the municipality’s intersections before it can be considered to represent the municipality’s standard. As a measure of this standard, the existing system must constitute at least fifty percent of the signalized intersections of a municipality. If this test is met, a proprietary bid requested by the municipality will be given consideration. Otherwise, alternate bids may be used to limit State and Federal participation to the generic system costs.
403-6.3 Preemption Emitters

The quantity of vehicle hardware provided with the system shall be as determined by the municipality, but should not exceed three emitters for each signalized intersection which will be equipped with preemption as a part of the project. Only fire, emergency medical, police and transit vehicles are eligible to be equipped. If alternate bids are used and the desired system utilizes vehicle-mounted emitters, the cost of this hardware shall be included in the alternate bid cost for comparison to the generic bids.

403-6.4 Local Maintaining Agency Policies

As a requirement for inclusion of vehicle preemption equipment in the contract, the local governmental agency shall have policies for the use of preemption. For safety forces, the policies shall specify the types of emergency calls for which preemption may be employed and shall define any use of preemption when lights and sirens are not simultaneously employed. For transit vehicles, the policies shall define when and under what conditions the preemption may be employed.

When possible, municipalities are strongly encouraged to develop signal preemption policies which coordinate with surrounding City, County and Township forces. They should take into account mutual aid agreements, access to hospitals and transit where a vehicle operates outside of its normal jurisdiction.

403-7 Flashing Yellow Arrow (FYA) Operation

The OMUTCD Section 4D.18 permits the use of a flashing yellow arrow (FYA) indication on applicable protected/permissive left-turn phases. However, the FYA indication shall not be used with traffic control signals on ODOT-maintained highways until such time as design and traffic signal cabinet standards approved by the Office of Traffic Engineering (OTE) have been developed and tested, and educational materials on the intended use of this new signal indication have been made available to the public.

Once the cabinet standards have been developed and tested, permission for pilot installation of the FYA may only be granted by OTE on a case-by-case basis to monitor and determine any crash and safety benefits. An education campaign shall be part of any project introducing this device in an area, and as noted in OMUTCD Section 4D.18, the LEFT TURN YIELD ON FLASHING YELLOW ARROW (R10-H12c) sign shall be used with the FYA for at least five years (see OMUTCD Figure 4D-7).

403-8 SIGNAL OPERATION CHANGED Sign (W23-H2a, W23-H2b)

Concurrent with the actuation of any new signal operation which alters the sequence of the signal displays from the existing operation, a SIGNAL OPERATION CHANGED sign (W23-H2a or W23-H2b) should be installed. The signs should be displayed for a minimum of fourteen days and a maximum of thirty days.

The W23-H2a sign should be installed on all approaches to an intersection and the W23-H2b sign should be installed on the span wire or mast arm adjacent to the signal heads.

The following are examples of signal operation modifications which would normally warrant installation of the sign:

1. Installation of a protected left turn
2. Switching from a lead to lagging left turn (or vice versa).
3. Installation of a split phase where two directions used to run together

The following are examples of signal operation modifications which normally not warrant installation of the sign:
1. Installation of a NO TURN ON RED sign.
2. Actuated phase being set to min (max) recall due to detector malfunction.

403-9  **Yellow Trap**

Yellow Trap is a term used to describe a condition which occurs during certain yellow change intervals. During a Yellow Trap event, drivers facing a CIRCULAR YELLOW signal indication are mistakenly led to complete their movement in order to clear the intersection by the display of the CIRCULAR YELLOW signal indication. What they fail to realize is that opposing motor vehicles are facing a CIRCULAR CREEN signal indication and not a CIRCULAR YELLOW signal indication. This condition can occur under the following conditions:

1. When Protected/Permissive Left-Turn Signal Face Displays are used and the sequence is changing from a concurrent through movement to a through and left-turn movement in the same direction of travel (lagging left turn).

2. During a transition into preemption, with or without Protected/Permissive Left-Turn Signal Face Displays and the sequence is changing from a concurrent through movement to a through and left-turn movement in the same direction of travel (lagging left turn).

Depending on the nature of the yellow trap condition, it may be necessary to address the condition in order to implement the desired signal sequence. The following are examples of methods which may be used to resolve the yellow trap condition:

1. Left-turn signal face displays on an approach to the intersection where yellow trap occurs can be changed to Protected Only displays.

2. Opposing movements may be reconfigured to provide exclusive or “split” phase sequencing.

3. During a transition into preemption, the controller sequence may be designed such that both directions of travel transition to red before the display of a green indication on a single approach. This ensures that there is a simultaneous display of CIRCULAR YELLOW on both approaches prior to the display of green on a single approach.

The use of W25-1 and W25-2 signs (ONCOMING TRAFFIC HAS EXTENDED GREEN and ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN, respectively) are not recommended by ODOT to resolve a yellow trap condition.

The signal plans shall contain plan notes to omit calls to protected/permitted left-turn phases as necessary to resolve yellow trap conditions. The traffic signal controller programming shall incorporate this information to resolve yellow trap conditions.

Whenever preemption is provided, careful consideration must be given to the design of the signal sequence under all modes to prevent the display of yellow trap.

403-10  **Railroad Preemption Control Systems**

403-10.1  **General**

As noted in ODOTMUTCD Section 4D.27, railroad preemption systems are used to give trains (both heavy and light rail) control over traffic signal operation. These systems use an interconnection between the railroad control system and the traffic signal controller to preempt the normal operation of signalized intersections. TEM Part 8 provides detailed information regarding railroad preemption, standardized terminology and associated design requirements. This Section addresses minimum functional requirements for traffic signal control equipment to provide the proper operation required for railroad preemption.

Traditional railroad preemption interconnection relied on a single pair of wires which were
normally closed through a relay in the railroad signal control equipment to provide a failsafe mode of operation. This normally closed circuit is required by OMQTCD Section 8C.09. If the connection between the wires was opened, the railroad preemption sequence in the traffic signal controller was initiated.

In recent years, much research has been conducted to further understand the operational needs transitioning into and during the railroad preemption sequence as well as the functioning of the interconnection circuit. The results of this research have led to significant changes in the TEM to implement new technology to further enhance safety at signalized intersections adjacent to railroad grade crossings.

ODOT has developed a required practice for the design and functionality of the railroad interconnection. This practice is contained in TEM Part 8. It provides information on both the traffic signal controller interface and the railroad warning system interface (see Section 804-4). There is also a requirement for an indicator panel to verify that the railroad circuitry is activating the interface at the traffic signal controller cabinet.

403-10.2 Controller Functionality

In order to properly implement railroad preemption operation, additional requirements have been developed for the operation of railroad preemption in the controller unit. The functionality has been divided into a basic set of requirements and an enhanced set of requirements. All new controller units which are to be interconnected with a railroad warning system must provide the following basic operational features:

1. Per unit setting for alternate minimum green interval during entry into any railroad preemption sequence.
2. Per unit setting for alternate pedestrian walk interval during entry into any railroad preemption sequence.
3. Per unit setting for alternate pedestrian change interval during entry into any railroad preemption sequence.
4. Two independent railroad preemption sequences.
5. Three programmable sequence steps. The first step may be programmed to create an all red state for resolution of yellow trap. The first step is followed by up to two track clearance green intervals per preemption sequence with an individual setting for minimum track clearance green for each interval. Each track clearance green interval shall be programmable for no phases (all red), a single phase, or a pair of non-conflicting phases. Each overlap shall be capable of being forced to red or green during each track clearance green interval. The gate down control input shall hold the second (final) track clearance green interval.
6. Ability to program railroad dwell interval as all red (no phase(s)), any phase or pair of non-conflicting phases or to provide limited sequence of programmed or permitted phases.
7. Ability to inhibit pedestrian movements per phase during railroad dwell interval.
8. In the event the controller unit is operating under manual control and either railroad preemption input goes false, the manual control shall be inhibited and the railroad sequence shall govern. Once the railroad preemption input goes true and the manual control input is active, manual control shall be restored.
9. A maximum preemption timer shall be provided for each preemption sequence. This timer shall have a minimum range of 0 to 10 minutes with a maximum 1 minute
resolution. This timer shall begin to time whenever the railroad preemption input goes false. This timer is reset whenever the railroad preemption input returns to a true state. If the maximum railroad preemption expires and the railroad preemption input is still false, the controller unit shall exit the dwell sequence and transition to soft all-red flash. If the railroad preemption input returns to a true state after the controller unit has entered the flash state, the controller unit shall exit the all red flash state via a programmable steady all red period followed by the startup phase(s).

10. The following inputs shall be provided for railroad preemption:

a. Railroad Preemption Sequence #1 Activation – This input is normally true with no train present. It is false whenever railroad preemption sequence #1 is in effect.

b. Railroad Preemption Sequence #1 Supervision - This input is normally false with no train present. It is true whenever railroad preemption sequence #1 is in effect.

These two inputs shall both change state whenever the railroad preemption sequence becomes active. If the two inputs are ever both true and both false at the same time, a railroad preemption error shall be logged and the controller unit should transition the signal display to soft all-red flash. The controller unit should exit the soft all-red flash state via a normal start-up sequence whenever the railroad preemption inputs resume a normal state.

c. Railroad Preemption Sequence #2 Activation – This input is normally true with no train present. It is false whenever railroad preemption sequence #2 is in effect.

d. Railroad Preemption Sequence #2 Supervision - This input is normally false with no train present. It is true whenever railroad preemption sequence #2 is in effect.

These two inputs shall both change state whenever the railroad preemption sequence becomes active. If the two inputs are ever both true or both false at the same time, a railroad preemption error shall be logged and the controller unit should transition the signal display to soft all-red flash. The controller unit should exit the soft all-red flash state via a normal start-up sequence whenever the railroad preemption inputs resume a normal state.

e. Railroad Preemption Sequence #1 Gate Down – This input is normally false with no train present. It is true whenever railroad preemption sequence #1 is in effect and the appropriate railroad gate or gates are down.

f. Railroad Preemption Sequence #2 Gate Down – This input is normally false with no train present. It is true whenever railroad preemption sequence #2 is in effect and the appropriate railroad gate or gates are down.

i. If a single track clearance interval is used, the controller unit should time the programmed value for the track clearance green interval and then hold in the track clearance green interval.

ii. If two track clearance intervals are used, the controller unit should time the programmed value for the first track clearance green interval and then advance to the second track clearance green interval. The controller unit should time the programmed value for the second track clearance green interval and then hold in the track clearance green interval.

iii. Once the track clearance hold state is reached, the controller unit should not leave until the proper gate down input is received. Once the gate down input is received and the track clearance green interval has completed timing its programmed value, the sequence should advance to the programmed dwell
interval. If the gate down input is received prior to completion of the track clearance green interval, the track clearance green interval shall remain active until the timer has completed its programmed period of time.

iv. If the sequence has advanced to the dwell interval and the gate down input is lost, the sequence should revert to the track clearance green hold interval until the gate down input is again received.

11. A hardware output for controller unit health shall be provided. This output shall be false whenever the controller unit has detected a fault, is in conflict flash or has a true input for stop timing. This output shall also be set false if the maximum preemption period timer has expired or a communication error is detected.

12. Any controller unit proposed for use on a project where railroad preemption is required shall be furnished to the ODOT signal shop for testing prior to acceptance if the controller will be owned or maintained by ODOT. (Local agencies may have their controllers delivered directly to the project.)

Controller units required to provide enhanced railroad preemption functionality must provide the following functions in addition to the basic features described above:

1. The controller unit shall have the ability to accept the preemption input and output functions via a serial port utilizing IEEE 1570 protocol. IEEE 1570 is the standard ITS HRI interface for railroad wayside devices and highway field devices. Information regarding the use and operation of this protocol is available from the IEEE. The following functionality is required:

   a. Communication port input for activation of railroad preemption sequence #1.
   b. Communication port input for activation of railroad preemption sequence #2.
   c. Communication port input for activation of the railroad warning system.
   d. Communication port input for railroad preemption sequence #1 gate down control.
   e. Communication port input for railroad preemption sequence #2 gate down control.
   f. Communication port input for railroad island occupancy.
   g. Communication port output for traffic signal health.

2. The following additional controller unit features shall be provided:

   a. Setting for the Maximum RWTT. Whenever the preemption activation input goes false, the controller unit shall calculate the actual RWTT. If the controller unit determines that surplus time is available prior to initiating track clearance, then the preemption sequence shall provide the ability to permit other movements to begin as long as adequate time remains to transition to track clearance green when required.

   b. Dynamic RWTT adjustment on train restart. If the railroad warning system active input goes false prior to the completion of RWTT, any remaining alternate minimum green, alternate pedestrian walk or pedestrian change time shall be set to zero. This will assure the beginning of the track clearance green interval following the completion of any remaining green extension time, yellow change and red clearance time.

   c. Comprehensive railroad preemption log throughout the railroad preemption
sequence. Logging shall include eight controller state changes prior to the activation of the preemption sequence, all state changes throughout the preemption sequence and eight state changes following the completion of the preemption sequence. Each state change shall be logged including date and time (to one second resolution). The log shall include each phase green, yellow and red, each pedestrian walk, pedestrian change and DONT WALK, and each overlap green, yellow and red. In addition, the log shall include the state change of each preemption control input from the railroad.

3. Any controller unit proposed for use on a project where railroad preemption is required shall be furnished to the ODOT signal shop for testing prior to acceptance if the controller will be owned or maintained by ODOT. (Local agencies may have their controllers delivered directly to the project.)

403-10.3 Cabinet Functionality

In order to properly implement railroad preemption operation, design specifications have been developed which describe both the traffic signal controller cabinet and railroad warning system interconnection (see Section 804-4).
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404 PEDESTRIAN CONTROL FEATURES

404-1 General

Pedestrian signal indications (see MUTCD Figure 4E-1) are special types of traffic signal indications intended for the exclusive purpose of controlling pedestrian traffic. Pedestrian signals are discussed in MUTCD Chapter 4E. Construction mounting details are shown on SCD TC-85.10, and pedestrian signal equipment is specified in CMS Item 632 and CMS 732.

404-2 Pushbuttons

MUTCD Section 4E.08 addresses pedestrian detection, usually accomplished using pushbuttons.

On actuated signal phases, if there is a reasonable expectation of regular pedestrian use, the phase shall be equipped with pedestrian pushbuttons to provide access to all corners of the intersection with sufficient time to safely cross the highway; and countdown pedestrian heads, applicable signs and ADA ramps shall be provided.

This is especially important on side-street phases where the signal green time is usually based on a short initial green interval with the green time extended by signal actuations. The initial green interval is usually not long enough to allow a pedestrian to cross the mainline. The pedestrian pushbutton will initiate a guaranteed crossing time without input from vehicular traffic. The pushbutton will also provide the pedestrian with a means to cross the mainline when there is no side-street traffic to initiate the signal phase for the pedestrian crossing.

If pushbuttons are provided, they shall be wheelchair accessible according to current ODOT pedestrian design standards. Pedestrian signal heads and marked crosswalks shall be required whenever pushbuttons are provided. When pushbuttons are provided, pushbuttons shall allow pedestrians to reach all corners of the intersection. Designers should be aware of this requirement and consider the possible future location of crosswalks when locating stop bars and stop bar detectors at signals that do not presently include pedestrian facilities.

404-3 Accessible Pedestrian Signals and Locator Tones

As noted in Section 401-9, use of accessible pedestrian signals and locator tones are major ADA requirements that affect traffic signals. Accessible Pedestrian Signals supplement visual WALK indications and are designed to aid visually impaired pedestrians; and Locator Tones enable pedestrians who have visual disabilities to locate the pushbutton.

The installation of Accessible Pedestrian Signals and/or Locator Tones may be considered at ODOT-maintained traffic signals when an engineering study, which considered the factors specified in MUTCD Sections 4E.09 and 4E.10, has been conducted and the following minimum conditions are met:

1. The proposed intersection crosswalk must be signalized.
2. The audible devices should be retrofittable to the existing traffic signal hardware.
3. The signalized intersection should be equipped with pedestrian pushbuttons.
4. The selected crosswalk must be suitable for the installation of Accessible Pedestrian Signals and/or Locator Tones, in terms of surrounding land use and traffic patterns.
5. There must be a demonstrated need for the audible devices in the form of a request from an individual or group that would use the audible signal.
6. The individual or group requesting the device should agree to train the visually impaired users in the use of the Accessible Pedestrian Signals and/or Locator Tones, as appropriate.

Additional guidance is available in **OMUTCD Part 4**.
405 FLAShING BEACONS

405-1 General

Flashing Beacons are addressed in OMUTCD Chapter 4L.

405-2 STOP Signs and Intersection Control Beacons

A STOP sign shall be used with a flashing red Intersection Control Beacon.

405-3 Rectangular Rapid Flashing Beacon (RRFB)

FHWA has issued an Interim Approval (IA-11) for use of this device. The procedures for use of interim approval items are described in OMUTCD Section 1A.10. See Sections 240-9 and 242-8 for information on use of these beacons on ODOT-maintained highways.
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406 SPECIAL PURPOSE TRAFFIC CONTROL SIGNALS

406-1 General

OMUTCD Chapters 4G through 4L present information on miscellaneous types of highway traffic signals including signals for emergency-vehicle traffic, lane-use control, movable bridges, freeway entrance ramps and one-lane, two-way facilities.

406-2 Temporary Traffic Signals

Temporary traffic signals are currently addressed in OMUTCD Section 4D.32. Additional information about traffic signals used in temporary traffic control zones is provided in OMUTCD Section 6F.84 and Part 6 of this Manual.

406-3 Traffic Control Signals for Emergency Vehicle Access Guidelines

Traffic control signals for emergency vehicle access may be justified if the cross-corner sight distance is less than the appropriate value given in Figure 498-1, or if the volume of traffic during an average day exceeds the values given below:

<table>
<thead>
<tr>
<th>Number of Lanes</th>
<th>ADT (Both Directions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 or more</td>
<td>16,000</td>
</tr>
<tr>
<td>3</td>
<td>9,000</td>
</tr>
<tr>
<td>2</td>
<td>6,000</td>
</tr>
</tbody>
</table>

OMUTCD Chapter 4G presents information on the design and operation of traffic control signals for emergency vehicle access. Also, see TEM Section 403-6 for information about Preemption Control Systems.
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407 OTHER ELECTRICAL DEVICES

407-1 General

This Chapter is used to address other traffic control electrical devices, including active signs, used on ODOT-maintained highways.

407-2 PREPARE TO STOP WHEN FLASHING Signs (W3-H4a)

407-2.1 General

The PREPARE TO STOP WHEN FLASHING (PTSWF) sign (W3-H4a) is used to provide drivers approaching a traffic signal with additional information concerning the changing of the traffic signal indication from green to yellow. Drivers who are past the dilemma zone will usually decide to continue through the intersection when the yellow indication is displayed, while drivers who have not yet entered the dilemma zone will decide to stop. This sign can also be used to provide advance information when the geometric design of the intersection approach prevents the signal display from being seen in time to stop.

407-2.2 Applications

Any proposed ODOT or federally-funded PTSWF sign installations must be reviewed and approved by the Office of Traffic Engineering (OTE). Installation of the PTSWF sign should only be implemented upon failure of the progressive application of countermeasures described in Section 407-2.3. The following are typical applications for PTSWF signs:

1. A location (usually four-lane divided) with high approach speeds (> 45 miles per hour), a high rear-end accident rate, and evidence of rear-end conflicts (skid marks) at the intersection.

2. A remote rural location with high speeds where the presence of a signal is unexpected.

3. A location with high approach speeds and diminished signal sight distance due to horizontal and/or vertical curves or structures.

4. A location with a high percentage of high-speed truck traffic with frequent violations of the clearance interval and excessive angle and rear-end accidents.

Installing PTSWF signs in corridors where multiple signals exist is not recommended.

The installation of a signal can be expected to significantly increase rear-end accidents even at locations without the above described characteristics. No signalized intersection is likely to be completely free of rear-end accidents. Consequently, restraint should be exercised in the use of PTSWF signs since the overuse of any warning device can reduce its effectiveness. It should also be noted that the use of this device reduces the efficiency and safety of the signal operation by delaying the termination of the green and compromising true gap-out phase transitions. Also, studies of PTSWF applications have shown that vehicle speeds through the intersection may increase.

407-2.3 Procedure / Reviewing Other Countermeasures

Prior to installation of the PTSWF signs, it should be determined that proper advance signing has been in place and that the detectors are operating correctly and are located beyond the dilemma zone for the approach speeds involved. Ideally, detection should exist at or upstream of the PTSWF sign. If the detectors and Signal Ahead (W3-3) signs are improperly located, this should be corrected and evaluated before installing PTSWF signs. Other
detector design techniques to minimize dilemma zone exposure may also be employed.

Generally, the PTSWF sign should be used only where conventional traffic control devices have been tried and found ineffective in reducing accidents, or where operational problems related to rear-end, or other accidents caused by failure to stop, have occurred. The brightness and reliability of LED traffic signal lamps have improved the visibility distance of signal indications. For existing signalized intersections, the following progressive application of countermeasures should be utilized to address accidents caused by failure to stop:

1. Installation of a single Signal Ahead (W3-3) sign.
2. Dual W3-3 signs.
3. Oversized, dual W3-3 signs.
4. W3-3 signs with continuously flashing beacons.
5. Extended Call - Delay Call Loops (EC-DC Loops).
6. PTSWF (W3-H4a) signs, timed concurrently with the yellow change (YC) and all-red (AR) clearance intervals.
7. PTSWF signs, with advance warning time.

407-2.4 Operations and Placement

The PTSWF sign installation is addressed in Plan Insert Sheet (PIS) 203020 and typically consists of the following equipment:

► PTSWF sign,
► Flashing beacons,
► Sign bracket assembly,
► Sign support with breakaway foundation,
► Flasher and flash control assembly, and
► Wiring to connect flashing beacons and controller.

Auxiliary equipment shall be provided in the signal controller to operate the PTSWF sign beacons. This equipment shall be set to: 1.) time concurrently with the YC and AR intervals or 2.) start the sign beacons flashing for a predetermined advance warning time (with variable settings) before the termination of green. Flashing operation of the PTSWF sign shall typically end when green is displayed to the approach. The beacons shall flash simultaneously. The beacons shall not be activated when the signal controller operation goes to “flash” mode. For high-speed applications at four-legged intersections, PTSWF signs shall be employed for both directions of a roadway unless there are factors which would dictate the need for one direction only. When PTSWF signs are used on four-lane divided highways, dual installation should be the default treatment.

When a PTSWF sign is added to an approach with W3-3 signs with beacons already in place, the beacons on the W3-3 signs shall be removed.

The symbolic Signal Ahead (W3-3) sign shall be used in conjunction with a PTSWF sign and governed by the following provisions:
► The W3-3 sign shall always be located in advance of the PTSWF sign.

► It shall be no closer than 200 feet to the PTSWF sign, and must also meet the minimum placement criteria described in OMUTCD Section 2C.36.

► If the PTSWF sign is installed after the W3-3 sign (which is usually the case), the W3-3 sign may require relocation to comply with the 200 foot sign spacing criteria.

The following factors are needed to determine PTSWF sign location (S) and timing (T):

\[ t = 1.0, \text{ perception-reaction time in seconds} \]

\[ 1.47 = \text{ conversion factor from miles per hour to feet per second,} \]

\[ V_1 = 85\text{-percentile approach speed, mph} \]

\[ V_2 = 15\text{-percentile approach speed, mph} \]

\[ f = .266 \text{ coefficient of friction (wet)} \]

\[ g = \text{ approach grade, percent/100} \]

\[ S = \text{ sign location from stop line, ft} \]

\[ T = \text{ delay timing, sec.} \]

\[ a = 100 \text{ feet, represent a zone in front of sign where drivers would be unable to perceive meaning of flashing sign} \]

\[ b = \text{ distance } [1.47(t)(V_2), \text{ space in front of the dilemma zone where most drivers would not attempt to stop.} \]

S & T are calculated by:

\[ S = 1.47 V_1 t + \frac{V_1^2}{30(f + g)} = 1.47V_1 t + d_{stop85} \]

where \( d_{stop85} = \frac{V_1^2}{30(f + g)} \), \( d_{stop15} = \frac{V_2^2}{30(f + g)} \)

\[ T_{15} = \frac{S + a + b - DZ_{stop15}}{1.47V_2} \]

\[ T_{85} = \frac{S + a + b - DZ_{g85}}{1.47V_1} \]

Generally, choose smaller of these two for Warning Time where DZ is the dilemma zone:

\[ DZ_{stop} = 7.2V_s \]

\[ DZ_{go} = DZ_{stop} - 200 \]

\[ T = \text{ smaller of } T_{15}, T_{85} \text{ if } T_{15} < T_{85} \]

\[ T = \text{ mean of } T_{15}, T_{85} \text{ if } T_{15} > T_{85} \]
407-2.5  Typical PTSWF Advance Warning Times

The following table is provided for convenience and reflects level approach grades, 1.0 second perception-reaction time and 0.266 coefficient of friction:

<table>
<thead>
<tr>
<th>$V_{15}$ (mph)</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
<td>5.6</td>
<td>5.8</td>
<td>6.0</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>4.1</td>
<td>4.6</td>
<td>5.2</td>
<td>5.8</td>
<td>6.0</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td>4.3</td>
<td>4.8</td>
<td>5.4</td>
<td>6.0</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td>4.5</td>
<td>5.1</td>
<td>5.7</td>
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<td></td>
<td></td>
<td>4.7</td>
<td>5.3</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

407-2.6  Criteria for Removal

The following should be used as criteria for removal:

1. When there are two or more signalized intersections on the same route and the spacing between each signal is 0.5 mile or less.
2. When a signal becomes part of a coordinated system.
3. When the posted speed is reduced to less than 45 miles per hour.
4. Upon mitigation of the condition that caused the sight distance limitation where the PTSWF sign is installed.

Prior to removal of the PTSWF signs, the signs shall be covered and flashers disconnected for a minimum of ten days.

407-2.7  Alternatives to Removal

If existing PTSWF installations with advance warning time are to remain in place, the advance warning time should be eliminated. In this approach, signal operation is simplified by driving the PTSWF beacons concurrently with the associated phase yellow clearance and all red intervals. This is equivalent to reducing the PTSWF advance warning time to zero. The preferred zero-warning-time implementation shall use a separate load switch and/or flasher module to activate the PTSWF flasher using a wire of the yellow and red load switch outputs.

Older PTSWF installations with timing based on earlier TEM formulas should have the advanced warning time reduced to comply closely with the new formula. If a District decides the older PTSWF warning time must be maintained, then the control zone of the signal shall be extended to 100 feet upstream from the PTSWF sign to assure that no vehicles between the PTSWF sign and the next downstream detector are caught in the Dilemma Zone at the end-of-green. Consider using advanced dilemma zone radar detection with this alternative.
408 IN-ROADWAY LIGHTS

408-1 General

In-Roadway Lights (see OMUTCD Chapter 4N) are considered a type of Highway Traffic Signal. They are installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. Typical uses for this device would be marked school crosswalks and marked midblock crosswalks. In-Roadway Warning Lights at crosswalks shall not be used at crosswalks controlled by YIELD signs, STOP signs, or Traffic Control Signals.

408-2 Use of In-Roadway Lights on State Highways

Because of the high speeds and volumes associated with state highways, an engineering study should be conducted to determine if other measures, such as increased signing and pavement marking, should be implemented before the use of in-roadway crosswalk warning lights on ODOT-maintained highways. Any engineering study pertaining to the installation of in-roadway lights on state highways should be coordinated with the Office of Traffic Engineering.

The use of in-roadway lights at highway-rail grade crossings should also be coordinated with the Ohio Rail Development Commission (ORDC). The ORDC’s web address is http://www.dot.state.oh.us/divisions/rail/Pages/default.aspx
Intentionally blank.
420 MATERIALS AND SIGNAL HARDWARE

420-1 General

Construction details are shown on SCDs TC-81.10 through TC-85.20. Traffic signal equipment is specified in CMS Items 632 and 633 and CMS 732 and 733.

CMS and SCD information may be viewed on-line at http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/2010CMS.aspx and www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/SCD/Pages, respectively.

420-2 Patented or Proprietary Materials, Specifications or Processes

The use of patented or proprietary materials, specifications or processes is addressed in Section 120-4.

420-3 Purchasing Materials for Installation and Use by Local Agencies

To help encourage uniformity and provide a method whereby local agencies can buy traffic control materials and equipment using Federal funds, Sections 120-5 and 120-6 describe processes that have been established whereby local agencies can purchase such items through ODOT.

420-4 Vehicular Signal Heads

420-4.1 General

Standards related to vehicular signal heads are addressed generally in OMUTCD Chapter 4D.

For any project using State or Federal funds, louvered reflective backplates in accordance with CMS 732.22 are required for all new signal heads (backplates are required for both mast-arm and span-wire installations). It is recommended that signal heads be polycarbonate plastic and be tethered per Plan Insert Sheet (PIS) 208521 to minimize sway for span-wire type configurations. A signal support analysis should be performed on all existing strain poles and mast-arm type signal supports to insure they are structurally adequate for the proposed changes. If span-wire supports are found deficient for backplates in all directions, then the intersection should be analyzed for mainline or East/West backplates only. Written documentation and calculations are required if the proposed additions/changes cannot be implemented.

420-4.2 Signal Head Color

In ODOT-maintained traffic signal installations, the vehicular signal head housings and the outside of the visors shall be highway yellow or black. The two colors shall not be mixed within an intersection.

420-4.3 Signal Lens

Signal lenses may be made of glass or plastic. In ODOT-maintained traffic signal installations, glass signal lenses should be used. At rural ODOT intersections, the signal may dwell in a phase for long periods of time during the night causing heat damage to a plastic lens.

The size of signal lenses may be 8 inch or 12 inch depending on the provisions of OMUTCD Section 4D.15. In ODOT-maintained traffic signal installations, the 12-inch lens should be
used. The 8-inch lens is typically used for low-speed, urban applications.

420-4.4 Location of Five-Section Signal Heads for Protected/Permissive Turns

OMUTCD Sections 4D.17 through 4D.20 contain the requirements for signal head use for protected/permissive left turns. In protected/permissive signal phasing, the left (or right) turns can be made in both a protected (green arrow) and a permitted (circular green) signal phase.

“Shared” five-section signal face:

Because the circular signal indications in this five-section signal head apply to both the through and turning vehicles, the signal head should be located on an extension of the Channelizing Line that separates the through and turn lanes. The “shared” type of five-section signal face is used extensively throughout Ohio.

Left-turn lanes on four-lane highways with wide medians are often separated from the through lanes by a large painted channelizing island in order to provide good alignment and sight distance for opposing left-turn vehicles. In this case, the five-section head should be located in front of the left-turn lane with an R10-12 sign, LEFT TURN YIELD ON GREEN, next to the signal head. Two additional three-section signal heads should be provided for the through-traffic lanes. The maintaining agency should monitor accidents for this type of operation with the wide median. ODOT’s experience in some parts of the State showed that left-turning drivers were not yielding on the circular green and the phase operation had to be converted to “protected only.”

420-4.5 Aluminum versus Polycarbonate

Vehicular signal heads are manufactured in either aluminum or polycarbonate plastic. The choice of which material to use will be made by the maintaining agency. Many urban jurisdictions prefer the use of polycarbonate, because they are much lighter and easier to handle. Because of the lighter weight, they are often used when adding left-turn signal heads to an existing signal support system. Polycarbonate signal heads are most often associated with rigid-mounted signal heads on mast arms where wind sway will not be a factor.

In ODOT-maintained traffic signal installations, aluminum signal heads should be used to reduce signal head sway in windy conditions unless rigid mounting or span-wire tethers are used. The preferred signal head material for any installation with backplates and tethers, per Plan Insert Sheet (PIS) 208521, is polycarbonate.

420-4.6 Programmable Signal Heads

A programmable signal head utilizes a special optical lens that can be “programmed” to provide the signal display to only desired portions of the roadway. The programming is accomplished by masking (with tape) portions of the lens through the rear of the housing or by steerable LED arrays behind the lens. Applications for the use of programmable heads may be severely skewed roadways where the signals may be visible from more than one approach and closely spaced intersections, or closely spaced intersections.

Because the lens is programmed to be visible from certain areas, the signal head should be rigid mounted or tethered. Programmable signal heads are much more expensive than a regular signal head and, if programmed incorrectly, can create an unsafe condition. Signal designers should give careful thought to their use and provide plan sheets clearly showing the desired visibility cutoffs.

See Section 450-10.5 for additional details on optically programmable signal heads.
420-4.7 Signal Indications on the Stem of a T Intersection

For through traffic, a minimum of two signal faces shall be provided and shall be continuously visible per the requirements of OMUTCD Section 4D.11.

On the stem of a T intersection, where there is no through traffic, at least one of the turning movements shall be provided with dual indications. If two three-section heads are used, one with a left-turn green arrow and the other with a right-turn green arrow, the approach does not meet the minimum requirements of the OMUTCD. Two circular greens are sufficient, or two circular greens with one or two arrows (four-section heads) are acceptable. The purpose of providing dual indications is to ensure that if one lamp fails, a second lamp will be provided to the predominant movement.

420-4.8 Signal Head Clearance

OMUTCD Section 4D.15 requires that the bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway shall be at least 15 feet above the pavement. The top of the signal housing of a vehicular signal face located over a roadway shall not be more than 25.6 feet above the pavement. For new construction, SCD TC- 85.20 requires a clearance of 16 to 18 feet above the pavement elevation at the center of the roadway, 17 feet if tethered. If the installation cannot be adjusted to the proper clearance, the engineer, in consultation with the maintaining agency, may direct the use of drop pipes or waive the maximum clearances requirement for each head.

420-4.9 Use of Balance Adjusters Prohibited

Balance adjusters shall not be used on signal installations with backplates. Experience has shown that balance adjusters allow enough twisting motion in the signal head to produce tether wire fatigue at the tether attachment point.

420-5 Detector Loop Placement

420-5.1 General

Figures 498-3 through 498-5 illustrate suggested loop placements for traffic control signals in the following situations: High-Speed Mainline vs. Large-Volume Side Street, Mainline vs. Ramp/T Intersection, and High-Speed Mainline vs. Low-Speed Side Street, respectively. Section 450-10.7 provides additional detail information about loop placement and wiring.

These are intended only as suggestions for detector placement and a naming convention. Actual placement will depend on individual conditions and District practices. Electronic copies of the drawings are available upon request.

420-5.2 Detection of Motorcycles and Bicycles

For any project using State or Federal funds, all stop line detection zones shall reliably detect motorcycles and bicycles, and all dilemma zone detectors shall reliably detect motorcycles. To assist the traffic signal designer, the following information is provided:

1. Motorcycles and bicycles are more easily detected by inductance loop detectors (ILDs) when traveling over a wire that is parallel or skewed to the direction of travel. All loop configurations have a bicycle/motorcycle dead zone at their center.

2. Video stop line detection is usually a reliable detection system for motorcycles and bicycles. The detection zone at the stop line should be kept small so that motorcycles and bicycles will impact a larger percentage of the detection zone. Other detection zones may be added in advance of the stop line detection zone to provide large area detection. Locking of detection calls may be required during nighttime hours, especially at unlighted intersections.
3. An 8-foot wide rectangle or square ILD in a lane of 12 feet or less in width places the wires too close to the edge of pavement or adjacent lane to be considered a traveled path for motorcycles. A 6-foot wide ILD in a 12-foot wide lane will position the wires closer to the traveled path, increase sensitivity in the center of the zone, and allow the detector unit sensitivity setting to be increased while minimizing adjacent lane false calls.

4. The long rectangular stop line ILD is not a reliable detector of small vehicles. While the commonly used rectangular ILD has good detection of high-bed vehicles, the center dead zone does not reliably detect motorcycles and bicycles. Increasing sensitivity to a level that will detect motorcycles and bicycles may cause false calls in the adjacent lane.

5. For dilemma zone detection, the commonly used 6-foot diamond, square, or rectangle shape may not reliably detect motorcycles traveling in the center of the lane over the ILD corners. The Angular Design Detection (ADD) loop shown on SCD TC-82.10 will provide more reliable detection.

6. To provide large area ILD detection at stop lines:
   a. The Powerhead configuration provides both motorcycle/bicycle and large area detection with a single loop. Shorter Powerhead loops (e.g., 6 x 20 feet) provide the best performance, with a maximum permissible length of 35 feet.
   b. A short quadrupole (10 feet or less) with 3-6-3 wire configuration can be used at the stop line for the detection of motorcycles and bicycles, with a longer rectangular or ADD ILD in advance of the quadrupole to detect other vehicles including high-bed vehicles. This arrangement provides better performance than a single Powerhead loop, but requires more detector module channels.
   c. A series of 6 foot rectangular ILDs can be used to provide a zone of coverage in advance of the stop line with the ILD at the stop line being either a short Powerhead or a short parallel quadrupole.
   d. The stop line ILD shall not be wired to any other loops and shall have its own detector channel.
   e. System loops may be 6 x 6 foot square or diamond shapes.

At locations of high bicycle use or where the outline of the ILD is not visible on the pavement, signing and pavement marking (OMUTCD Section 9B.13 and Figure 9C-7) may be used to denote the location on the ILD for the most reliable detection area after testing with a bicycle.

All stop line detection zones should be tested for a bicycle target, and all dilemma detection zones tested for a motorcycle target for reliable detection. See Figure 498-27 for standard vehicle test targets.

420-5.3 Inductive Loop Detection Zones at High Speed or Freeway Ramp Locations

Figures 498-3 through 498-5 illustrate suggested loop placements for traffic control signals in the following situations: High-Speed Mainline vs. Large-Volume Side Street, Mainline vs. Ramp/T Intersection, and High-Speed Mainline vs. Low-Speed Side Street, respectively. Section 450-10.7 provides additional detail information about loop placement and wiring.

These are intended only as suggestions for detector placement and a naming convention. Actual placement will depend on individual conditions and District practices. Electronic copies of the drawings are available upon request.

420-5.4 Video Detection Prohibited for Dilemma Zone Applications

Video detection shall not be used for advance (Dilemma Zone) detection on any approach with a posted or prevailing speed of 35 mph or greater. Video detection is suitable for stop line applications only. Within 200 feet of the stop line, video detection may be employed for
(green) extension detection. Beyond 200 feet, extension detection shall be provided by inductive pavement loops or Advance Dilemma Zone Detection System (Section 442-39).

420-5.5 Second-Car Detection

420-5.5.1 Background

The use of second-car detection eliminates timing of the associated protected left-turn phase when only one vehicle is waiting for service. This amounts to an “early return” of the opposing green through movement equal to the minimum duration for the left turn. In general, left turns have minimum times similar to those below, to be used for this example calculation:

1. Minimum Green: 7 seconds
2. Yellow Change: 4 seconds
3. All-Red Clearance: 1 second

The total for this minimum phase time is 12 seconds. The queue clearance time (QCT) in seconds is given by:

$$QCT = 4 + 2n$$

(where \(n\) = the number of vehicles clearing from queue past the stop line).

Rearranging, we can calculate the number of vehicles (per opposing through lane) that move into the intersection during this interval: \(n = 0.5 \times (QCT - 4)\).

For the typical left-turn phase timings above, this gives: \(n = 0.5 \times (12 - 4) = 4\).

Thus, only an additional four vehicles per lane are cleared in the opposing through phase by eliminating the protected left-turn movement using second-car detection. The signal designer is advised to consider this minor increase in through-phase service volume relative to the safety considerations associated with eliminating the protected left-turn interval.

420-5.5.2 Use of Second-Car Detection

The deliberate placement of protected/permissive left turn presence loops and detection zones at locations with their trailing edge more than one vehicle length behind the stop line is sometimes used by signal designers. The rationale for this placement is the perceived increased efficiency obtained by skipping the associated left-turn phase if only one vehicle is present at the stop line, forcing that vehicle to make a permissive turn at some point during the adjacent green through phase. Such operation yields its greatest mainline efficiency benefit under heavy through volume conditions. However, under heavy volume conditions, the permissive left turn often cannot be made until the opposing phase termination. For high-speed, multi-lane, divided highways, offset-left approaches and other conditions, this can be a dangerous vehicular movement, contributing to angular collisions.

For the reason noted above, left-turn second-car detection shall not be used at ODOT-maintained signals under (but not limited to) the following conditions:

1. High approach speeds (over 35 mph posted or prevailing).
2. More than one opposing through lane regardless of approach speeds.
3. Median-divided highways.
4. Offset left-turn lanes.
5. Left-turn lanes with permitted U-turns.
6. An intersection with PREPARE TO STOP WHEN FLASHING advance warning flashers.
7. High-skew or other geometrics or conditions with limited visibility.
421 SIGNAL SUPPORTS

421-1 General

MUTCD Section 4D.33 presents information on the lateral placement of signal supports. Construction details are shown on SCDs TC-21.20, TC-81.10 and TC-81.21. Signal supports are specified in CMS Item 632 and CMS 732.

CMS and SCD information may be viewed on-line at http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/2010CMS.aspx and www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/SCD/Pages/, respectively.

421-2 Signal Support Inspections

A statewide uniform practice for the periodic inspection of the structural components of ODOT-maintained signal supports is necessary to assure their structural integrity. All strain pole and mast arm supports should be periodically inspected. The inspections should be conducted in a systematic and organized manner that will be efficient and minimize the possibility of any item being overlooked. The use of an inspection form is recommended. See Section 496-1 for a Sample Signal Support Inspection Form which may be used as is or modified by the District as desired. A copy of this form may be downloaded from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.

Supports should be visually inspected from the ground. Binoculars should be used as an aid for visual inspections. Use of a bucket truck or other means is not necessary on a routine basis, but may be used to more closely examine a defect that has been detected from the ground. Anchor bolts should be tested for structural integrity by sounding with a hammer. Non-destructive testing procedures, such as dye penetrant, ultrasonics, and magnetic particle, are not necessary on a routine basis, but can be used to define the extent of a defect that has been detected by visual means. Written documentation of all inspections should be kept.

Items to be inspected should include, but not be limited to, foundation concrete, soil around foundation, anchor bolts and nuts, structural members and structural connections.

Deficiencies to be inspected for should include, but not be limited to, cracks in concrete, soil erosion, non-bearing leveling nuts, loose anchor nuts, bent or distorted structural members, cracked welds, missing or loose hardware, and corrosion.

Appropriate corrective action, in accordance with sound engineering practices, should be taken to correct detected deficiencies. Repairs should be made within a reasonable time frame, commensurate with the extent of the deficiencies found. Temporary remedial actions, up to and including complete removal of the structure, may be appropriate until permanent repairs can be accomplished. Written documentation of corrective actions should be kept.

All signal supports shall be inspected at a maximum five-year interval. New signal supports shall be inspected at the time of construction.
This Chapter has been reserved to address, as needed, planning and programming information related to traffic control signals.

The Systematic Signal Timing & Phasing Program (SSTPP) is funded by the ODOT Safety and Congestion Program. Its purpose is to systematically update the timing and phasing of signal systems at approved candidate intersections and/or corridors. See Section 1213-6 for more information regarding this program.
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440-1 General

The L&D Manual Volumes One and Three and Chapter 140 provide general background regarding design information for ODOT projects, including the three-stage review process typically used for traffic control plans. Additional design information has been provided in this Chapter, including checklists for Stage 2 and 3 submittals (see Section 440-7). See Chapter 441 for additional information specifically related to plan preparation. Plan Notes are addressed in Chapter 442 and Chapter 443 provides a listing of related CMS items.

440-2 Electrical Power for Traffic Signals

Each signalized location should, whenever possible, be powered from a separate, independent power source point arranged with the power company. This should be a 120 volt (two-wire) service of adequate ampacity for the predicted loads. A 120/240 volt, three-wire, service should only be considered when it will also be used to power a few roadway luminaries at the intersection, and in this case, disconnects shall be arranged so that it is possible to disconnect the lighting circuit for repairs without disturbing signal operation.

SCD TC-83.10 addresses pole mountings for controllers and power service. ODOT-maintained signals shall use padlocks at all times to prevent unauthorized disconnect operation.

Provision of traffic signal power service will cover the same general considerations as designated for separate independent sign lighting power services (Section 240-7.7, 1 and 3). The availability of power at various locations in the intersection may tend to make some locations more favorable for the controller mounting.

Plan Note 442-2 (see Section 442-2) should be included on projects with traffic signals. The name and address of the power company and the voltage to be supplied shall be specified in the appropriate blanks.

440-3 Single-Arm Overhead Signal Support

Various types of overhead signal supports are depicted in Table 497-4. In designing a single-arm overhead signal support, the following instructions are used in conjunction with SCD TC-81.21 for new supports and SCD TC-81.20 for retrofit situations:

1. Determine the approximate arm length as the horizontal distance from the pole flange plates to a point 1 foot beyond the most remote attachment (signal or sign).

2. Locate each signal or sign on the arm. Select the proper area for each signal head from Table 497-5, and for a sign.

3. Calculate the area moment design factor (K) by multiplying each area (A) by the distance (b) from its attachment point to the pole centerline and add the products.

\[ K = b_1A_1 + b_2A_2 + b_3A \]

See figure shown on next page. Area moment for standard luminaires and bracket arms may be calculated as 3L, where L = length of bracket arm in feet.
4. For a new support, select the proper design based on maximum arm length (from TC-81.21) and area moment design factor (K) from the design chart shown below.

<table>
<thead>
<tr>
<th>Design No.</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>11</th>
<th>12</th>
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<tr>
<td>K</td>
<td>637</td>
<td>787.5</td>
<td>937.5</td>
<td>1575</td>
<td>1780</td>
<td>1995</td>
<td>2380</td>
<td>2641</td>
</tr>
<tr>
<td>Max Arm Length (ft)</td>
<td>25</td>
<td>32</td>
<td>38</td>
<td>38</td>
<td>45</td>
<td>48</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

5. As long as the K value is not exceeded, it is acceptable to exceed the “Maximum Design Area” shown on TC-81.21.

6. When an existing TC-81.20 support is to be retrofitted with backplates and/or rigid-mounted signals, the following design chart shall be used.

<table>
<thead>
<tr>
<th>Design No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>318.5</td>
<td>378</td>
<td>412.5</td>
<td>825</td>
<td>845.5</td>
<td>1045</td>
</tr>
<tr>
<td>Max Arm Length (ft)</td>
<td>25</td>
<td>32</td>
<td>38</td>
<td>38</td>
<td>45</td>
<td>48</td>
</tr>
</tbody>
</table>

7. The value should not exceed that listed for the selected design number. If the values are exceeded, the designer shall be responsible for determining the support size required.

8. Any mast arm length greater than 59 feet is required to have a wind damping system.

9. If the design numbers for the supports at a particular intersection are similar (for example, 2 design number 11 and 2 design number 12 at the same intersection), then the smaller supports may be changed to the larger design number in the plans.

The designer shall submit detailed structural calculations showing the adequacy of any proposed non-standard signal support design. The proposed design shall include the foundation. The plan
designer shall include a Plan Note reflecting the non-standard signal support design requirements in this section. The note shall include requirements for an engineer’s seal on both structural calculations and shop drawings for the proposed structure.

Calculations must be submitted to the owner agency for approval prior to fabrication. Shop drawings may be provided at time of delivery of the structure.

The supports shall be designed using the 2009 Edition of the AASHTO Standard Specifications for Highway Signs, Luminaires, and Traffic Signals. The following criteria shall be used for the design:

- Basic Wind Speed – 90 mph
- Design Life – 25 years
- Fatigue Category III

The support designs shall not include galloping or truck induced gust loading.

**440-4 Two-Arm Signal Support Design**

Various types of overhead signal supports are depicted in Table 497-4. To determine arm and pole sizes for the two-arm signal supports where the arms are approximately at 90 degrees (± 15 degrees), proceed as follows:

1. Considering each arm as a single arm signal support, follow the design instructions noted in Section 440-3 for SCD TC-81.21.

2. Using the arm sizes detailed for the SCD TC-81.21 design numbers selected in step 1, use the following chart to select the pole size required.

![Diagram of Two-Arm Signal Support Design](attachment:diagram.png)

Where the following defines the related pole designations:
3. The **SCD TC-81.21** or **TC-12.30** design number for the pole shall be used in the plans as reference for the proper pole base and foundation details.

3. **SCD TC-81.21** will apply for arm details and arm attachments.

4. **Section 441-10** provides a recommended bid item description for a two-arm signal support.

440-5 **Span Wire Signal Support Design Software (SWISS)**

**ODOT** has developed a software program to calculate the moment at the base of a strain pole for various span wire configurations. The base moment is compared to **SCD TC-81.10** to select an adequately sized strain pole for the span wire configuration analyzed. The software program is available to consultants and local jurisdictions on the **Office of Roadway Engineering (ORE)** website.

Unless specifically necessary, all strain poles for a given span shall be the same design number. This is done by setting all pole designs in the plan to be the same design number as the largest pole indicated by the SWISS software.

The use of H-spans is discouraged in favor of the Box-With-Tails span configuration. Bullrings shall be located along imaginary diagonal lines between the poles. Questions about span wire configuration selection can be directed to the **ORE** staff.

See **Table 497-6** for the height from the bottom of the signal head to the messenger wire or mast arm.

440-6 **Traffic Signal Timing Analysis**

440-6.1 **Traffic Signal Timing Software**

**ODOT** currently uses versions 6 and 7 of **Synchro** (signal timing and coordination) and **SimTraffic** (simulation) software.

440-6.2 **Diamond Interchange Traffic Signal Timing**

When developing traffic signal timing for diamond interchanges, the designer should also analyze the interchange using controller phasing operation developed by the **Texas Department of Transportation**. The interchange signal operation typically uses one controller to operate both ramp intersections. Two forms of the controller operation are available:

- **Three-phase** diamond operation is best suited for wide interchanges (>400 feet) with
adequate internal left-turn storage and heavy through movements usually associated with rural/suburban type interchanges. The 3-phase operation may provide better two-way arterial coordination than the 4-phase operation.

Four-phase diamond operation is best suited for interchanges where the ramp intersections are close together and have heavy left turning movements usually associated with urban type interchanges. This operation will usually reduce congestion within the interchange and should be considered where arterial left turn storage is inadequate.

The signal timing analysis for the diamond interchange is initially performed in Passer III which provides various signal timing/cycle length combinations with performance measures for each. Synchro/SimTraffic software is then used to analyze the arterial performance of the various cycle lengths to obtain the best match for the arterial system operation.

Plan Insert Sheets (PISs) are available for both the 3-phase and 4-phase operations that provide controller and detector information that can be included in the signal plans.

440-7 Stage 2 and 3 Plan Submittals

The following information has been provided here as checklists for Stage 2 and 3 plan submittals.

1. Stage 2 Plan Requirements:
   a. Base plan drawn to a scale of 1:20 and it shall include roadway base lines.
   b. Traffic signal pole locations and skew angles, if required. Reference numbers for all poles.
   c. Signal head locations and direction; identify signal heads having turn arrow lenses, louvers or special optically programmed features; signal head sizes; and reference numbers for all signal heads.
   d. Signal controller location and orientation.
   e. Detector locations, loop configurations and detector chart (Form 496-4).
   f. Underground conduit and pull boxes.
   g. Overhead sign locations, whether on signal spans, mast arms or located on separate supports.
   h. Legend for symbols used.
   i. Pavement marking pertinent to the signal operation.
   j. Signal phasing diagram, method of addressing yellow trap (where applicable) or field hook-up chart (see Forms 496-19 and 496-20) and signal timing. See Forms 496-3 and 496-5 for typical signal timing charts.
   k. Handicap ramp locations.
   l. Right-of-Way lines.
   m. Corporation lines.
   n. Any existing features to be incorporated into the new signal. Any decision to reuse equipment must be based on a field check of the structural integrity and condition of the devices and agreement with the maintaining agency.
   o. Other physical features within the intersection and sidewalk area which may conflict with traffic flow, pedestrian flow or sight distance.
2. Stage 3 Plan Requirements:
   a. General Notes.
   b. Estimated quantities.
   c. Special details.
   d. Pole orientation chart.
   e. Wiring diagram. It shall indicate the type of cable and number of conductors connecting each signal head, pedestrian head, detector, push button, etc.
   f. Coordination timing. All coordination timings shall be in seconds.

The Traffic Signal Stage 3 check list is given in Form 496-2.

440-8 ADA Requirements on Traffic Signal Projects

440-8.1 General

As noted in Section 401-9, there are generally four major ADA requirements that affect traffic signal projects:

1. Accessible pedestrian signals;
2. Audible pedestrian pushbuttons (locator tones);
3. Curb ramps;
4. Truncated domes (tactile bumps on the curb ramp).

440-8.2 Accessible Pedestrian Signals and Locator Tones

Section 404-3 covers accessible pedestrian signals and locator tones at ODOT-maintained traffic signals. On traffic signal projects, local governmental agencies may install these devices at their intersections if it is part of their local policy/standards.

A common mistake made at rural type intersections is to provide a pedestrian pushbutton on a pole that is located far back from the roadway. When provided, pedestrian pushbuttons shall be accessible to the disabled. This may mean providing a paved pathway back to the pushbutton. Alternatively, a pedestal can be provided to put the pushbutton near the intersection.

440-8.3 Curb Ramps

Refer to Location and Design Manual, Volume 1, Section 306 for basic guidelines for pedestrian facilities (curb ramps and sidewalks).

On traffic signal projects, ADA compliant curb ramps shall be provided at locations where work is being performed. This includes upgrading any existing curb ramps to meet current ADA design requirements. Generally, every intersection where a traffic signal is installed or upgraded shall be provided with ADA compliant curb ramps. In cases where an intersection is not disturbed, i.e., only running aerial interconnect, curb ramp work would not normally be required (though the locals may include the work). If the interconnect is being trenchen
through an intersection, curb ramps would be required as part of the project. The litmus test is if the work being proposed will disturb the intersection, then curb ramp work will be required. For maintenance type work, curb ramp work would not be required. Controller and cabinet upgrade only locations shall be considered substantial enough to require curb ramp upgrading.

440-8.4 Truncated Domes (TDs)

TDs are raised “bumps” used by people with vision impairments to be able to feel where the ramps are. All new, existing or upgraded curb ramps shall have truncated domes upon completion of a traffic signal project.

Roadway Engineering’s SCD BP-7.1 addresses new ramps, and BP-7.2 addresses existing curb ramps. For guidance in the use of these drawings, contact the Office of Roadway Engineering. The information is available on-line at: www.dot.state.oh.us/divisions/prodmgt/roadway/pages/default.aspx

440-9 Paying Locals with Project Funds

On some projects, the local authorities desire to have one of their employees in attendance when the contractor is working in their traffic signal controller cabinets. This is a legitimate request and the plans should include a general note requiring the contractor to inform the local authorities prior to working in their traffic signal controller cabinets. The cost of providing the local employees shall be borne by the local authorities. Project funds shall not be used to pay the local representative’s salary, either straight or overtime pay.
441-1 General

The L&D Manual Volume Three and Chapter 140 generally describe ODOT plan preparation and production guidelines. Additional information is provided in this Chapter and Chapter 440 regarding traffic signal items in plans.

441-2 Reserved for Future Information

This Section is reserved for future information.

441-3 Signal and Sign Supports

The following location requirements apply to Stage 2 Plans:

1. Consider sight distance conflicts between signals and overhead signs included within the project, as well as other visibility obstructions. Signals take precedence for prime locations.

2. Combine signal, sign and/or light poles where practical; in so doing the support shall be a signal support bid item.

3. Distance from Stop Line to signal heads shall be in accordance with O MUTCD Sections 4D.13 and Figure 4D-4. Stop Lines shall be located to suit geometric conditions, then signal head locations provided to suit.

4. Minimum lateral clearances to pole or signal equipment attached thereto shall be as per Section 600 of the L&D Manual Volume One.

5. Where sidewalks are encountered, signal poles and equipment shall be located behind them if physically possible.

6. Locate signal poles behind existing guardrail wherever possible, with a minimum clearance of 6.5 feet from the face of guardrail to the centerline of the support. Other signal equipment shall have a minimum clearance of 6 feet from the face of guardrail to the nearest edge of the equipment.

7. Determine the exact location by station to the nearest 1 foot. This information will be needed in Stage 3 Plans.

441-4 Power Service

Tentative power service locations shall be specified as needed on the plans either on the signal support or at separate service poles (separate bid item). The contractor’s work will generally consist of providing sufficient length of two-wire power cable out of the weatherhead, to which the power company will make their attachments and connections. See Section 450-9 for the measurement of power and service cables.

See Section 440-2 for design information on electrical power for traffic signals. Prior to filing the tracings, the design agency shall confirm in writing, agreements made with the power company, to the District Production Administrator and City Traffic Engineer (if applicable).

441-5 Underground Facilities

Conduit runs shall usually be limited to 200 feet between pull boxes, but up to 400 feet may be used if the run is straight and not too full.
Conduit crossing bridge structures shall, if possible, be included in parapets. As an alternative, it may be attached to the underside of the parapet by means of clamps. Necessary flexible conduit at expansion joints shall be provided.

Conduit under the roadway shall be a minimum of 3-inch diameter. All conduit shall be of sufficient size to contain the conductors as per the National Electric Code. See Section 450-3.4 for additional information.

441-6  Quantities

In the General Summary, all quantities should be shown in whole units of measurement, except concrete which shall be shown to a tenth of a cubic yard and any pavement marking item measured in miles, which shall be shown to a hundredth of a mile.

441-7  Bid Item Descriptions

Bid item descriptions are required to exactly match the descriptions published in the “Item Master.” This “Item Master” is available from the ODOT Design Reference Resource Center (DRRC) web page at www.dot.state.oh.us/drrc/Pages/default.aspx.

When the standard bid item description is inappropriate, the words "As Per Plan" shall be added to the description, and a note shall be provided to describe the deviation from the standard specifications and/or details. See Chapter 442 for examples of typical Plan Notes.

441-8  Signal Support, Detail Design Requirements

Figures 498-36, 498-37 and 498-38 provide examples of tables for presenting signal support information in the plans for support types described in SCDs TC-81.10 and TC-81.21.

Use of the sample tables is recommended as a means of uniformly presenting support information to the contractor or support manufacturer. The support designer should note that the orientation angles consist of:

- A field angle that establishes the angular relationship between the project centerline perpendicular and a pole feature (handhold or mast arm) which serves as an index.

- Angles for all pole appurtenances that are measured from this index pole feature.

Complete instructions for designing the single arm overhead signal support described in SCD TC-81.21 are contained in Section 440-3. Instructions for the design of two-arm signal supports are contained in Section 440-4.

The following information relates to the detail design of signal supports for Stage 3 plans.

1. Foundation elevations and span wire attachment heights are optional for signal strain poles. Top and bottom foundation elevations should be provided if foundation dimensions are not as shown on SCD TC-21.20, or when steep roadside slopes or roadway superelevation would make foundation elevations difficult to otherwise determine.

2. Station and offset information is not necessary for signal strain poles in the strain pole table. Poles should be clearly labeled and locations dimensioned on the signal intersection sheets.

3. Do not give conduit angles for foundations because these will be field located by the contractor according to the plans and field conditions. An exception would be for unused, capped conduit ells for future use.
4. A column may be added to define the street from which the centerline and angles are determined.

5. For a project with many installations, a column for cross reference to the signal or sign plan sheet should be added.

6. Elevation views of the signal spans are optional. However, if elevation views are not used, span dimensions between signal heads and signs shall be shown on each signal intersection sheet.

7. Strain poles (SCD TC-81.10) can typically be located with the base plate either square or at 45 degrees to the roadway centerline. The pole and foundation are designed for loading in any direction and the anchor bolts do not need to be located exactly in line with the resultant span wire load.

8. If two pedestrian signal heads are located on a pole, the designer must choose between a single mounting bracket for two heads or separate mounting brackets for each head. Also, SCD TC-85.10 allows field installation of holes with alternate mounting methods instead of threaded blind half couplings. The maintaining agency's choice of mounting method should be clearly noted in the plans.

9. If luminaire bracket arm attachment plates are required, a column should be listed in the table to show the orientation angles. The plan should note whether one or two plates are required. The power company or maintaining agency should be contacted concerning any special mounting attachment requirements. ODOT standards are shown on SCD HL-10.12.

**441-9 Service Cable**

In CMS 732, service cable is specified primarily as aluminum conductors. This was done because aluminum is typically most cost effective in these sizes, and more readily available. The specification allows the substitution of copper conductors of one size smaller. This is because the greater conductivity and lower resistance of copper approximately accounts for one wire size. For instance, a #8 AWG copper conductor with an ampacity of 45 AMPS may be substituted when the plan calls for a #6 AWG aluminum conductor which would have an ampacity of 50 AMPS.

This relationship is considered acceptably close for the required usage. The specifications call for appropriate connectors to match wire material.

There is a potential problem if the designer uses a specific size of copper service cable, out of habit, without recognizing that the change to aluminum has effectively reduced ampacity of these cables by 12 to 25 percent.

A similar relationship exists for cases where long runs of service cable require consideration of voltage drop.

Under CMS Item 632 and CMS 732, service cables should be sized to the following minimums:

<table>
<thead>
<tr>
<th>Total Control Load (AMPS)</th>
<th>Aluminum Wire Size (AWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>#10</td>
</tr>
<tr>
<td>30</td>
<td>#8</td>
</tr>
<tr>
<td>45</td>
<td>#6</td>
</tr>
<tr>
<td>65</td>
<td>#4</td>
</tr>
</tbody>
</table>

Also note that aluminum service cable (duplex or triplex) is not readily available in smaller than #8 AWG.
441-10 Two-Arm Signal Supports

Section 440-4 describes the procedure for designing a two-arm signal support. As noted in that Section, the SCD TC-81.21 or TC-12.30 design number for the pole may be used in the plans as reference for the proper pole base and foundation details. SCD TC-81.21 will apply for arm details and arm attachments.

The bid item for the structure should be in the form:

Item 632 (Combination) Signal Support, Type (TC-12.30 or TC-81.21) Design ___ Pole, with
Mast Arms TC-81.21 Design ___ and TC-81.21 Design ___

A detailed elevation view and any other special details required for the two-arm support that are not covered by the SCD should be included in the plans.

441-11 Guarantees

For projects not requiring detail guaranteeing, the requirements of CMS Item 633 will apply. On traffic control projects or other projects where the cost for traffic control is more than one-third of the total cost, a Plan Note based on Section 442-15 may be included. The period of guarantee should be adjusted in relation to equipment complexity, i.e., 90 days for simple equipment, 120 days for traffic adjusted equipment and a maximum of 180 days for computerized control of many intersections. When the note is included, notice of the fact should be communicated in the transmittal of final tracings to Central Office, so that affected groups may make provision in the proposal for the extended completion date.

441-12 Alternate Bids

The use of alternate bidding procedures must be requested and the maintaining agency must agree in writing to the procedure. Alternate bids are typically used for projects where a particular type or brand of equipment is desired, usually the signal controller. Section 442-16 presents an example of an alternate bid note (Plan Note 442-16) setting up an alternate bid item in the plans. This note should be placed in the plans at the end of the general notes for traffic signal items. In the general summary, the alternate bid item should be at the end of the list of traffic signal items.
442 PLAN NOTES

442-1 General

Typical Plan Notes have been consolidated here for convenience in preparing plans. The number used for the Plan Note will be the same as the Section number. When a Plan Note revises the material or contractor requirements from that which is specified in the CMS, both the note and the bid item will be “as per plan”. Where there are design instructions pertaining to a specific note, they are listed at the end of the note. These notes may be modified to further define the conditions of a project or maintaining agency.

In keeping with traditional format of Plan Notes, various format changes are used here that are not typical throughout the TEM, e.g., the terms Contractor and Engineer are capitalized.

442-2 Power Supply for Traffic Signals

Electric power shall be obtained from the ____________ at the location indicated on the plans. Power supplied shall be ____ volts.

**Designer Note:** See Sections 440-2 and 441-4.

442-3 Reserved for Future Use

442-4 632 Removal of Traffic Signal Installation

Traffic signal installations, including signal heads, cable, messenger wire, strain poles, cabinet, controller, etc., shall be removed in accordance with CMS 632.26 and as indicated on the plans. Removed items shall be reused as part of a new installation on the project or stored on the project for salvage by (name of agency receiving stored items) in accordance with the listing given herein.

(Items to be reused)

(Items to be stored)

In the event the items stored on the project for salvage by the local agency are not removed, the Contractor shall, when directed by the Engineer in writing, remove and dispose of the items at no additional cost to the project.

**Designer Note:** This note shall be included on projects where existing traffic signal installations are being removed. A listing of items to be reused and/or stored must be included. Pull boxes to be removed shall be itemized separately and paid for under Item 625 “Pull Box Removed”.

442-5 632 Interconnect Cable, Misc.: (by Size), with Support Messenger, As Per Plan

The Contractor will be permitted to use either of two types of interconnect cable construction and installation under this item as follows:

1. Integral messenger type interconnect cable meeting the requirements of CMS 732.19. Under this method any sections of cable shown in the plans to be contained in controllers, cabinets, poles, conduits or supported on messenger wire installed for other purposes shall have the supporting messenger and jacket web neatly removed by the use of a tool specifically designed and sized for this purpose. Deviations from the cable routing shown in the plan, for the sole purpose of reducing the amount of messenger to be removed, will not be permitted. The cable shall be installed with approximately one twist for each 15 feet of span length.
2. Separate interconnect cable meeting the requirements of CMS 732.19 plus a 1/4 inch messenger wire and lashing meeting the requirements of CMS 732.18. Under this method the Contractor will install a separate 1/4 inch messenger to support the spans of interconnect cables in all locations where the plans show interconnect cable which is not otherwise supported by a signal messenger wire or other suitable support. Utilization of existing messenger wire, not provided by the project or designated therein as available for use, is prohibited. Deviation from the cable routing shown in the plans, for the purpose of reducing the need for separate messenger wire, will not be permitted.

In either case the number of splice locations shall be kept to a minimum.

Measurement will be based upon the number of feet of CMS Item 632, "Interconnect Cable, Misc.: (by size), with Support Messenger, As Per Plan" in place in accordance with the method described in CMS 632.29 and no separate payment will be provided for any separate messenger wire used to support interconnect cables.

**Designer Note:** This note may be used on projects with overhead interconnect cable, if acceptable to the maintaining agency.

442-6  **632 Loop Detector Units, by Type, As Per Plan**

In addition to the requirements of CMS Item 632 and CMS 732.07 or 732.08, loop detector units shall have the following requirements or features:

The output device shall be a relay, and all contacts shall be in the wiring harness.

The unit shall be self-tuning.

The unit's electrical connection plugs or wiring harness shall allow ready replacement with a single channel amplifier as described in CMS 732.07.

Each unit shall be labeled to correspond to its phase and direction.

Delay inhibit shall be connected on all detector harnesses for their respective phase greens.

**Designer Note:** This note should be included for projects which will be maintained by Districts that use NEMA TS-1 controller cabinets. Bid items are not used unless detector units are installed in an existing cabinet.

442-7  **Reserved for Future Use**

442-8  **Reserved for Future Use**

442-9  **632 Loop Detector Lead-In Cable, Direct Burial**

This work shall include furnishing and installing loop detector lead-in cable of the type required in CMS 732.19. Installation shall be by cable plow or vibratory cable plow to a minimum depth of 18 inches. All entries into pull boxes, conduit systems, foundation or other enclosures shall be free of sharp edges and be covered by insulated bushings. Following installation, the ground surface shall be restored to the original contour and surface condition.

**Designer Note:** This method may be considered in lieu of cable in conduit to reduce project costs. It is applicable to long underground runs in tree lawns or grassed roadsides where minimal interference with driveways or utilities is expected, and where disturbance of the area due to construction is not contemplated. If the cable is to be routed up a pole, a conduit riser (extending below ground with an insulated bushing) should be called for and detailed.
442-10 632 Combination Signal Support, Type TC-81.21 and Sign Support, TC- (with Light Pole Extension)

This support shall consist of a TC-_______ Design ___ pole with a TC-81.21 Design ___ signal arm and a TC-_______ Design ___ sign support arm (with light pole extension). All signal support items required by CMS Item 632 and all sign support items required by CMS Item 630 shall be included as part of this support.

Payment will be at the contract unit price and will be full compensation for all labor, materials, tools, equipment and other incidentals necessary for each support furnished, in place, complete and accepted.

Designer Note: This note shall be used when combination traffic signal supports and sign supports are desired. The blanks shall be filled in with appropriate SCD numbers and designs.

442-11 632 Combination Strain Pole, Type TC-81.10 and Sign Support, Type TC- (with Light Pole Extension)

This support shall consist of a TC-_______ Design ___ pole with a TC-_______ Design ___ sign support arm (with light pole extension). All signal support items required by CMS Item 632 and all sign support items required by CMS Item 630 shall be included as part of this support.

Payment will be at the contract unit price and will be full compensation for all labor, materials, tools, equipment and other incidentals necessary for each support furnished, in place, complete and accepted.

Designer Note: This note shall be used when combination traffic signal strain poles and sign supports are desired. The blanks shall be filled in with appropriate SCD numbers and designs. The following is a bid item example: Combination Strain Pole, Type TC-81.10 and Sign Support, Type TC-12.30 (with Light Pole Extension).

442-12 Strain Pole Foundation Elevations

Elevations shown in the plans for strain pole foundations are for computational purposes only. The actual elevation of the foundation shall be in accordance with SCD TC-21.20 provided the existing slope is less than 6:1.

At locations where the existing slope is 6:1 or greater, the buried depth of foundation, as shown in SCD TC-21.20 shall apply to the low side of the slope. The top of the foundation shall be set 2 inches above the existing surface on the high side of the slope. The additional depth of foundation necessary to meet these requirements shall be added to the formed top.

Designer Note: This note shall be used when strain pole foundations are located in slopes of 6:1 or greater.

442-13 632 Vehicular Signal Head, Color, Material, By Type, (with Backplate) As Per Plan

In addition to the requirements of CMS 632 and 732, the following requirements shall apply:

1. All upper signal support hardware and piping up to and including the wire inlet fitting shall be ferrous metal for signal displays of two or more sections.

2. The entrance fitting shall be of the tri-stud design with serrated rings in order to achieve positive locking.

Designer Note: This note should be included for projects which will be maintained by ODOT.
442-14  **632 Power Service, As Per Plan**

Power service shall be as per CMS Item 632 and SCD TC-83.10 with the following exceptions:

1. The meter base mounting height shall be no more than 5 feet high to the center of the meter base from the ground.

2. The Contractor shall supply the necessary meter bases.

3. All power services shall be metered. The meter shall have a lever operated bypass.

Disconnect switch enclosures furnished in accordance with CMS Item 632, Power Service, as per plan, shall include a padlock equal to Master no. 4BKA or Wilson Bohannon 660, with lock body of bronze or brass and keying shall be to the state master.

The Contractor shall contact the meter section of the power company for information regarding the meter base installation prior to ordering poles. The Contractor will be responsible for requesting and scheduling any inspections the power company may require for the power service hook up. The Contractor shall be responsible to contact the power company for the electrical service connection. Under no circumstances shall the Contractor splice power cable into the power company's circuits. The voltage supplied shall be nominally 120 volts. The Contractor is responsible for obtaining any necessary permits and the paying of all fees. The Contractor shall pay all power charges until the signal is accepted by the maintaining agency.

**Designer Note:** This note may be used when requested by the maintaining agency.

442-15  **Guarantee**

The Contractor shall guarantee that the traffic control system installed as part of this contract shall operate satisfactorily for a period of _____ days following completion of the 10-day performance test. In the event of unsatisfactory operation the Contractor shall correct faulty installations, make repairs and replace defective parts with new parts of equal or better quality. Equipment, material and labor costs incurred in correcting an unsatisfactory operation shall be borne by the Contractor.

The guarantee shall cover the following items of the traffic control system: controllers and associated equipment, detector units, interconnection items and master control equipment.

Customary manufacturer's guarantees for the foregoing items shall be turned over to the state or the maintaining agency following acceptance of the equipment.

The cost of guaranteeing the traffic control system will be incidental to and included in the contract unit price of the various items making up the system.

**Designer Note:** See Section 441-11.

442-16  **633 Alternate Bid Item**

633 Controller Unit, Type____, with Cabinet, Type ____

(Example of a standard bid item)

633 Controller Unit, Type ____ , with Cabinet, Type ____ (Acme) - Alternate Bid

The controller shall be a Model (xx-99 as manufactured by Acme Signal Company, Santoy,
Ohio) and shall incorporate or be furnished with all the design features, auxiliary equipment, accessories, and prewired cabinet features as required in the standard bid item.

Payment will be at the contract unit price for each, in place, all connections made and wiring completed, tested and accepted.

(Example of an alternate bid item)

**Designer Note:** See Section 441-12.

### 442-17 632 Vehicular Signal Head, Color, Material, By Type, (with Backplate), As Per Plan

In addition to the requirements of CMS 632 and 732, the following requirements shall also apply:

**Mounting Hardware:** *(select items as needed)*

[#. All signal heads shall be rigidly mounted to the mast arm with the (color) lens located in front of the mast arm.]

[#. All upper signal support hardware and piping up to and including the wire inlet fitting shall be ferrous metal for signal displays of two or more sections.]

[#. The entrance fitting shall be of the tri-stud design with serrated rings in order to achieve positive locking.]

The Department will measure “Vehicular Signal Head, Color, Material, By Type, (with Backplate), As Per Plan” by the number of complete units furnished and installed, and will include all support and mounting hardware, disconnect hangers, closure caps, dimmers, and lamps as specified.

**Designer Note:** Since maintaining agencies will use different combinations of signal sections, this note will allow the designer to choose the various options that will provide the maintaining agency with features that they prefer. Items that are enclosed in brackets [ ] should be carefully considered and retained or deleted based on maintaining agency preferences. Care should be taken not to include duplicate requirements for the same item. Some designer notes are in italics.

### 442-18 Reserved – Existing Note Deleted

The **Plan Note** for “632 Pedestrian Signal, (LED), (Countdown), Type A2, As Per Plan” has been deleted due to the fact that polycarbonate vehicular signal heads have been added to the CMS book.

### 442-19 632 Relamp Existing Signal Section with LED Lamp Unit, By Lens Type, As Per Plan

This item of work shall consist of replacing the 12 inch lens and incandescent lamp in an existing signal head section with a 12 inch LED lamp unit.

The light emitting diode (LED) signal lamp units shall meet the requirements of CMS 732.04-C. An LED signal lamp unit shall be furnished and installed for the type of signal lens specified in the bid item description.

[The existing reflector unit and lens shall be removed and returned to the maintaining agency. The existing incandescent lamp shall be disposed of by the contractor.]

The Department will measure “Relamp Existing Signal Head with LED Lamp Units, By Lens Type, As Per Plan” by the number of complete units furnished and installed, and will include all hardware and lamps as specified.
Designer Note: Since maintaining agencies will use different combinations of LED/incandescent lamp and aluminum/polycarbonate signal sections, this note will allow the designer to choose the various options that will provide the maintaining agency with features that they prefer. Items that are enclosed in brackets [ ] should be carefully considered and retained or deleted based on maintaining agency preferences. Care should be taken not to include duplicate requirements for the same item.

**442-20 633 Controller Unit, Type 170E, with Cabinet, Type (332 or 336), As Per Plan**

The 412C PROM module for the local controller shall be supplied without controller software to the ODOT District Office 14 days in advance of when the software is needed. The PROM modules shall be configured for Wapiti software and include a blank PROM module for program installation. ODOT will install the local controller software program. The Contractor shall pick up the PROM modules with the installed software from District. It shall be the Contractor’s responsibility to use the returned PROM modules to program the signal controllers per the plans.

The Contractor shall not reassign the detector inputs in order to reduce the number of 2-channel detector units supplied, but shall use the standard CalTrans input file designations.

Designer Note: This note should be used at signalized intersections using Type 170E local controllers that are to be owned and maintained by ODOT.

**442-21 633 Controller Unit, Type 2070L, with Cabinet, (By Type), As Per Plan**

The controller unit shall be equipment manufactured in conformance to the California Department of Transportation (Caltrans) specifications titles “Transportation Electrical Equipment Specifications (TEES).” The controller unit, Model 2070L, shall be an Econolite Model 2070L, Build: 1.01.08.02b, Siemens Model 2070L, Build: 6.2.0.0.0.81, or approved equal.

The 2070L controller unit shall include the following:
1. Unit Chassis
2. 2070-1B CPU module
3. 2070-2A Field I/O Module
4. 2070-3B Front Panel
5. 2070-4A Power Supply
6. 2070-7A Serial Communication Module

The controller shall be supplied without traffic signal intersection control software. The controller shall be supplied with Microware Embedded OS-9 Release 1.3 or later with kernel edition #376 or later, as required by Caltrans TEES. For warranty purposes, a vendor-specific decal, as per ODOT CMS 733.02 shall be applied to each controller unit at time of delivery to the project.

The controller shall be shipped by the Contractor to the ODOT Signal Shop, 1606 West Broad Street, Columbus, Ohio 43223, either directly or via the ODOT District Office, a minimum of 14 days in advance of when the software is needed. ODOT will install the local intersection control software. The controller will then be performance tested by the ODOT Signal Shop. Every effort shall be made to have loading and performance testing completed by the ODOT Signal Shop within 2 weeks of receipt of an individual controller; larger groups of controllers submitted at the same time may take longer. Should any controller fail this performance test after being loaded with ODOT-licensed software, the software will be removed by the ODOT Signal Shop and the controller rejected. Rejected controllers will be returned, either directly to the Contractor or to the ODOT District Office. Controllers passing the performance test will be labeled by the ODOT Signal Shop with the OS Image Number, CPU serial number, Software Revision Number, and upload date. This label is not to be removed by the Contractor and serves as proof that the controller has been loaded, tested
and approved for initial installation on the project. Such proof does not alter the required 10-day Performance Test outlined in CMS Sections 632 and 633.

The Contractor shall not reassign the cabinet detector inputs in order to reduce the number of 2-channel detector units supplied, but shall use the standard Caltrans Input File designations.

**Designer Note:** This note should be used at signalized intersections using Type 2070L local controllers that are to be owned and maintained by ODOT.

### 442-22 633 Controller, Master, Traffic Responsive, As Per Plan

The 412B2 PROM module for the Type 170E master controller shall be supplied without controller software to the ODOT District Office 14 days in advance of when the software is needed. The PROM modules shall be configured for Wapiti software and include a blank PROM module for program installation. ODOT will install the master controller software program. The Contractor shall pick up the PROM modules with the installed software from District. It shall be the Contractor’s responsibility to use the returned PROM modules to program the signal controllers per the plans.

**Designer Note:** This note should be used at signalized intersections using Type 170E master controllers that are to be owned and maintained by ODOT

### 442-23 633 Controller, Master, Traffic Responsive, As Per Plan

The Type 2070 master controller shall be supplied without controller software, but will be supplied with the operating system and CalTrans required software. The controller unit shall be delivered to the ODOT District Office 14 days in advance of when the software is needed. ODOT will install the master controller software program. The Contractor shall pick up the controller unit with the installed software from District. It shall be the Contractor’s responsibility to program the Type 2070 signal controller per the plans.

**Design Note:** This note should be used at signalized intersections using Type 2070 master controllers that are to be owned and maintained by ODOT

### 442-24 Reserved for Future Use

### 442-25 633 Preemption

This item of work shall consist of furnishing and installing preemption equipment in the locations and local controllers as shown in the plans. The preemption shall conform to ODOT Specification 633 and shall utilize communications to identify the presence of an emergency priority vehicle. It shall cause the traffic signal controller to select a pre-programmed preemption plan that will display and hold the desired signal phase for the direction of the emergency vehicle.

The communications medium shall employ either sound, light or radio detection techniques to determine and log the presence of the emergency vehicle. The system shall detect the presence of the vehicle through an emitting device located on the emergency vehicle. The system shall activate the preemption sequence by applying a signal to one of the controller's preempt discrete inputs. The system shall be completely compatible with the controller.

The equipment shall be shelf or rack mounted and easily removable and replaceable within the cabinet. The equipment shall be supplied completely wired in the controller cabinet and tested. The system shall be capable of preempting and receiving priority for each approach to the intersection. It shall be possible to detect the emergency vehicle up to 1200 feet from the intersection.

Each intersection shown in the plans shall be supplied with the following components, each
bid separately:
1. Preempt receiving unit.
2. Preempt detector cable.
3. Preempt phase selector assembly and interface wiring panel.

If a light activated system is specified, the Contractor shall inventory the City’s existing emitters to determine compatibility with the proposed system. If existing emitters are found to be not compatible, then the City shall be supplied (at costs incidental to the system) with the emitters, transmitters, switches, wiring and all required vehicle equipment for the following emergency vehicles. The City shall be responsible for installing vehicle equipment. The model supplied shall be Opticom manufactured by Global Traffic Technologies LLC, Strobecom II manufactured by Tomar Electronics Inc., or approved equal.

If a radio activated system is specified, the Contractor shall supply the above emergency vehicles with emitters at cost incidental to the system. The model supplied shall be Opticom GPS manufactured by Global Traffic Technologies, LLC, Emtrac Priority Management System Model GPS manufactured by STC, Inc., or approved equal.

If a sound activated system is specified, the Contractor shall inventory the above emergency vehicles to determine compatibility of the sirens with the system. Each vehicle that is determined to be not compatible shall be supplied with new sirens at cost incidental to the system. The model supplied shall be Sonem 2000 manufactured by Traffic Systems LLC, Right-O-Way manufactured by Wapiti Microsystems, or approved equal.

If a light, radio, or sound activated system is not specified, then Contractor may supply any of the three types.

The City shall be supplied with software required to calibrate, log, and operate the system. The software shall be capable of operating under Windows 7, 32-bit operating system. Two (2) operating and instruction manuals shall be supplied with the software.

The Contractor shall thoroughly test the installed system. As a minimum, the Contractor shall verify that all connections are properly made to the controller cabinets. The Contractor shall check that the range setting is proper for each intersection. The Contractor shall determine that all phase selectors are selecting the proper phase and timing accurately. The Contractor shall verify that all vehicle emitters are being properly detected.

If the proposed preempt system is not compatible with the existing system, the Contractor shall provide training for up to fifteen (15) persons in the operation of the system. It shall be provided within 48 hours of the installation of the system. It shall consist of hands-on instruction for a minimum of sixteen (16) hours. The Contractor shall provide training for up to four (4) persons in the installation and maintenance of the system. It shall consist of a minimum of eight (8) hours of instruction. Training shall be supplied within seven (7) days of the installation of the system. All training shall be held in a City supplied location. Training shall be conducted by someone who has performed this within the last year and does it on a regular basis. The cost of training, including course material, travel subsistence and related costs, shall be entirely borne by the Contractor and shall be incidental to the preemption equipment.

Payment for Item 633 “Preemption” shall be made at the contract unit price for each preemption in place and fully operational as shown in the plans, except for those items bid separately.

**Designer Note:** This note may be used for generic preempt systems. The quantity in the plans should be one each for the system; not the number of intersections.
442-26 633 Preemption Receiving Unit

Receiving units shall consist of a lightweight, weatherproof and directional assembly. Each receiving unit shall be 360 degree adjustable. The receiving unit shall be capable of sending the proper electrical signal to the traffic signal controller via the preemption detector cable. Receiving units shall be supplied with mast arm mounting hardware as shown in the plans.

Furnish preemption receiving units with 60-month warranties or for the manufacturer’s standard warranty whichever is greater. Ensure that the warranty period begins on the date of shipment to the project. Ensure that each unit has a permanent label or stamp indicating the date of shipment.

Payment for Item 633 “Preemption Receiving Unit” shall be at the contract unit for each receiving unit in place, completely installed at the location shown in the plans, wired, tested and accepted.

Designer Note: The note may be used when preemption is included for in the plans.

442-27 633 Preemption Detector Cable

This item shall consist of furnishing and installing preemption detector home run cable in the locations shown in the plans. It shall connect the preempt receiving units to the phase selectors in the local controller cabinet.

Preemption detector cable shall conform to ODOT Specification 632. Only one external splice shall be permitted between preemption receiver unit and controller cabinet. This splice shall meet the requirements of C&MS 632.23 using a waterproof epoxy splice kit. The cable shall be approved for both overhead and underground use. The jacket shall withstand exposure to sunlight and atmospheric temperatures and stresses reasonably expected in normal installations.

Payment for Item 633 “Preemption Detector Cable” shall be made at the contract unit price per foot for the cable furnished, in place, all connections made and wiring completed, tested and accepted.

Designer Note: This note may be used when preemption is included for in the plans.

442-28 633 Preempt Phase Selector

This item shall consist of furnishing and installing preempt phase selectors including wiring interface panels in the local controller cabinet and all other accessories that are necessary to make the preempt phase selectors completely functional and operational as shown in the plans. This item shall include the extra cabinet space necessary to be located in the local controller cabinets where indicated in the plans.

The phase selectors shall consist of a module or modules that will provide the necessary inputs to the controller. Phase selectors shall be supplied with sufficient quantities of channels to provide preemption for all approaches to the intersection separately. Power shall be obtained from the phase selector or phase selector power supply and not from the local controller timer.

The phase selectors shall have front panel indicators for active preempt channel status. It shall have test switches to activate all preempt channels.

Furnish preempt phase selectors with 60-month warranties or for the manufacturer’s standard warranty whichever is greater. Ensure that the warranty period begins on the date of shipment to the project. Ensure that each unit has a permanent label or stamp indicating the
date of shipment.

Payment for Item 633 “Preempt Phase Selector” shall be made at the contract unit price for each phase selector in place, completely installed in the local controller shown in the plans, wired, tested and accepted.

**Designer Note:** This note may be used when preemption is included for in the plans.

### 442-29 633 Preempt Confirmation Light, LED

This item shall consist of furnishing and installing preempt confirmation lights including hardware and all other accessories that are necessary to make the preempt confirmation light completely functional and operational as shown in the plans.

A confirmation light shall be supplied for each intersection to indicate that the emergency vehicle has achieved control of the traffic signal.

The confirmation light shall be a vapor tight aluminum lighting fixture. It shall be supplied with a clear globe, LED lamp and mounting hardware to attach to the traffic signal mast arm. The confirmation light shall be powered by a load switch in the traffic signal controller. Signal cable conforming to 732.19 shall be used for confirmation lights. A minimum of 4-conductor cable shall be used with the green wire serving as the safety ground conductor.

Payment for Item 633 “Preempt Confirmation Light, LED” shall be made at the contract unit price for each light in place, completely installed in the location shown in the plans, wired, tested and accepted.

**Designer Note:** This note may be used when requested by the maintaining agency. The signal cable is a separate pay item.

### 442-30 Pull Box, 24” x 35” x 26”

Pull boxes shall have nominal opening dimensions of 24 inches by 35 inches. Materials shall conform to 725.06, 725.07 or 725.08. The word “Traffic” shall be integrally cast as part of the cover or securely fastened with corrosion resistant hardware. The supplied pull boxes shall support a 20,000 pound minimum vertical loading without permanent damage or deflection to the unit. Dispose of surplus material and restore disturbed facilities and surfaces.

The largest bend radius possible shall be maintained for the fiber optic cable.

All costs resulting from the above requirements shall be included in the unit price bid per each for Item 625 “Pull Box, 24” x 35” x 26”.

**Designer Note:** The pull box cited in this note is bell shaped at the bottom to help maintain fiber optic cable minimum bend radii. Any pull box where a splice is required or a change in cable direction is made should use this larger pull box.

### 442-31 632 Pole Entrance Fitting

A pole entrance fitting shall be provided in accordance with the plan details to allow fiber optic cable entrance into both existing and proposed steel poles. In proposed poles the Contractor shall have the 2 inch entrance holes shown in the details pre-manufactured. Blind half couplings shall be welded into any new strain poles supplied as part of the project.

Existing strain poles shall require the Contractor to field locate the pole entrance hole and drill two pilot holes and use a hole saw to cut the 2 inch hole. All non-galvanized pole surfaces exposed after cutting the hole shall have three coats of zinc enriched paint applied.
No pole entrance fitting holes shall be located vertically within 24 inches of any other holes or blind half couplings.

All costs to provide a pole entrance including material, equipment and labor shall be included in the bid item price for each Item 632 “Pole Entrance Fitting”.

**Designer Note:** The maintaining agency may opt to have the Contractor route drop cables down the outside of strain poles.

### 442-32 Grounding and Bonding

The requirements of the Construction and Material Specifications (CMS) and the TC series of Standard Construction Drawings are modified as follows:

1. All metallic parts containing electrical conductors shall be permanently joined to form an Effective Ground Fault Current Path back to the grounded conductor in the power service disconnect switch.
   a. Provide an equipment grounding conductor in metallic conduits (725.04) in addition to the conductors specified and bond the conduit to this grounding conductor.
   b. When an equipment grounding conductor is required in plastic conduit (725.05), the installation shall include a separate equipment grounding conductor in addition to the conductors specified.
   c. Metallic conduit carrying the loop wires from in the pavement to the pull box splice location will only be bonded at the pull box end, and will not contain an equipment grounding conductor.
   d. If multiple conduit runs begin and end at the same points, only one equipment grounding conductor is required.
   e. If an equipment grounding conductor is needed in conduit between signalized intersections for underground interconnect cable, the grounding system for each signalized intersection will be separated about midway between the intersections.
   f. The messenger wire at signalized intersections will be used as the conductive path from corner to corner if conduit is not provided under the roadway. When conduit connects the corners of an intersection, an equipment grounding conductor shall be used in the conduit.

2. Conduits.
   a. The 725.04 conduit shall have grounding bushings installed at all termination points. The bushing material shall be compatible with galvanized steel conduit and the grounding lug material shall be compatible for use with copper wire. Threaded or compression type bushings may be used.
   b. The 725.05 conduit shall have the inside and outside diameters of the conduit deburred at all termination points.
   c. Both ends of metallic conduit shall be bonded to the equipment grounding conductor.
   d. Metallic conduit may be bonded to metallic boxes through the use of conduit fittings UL approved for this type of connection, with the box bonded to the equipment grounding conductor.

3. Wire for grounding and bonding.
   a. Use insulated, copper wire for the equipment grounding conductor. Bonding jumpers in boxes and enclosures may be bare or insulated copper wire. Wire size shall be as follows:
      i. Use 4 AWG between the power service and supports, poles, pedestals, controller or flasher cabinets.
      ii. Use a minimum 8 AWG between loop detector pull boxes and the first conduit that requires a larger size as specified in 3.a.i above.
iii. Use a minimum 8 AWG between the “Prepare to Stop When Flashing” installation (including support) and the first conduit that requires a larger size as specified in 3.a.i above.

iv. The insulation shall be green or green with yellow stripe(s). For 4 AWG or larger, insulation may also be black with green tape/labels installed at all access points.

b. In a highway lighting system, the equipment grounding conductor shall be the same wire size as the duct cable or distribution cable circuit conductors, with the minimum conductor size of 4 AWG. Bonding jumpers will be minimum size 4 AWG.

4. Ground rod.
a. A 3/4 inch Schedule 40 PVC conduit will be used in foundations and concrete walls for the grounding conductor (ground wire) raceway to the ground rod. Should metallic conduit be used, both ends of the conduit shall be bonded to the grounding conductor.

b. The typical grounding conductor (ground wire) shall be 4 AWG insulated, copper.

5. The green conductor in signal cables (conductor #4) shall not be used to supply power to a signal indication. It will be connected to the signal body as an equipment ground in aluminum heads and it will be unused in plastic heads. Unused conductors shall be grounded in the cabinet. Typical use of conductors is as follows:

<table>
<thead>
<tr>
<th>Cond. no.</th>
<th>Color</th>
<th>Vehicle signal</th>
<th>Pedestrian signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black green ball</td>
<td>#1 Walk</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>White AC neutral</td>
<td>AC neutral</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Red red ball</td>
<td>#1 DW/FDW</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Green equipment ground</td>
<td>equipment ground</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Orange yellow ball</td>
<td>#2 DW/FDW</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Blue green arrow</td>
<td>#2 Walk</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>White/black stripe yellow arrow</td>
<td>not used</td>
<td></td>
</tr>
</tbody>
</table>

6. Power Service and Disconnect Switch.
a. At the power service location, the grounding conductor (ground wire) from the disconnect switch neutral (AC-) bar to the ground rod shall be a continuous, unspliced conductor. If spliced, it shall be an exothermic weld butt splice.

b. The service neutral (AC-) shall only be connected to ground at the primary power service disconnect switch.
   i. NEMA controller cabinets: If a power service disconnect switch is located before the controller cabinet, the neutral (AC-) and the grounding bars in the controller cabinet shall not be connected together as shown in NEMA TS-2, Figure 5-4.
   ii. If secondary disconnect switches are connected after the primary disconnect switch, the neutral (AC-) shall only be grounded at the primary switch. Equipment grounding conductors shall be brought to the primary switch, but shall be grounded at both secondary and primary switches.

7. Payment – All materials and work required to complete the Effective Ground Fault Current Path system are incidental to the conductors installed by contract.

**Designer Note:** This note shall be used on all projects with electrical items (631, 632, 633). *Figures 498-39 through 498-42* provide examples of wire sizes for equipment grounding conductor.

442-33 **Reserved – Existing Note Deleted**

The **Plan Note** for “804 Fusion Splicer” has been deleted because the information is now in a fiber optic supplemental specification.
442-34 Reserved – Existing Note Deleted

The Plan Note for “804 Fusion Splicer” has been deleted because the information is now in a fiber optic supplemental specification.

442-35 Reserved – Existing Note Deleted

The Plan Note for “804 Cleave Tool” has been deleted because the information is now in a fiber optic supplemental specification.

442-36 Reserved – Existing Note Deleted

The Plan Note for “804 Optical Time Domain Reflectometer (OTDR)” has been deleted because the information is now in a fiber optic supplemental specification.

442-37 Reserved – Existing Note Deleted

The Plan Note for “804 Mechanical Splice Tool Kit” has been deleted because the information is now in a fiber optic supplemental specification.

442-38 Reserved – Existing Note Deleted

The Plan Note for “804 Fiber Optic Training” has been deleted because the information is now in a fiber optic supplemental specification.

442-39 633 Advance/Dilemma Zone Detection System

This item of work shall consist of furnishing and installing an Advance/Dilemma Zone Detection unit capable of intersection advance detection control utilizing above ground Digital Wave Radar Techniques. The unit shall be non-intrusive and shall detect vehicles from 50 feet up to 600 feet from the unit. The unit shall provide up to 8 detection zones simultaneously for intersection control. One unit shall be provided per approach, where specified in the plans, covering multiple lanes where advance detection is required. The detection unit shall include the following list of features and capabilities:

- The unit shall provide accurate presence-detection of both stopped and moving vehicles. The unit shall be mounted in a forward-fire, looking at either approaching or departing traffic and shall only detect vehicles in one direction of travel.
- The unit shall be tested to meet NEMA TS2 environmental standards and maintain accurate performance in the following operating conditions:
  - Rain up to 4 inches per hour
  - Freezing rain
  - Snow
  - Wind
  - Dust
  - Fog
  - Changing temperature
  - Changing lighting
- The radar design for each unit shall conform to the following:
  - Operating frequency: 10.5–10.55 GHz (X-band)
  - Matrix of a minimum of 16 radars
  - No manual tuning to circuitry
  - Transmits modulated signals generated digitally
  - No temperature-based compensation necessary
  - Bandwidth stable within 1%
  - Printed circuit board antennas
  - Antenna vertical 6 dB beam width (two-way pattern): 80 Degrees
  - Antenna horizontal 6 dB beam width (two-way pattern): 10.5 Degrees
  - Antenna two-way sidelobes: -40 dB
Transmit bandwidth: 45 MHz
Un-windowed resolution: 11 feet
RF channels: 4

- The unit shall include a simple setup routine that shall automatically configure and calibrate the unit for proper operation during installation. The unit shall also be capable of being programmed and updated from a laptop computer or other portable programming device, such as a Pocket PC, via a local or remote ethernet connection using vendor supplied software. The software shall support TCP/IP connectivity, unit configuration back-up and restore, and virtual sensor connections. The graphical user interface shall operate on a Windows platform.

- The unit shall have one full-duplex RS2-232 and one half-duplex RS-485 communication ports and shall have the ability to upgrade firmware over any communication port.

- The unit shall be mounted directly to a pole or most arm, as recommended by the manufacturer. Cable(s) shall be provided as required and recommended by the manufacturer.

- Surge protection devices, as recommended by the manufacturer, shall be included both at the pole where the unit is located to protect the unit and in the traffic cabinet to protect the cabinet electronics.

- Power shall be provided from the traffic cabinet. The unit shall consume less than 10 watts and operate from a DC input between 9 VDC and 28 VDC. Complete and automatic recovery from a power failure shall be within 15 seconds after resumption of normal power.

- All required inputs cards shall be included in the traffic cabinet and shall be compatible with CalTrans, NEMA TS1 and NEMA TS2 detector racks. The cards shall provide true presence detector calls or contact closure to the traffic controller.

- The manufacturer's representative shall be on site during installation and testing and shall provide onsite training on the setup, operation and maintenance of the unit.

- The unit shall come with a 2-year manufacturer supplied warranty.

Payment for Item 633 Advance/Dilemma Zone Detection System shall be made at the contract unit price for each unit, complete and in place including all required cabinet hardware, mounting brackets, cables, conduit, connections tested and accepted, and any other necessary hardware to establish a fully functional detection system.

**Designer Note:** This note may be used when dilemma zone detection is included in the plans.

### 442-40 633 Uninterruptible Power Supply (UPS), Battery Replacement

In addition to the requirements of 733.09, provide four (4) batteries for each existing Uninterruptible Power Supply (UPS) cabinet location selected.

Batteries shall be provided from the Department’s Qualified Product List.

Furnish batteries certified by the manufacturer to operate over a temperature range of -13 °F to +165 °F.

Place all batteries on battery heater mats in the enclosure.

Batteries shall be warranted for full replacement for two (2) years from date of purchase.

The Department will pay for Item 633 Uninterruptible Power Supply (UPS), Battery Replacement at the contract price bid for each UPS location where the four (4) existing batteries are replaced. Payment shall be full compensation for all labor, materials, tools, equipment, disposal and other incidentals necessary to replace the UPS batteries complete, in place, and accepted.
442-41 633 Uninterruptible Power Supply, As Per Plan

In addition to the requirements of CMS 633 and 733, the Contractor shall furnish, install and test Uninterruptible Power Supply (UPS) status indicator lamps that allow maintenance personnel and law enforcement to quickly assess whether a traffic signal cabinet is being powered by a UPS. A 1-inch waterproof NEMA 4X or IP66 lamp with a domed RED lens shall be used to indicate the cabinet is operating under UPS backup power (the “backup” operating condition). This lamp shall be wired using minimum 20ga stranded, insulated hookup wire to the status relay outputs of the UPS. The wires shall be terminated by lugs at the display end and permanently labeled “BACKUP POWER STATUS DISPLAY,” with wire polarity indicated. This item includes programming the UPS status relay outputs to produce the lamp status displays. The status display shall be solid 100% duty cycle (not flashing). The lamp shall be placed in the UPS cabinet wall (not the roof) in such a manner as to be sealed from water intrusion and visible from a vehicle at the stop line in the closest lane of at least one approach to the signalized intersection. The operating voltage of the LED lamp shall be 120V AC.

442-42 Reserved for Future Use

442-43 633 Stop Bar Detection Radar

This item of work shall consist of furnishing and installing a Stop Bar Detection unit capable of intersection detection control utilizing above ground Digital Wave Radar Techniques. The unit shall be non-intrusive and shall detect vehicles from 6 feet up to 140 feet for a 90 degree field of view from the unit. The unit shall provide real-time presence data for at least 10 lanes. The unit shall provide at least 16 detection zones simultaneously for intersection control. One unit shall be provided per approach, where specified in the plans, covering multiple lanes where stop bar detection is required. The detection unit shall include the following list of features and capabilities:

- The unit shall provide accurate presence-detection of moving vehicles. The unit shall be mounted in a forward-fire or side-fire position, looking at either approaching or departing traffic and shall only detect vehicles in one direction of travel.
- The unit shall be tested to meet NEMA TS2 environmental standards and maintain accurate performance in the following operating conditions:
  - Rain up to 1 inches per hour
  - Freezing rain
  - Snow
  - Wind
  - Dust
  - Fog
  - Changing temperature
  - Changing lighting
- The radar design for each unit shall conform to the following:
  - Operating frequency: 24.0–24.25 GHz (K-band)
  - Matrix of 16 radars
  - No manual tuning to circuitry
  - Transmits modulated signals generated digitally
o No temperature-based compensation necessary
o Bandwidth stable within 1%
o Printed circuit board antennas
o Antenna vertical 6 dB beam width (two-way pattern): 65 Degrees
o Horizontal field of view: 90 Degrees
o Antenna two-way sidelobes: -40 dB
o Transmit bandwidth: 245 MHz
o Un-windowed resolution: 2 feet
o RF channels: 8
o Self-test for verifying hardware functionality
o Diagnostics mode for verifying system functionality

• The unit shall include a simple setup routine that shall automatically configure and calibrate the unit for proper operation during installation. The unit shall also be capable of being programmed and updated from a laptop computer or other portable programming device, such as a Pocket PC, via a local or remote ethernet connection using vendor supplied software. The software shall support TCP/IP connectivity, unit configuration back-up and restore, and Real-time traffic visualization for performance verification and traffic display. The graphical user interface shall operate on a Windows platform.

• The unit shall have two half-duplex RS-485 communication ports and shall have the ability to upgrade firmware over any communication port.

• The unit shall be mounted directly to a pole or mast arm, as recommended by the manufacturer. Cable(s) shall be provided as required and recommended by the manufacturer.

• Surge protection devices, as recommended by the manufacturer, shall be included both at the pole where the unit is located to protect the unit and in the traffic cabinet to protect the cabinet electronics.

• Power shall be provided from the traffic cabinet. The unit shall consume less than 10 Watts and operate from a DC input between 9 VDC and 28 VDC. Complete and automatic recovery from a power failure shall be within 15 seconds after resumption of normal power.

• All required inputs cards shall be included in the traffic cabinet and shall be compatible with CalTrans, NEMA TS1 and NEMA TS2 detector racks. The cards shall provide true presence detector calls or contact closure to the traffic controller.

• The manufacturer's representative shall be on site during installation and testing and shall provide onsite training on the setup, operation, and maintenance of the unit.

• The unit shall come with a 2-year manufacturer supplied warranty.

Payment for Item 633 Stop Bar Detection Radar shall be made at the contract unit price for each unit, complete and in place including all required cabinet hardware, mounting brackets, cables, conduit and connections tested and accepted.

**Designer Note:** This note may be used when stop line detection is included in the plans.

**442-44 633 Controller Unit, Type 2070L, As Per Plan**

The controller unit shall be equipment manufactured in conformance to the California Department of Transportation (Caltrans) specifications titles “Transportation Electrical Equipment Specifications (TEES).” The controller unit, Model 2070L, shall be model and build version listed on the ODOT QPL.

The 2070L controller unit shall include the following:
1. Unit Chassis
2. 2070-1B CPU module
3. 2070-2A Field I/O Module
4. 2070-3B Front Panel
5. 2070-4A Power Supply
6. 2070-7A Serial Communication Module
The controller shall be supplied without traffic signal intersection control software. The controller shall be supplied with Microware Embedded OS-9 Release 1.3 or later with kernel edition #376 or later, as required by Caltrans TEES. For warranty purposes, a vendor-specific decal, as per ODOT CMS 733.02 shall be applied to items 1 through 4 of the list above at time of delivery to the project.

The controller shall be shipped by the Contractor to the ODOT Signal Shop, 1606 West Broad Street, Columbus, Ohio 43223, either directly or via the ODOT District Office, a minimum of 14 days in advance of when the software is needed. ODOT will install the local intersection control software. The controller will then be performance tested by the ODOT Signal Shop. Every effort shall be made to have loading and performance testing completed by the ODOT Signal Shop within 2 weeks of receipt of an individual controller; larger groups of controllers submitted at the same time may take longer. Should any controller fail this performance test after being loaded with ODOT-licensed software, the software will be removed by the ODOT Signal Shop and the controller rejected. Rejected controllers will be returned, either directly to the Contractor or to the ODOT District Office. Controllers passing the performance test will be labeled by the ODOT Signal Shop with the OS Image Number, CPU serial number, Software Revision Number, and upload date. This label is not to be removed by the Contractor and serves as proof that the controller has been loaded, tested and approved for initial installation on the project. Such proof does not alter the required 10-day Performance Test outlined in CMS Sections 632 and 633.

The Contractor shall not reassign the cabinet detector inputs in order to reduce the number of 2-channel detector units supplied, but shall use the standard Caltrans Input File designations.

**Designer Note:** This note should be used at signalized intersections using Type 2070L local controllers that are to be owned and maintained by ODOT.

**442-45 632 Signal Support, Mechanical Damper for TC-81.21 Mast Arm (Greater Than 59' in Length), As Per Plan**

This item shall consist of the Contractor installing a tuned mechanical stockbridge or mass-spring type damper on a TC-81.21 mast arm signal support to reduce the possibility of harmonic vibrations caused by wind loads. A mechanical damper shall be applied to all mast arms over 59 feet in length. The installed damper shall be capable of reducing the loaded maximum vertical movement at the tip of the arm to 8 inches measured from the highest to the lowest point of deflection at wind speeds of 5-20 mph.

All attachment hardware connections shall be stainless steel. Stockbridge-type dampers shall have a stainless steel safety chain anchored to the mast arm to prevent weights from falling should they become separated from the rest of the assembly. The damper shall be attached to the arm within 8 feet of mast arm tip. Installation shall be per the manufacturer’s guidelines. Static dampers such as horizontal flat sign mountings shall not be used. Acceptable devices include the following or approved equal:

1. Union Metal Alcoa Damper Device – DWG. NO. 2G-1817-C1
2. Valmont Structures Alcoa Device – DWG. NO. OH104242P1

Payment for Item 632 “Signal Support, Mechanical Damper for TC-81.21 Mast Arm (Greater Than 59’ in Length), As Per Plan” shall be made at the contract unit price per each complete and in place, and shall include all labor, materials, and equipment necessary to complete the work.

**Designer Note:** This note is required on all projects installing TC-81.21 Mast Arms greater than 59 feet in length.
In addition to provisions of the ODOT CMS, furnish and install signal poles as specified in the plans.

The signal support designer shall provide drawings of a signal support with structural aspects of the design and materials in compliance with the 2001 AASHTO Standard Specifications, with 2006 Interim Revisions, for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. The signal support shall be ASTM A595 Grade A with a minimum yield strength of 50 ksi. The following design parameters shall be used:

1. Basic Wind Speed = 90 mph
2. Design Life = 25 years
3. Fatigue Category = III
4. Galloping: No
5. Truck Induced Gust: No

Submit, to the Engineer prior to incorporation: two copies of the signal support drawings and shop drawings, which identify and describe each manufactured signal support and signal support item which is being incorporated into the construction. The signal support drawings and shop drawings shall each be reviewed, sealed, stamped, and dated by two Ohio registered Professional Engineers.

Payment for Item 632 “Signal Support, (By Type), As Per Plan” shall be made at the contract unit price per each complete and in place, and shall include all signal support design, labor, materials, and equipment necessary to complete the work.

**Designer Note:** This note is required on all projects where non-standard signal supports are included in the plans.

The Contractor shall remove existing messenger wire lashing rods and reinstall them as necessary for the installation of any new cables on the existing intersection signal spans. The cables shall enter the existing strain pole through the pole cable entrance fitting and use the existing conduit system to get to the controller cabinet. The new cables shall be supported by a new cable support assembly at the top of the strain pole.

The new signal cables shall be bid by separate bid items.

Payment for Item 632 "Signalization Misc.: Unlash and Relash Messenger Wire" shall be made at the contract unit price per per foot and shall include all labor, materials, cable support assemblies and equipment to install new cables on existing signal span wire installations.

**Designer Note:** This note is intended for use on projects where unlashing and relashing the messenger wire is required in the plans. Typical use would be for a traffic signal retrofit, where a new signal head and associated cables are to be added to the existing span.

This item consists of installation and testing of FAA L-864-compliant obstruction lighting for marking of structures over 150 feet. Location and wiring shall be as shown in the Bridge Plans. Each obstruction lamp shall utilize Light Emitting Diodes (LEDs). The obstruction lamp shall have a written minimum 5-year manufacturer warranty. The lamp shall be ETL verified to FAA Advisory Circular AC150/5345-43F, Type L-864 and shall be one of the following or approved equal:

1. Specialty Tower Lighting Model RB-LED
2. International Tower Lighting Model IFH-1710
Each obstruction lamp shall have its own controller, housed in its own metal enclosure accessible by maintenance personnel standing at floor level. The controller shall operate at 120VAC, 60Hz and have its own dedicated circuit breaker in a nearby panelboard as detailed in the Bridge Plans. The controller shall produce the appropriate FAA-required flashing rate, and the obstruction lamp shall operate continuously twenty-four (24) hours per day, with no intervening photocell control. The controller shall provide at least one unused alarm status output in the form of a dry-contact or solid-state relay closure that responds to defective or inoperative obstruction lamp conditions. At least one relay with complete contacts (Normally Open, Normally Closed, and Common) shall be provided. Alarm relay contact ratings shall be at least 500 mA resistive at 120VAC/30VDC. The controller shall provide at least one visible alarm status indicator for lamp failure indication. This indicator shall be in the form of a panel-mounted red dome-type LED visible from the outside of the enclosure.

The controller enclosure shall utilize a vertically hinged, swing-open door, and be rated NEMA 3R, minimum. Enclosure shall include at least one commercial grade NEMA 5-15 receptacle to accommodate wireless communication equipment to be installed later by ODOT for alarm status monitoring. An integral shelf shall be provided for this equipment inside the enclosure, and shall provide an open, accessible space for equipment measuring at least twelve (12) inches wide, eight (8) inches deep, and six (6) inches in height.

The Contractor shall fully test the system and arrange for acceptance inspection of the Obstruction Lighting installation by ODOT District signal maintenance personnel after the system is operational. During acceptance inspection, the Contractor shall demonstrate the proper operation of all lamps and alarms. Contractor shall provide written manufacturer warranty and all operating manuals for obstruction lighting controller and lamp to ODOT District signal maintenance personnel at the time of inspection.

The Department shall measure LED FAA Type L-864 Obstruction Lighting by each individual obstruction light, complete and installed including any control devices and all wiring and conduits.

**Designer Note:** Although obstruction lighting is thought of as an incidental bridge item, this note appears in the TEM as a 632 Item because bridge lighting maintenance typically falls to District signal and lighting electricians. FAA regulations require daily visual monitoring of obstruction lighting by the operator (ODOT) if they are not equipped with automatic monitoring. Very fast notification and response times are required for repair of malfunctioning obstruction lights. The use of LED lighting significantly reduces ODOT’s maintenance operations and provides much better reliability by eliminating the frequent outages and routine lamp changes associated with obstruction lights using older incandescent lamp technology. The use of cellular modems for automatic monitoring is recommended and is coordinated through the Office of Traffic Engineering.

442-49 632 Signalization, Misc.: Bridge-Mounted Marine Navigation Lighting, LED

This item consists of installation and testing of IALA/AISM-compliant, U.S. Coast Guard approved marine navigation lighting for marking of structures over navigable waters. Location and wiring shall be as shown in the Bridge Plans.

Each marine navigation lamp shall utilize Light Emitting Diodes (LEDs). The marine navigation lamp shall have a written minimum 5-year manufacturer warranty. The lamp shall meet the color, brightness (range), sectoring, and divergence requirements as shown in the Plans and approved by the applicable Coast Guard District. The lamp shall be manufactured by one of the following manufacturers or an approved equal:

1. Tideland Signal Corporation, Houston, TX
2. B&B Roadway, Russellville, AL
Each marine navigation lamp shall have its own controller/power supply, housed in its own metal enclosure accessible by maintenance personnel, as shown on the Bridge Plans. The controller shall operate at 120VAC, 60Hz and have its own dedicated circuit breaker in a nearby panelboard as detailed in the Bridge Plans. The marine navigation lamp shall operate continuously twenty-four (24) hours per day, with no intervening photocell control. The controller shall provide alarm status output in the form of a blue LED confirmation light visible to ODOT maintenance personnel from deck level to indicate defective or inoperative marine navigation lamp conditions.

The Contractor shall fully test the system and arrange for acceptance inspection of the Marine navigation Lighting installation by ODOT District signal maintenance personnel after the system is operational. During acceptance inspection, the Contractor shall demonstrate the proper operation of all lamps and alarms. Contractor shall provide written manufacturer warranty and all operating manuals for marine navigation lighting controller and lamp to ODOT District signal maintenance personnel at the time of inspection.

The Department shall measure Bridge-Mounted Marine Navigation Lighting by each individual marine navigation light, complete and installed including any control devices and all wiring and conduits.

**Designer Note:** Although marine navigation lighting is thought of as an incidental bridge item, this note appears in the TEM as a 632 Item because bridge lighting maintenance typically falls to District signal and lighting electricians. The use of LED lighting significantly reduces ODOT's maintenance operations and provides much better reliability by eliminating the frequent outages and routine lamp changes associated with marine navigation lights using older incandescent lamp technology.

### 442-50 633 Controller Unit, Type 170E, with Cabinet, By Type

In addition to the requirements of CMS 633 and 733, the following requirements shall also apply:

1. Controller units shall be equipment manufactured in conformance with the California Department of Transportation (CalTrans) specifications titled “Transportation Electrical Equipment Specifications.” The manufacturer of the controller units shall be listed on the CalTrans QPL.
2. All circuit boards shall be vertically mounted. Ribbon cables, if used, shall terminate with properly rated and easily repairable connectors on each end. Ribbon cables shall not terminate onto plug-in modules.
3. The power supply shall be modular and easily removable from the chassis.
4. The unit shall contain separate input and output modules.
5. The controller unit shall include a Model 412C Program Module with the memory configuration for the software either shown in the plans or as provided by the maintaining agency.
6. All memory, microprocessor and ACIA devices shall be socket mounted. Sockets shall have machined beryllium copper contacts with gold plating.

Two controller unit manuals with schematics shall be supplied with each controller unit.

Controllers shall be warranted for a period of 60 months or for the manufacturer’s standard warranty, whichever is greater. The warranty period shall begin on the date of shipment to the project. Each unit shall have a permanent label or stamp indicating the date of shipment.

Payment for Item 633 Controller Unit, Type 170E, with Cabinet, By Type shall be made at the contract unit price per each controller unit with software, all required auxiliary
equipment, loop detector units and a prewired cabinet, with all items completely wired and tested. Ground mounted cabinets will include anchor bolts and conduit ells for installation in the foundation. Pole mounted cabinets will include pole mounting hardware.

**Designer Note:** This note may be used when the maintaining agency wishes to use 170E type controllers.
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ODOT specifications for the furnishing and installation of traffic signal equipment are contained in the following CMS sections, Supplemental Specification and Supplements.

- 625 and 725 Trench, conduit, ground rods and pull boxes
- 632 and 732 Traffic signal equipment
- 633 and 733 Traffic signal controllers

**Supplemental Specifications 840 and 940** address Fiber Optic Cable and Components.

**Supplement 1048** covers the prequalification procedure for loop detector sealant.

**Supplement 1063** addresses signal construction personnel requirements.

**Supplement 1076** covers the prequalification procedure for conflict monitors used with 2070 controllers.

**Supplement 1094** defines the certification procedure for signal support and strain pole fabricators.

**Supplement 1095** covers the prequalification procedure for Model 242 DC Isolators.

**Supplement 1097** covers the prequalification procedure for LED vehicular and pedestrian signal lamps.

CMS sections, the Supplemental Specification and Supplements related to specific traffic signal items are referenced individually as they are discussed in this Manual.

Information on the CMS may be viewed on-line at [http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/2010CMS.aspx](http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/2010CMS.aspx) and information on Supplemental Specifications and Supplements may be viewed at [http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/ProposalNotesSupplementalSpecificationsandSupplements.aspx](http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/ProposalNotesSupplementalSpecificationsandSupplements.aspx).
450 CONSTRUCTION

450-1 General

Information in this Chapter is intended to serve as a guide for construction personnel where the contractor furnishes and installs traffic control devices and appurtenances. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures for the various type traffic control devices are outlined, mainly in the form of check lists to assist project personnel in performing their duties. This information points out the various important features of each device and references the applicable specification or standard drawing. Illustrations are used for easy recognition of the device or feature being discussed.

All CMS Item 632 and 633 devices should be checked against the Qualified Product List before they are incorporated into a project. This list may be viewed on-line at: http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/QPL.aspx.

For purposes of this Chapter, see CMS 101.03 for definitions of the terms “contractor” and “engineer.”

450-2 Foundations

See Section 250-3 for additional information relative to concerns in the installation of foundations for poles and controller cabinets.

450-3 Electrical Appurtenances

450-3.1 General

This section will be used to provide additional information about various electrical appurtenances involved in the traffic signal installations, such as pull boxes, conduit and ground rods.

450-3.2 Pull Boxes

Pull boxes shall be of the specified sizes (see SCD HL-30.11 and the plans), typically 18 inches or 24 inches, and the specified material.

The word on the cover should be “TRAFFIC” when the pull box is part of a traffic signal system unless the plans require the word “ELECTRIC” or other marking. The word shall be formed on the surface or displayed on an attached metal plate in accordance with CMS 725.06, 725.07, 725.08 or 725.12.

The location of pull boxes shall be as shown on the plans. However, pull boxes in low drainage areas may be adjusted to eliminate drainage problems, or feasible methods of positive drainage may be used in accordance with CMS Item 611 and details on SCD HL-30.11, with the approval of the engineer.

Pull boxes located in sidewalks, traffic islands and curbed areas close to the roadway, where wide turning vehicles could drive over them, may be adjusted to eliminate the problem, or a concrete pull box with a heavy duty lid may be used with the approval of the engineer.

450-3.3 Trench

Trenching shall be in accordance with CMS 625.13 and as shown in Figure 498-7. Any change in dimensions will require approval by the engineer.
Trenching may be in earth or in paved areas, according to plan details. Trenching and subsequent restoration of surfaces in paved areas shall be in accordance with SCD HL-30.22. Trenching work in paved areas shall be divided into two pavement depths for payment; less than 6 inches and 6 inches or greater, as described in CMS 625.22.

The trench in paved areas may be 4 inches wide when cut by a Vermeer type trencher. In this case, the trench shall be backfilled with concrete full depth, except that the bottom 4 inches above the conduit may be CMS 625.13 tamped backfill.

450-3.4 Conduit

Metal conduit shall comply with CMS 725.04, with sizes according to the plans. It shall be made from domestically produced steel, and the domestic steel content of the conduit shall be certified by the manufacturer or supplier before it is approved for installation.

The routing of loop detector wire in conduit through curb or under shoulder shall be as shown on SCD TC-82.10.

Conduit containing cable and/or wire shall have the terminal at the high end completely sealed in an approved manner, with removable sealing compound or a molded plastic or rubber device compatible with the conduit, cable jacket and wire insulation, according to CMS 625.12.

After placement, a conduit which will not have cable or wire pulled into it during construction shall have a pull wire installed in it, and the terminal at the high end shall be sealed with removable sealing compound, a molded plastic or a rubber device, according to CMS 625.12.

Difficult pulling and possible jacket skinning may occur when an attempt is made to install too many cables or wires within a given conduit. The reason could be design error in new systems or attempts to insert an excess number or size of cable or wire in existing conduit.

Good electrical practice requires that the combined cross section of all cables and wire within a conduit should be less than (or equal to) 40 percent of the conduit inside area:

\[
a_1 + a_2 + a_3 + \text{etc.} \leq 0.40C_i
\]

\[
a = \text{cable or wire across section area, sq. in. (mm}^2)\]

\[
C_i = \text{conduit inside area, sq. in. (mm}^2)\]

A calculation can be made using the above formula. The cross section area of conduit, cable and wire is shown in Table 497-1.

450-3.5 Ground Rod

A ground rod shall be driven below groundline near the foundation of every strain pole and
overhead sign or signal support whether there is power in the vicinity or not, as shown on
SCDs TC-21.20, TC-32.10 and TC-32.11.

Ground rods shall comply with CMS 725.16 and be installed in accordance with CMS 625.16.
A ground wire of insulated 600-volt No. 4 AWG 7-strand soft drawn copper shall be attached
by an exothermic weld. The typical exothermic weld procedure is described in Section 450-
3.6. Insulating varnish shall be applied to the weld and any exposed conductor.

450-3.6 Exothermic Weld

The following procedure is typical and may be used unless the manufacturer’s instructions
differ.

1. The end of the ground wire shall be in an unflattened, unbent, clean and dry condition to
   assure a good weld.
   a. Bent and out-of-round conductor wire will hold the mold open causing weld material
      leakage. A cable cutter should be used to make undeformed ends. If a hacksaw is
      used, the insulation should first be peeled, as the saw tends to coat the cable with
      plastic material which must be cleaned off.
   b. Corroded cable shall be cleaned. Oily or greasy cable should be cleaned with a
      solvent that dries rapidly and leaves no residue. Very greasy cable can be “cooked
      out” by dipping into molten solder.
   c. Wet cable can cause the blowing of molten metal out of the mold, and the cable
      should be dried by a hand torch or a quick drying solvent such as alcohol.

2. Ground rod ends which have been mutilated in driving can hold the mold open and
   should be cut off. Rod ends shall be clean and dry.

3. The weld mold shall be clean before use. Damp or wet molds can cause porous welds
   and should be dried by heating.

4. The cable shall be inserted into the side of the mold so the cable is 1/8 inch back from
   the center of the tap hole. The mold shall be placed on the ground rod so the cable sits
   on top of the rod (see Figure 498-8). A clamp or locking pliers should be used on the rod
   to keep the mold from sliding down during the welding process, and the conductor should
   be marked at the mold surface so it can be verified that the conductor has not shifted
   before the weld is made.

5. The steel disk shall be inserted into the crucible and the cartridge contents poured on top,
   being careful that the disk is not upset. The cartridge should be tapped when pouring, to
   make sure the starting powder comes out and spreads evenly over the welding powder.
   A small amount of starting powder should be placed on the top edge of the mold under
   the cover opening for easy ignition.
   a. The proper cartridge size is marked on the mold tag and is the approximate weight of
      the powder in grams.
   b. If the proper cartridge size is not available, two or more small cartridges or part of a
      larger cartridge can be used.

6. The mold cover will be closed and the starting powder ignited with a flint gun. If it is
   necessary to hold down the cover during the flash of igniting powder, a long tool should
   be used and the hand should be kept away.
450-4 Power Service for Traffic Signals

450-4.1 General

Power service for traffic signals shall comply with SCD TC-83.10 and the plans. It shall consist of the equipment needed to provide a pole-attached wiring raceway and disconnect switch, for use with separately furnished power cable routed from the service point to the controller cabinet. As shown in Figure 498-9, unless otherwise specified, the equipment includes a weatherhead, a conduit riser with necessary fittings and attachment clamps when required, and a disconnect switch with enclosure (CMS 632.24).

A thorough review of the plans should be made to determine that the specific requirements of the maintaining agency for power service have been satisfied.

A ground wire shall be used as shown on SCD TC-83.10, leading to a ground rod installed in accordance with Section 450-3.5.

The LB type fitting under the controller cabinet (SCD TC-83.10) may have to be installed before erecting the pole because of interference with the foundation.

450-4.2 Electric Meter Base

When required, an electric meter base shall be furnished by the applicable utility and installed by the contractor as part of the power service work.

450-4.3 Conduit Riser and Weatherhead

Power cable is the only type cable or wire permitted through the power service conduit riser.

The conduit riser shall terminate at the meter base, if used; otherwise, termination shall be at the switch enclosure. From there conduit connection to the controller cabinet is as shown on the plans. Conduit connection could be: (a) immediately to the controller cabinet on the same pole; (b) downward by underground conduit and possibly a pull box to a nearby foundation-based controller cabinet; or (c) upward by another riser on the pole to spanwire and a remote cabinet location.

The conduit riser shall comply with CMS 725.04 and the plans, and the weatherhead shall be threaded aluminum or galvanized ferrous metal (CMS 732.16). Risers on painted poles shall be painted to match the poles.

450-4.4 Disconnect Switch

The disconnect switch shall be a UL listed single-throw safety switch or circuit breaker, meeting the voltage and capacity requirements of the specifications. The amperage rating of the fuse or circuit breaker shall be 5 to 10 amperes greater than the peak load rating of the equipment service. The enclosure shall be a UL listed water tight lockable stainless steel NEMA Type 4, supplied with UL listed conduit hubs, and the enclosure shall contain a solid neutral bar normally grounded to the enclosure (CMS 732.21).

450-5 Pole and Support Inspection - General

See Sections 250-4.2 through 250-4.4 for information about pole and support inspection.

450-6 Traffic Signal Supports

450-6.1 General

This Section is used to provide additional information about traffic signal supports. Various
types of overhead signal supports are also depicted in Table 497-4.

450-6.2 Strain Pole Type Support

Strain poles shall comply with the certified drawings, SCD TC-81.10 and the plans. They shall be galvanized unless paint is specified in the plans, and the general features should be inspected in accordance with Section 250-4.2.

Strain poles shall be tapered tubes with a cross section which is circular or a regular polygon of six or more sides.

Strain poles used to support traffic signals or signs (SCD TC-17.10) shall be furnished with one or more span wire clamps with shackles for attachment of messenger wire (see SCD TC-84.20). Only messenger wire may be attached by wrapping twice around the pole and securing with a three-bolt clamp, as shown in SCD TC-84.20, when used on round, tapered steel strain poles. The tether wire shall not use the alternate wrap method.

Erection of these poles shall be in accordance with the general procedure given in Section 250-4.6, except as noted in this section.

For the initial rake of strain poles, leveling nuts shall be adjusted to provide a rake of one-eighth to one-half inch per foot of pole in the direction opposite to the contemplated span wires and are to be made snug tight. Further adjustment may be necessary to assure that the strain poles are essentially vertical after the application of span wire load.

450-6.3 Single Arm Support

Single arm supports shall comply with the certified drawings, SCD TC-81.21 and the plans. General features of the support shall be inspected in accordance with Section 250-4.2, and except as noted in this section, erection of the support shall be in accordance with the general procedure given in Section 250-4.6.

Welds shall be inspected according to Section 250-4.3 and the galvanizing inspected according to Section 250-4.4.

For arms of two telescoping pieces, a 15 inch overlap is required. The overlapped arms shall be secured with a stainless or galvanized steel through-bolt with hex head or nut(s).

Arm caps shall cover at least 50 percent of the end area (CMS 732.11).

An arm clamp with clevis shall be furnished at each signal position, as well as a hole with a rubber grommet for the outlet of signal cable.

The installation of small signs and their attachment to the arms should be checked. Any possible interference between swinging signals and signs should also be checked.

Blind half couplings shall be located on the pole of the support for mounting pedestrian signal heads or controller cabinets when required by the plans.

Signal heads shall be installed with a clearance above pavement elevation at the center of the roadway of 16 to 18 feet. Drop pipes should be used only when necessary to maintain the clearance between 16 to 18 feet. If the clearance without a drop pipe will be over 18 feet, the engineer will, in consultation with the maintaining agency, direct the use of drop pipes or waive the maximum clearance requirement for each head.

Initial rake shall be adjusted so that under the load of signals, the pole will assume an essentially vertical position and the arm rise be within the limits specified on SCD TC-81.21, i.e., 3 inches minimum and 30 inches maximum. Under ice load, signals shall not drop below
16 feet above the pavement.

450-7  **Sag and Vertical Clearance**

*Figure 498-13* illustrates sag guidelines and vertical clearance standards for traffic signals.

450-8  **Signal Span Messenger Wire and Appurtenances**

450-8.1 General

This Section is used to provide additional information about signal span messenger wire and appurtenances.

Note that tether wire is distinct from messenger wire. Messenger wire supports a significant vertical load. Tether wire does not and is used to prevent swinging of hanging items.

450-8.2 Signal Messenger Wire and Cable

Messenger wire and accessories shall comply with SCD TC-84.20 and CMS 732.18. Messenger wire diameter shall be in accordance with the plans.

The height at which the messenger wire is to be attached to the pole will, in some instances, be shown on the plans. In cases where this is not shown, the contractor is responsible for determining the proper attachment height. This determination shall consider the relative elevation of pavement to pole foundation top, the desired clearance between pavement and the bottom of each signal, i.e., 16 to 18 feet, the sag in the messenger wire, and the height of each signal.

Alternate methods of attaching messenger wire to strain poles may be used, as follows:

1. Span wire clamp with clevis, anchor shackle and thimbles on the messenger wire, or

2. Messenger wire wrapped twice around the strain pole and secured with a three-bolt clamp of the proper size, when used on round, tapered strain poles.

If the messenger wire attachment to strain poles makes use of the alternative with pole clamps and anchor shackles, the wire is to be hooked through the shackle using a thimble and secured with a three-bolt clamp. A preformed guy grip shall not be used for messenger wire attachment at the pole. Guy grips of the proper size may be used at bull rings (aerial corners).

Thimbles with a correct groove size for the messenger wire (or the wire and eye of guy grips) are to be used at anchor shackles and bull rings. When three-bolt clamps are used, the wire tail is to be served as shown in *Section 450-8.3*. See *Section 450-8.4* for the installation procedure for preformed guy grips.

Messenger wire sag shall comply with CMS 632.22 and *Section 450-7*.

The signal cable shall be attached to the messenger wire by lengths of preformed lashing rod. The lashing rod shall be the proper internal diameter to snugly hold the cable, but not cut into its jacket. See *Section 450-8.6* for further information.

A drip loop shall be formed in the signal cable at each weatherhead, and should extend at least 6 inches below the weatherhead (*see Figure 498-14*).

Cables or groups of cables up to a maximum of four, hanging within pole interiors, shall have their strain relieved by cable support assemblies as described in *Section 450-8.7, Figure 498-14* and SCD TC-84.20.
450-8.3 Messenger Wire Served Ends

Messenger wire may be attached to various accessories by looping the wire to make an eye.

The wire end shall be secured by a three-bolt clamp, and the cut wire end or tail shall be “served” with construction wire or clamped with a sleeve device as shown on SCD TC-84.20. The following illustrations show both serving methods for the wire tail:

![Serving With Wire Diagram](image)

450-8.4 Preformed Guy Grips

Preformed guy grips are made of helically shaped high-strength steel wire. They are available in sizes fitting the outside diameters of messenger wire and form an eye permitting attachment to various accessories.

As shown in SCD TC-84.20, they should be used at bull rings of span wire aerial corners (see the following illustration). Thimbles are used in the eye of grips in accordance with standard details in the SCD.

![Serving With Strand Sleeve Diagram](image)

Grips are installed on an end of the messenger wire by wrapping a first leg of the grip to the messenger wire. In most cases, the accessory to which the grip is to be attached must be inserted in the eye of the grip with a thimble before the second leg of the grip is wrapped. The second leg is then applied to the combined first leg and messenger wire. The following illustrations show the wrapping sequence:
Guy grips shall not be used on messenger wire used for span wire sign supports. In this application, wind load on the signs can cause failure of the grips (see SCD TC-17.10(3)). Guy grips shall not be used for attachment to signal strain poles (SCD TC-84.20(5)).

**450-8.5 Cable and Wire**

In certain instances, the plans will assign a color code usage for each cable, or a typical usage by color code. All connections should be made observing these assignments, and any deviations, if determined necessary, should be recorded. When a color code usage is not provided, good electrical wiring practice would still dictate that color code wiring on the project be consistent. Typically, white is reserved for the neutral or common leg of a circuit. The following provides additional information about various types of cable and wire contained in CMS Table 732.19-1:

1. **Signal cable** is used as the electrical connection between signal heads and the controller cabinet at an intersection. The cable may be either IMSA 19-1, which has a jacket of polyvinyl chloride, IMSA 20-1, which has a polyethylene jacket. The number of conductors and wire gauge shall be as specified on the plans. Conductors shall be of copper and stranded, and conductor insulation shall be color coded. Splices are not permitted in signal cable (CMS 632.23), and the cable should be scanned to be sure that there are none. As temperatures decrease, signal cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing and installing. The method of measurement of signal cable is shown in Figure 498-16.

2. **Interconnect cable** is used as the connection between intersections for systems of signals (although there is no significant difference between signal and standard interconnect cable). The cable may be either IMSA 19-1 or IMSA 20-1 as in signal cable, or twisted pair/shielded interconnect cable conforming to RUS PE-39 may be required by the plans.

3. Twisted pair/shielded cables are less prone to pick up induced current as a result of nearby electrical devices or magnetic fields, and are necessary for certain types of communication systems which may be used to interconnect signals. The number of conductors and wire gauge shall be as specified. It should be noted that in the case of twisted pair/shielded cable, the number of conductors is typically referred to as the number of pairs (pair count), i.e., six-conductor cable would be referred to as a three-pair cable. Conductors shall be of copper and are usually solid.

4. **Interconnect cable of the integral messenger type** is aerial self-supporting cable with a "figure 8" cross section. The cable may be either IMSA 19-3, which has a jacket of polyvinyl chloride, or IMSA 20-3, which has a polyethylene jacket. Shielded versions, IMSA 19-4 and IMSA 20-4, may be required by the plans. The number of conductors and wire gauge shall be as specified. Conductors shall be of copper and stranded, and conductor insulation shall be color coded.
5. Twisted pair/shielded interconnect cable of the integral messenger type conforming to RUS PE-38 may also be required by the plans.

6. Loop detector wire is laid in turns in saw slots cut into the pavement and routed by the groove to the edge of pavement and to a pull box. The wire is single-conductor No. 14 AWG. The conductor shall be of copper and stranded. Loop detector wire consists of detector wire inserted into a flexible plastic tubing (CMS 732.19) meeting specifications IMSA 51-5. The tubing shall encase the wire completely from the splice at the lead-in cable through the entire loop turns and back to the splice.

7. Lead-in cable for detector loops is spliced to loop wire and routed to detector units in the controller cabinet. The cable shall be two-conductor No. 14AWG meeting specifications IMSA 50-2. Each conductor shall be stranded copper. The conductor pair shall be twisted and shielded.

8. Power cable is used as the connection between the service pole or service drop and the controller cabinet. The cable normally is two-conductor and UL:RHH/RHW/USE type. The wire gage shall be as specified. Conductors shall be color coded, of copper and stranded. When specified, power cable may be three conductor. Single conductor cables may be substituted for a two (or three) conductor cable, but color coding should still be provided.

9. Service cable is used to bring power to the vicinity of an isolated intersection. The cable is normally two-conductor (duplex) and XHHW type or cross-linked polyethylene with a 0.045 inch minimum jacket. The wire gage shall be as specified. The cable is aerial self-supporting with one conductor being an uninsulated ACSR (aluminum conductor, steel reinforced) messenger wire. An insulated conductor of stranded aluminum is twisted around the messenger. Stranded copper with an AWG one gage higher (wire one size smaller) may be substituted for the aluminum conductor. Three-conductor (triplex) may be specified where two insulated conductors are twisted around the messenger wire. The uninsulated messenger serves as the grounded neutral of the power supply.

10. Ground wire is used to connect signal or sign supports to ground rods. The wire shall be single-conductor No. 4 AWG made of seven-strand soft drawn copper with white insulation and rated at 600 volts. The wire is used as part of the Ground Rod item (see 625.16 Grounding).

450-8.6 Lashing of Overhead Cable

A preformed helical lashing rod shall be of the proper internal diameter to tightly secure overhead cable(s) to the messenger wire. A lashing rod should not be loose or so tight as to be impressed deeply or cut into the cable jacket. If either deficiency is observed, the proper internal diameter may be determined by the following formula: $C \approx (0.85) (D+m)$, where $C$ is the lashing rod internal diameter, $D$ is the cable jacket diameter and $m$ is the messenger wire gage (all dimensions in inches).

For groups of several cables of varying diameter, the internal diameter of the lashing rod may be best determined by a graphic layout to scale.

Signal cable routed on messenger wire should neatly pass the bull rings in its path. Also, signal cable routed around an aerial corner formed in the span wire at a bull ring should have a radius in its routing small enough to form a tangency with the bull ring.
450-8.7 Cable Support Assemblies

As shown in Figure 498-14, a cable support assembly makes use of a flexible tubular wire mesh device called a cable grip which has a gentle holding action over its length and which is used to eliminate strain or damage to the jacket of cable(s) hanging in the interior of poles. The support assembly consists of the grip attached to a single “U” eye support bale and a sling when necessary. The grip may be used on an individual cable or a group of cables up to a maximum of four (CMS 632.21). The grip shall be the proper size and strength for the cable(s), of stainless steel or tin coated bronze, and may be either a “closed” or “split with rod” type. The split type is used when a cable end is not available. In this application, the grip mesh is not a continuous tubular weave, but is split for wrapping around the cable(s) and is secured by a rod which is inserted through alternate weaves at each side to form a tube.

The support’s bale shall be hung over the pole J-hook if sufficient length is available; otherwise, a sling shall be made of messenger wire, clamps and thimbles. The sling wire is to be passed through the bale eye, adjusted to the proper length and hung on the J-hook.

Pole interiors should be checked by removing pole caps to verify that cable support assemblies are in place, hung on the J-hook and properly adjusted to eliminate cable jacket strain.

450-8.8 Aerial Interconnect Cable

For aerial interconnect cable, the following standards and guidelines apply:

1. Aerial interconnect cable and accessories shall comply with SCD TC-84.20 (illustrated in part in Figure 498-15). Interconnect cable may be supported on separate messenger wire or be the integral messenger self-supporting type with a “figure 8” cross section, if specified on the plans.

2. Metal poles with messenger wire supported interconnect cable are to be furnished with pole clamps. The pole clamp may provide clevis(es) to which the messenger is attached and terminated, or may provide a stud to which a clamp assembly can be bolted.

3. Messenger wire ends are to be looped and secured with three-bolt clamps or a messenger vise, or a preformed guy grip dead end may be used (see Section 450-8.4). If clamps or vises are used, the wire tail shall be served (see Section 450-8.3). Thimbles with a correct groove size for the messenger wire shall be used to connect to the clevis of the pole clamp.

4. When messenger wire is to be grounded to a metal pole, a ground clamp, an insulated ground wire and a bolt tapped into the pole shall be used (also see item 10 in this section).
5. Wood poles with interconnect cable shall be fitted with through-bolts holding a clamp assembly or with a thimble eye-bolt to which the messenger may be attached and terminated.

6. The clamp assembly shall be suitable to the type of cable support, either messenger wire or self-supported cable with "figure 8" cross section. Clamp assemblies for "figure 8" interconnect cable differ slightly from those intended for use with separate messenger, inasmuch as the clamp used with "figure 8" must allow a small gap for the web of the "figure 8" cable which joins the messenger to the cable.

7. When messenger wire or "figure 8" cable is to be grounded on a wood pole, a ground clamp and an insulated ground wire stapled to the pole and covered by a molding shall be used (also see Item 10 in this section). The ground clamp used with "figure 8" cable shall be a type with teeth to penetrate the jacket over the messenger. The ground wire shall be bonded to an existing ground wire or to a ground rod.

8. Standard interconnect cable shall conform to CMS Table 732.19-1 and have the number of conductors and wire gage specified. There is no difference between standard interconnect cable and signal cable, only in the application. Interconnect cable of the shielded type may be specified in the plans. The interconnect cable should be marked with the correct nomenclature. Solid conductors are not permitted (CMS 732.19) unless specified in the plans. Splices may be used on long lengths of interconnect cable (CMS 632.23) and shall be accomplished only in weather-tight splice enclosures. Splice enclosures may be either aerially located on the messenger wire or be a pole-mounted box type (see SCD TC-84.20). Where the aerial enclosure is clamped to the span, it should be within 2 feet of a pole to improve accessibility. No measurement allowance is given for splices.

9. Aerial interconnect cable is to have a sag between three to five percent of pole spans or is to match existing utility lines.

10. Messenger wire supporting interconnect cable, and the integral messenger of self-supporting type cable, is to be grounded in cable runs at the first and last poles and on intermediate poles at intervals not to exceed 1200 feet (also see item 4 of this section for grounding on metal poles, and item 7 for grounding on wood poles).

11. As temperatures decrease, interconnect cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing and installing.

12. Standard interconnect cable may be attached to supporting messenger wire by lengths of preformed lashing rod or by spinning wire. Lashing rods shall be of the proper internal diameter to snugly hold the cable but not cut into its jacket (see Section 450-8.6).

13. Aerial interconnect cable of the integral messenger self-supporting type (with a "figure 8" cross section) shall have its wind stability increased by being twisted or spiraled once every 15 feet of span. This is done by clamping the tensioned cable to every other pole and then going to intermediate poles and twisting the cable before tightening their attachment clamps.

When the interconnect cable is attached to a pole and continues in a relatively straight line past the pole, this is an intermediate support; whereas, if the interconnect cable turns at the pole, it is a corner or turning point. Certain types of clamps may be well suited for intermediate support applications, while other designs are required for corner clamps. The clamps shown on the left side in SCD TC-84.20 are usually not suitable for corner clamps if the change of direction is more than about 10 degrees. See SCD TC-84.21 when the change of direction is more than about 10 degrees.
450-8.9 Tether Wire and Appurtenances

Tether wire and accessories shall comply with Plan Insert Sheets (PISs) 208521 and 208522 and CMS 732.185. S-hook wire diameter shall be in accordance with the strain pole Design Number, as shown in the plans.

The tether span, as shown in the standard drawings, is designed to yield under either high wind loads or vehicle snags. The S-hooks are designed to yield in a wind event, allowing the signal span to revert to a free-swinging configuration. The breakaway tether anchors are designed to release the tether in the event of a vehicle snag.

The use of a backplate and tethered span increase the frontal area of a 3-section signal head by a factor of approximately nine times that of a free-swinging signal head without backplates. Such an increase, in a design wind, will exceed AASHTO allowable stress levels in the strain pole. For this reason, it is important to provide a yielding element on the tether span that unloads the tether at the proper tether wire tension. For purposes of design, ODOT has chosen S-hook sizes based on the strain pole Design Number. The table in PIS 208521 gives the diameter of the S-hook corresponding to various pole Design Numbers. The S-hook must be galvanized mild low-carbon steel. High-strength alloy steels such as Grade 80, sometimes used for load-rated S-hooks in the rigging industry, are not acceptable. These are much too strong for the application and will overload the strain pole in a design wind.

The use of breakaway tether anchors to attach signal heads to tether wire is required. Designs which use an L-shaped clamp, as shown in PIS 208522, are acceptable. These shall be properly installed, with the cable clamped below the pinch bolt, and with the opening facing downward. This allows the tether wire to slip out in the event of a vehicle snag.

The turnbuckle used at the end of the tether span is a tensioning and leveling device, to bring the tether into its proper configuration after erection. On all spans, the tether wire must remain essentially horizontal.

The guy grip end also serves as the anchor point for the safety tie. The safety tie is an accessory feature designed to prevent the loose end of a tether span from dropping into the roadway in the event of an S-hook yield. As such, the safety tie need not be particularly strong. In the event of a strong vehicle snag, the 1/8-inch safety tie is designed to yield at a lower load than the 1/4-inch tether wire. If a full-strength safety tie matching the tether wire diameter were used, the possibility would exist of a snagged tether wire overloading the pole. Since the safety tie is small-diameter wire rope, it is specified to be stainless steel, with stainless steel hardware, to minimize corrosion.

450-9 Method of Measurement for Cable and Wire

Figures 498-16 through 498-20 illustrate the method of measurement for signal cable, interconnect cable, detector lead-in cable, power cable and service cable, respectively. CMS 632.29 also specifies the method of measurement for cable and wire.

450-10 Signal Equipment and Wiring

450-10.1 General

This Section is used to provide additional information about other signal equipment and wiring.

450-10.2 Controller Cabinet

While the layout of controller cabinets may vary, the following requirements and guidelines apply:
1. The prewired cabinet should be checked against certified drawings, the wiring diagram for the cabinet and the plans.

2. The cabinet should be fitted with a small door-in-door (police door) unless otherwise specified. The cabinet should be in good condition, revealing no evidence of damage, with its material free of cracks and pinholes. The doors and seals should fit properly. The cabinet exterior should appear as metallic aluminum unless a color is specified. The cabinet interior may be similar to the exterior or may be flat white. The method of cabinet mounting should be as shown on the plans and the cabinet should be securely mounted.

3. Cabinets equipped with solid state controllers shall be provided with a suitable number of sturdy adjustable metal shelves to mount the specified equipment and to provide the required space for designated future equipment (CMS 733.03).

4. The equipment shall be arranged for easy withdrawal and replacement, without the necessity of disturbing adjacent equipment. The permanent location of equipment within the cabinet, as well as the shelves themselves, should allow free circulation of air and not restrict airflow from fan ducts or vents. Components on shelves and devices on the door shall be arranged so that a 1 inch minimum space separates them when the door is closed. This minimum space shall not be compromised by plugs, wires, controls or similar items. Terminals and panel-mounted devices with exposed contact points located next to shelf-mounted equipment shall be provided with spacers, shelf lips or other means to assure that component units cannot be accidentally moved into contact with any exposed electrical terminal points. A minimum 4 inches clear area from the bottom of the cabinet should be reserved for the routing of cables. No shelf component or panel-mounted item shall be located in the bottom 6 inches (of cabinets, with the exception that terminal blocks only in pedestal or pole mounted cabinets may be installed as close as 4 inches to the bottom.

5. Ready accessibility should be provided for items such as load switches, flasher, relays, terminal blocks and fuses which are mounted on or plugged into panels on the cabinet back or sides. Switches, controls and indicator lights should be easily operable and visible without having to move equipment from their positions.

6. Major equipment items should bear a name plate, brand or indelible marking for identification as to type, model, catalog number and manufacturer’s name or trademark.

7. The furnished controller unit should be checked for the correct type, number of phases, and available control functions required by the plans. Controller units should be furnished with all auxiliary equipment necessary to obtain the operation shown in the plans.

8. When specified, other equipment may be a part of the prewired cabinet, such as: an on-street master, interconnection equipment, preemption equipment, video detection equipment, and special relays.

9. Furnished detector units should be checked to see if the correct quantity is installed, and the proper type used with each loop and each detector phase. When multi-channel detector units are furnished, the plans may require the provision of special cabinet wiring and an adapter harness to allow single channel detector units to be readily substituted.

10. The prewired cabinet should also be checked for the following auxiliary equipment:

   a. A forced air ventilating fan automatically controlled by a thermostat shall be furnished.

   b. A conflict monitor shall be furnished according to CMS 733.03(A.2.c.). The minimum number of monitor channels, related to the number of phases for the intersection, should conform to CMS 733.03.
c. Load switches should be provided in sufficient quantity for the interval sequence shown in the plans. The switches shall be solid state NEMA triple signal type with input indicator lamps. The minimum number of load switch sockets furnished, related to the number of phases for the intersection, shall conform to CMS 733.03.

d. A flasher (or flashers) shall be solid state NEMA type.

e. Relays required for the proper operation of the specified equipment shall be furnished.

f. Lightning protection devices shall be furnished for the protection of solid state controllers. They should be located on the incoming power line and on loop detector leads where these connect to the terminal block. Interconnect cable shall be protected by devices across each conductor and ground (see CMS 733.03(A.2.f.)).

g. A convenience outlet and lamp shall be furnished. The outlet should contain at least one standard three-wire plug receptacle of the ground-fault circuit-interrupting type. The lamp should be an incandescent type, located in the upper part of the cabinet, and controlled by a switch.

h. A main power breaker shall be furnished. The fan, convenience outlet and lamp should be wired on a branch of the AC+ power line preceding the main breaker, so that these may be operated independently of the main breaker control. This preceding branch should itself contain an auxiliary breaker rated at 15 amp.

i. A radio interference filter should be installed in the incoming AC+ power line between the main breaker and solid state equipment. If the equipment furnished does not provide signal and flasher circuit switching at the zero voltage point of the power line sinusoid wave form, filters should also be provided for the load switches and flasher.

j. A manual control cord with push button should be furnished only when the plans so require (CMS 733.03). The cord should be at least 5 feet long.

k. Switches required for the proper operation of specified equipment should be furnished and labeled as to function and setting position. The following switches should be grouped behind the small door-in-door (police door): signal shutdown switch, flash control switch and an automatic/manual transfer switch (when manual control is specified).

l. Terminal blocks should not be obstructed by other equipment. Terminal points should accept spade type wiring terminals except for incoming power terminal points which may be either the type to accept bare wire or spade terminals. Contact between adjacent terminal points may be either by bus bar or by wire jumpers with spade terminals.

11. The incoming power bus should be fed from the line side of the incoming 120 VAC power line after the circuit has passed through the main power breaker. A signal bus relay should control power to the bus supplying power for the signal load switches. The requirement for radio interference filters (CMS 733.03) should be adhered to, with the buses supplying load switches and flashers being filtered if load switches do not switch at the zero voltage point of the power line sinusoid wave form. A common terminal bus insulated from the cabinet should be furnished for the connection of the neutral wire of the incoming 120 VAC power line. This common bus should have sufficient terminal points to accommodate all potential cabinet wiring as well as field wiring. A separate common terminal, insulated from the panel, should be used for the interconnect common (if interconnection is a part of the system).
12. The cabinet should include a ground bus bar with an adequate number (at least three) of ground terminal points (CMS 733.03). This bus bar should be grounded to the cabinet.

13. Wiring bundles should be neatly arranged and grouped as to voltage and function, and they should be lashed or restrained so that they do not interfere with the access to equipment, including terminal blocks or buses. The harnesses should be of sufficient length and should be easily traced through the cabinet. All conductors should be stranded, with labeled spade type terminals or plug connectors. The wiring should be color coded, with solid white for the AC common, black for the AC line side power (AC+), and solid green or white with green stripes for the safety ground.

14. Incoming cable and wire should be identified by tags or bands (CMS 632.05). The size, material and method of tag or band identification should be in accordance with CMS 725.02, except that marking may be by indelible pen on plastic tags instead of embossed letters. The identification on the tags or bands should conform to the wiring diagram for the cabinet and its intersection, with typical abbreviations in accordance with CMS Table 632.05-1, which has been reproduced in this Manual as Table 497-2.

15. Two copies of the schematic and wiring diagram for each cabinet and its intersection should be furnished by the contractor. The diagrams are to be updated to reflect any changes made during construction. The diagrams should be neat and legible, on durable paper, and folded in a moisture-proof envelope fastened to the cabinet interior.

450-10.3 Cable and Wire Identification

As noted in CMS 632.05, cables and wires shall be identified as shown in CMS Table 632.05-1, which has been reproduced in this Manual as Table 497-2.

450-10.4 Vehicular Signal Heads and Wiring

Illustrations of the signal head visors, hangers and wiring discussed herein are presented in Figure 498-21.

1. Signal heads shall conform to the plans, CMS 732.01, SCD TC-85.20 and PIS 208522. Signal heads shall have the correct number of faces (one-way, two-way, three-way or four-way) and each face shall be made up of the correct number of optical sections (one, three, four or five). Sections shall be of the correct lens size, i.e., 8 or 12 inches, color and ball or arrow configuration. Arrow lenses shall be the 12 inch size. It should be noted that arrow lenses are made in Rights, Lefts and Throughs (up). The use of the proper arrow lens should be checked.

2. Lenses shall be aligned properly in their frames so their optical configuration directs most of the light to the forward sector.

3. As noted in Section 420-4.2, signal heads shall have a yellow or black finish, unless otherwise specified in the plan.

4. Cutaway type visors (CMS 732.01) shall be fastened to each optical section, unless open bottom tunnel visors or other types are specified, and the interior finish of the visors shall be flat black.

5. Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches should be in good working order. All openings not used for mounting purposes shall be closed by waterproof caps.

6. Five-section faces, arranged in accordance with SCD TC-85.20, PIS 208522 and the plans, are to use galvanized pipe, elbows and tubular hardware, painted to match the signal head.
7. Swinging signals shall be installed in a plumb condition. A balance adjuster should be used only when necessary to achieve plumb (CMS 632.06).

8. Swinging signals suspended from a mast arm shall be fitted with a universal hanger permitting swinging in both longitudinal and transverse directions (CMS 632.06).

9. When specified by the plans, disconnect hangers shall be used with signal heads.

10. Drop pipes, 1 1/2 inch diameter galvanized pipe, are a source of trouble and are aesthetically unattractive; therefore, they are intended to be used only when they are necessary to permit signals to be suspended above the roadway within a clearance of 16 to 18 feet. Signals supported by span wire, with sag required between 3 and 5 percent (SCD TC-84.20), shall be brought to proper clearance by adjusting the attachment height of the span wire to the poles. Because of the 2 foot clearance tolerance, drop pipes should not be necessary in most cases.

11. When the plans so specify, backplates shall be fitted to signal heads.

12. Signal cable shall be routed into the interior of heads through the entrance fitting using a grommet. The cable shall be routed to each face’s terminal block, which is typically in the yellow indication section but may be in the green section. Conductors shall be fitted with spade type terminals and shall be fastened securely to the correct terminal points. Conductors shall be identified according to the wiring diagram. Signal cable shall not be spliced, either between signals or in signal face interiors.

13. External signal cable shall to be fashioned into a drip loop extending at least 6 inches below the entrance fitting but shall not chafe on the signal.

14. Lamps shall be light emitting diode (LED) (CMS 732.04(C)). All vehicular signal lamps shall be prequalified in accordance with CMS 732.04(C).

15. Each face of a signal head shall be oriented to its approach of traffic and its locking device securely tightened. Orientation or aiming of standard signals should be done so that the maximum light intensity from a standard signal is directed slightly below the horizontal center; thus, on a level approach, the face of the signal should be essentially vertical. When an approach to a signal is on a grade, the signal may be tilted slightly to point the signal axis parallel to the grade of the approach. Horizontal aiming should orient the axis of signal display parallel to the centerline of the approach for straight approaches when the signal is over the roadway. When the approach roadway is curved, or when a signal is not over the roadway, the axis should be directed at a point on the approach which is 175 to 625 feet in advance of the intersection, the distance being dependent on the speed of approaching traffic. For convenience, O MUTCD Table 4D-2 has been reproduced as Table 497-3.

16. When a vehicular traffic signal head has been erected and faces approaching traffic, it shall either be in operation as a stop-and-go signal or a flasher, or it shall be covered or bagged. This is an O M U T C D requirement (OMUTCD Section 4D.01) and cannot be ignored. Typically, the plans will contain an item for “Covering of Vehicular Signal Heads” which will require the contractor to cover, maintain the covering, and subsequently remove the covering when the signal is ready to commence operation.

17. Normally, the plans will provide the “covering” item for each new signal head, but will not provide them for any existing heads which are to be removed. The intent is that “covering” will be necessary for the new heads until they and their associated controller and wiring have been checked by circuit testing (see Section 450-11), while any existing signals at the intersection will continue to control traffic. When the new signals are uncovered and placed in operation, the existing signals can be quickly removed. Specific
maintenance of traffic requirements in any plan may require a different means to assure the unused signals are not exposed to traffic.

**450-10.5 Optically Programmed Signal Heads**

Programmed heads *(see Section 420-4.6)* shall conform to certified drawings, CMS 732, and the plans. They are to have the correct number of optical sections making up each face. Programmed heads have many points of similarity to regular heads. **Items 2, 3, 5, 11, 12, 13, 16 and 17 of Section 450-10.4** also apply to these signal heads. For more detailed information, see publications by the manufacturer.

Each optical section shall be fitted with a visor and the interior surface of visors shall have a flat black finish.

Programmed heads shall be mounted in a manner permitting little or no motion. If mounted on a mast arm, a rigid adapter shall be used. Heads of more than three vertical sections mounted on a mast arm shall be fitted with pipe backbracing, as shown on SCD TC-85.20. The pipe shall be a minimum of 17 inches behind the signal center axis so that adequate clearance is provided for the programming procedure. If heads are supported by span wire, a tether messenger wire shall be attached to a fitting in the bottom of the signal's lower section.

Customarily the manufacturer’s representative will program the signals, but in accordance with the plans, the contractor is responsible for the correct aiming and masking of the signal so as to be visible to drivers or pedestrians only in the area indicated on the plans.

**450-10.6 Pedestrian Signal Heads**

Pedestrian signal heads shall conform to CMS 732.05, certified drawings, the plans and SCD TC-85.10. Signals shall have the correct type of light source and lettering height in accordance with the plans *(CMS 632.08)*.

Housings shall have a black finish, unless otherwise specified *(CMS 732.05)*. Visors shall be fitted over each message, except one type may have the entire face protected by a flat black sunshade fastened close to the lens. The interior surface of visors shall be flat black finish.

Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches in good working order.

Housings shall be positioned with a minimum set back of 2 feet from the curb and a height of 8 to 9 feet above the sidewalk for adequate clearance. The heads shall be oriented toward their crosswalk and locked securely in position.

Lamps for pedestrian signal heads shall be light emitting diode *(LED)* *(CMS 732.04(C))*.

Pedestrian push buttons shall conform to **Section 404-2**, certified drawings, and CMS 732.06. Push button housings shall have a yellow finish, unless otherwise specified. The push button shall be positioned 3.5 to 4 feet above the sidewalk.

Push buttons on metal poles shall be installed over a 3/4 inch maximum field drilled hole with edge protected by two coats of zinc-rich paint and a rubber grommet inserted. The push button housing curved back shall be positioned over the hole, wiring routed through to the electrical mechanism and the housing secured by stainless steel screws. Unused holes in the housing shall be plugged. Push buttons on wooden poles shall have their wiring in conduit connected to a fitting of the signal support.

Signal head supports (conduit and fittings) on wooden poles shall be grounded, using a ground clamp and an insulated ground wire stapled to the pole and covered by a molding.
If specified in the plans, pedestrian signal heads may be covered in accordance with CMS Item 632.25.

OMUTCD Section 2B.51 addresses standards for the signs used where push buttons are provided to actuate pedestrian signals. The sign legend shall conform to the plans.

450-10.7 Loop Detector Slot and Wire

Figures 498-23, 498-24 and 498-25 illustrate details related to the following discussion of loop detector slots and wiring.

1. Slots cut into the pavement forming rectangular detection loops shall be in accordance with the plans and SCD TC-82.10.

2. The slots shall be a minimum of 3/8 inch in width and shall have a minimum depth of 2 inches in concrete and 4 inches in asphaltic concrete. The maximum depth in concrete shall be 2.5 inches. SCD TC-82.10 requires that loop corners be made at a drilled or bored hole, about 1 1/4 inches in diameter, and with the same depth as the saw slot. Any sharp edges at the saw slots and the holes shall be chiseled out.

3. The slot depth shall accommodate the specified number of turns of wire laid so that the uppermost wire has a covering of at least 3/4 inch. The number of wire turns shall comply with the plans and the table in SCD TC-82.10 (also shown in Figure 498-23). A separate slot leading from the loop to the pavement edge is typically cut for each loop.

4. When permitted by the engineer, loops installed in new asphaltic concrete may be sawed and the loop wire(s) embedded with sealant in a subsurface course with subsequent covering by the surface course.

5. Some plans may specify the use of preformed loops placed on the pavement for covering by a surface course of asphaltic concrete.

6. If the problem of loop installations in brick streets is encountered, the engineer should consult with the local traffic engineer for recommendations.

7. Loop locations may be adjusted to avoid manholes. Loops should not be placed across pavement joints. Instead, lateral and longitudinal adjustments should be considered, with the approval of the engineer. If joint crossing is unavoidable or major pavement cracks are encountered, the following techniques may be used (see Figure 498-24).

   a. In Technique A, the loop wires are laid over the joint or crack within a 3 inch square or circular hole cut to slot depth. The wires are laid in an “S” shape and the hole filled with elastic joint material or asphaltic concrete.

   b. In Technique B, the slot at the joint or crack is saw cut to twice normal width and depth. The wires are laid so as to conform to the deepened slot which is injected with soft-setting butyl rubber up to the depth of the original slot. The original slot depth and the remaining perimeter of the slots are embedded with standard sealant cured to a flexible state.

   c. In Technique C, the slot at the joint or crack is enlarged. The wires are encased in a length of plastic tubing which should be large enough to loosely hold all wires and may be slit lengthwise to facilitate construction. Before placing it in the slot, the ends and the longitudinal slit are to be taped shut to prevent the entry of loop sealant. The enlarged slot is then filled with loop sealant.

8. Before loop wire is placed, all slots shall be brushed, blown clean of loose material and
9. Loop detector wire shall be single-conductor No. 14 AWG insulated wire, type IMSA 51-5 with stranded copper conductors, unless otherwise specified. The wire should be marked at intervals with the wire gage, UL label and type. The detector wire is contained inside a flexible plastic tube, as required by IMSA 51-5.

10. The correct turns of loop wire (Figure 498-23), up to a maximum of six, shall be placed in the slots, to comply with CMS 632.23 and the plans. The wire shall be pushed to the bottom of the slots with a blunt wooden tool (or equivalent) to avoid damaging the insulation.

11. The wires with tubing at the pavement edge or curb shall be led into a conduit of the size shown in SCD TC 82.10. Care should be taken to prevent excessive slack at the point where the wires enter the conduit. The high end of the conduit shall be sealed in accordance with SCD TC 82.10.

12. The detector wire shall be twisted in the conduit leading from the pavement edge to the pull box. The flexible plastic tubing shall cover the wire completely from the splice at the lead-in cable, through the entire loop turns and back to the splice. The tubing provides extra protection from abrasion and allows the wire to slide inside the tubing in case of pavement shift or cracks, thus minimizing the possibility of breakage. Since wire/tubing includes an air pocket, it will tend to float to the surface when sealant is applied to the slot. For this reason it is usually necessary to wedge short lengths of the tubing, or similar devices, into the slot to wedge down the tubing/wire. These are usually needed at 1 to 2 foot intervals.

13. The slots shall be completely filled with approved sealant and left undisturbed until cured to a flexible state. Sealants on the ODOT prequalified list shall be used, in accordance with the manufacturer’s recommendations. Materials which set up to a hard or brittle state are not acceptable.

14. Detector loops are measured as “each” loop installed and the item includes wire, pavement cutting, sealant, conduit and trenching to the pullbox.

450-10.8 Loop Detector Lead-In Cable

Unless otherwise specified, loop detector lead-in cable (CMS Table 732.19-1) shall be two-conductor No. 14 AWG twisted pair shielded, Type IMSA 50-2 with conductors of stranded copper.

Within the pull box, loop wire ends shall be joined to the conductors of the lead-in cable by soldering and covered with insulating material (see Figure 498-25). An approved, poured epoxy waterproof splice kit shall be used. It is understood that epoxy splice kits are easily damaged by freezing temperatures encountered prior to mixing. Damaged epoxy components may sometimes be recognized if either of the components has turned or is streaked milky white.

Lead-in cable shall be routed to the controller cabinet, fitted with soldered spade type terminals and fastened to the correct points of the terminal block. The lead-in cable’s shielding shall be grounded to the ground bus within the cabinet.

If a pull box is not specified on the plans, the splice between the loop wire and lead-in cable shall be made in the first entered pole or pedestal, except where the controller cabinet is mounted on the pole or pedestal. If the controller cabinet is mounted on the pole or pedestal, the loop wires may be routed directly into the cabinet and no lead-in cable is necessary.

Loop detector lead-in cable is measured in accordance with Section 450-9 and Figure 498-
18. The poured epoxy splice in the pull box is included.

450-11 Signal Performance Tests and System Checks

450-11.1 General

Traffic control signal components and the entire system shall be tested as required by various specifications to assure proper operation before acceptance. Ground rods shall be tested for satisfactory low resistance to ground. A circuit test should be performed on all conductors to make sure there are no shorts, crosses and high resistance or other improper connections. A cable insulation or megger test shall be performed on all conductors to verify the integrity of the insulation covering. All traffic control equipment in the controller cabinet should be checked for correct settings and all controls manipulated for assurance of an operable system.

Finally, the traffic control system shall successfully pass a ten-day performance test, which will give an opportunity for any hidden flaws to reveal their presence. As a final “housekeeping” check, equipment should be observed for any evidence of unattached ground wire, unlatched or unbolted doors, etc.

The results of the various tests are to be entered by the contractor on test report forms (Form 496-6) as required by CMS 632.28.

450-11.2 Ground Rod Test

All ground rods shall be tested by the contractor for earth resistance to ground, as required by CMS 632.28(B).

450-11.3 Short-Circuit Test

Before the performance of any cable insulation (megger) test or the ten-day performance test, a short-circuit test shall be performed by the contractor using a volt-ohmmeter or other approved instrument (Form 496-6 and CMS 632.28(C)). Short-circuit tests shall be conducted with all electrical loads, power sources, equipment grounds, and earth grounds disconnected (see Figure 498-28).

Signal cable routed to signal heads may be tested with connection made to the lamp sockets, but without the lamps being installed.

Each conductor shall be measured against every other conductor and ground to assure that no short-circuits, cross-circuits, or other improper connections exist. Continuity should not exist between any conductor and any other conductor including ground.

450-11.4 Circuit Continuity Test

Each circuit branch shall be disconnected and tested by the contractor for continuity by temporarily jumpering each branch at its termination and measuring the temporarily looped circuit for assurance that no open circuits exist (Form 496-6 and CMS 632.28(D)). This testing is illustrated in Figures 498-29 through 498-32. Each circuit branch should be according to plan, with no high resistance connections and with the proper identification.

Lead-in cable for loop detector wire shall be tested before and after the cable is spliced to the loop wire.

Circuit continuity of signal cable may be done by applying 120 volts to each outgoing circuit and observing that only the specific lamps are lighted.
450-11.5 Cable Insulation Test (Megger Test)

This testing is illustrated in Figures 498-33 and 498-34.

1. Each conductor of cable or wire terminating at the controller cabinet shall be tested by the contractor for insulation resistance measured to ground (Form 496-6 and CMS 632.28(E)). A listing of the resistance reading for each conductor is to be included in the test results furnished to the engineer.

2. Cable and wire insulation can be faulty but the imperfections can be easily overlooked, leading to eventual electrical failure of the wiring. Weakening of insulation properties may be caused by poor storage conditions and stress due to rough handling during installation. Dirt is especially troublesome, since it is an electricity conductor and can penetrate small cracks in the insulation.

3. Insulation testing shall be performed with all conductors disconnected from their points on the terminal block in the cabinet so there is no chance of any voltage being present, and to prevent damage to any connected equipment. One megger instrument terminal shall be attached to a termination of jumpered together ends of conductors or to the end of a single conductor cable or wire undergoing testing. The other megger instrument terminal shall be attached to the cabinet ground bus bar.

4. Insulation resistance shall be measured for the wire of roadway loops after the embedding of the wire with sealant in slots.

5. The meter pointer of the megger instrument (or equivalent indication) should be adjusted to zero and the test switch activated. Test duration should be as recommended by the instrument manufacturer.

6. The insulation resistance measured to ground for each conductor shall not be less than 10 megohms. Cable or wire not meeting this reading shall be replaced.

7. After completion of the cable insulation test, all cabinet wiring shall be connected in accordance with the wiring diagram. The contractor shall demonstrate to the satisfaction of the engineer that all circuits are continuous and operating correctly, free from shorts, crosses and unintentional grounds.

450-11.6 Functional Test

Before energizing the traffic signals the following functional checks should be made (Form 496-6 and CMS 632.28(F)):

1. The incoming AC voltage should be checked.

2. Operation of the following equipment should be checked: cabinet ventilating fan, fan thermostat, and convenience outlet with lamp (when furnished). The filter(s) used with the fan should be unobstructed.

3. Timing settings on solid state controllers should be varied over their ranges and all functions activated to verify that the controls are operable without fault.

4. Timing settings in accordance with the plans should now be entered on the controller, time clock, etc. and checked for corrections. On some projects, timing settings will be provided by the maintaining agency and are not listed in the plans.

5. An agreement should be reached with the contractor and the maintaining agency on the procedure to be followed in the event of a signal failure prior to acceptance.
6. Before signals are energized to control traffic, the maintaining agency should be notified and given an opportunity to check the installation and timing settings.

After energizing the traffic signals the following functional checks should be made. In the event the signals are controlling traffic at the time, these checks should be made with caution to protect the safety of workers, pedestrians and drivers.

1. The function of all cabinet switches should be checked, including the power on/off switch and manual control (when furnished).

2. The traffic signals (and controller indicator lights) should be observed to verify that the controller is timing consistently the intervals and phases set into the controls. A stopwatch is suggested, especially to check critical short intervals. All controller functions should be activated to verify that operation is proper.

3. The detector units should be investigated to determine which pavement loop(s) or other type sensor is associated with which unit. The visual indication of units (light, meter, etc.) should be observed to determine that each vehicle (truck, car, motorcycle, etc.) entering sensor areas is properly detected on the associated unit. All inductive loops shall have their sensitivity set to detect a small, high ground-clearance motorcycle (e.g., 200cc dual sport) at the minimum call strength indication. A loop test target equivalent to this small motorcycle can be fabricated as shown in Figure 498-27. This loop test target can be held parallel to the traveled way, with the bottom at or near ground level in the most sensitive part of the loop (close to the saw cut) to simulate the inductive signature of the desired vehicle. For bicycles, a similar loop test target may be constructed, also shown in Figure 498-27. Once the proper sensitivity is attained, the detector module may occasionally detect adjacent-lane vehicles (“splashover detection”). This is an acceptable condition in order to obtain reliable detection of small two-wheel vehicles. Properly designed and placed loops will exhibit minimal or no adjacent-lane detection, even with detector module sensitivities set for small target detection. (Additional information on loop design for detection of motorcycles and bicycles is available in Section 420-5.2.) When a detector unit is set for “presence,” a detection call should continue as long as a vehicle is positioned over the associated sensor. Concurrent with detection, the appropriate controller indicator should also exhibit the detection. Stop line loops shall be connected to separate detection channels.

4. The flasher switch should be activated to cause the signal heads to flash. Their indications should be checked to verify if they are correct. The flasher switch is then to be returned to the normal or signal mode and a check made of the resumption of normal stop-and-go-operation.

5. The conflict monitor should not be activated by normal signal operation or by the manipulation of cabinet switches. If at any time the monitor is activated, the contractor is required to determine the cause of the problem and make appropriate changes and adjustments before beginning the ten-day performance test. The contractor should test the conflict monitor by artificially causing a number of different conflicting indications and checking that at each test the monitor causes the signals to begin flashing and places the controller in a “stop timing” mode. Artificial conflict may be caused by touching a jumper wire between two load switch outputs that would signal a traffic conflict. Other methods of artificially caused conflicts may be used at the discretion of the contractor.

6. Signals which are interconnected should be observed to determine if offset relationships are maintained in accordance with settings during all periods of the day.

7. When preemption equipment is furnished as part of the cabinet installation, the proper functioning of the equipment should be checked. The equipment should be activated and observations made to determine if the required sequence of intervals and phases is called for in a correct and safe manner.
8. On projects having equipment furnished for future use only, the equipment should be checked to verify that it is properly installed and operable in a correct manner.

Some signal control equipment is intended to vary the timing patterns at different periods of the day or days of the week. To determine if these required changes are occurring at the proper times, it is necessary that observations be made to check the operation at transition times over a period of several days. The change in timing shall not be extremely drawn out or abrupt. The accuracy of time clocks and weekly programmers should be checked. Programmed changes should occur within one minute for clocks of the solid state type. No significant cumulative clock error should be noted during the ten-day performance test.

After successful completion of the ten-day performance test, and after a partial or final acceptance of a project, the contractor is to turn over to the engineer all manuals, diagrams, instructions, guarantees and related material, as required by CMS 632.05. It is recommended that the engineer list this material in the project diary as a permanent record of the transfer. The engineer should transfer the material to the maintaining agency. For ODOT-maintained signals the material should be given to the District Roadway Services Manager.

After a traffic control system project has been accepted by ODOT, the engineer should immediately notify the maintaining agency that as of a certain exact time and date, the agency is responsible for the operation and maintenance of the system.

450-11.7 Ten-Day Performance Test

Before acceptance of the traffic control system, the contractor shall furnish all personnel and equipment required to successfully operate the system continuously for ten consecutive days without major malfunction or failure (CMS 632.28(G)).

At least seven days prior to the beginning of the performance test, the contractor shall notify the engineer of the starting date. The engineer will notify the maintaining agency (CMS 632.28(G)).

The contractor shall arrange with the utility supplying the power for purchase of the energy required to conduct the test. All costs of personnel, equipment, electrical energy and incidentals required to perform the test are to have been included in the contract unit prices for the respective items tested.

Minor failures such as lamps, a single detector or an individual signal head, etc. shall be immediately replaced or repaired and will not cause restart of the test.

A major malfunction or failure, such as a master or local controller, interconnect equipment, etc. will cause termination of the test, and after replacement or repair of the malfunctioning or failed equipment, the beginning of a new ten-day test.

Items which have been repaired or which are replacements are to be monitored by the contractor for a period of ten days to provide assurance of their reliability.

The complete test results are to be furnished to the engineer on test reporting forms in accordance with CMS 625.19. The contractor is to record in the test results the beginning and end of the test, and the method and date of the correction of each fault.

The engineer should record the following events in the project diary: the date of the beginning of the ten-day performance test, a day-by-day record of faults as they occur during the test, and the date of the successful completion of the performance test.

450-11.8 Final Signal Installation Check

After all wiring is completed and all testing completed and accepted, a final inspection of the
traffic control system should be performed to assure a neat and workmanlike appearance.

1. All spare conductors should be connected to the ground bus bar in the controller cabinet.

2. All ground wires should be properly connected.

3. The spade type ends of conductors should be sound. After all testing is complete, they should be reinstalled on their correct points of terminal blocks and tightened.

4. A visual check should be made for any signs of arcing, melted insulation, etc.

5. All debris from wiring work or packaging materials should be cleaned from the bottom of cabinets.

6. Cabinet vents should be checked to assure that they are unobstructed and all filters should be clean and in place.

7. Duct sealing material shall be used to seal the conduit entering the cabinet from the base.

8. All doors on the optical sections of vehicular and pedestrian signal heads shall be closed and latched.

9. No wires or cable should be visible under the base plates of poles and pedestals.

10. The handhole covers on poles and end-frames shall be securely fastened.

11. Pedestals with transformer type bases shall have the access door securely fastened.

12. The covers on pull boxes shall be securely bolted.

450-12 Controller Change Orders

Once a project is bid with 2070, NEMA or 170 controller technologies, it is not permissible to switch to a different technology after the project bids.

This is not allowed even if it is a no cost change order. This practice circumvents the competitive bidding practice and could lead to legal action being taken against ODOT by suppliers who were not afforded the opportunity to bid on the replacement technology type.

These types of change orders are not allowed even if the local maintaining agency requests it. They need to make their preference for controller technology known during the design so that it can be competitively bid.
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460 MAINTENANCE / OPERATIONS

460-1 General

Because traffic signals by their very nature provide positive guidance to conflicting traffic movements, it is imperative that they be maintained in order for them to function reliably. The mean time before failure of a traffic signal installation can be dramatically reduced through proper maintenance practices. The consequence of poor maintenance practices are a reduction in safety to road users and an unnecessarily large exposure to liability claims. District Roadway Services personnel and signal maintenance contractors are required to perform maintenance on traffic signals according to a preset schedule.

460-2 Responsibilities

The Office of Traffic Operations (OTO) shall:

1. Staff and maintain a central repair facility for the purpose of repairing components of electrical traffic control devices.

2. Assist Districts in maintaining reasonable stock levels of all major electrical items, and their appurtenances, required for new installations and maintenance through the management of annual term contracts and spot purchase contracts.

3. Assist the Districts, through procedure manuals, training programs, inspections, and other methods, in providing quality maintenance.

The OTO Signal Shop shall:

1. Repair, check and make serviceable for installation all signal controllers, signal relays, detectors, flashers, conflict monitors and other associated items.

2. Provide the loop detectors and other miscellaneous parts to custom wire as per plan new controller cabinets purchased by the Districts or rewire/refurbish existing controller cabinets.

3. Periodically provide the Districts with technical information concerning old and new equipment, such as: a list of outdated equipment that will not be repaired by the Signal Shop, changes, problems, software updates and etc. for any equipment owned by ODOT, and other tips or tricks that may help the District personnel.

4. Distribute to the Districts, at least once per calendar year, a list of all equipment, parts, and services available from the Signal Shop.

Each District shall:

1. Maintain a stock of traffic control equipment and other spare parts sufficient for normal preventive maintenance and emergency field repairs.

2. Have a plan to support the extraordinary (i.e., severe storm damage) traffic control equipment needs of the District.

3. Evaluate, authorize and maintain records of all changes in the location or operation of electrical traffic control devices.

4. Transport defective controllers, detector relays, detectors, conflict monitors, etc., to the OTO Signal Shop (or approved contractor/vendor) for service, maintenance and repair, along with a Signal Shop Order and a tag indicating the exact type of malfunction. These units shall at all times be properly cushioned to prevent physical damage during shipping and handling.
5. Generate an “as built” drawing for each electrical traffic control device installation, including each new or upgraded intersection control beacon, school flasher or signal. The drawing shall be in MicroStation V8 or later format and shall include the following, if appropriate:

   a. Geometrics of the intersection.

   b. Materials list.

   c. Layout and location of the detectors, poles, pull boxes, cable runs, span wire, signal and pedestrian heads, controller, power service, phase diagram, detector operation, date of installation, revision block, and any other information which shows the intended operation.

   d. Changes which affect the geometrics of the intersection and/or the operation of the signal shall be added to the drawing as revisions.

These electronic files shall be accessible to the Central Office in a read-only mode. Signal drawings which exist in a raster or single element format and cannot be modified shall be digitized or converted by other means when revisions become necessary.

6. Perform appropriate engineering studies, as needed, upon which revisions in signal operations, e.g., phasing may be based. When such revisions are required, an engineering report and necessary supporting data shall be submitted for approval to the appropriate District staff person.

Some signalized intersections and/or signalized corridors may be eligible to apply for, and participate in, the Systematic Signal Timing & Phasing Program (SSTPP). See Section 1213-6 for more information about this program.

460-3 Preventive Maintenance

460-3.1 General

ODOT-maintained traffic signal installations shall be inspected a minimum of one time annually. In addition to the annual traffic signal inspection, the following routine scheduled maintenance shall be performed by either District Roadway Services section personnel or a signal maintenance contractor.

460-3.2 Traffic Control Signals and Intersection Control Beacons

Every seven years, all LED traffic control signal lamps and intersection control beacons shall be replaced. A twelve-month compliance interval shall apply to this process such that no device shall be in service for more than eight years. The entire signal head should be replaced.

Incandescent lamps shall no longer be used.

Every twelve months the conflict monitor shall be tested with an automatic conflict monitor tester.

Conflict monitors that are over ten years old need to be removed from service.

460-3.3 Other Electrical Traffic Control Devices

For School Flashers, flashing and illuminated signs, and other electrical traffic control devices:
Incandescent lamps shall no longer be used.

- Every seven years all LED lamps shall be replaced and the electrical cable and its connections in and near the signal head shall be checked.

- Every four years mercury vapor lamps shall be replaced, and all reflectors, lenses, tubes and/or lamps shall be cleaned.

### 460-3.4 Signal Support Inspection

All signal supports shall be inspected at a maximum five-year interval. New signal supports shall be inspected at the time of construction. Refer to Section 421-2 for additional information on signal support inspections.

### 460-4 As Required Maintenance

The following maintenance shall be conducted as required:

At signalized intersections, and for School Flashers and Intersection Control Beacons (overhead flashers):

1. Replace premature failure of lamps. Clean all reflectors, lenses, tubes and/or lamps.

2. Repaint painted steel poles, controller housings and signal heads as necessary to maintain good appearance and protection.

3. If required by local conditions of smoke, smog, etc., clean all reflectors, tubes and/or lamps using a mild detergent.

At flashing signs, illuminated signs, and other electrical traffic control devices:

1. Replace premature failure of lamps. Clean all reflectors, lenses, tubes and/or lamps.

2. Maintain and replace all other items as required.

Maintain all signs and pavement markings directly associated with any of these devices.

### 460-5 Malfunction Response

Each District shall seek the cooperation of the Ohio State Highway Patrol (OSHP), local law enforcement, and ODOT work crews in reporting outages and malfunction of electrical traffic control devices. The District shall provide directions for reporting malfunctions twenty-four hours a day.

Upon becoming aware of a traffic signal malfunction (i.e., single red or yellow outage, power outage, signal on flash, and other malfunctions or damage as deemed necessary), the District shall be reasonably prompt in responding at all times, including outside normal working hours. Other repairs, especially green outages, may be made when practicable.

The District shall establish procedures for addressing malfunction responses. At a minimum these shall include:

1. If necessary, notify the OSHP or other appropriate law enforcement agencies, and ask for immediate assistance with traffic control until operation can be restored to a safe condition.
2. Assure that the signal is examined by a signal electrician or other qualified individual to verify that the signal was not damaged by the outage.

3. When a response is made to a reported traffic signal malfunction, the nature and time of malfunctions and corrective action taken shall be recorded.

4. All maintenance of traffic operations shall follow the requirements of the OMUTCD and Part 6 of this Manual.

460-6 Record Retention

The District shall be responsible for retaining records on all traffic signal maintenance, installations, upgrades, transfers, and removals. These records shall be retained for seven years and then reviewed by the State Archives for possible transfer. If the State Archives determines there is no historical value, they can be destroyed. These records shall include:

1. Date of lamp replacements and a description of all other signal maintenance and repairs preformed.

2. The record response to each reported traffic signal malfunction.

3. Documentation to reflect the history of the signals, shall also be maintained for each location. Copies of the original installation and each revision shall be retained either in paper or electronic form or both.

A current signal timing chart, current “as-built” plan, current programming chart for coordination if necessary, cabinet wiring diagram, and special function device diagrams in each controller housing and in the District office. If laptop computers are used instead of paper copies, a plan for updating all the signal electrician’s laptops shall be developed by the District.

460-7 Training

The District shall be responsible for training its personnel. The Office of Training and the Office of Traffic Operations, in cooperation with the Districts, will make the necessary classes and training available. The schedule for the training classes will depend on the needs of the Districts. The following are recommended classes and training for personnel responsible for the maintenance of electrical traffic control devices:

1. International Municipal Signal Association (IMSA) Training:
   a. Work Zone Safety.
   b. Traffic Signal Technician Level I.
   c. Traffic Signal Technician Level II.


3. Electrical Safety Training

460-8 Organizational Performance Index (OPI)

The Traffic Signal Maintenance Organizational Performance Index (OPI) is intended to establish a measurable performance of the District’s traffic signal maintenance. Through the OPI process, Districts will be identified that are adhering to ODOT’s traffic signal maintenance policies, and the condition of ODOT traffic signal installations will be quantified.
The OPI provides a snapshot view of the condition of the signal installation when the inspector arrived at the intersection.

For more information on the OPI, refer to the Traffic Signal Maintenance Inspection Manual (see Section 495-2).

460-9 Signal Databases

460-9.1 General

Two enterprise data systems have been created by the IT Department for traffic-related items. PC based programs have also been developed for accessing and reporting signal information. Internet and Intranet access have been discussed and details will be worked out as the traffic signal databases evolve.

460-9.2 Traffic Signal Maintenance

This database contains the information from the Signal Inspection Form (Form 496-7) and the resulting OPI points for the measurable maintenance items. The database allows ODOT to track signal maintenance inspections.

460-9.3 Traffic Signal Inventory

This database contains detailed information about every traffic signal installation and may include: location, timing, phasing, equipment information, digital pictures, and a repair history of individual pieces of equipment. The inventory will be completely compatible with the GIS system.

460-10 Signal Inspection Items

A sample Signal Inspection Form is presented in Form 496-7. The PC based interface software will print out this form as either a blank form or with the header information filled in, if the signal installation has already been entered into the signal inventory database.

When a traffic signal installation is originally entered into the signal inventory database, an unique number will be generated by the computer system called the “ODOT signal system number.” This number will then become the primary tracking number for all information pertaining to this signal installation. The District may also retain the "signal file number" which has been in use for many years as an internal reference.

If the header information is printed out, the inspector should verify the controller and conflict monitor manufacturer and serial number for inventory purposes.

460-11 Dark Signals

ORC Section 4511.132 establishes a driver’s duties upon encountering a dark signal (signal not operating due to a power outage).

When responding to notice of a dark signal, the District has the following options available:

1. No action.

2. Generators.

3. Temporary ALL-WAY STOP signs (erected in accordance with MUTCD Section 6F.03) – If it cannot be ensured that the signal will come back in all-red flashing mode in conjunction with the temporary STOP signs, STOP signs shall not be placed at the intersection.
4. Law enforcement officer to flag traffic.

5. **ODOT** personnel to flag traffic.

The District’s response to a dark signalized intersection may be based on the following factors:

1. Utility company time estimate for repairs.
   a. Short term.
   b. Long term.

2. Power outage being wide area or localized area.

3. Number of roadway lanes or type of roadway.
   a. 2 lane and 2 lane.
   b. 4 lane and 2 lane.
   c. 4 lane and 4 lane.
   d. Freeway ramp, urban.
   e. Freeway ramp, suburban or rural.

4. Prioritized listing of intersections constructed from such factors as volume, roadway types, location, etc.

5. Law enforcement request.

The following devices are also available for responding to a dark signal. Some of these devices need to be in place before the power outage.

1. Battery back-up.

2. Signal head backplate with reflective yellow tape outline.

3. SIGNAL AHEAD sign(s).
470 OTHER CONSIDERATIONS

This Chapter is reserved for any material about other considerations that do not fit into the other Chapters in Part 4.

480 RESEARCH

This Chapter is reserved for discussion of research related to traffic control signals.

495 REFERENCE RESOURCES

495-1 General

Various reference resources that may be useful have been noted in Chapters 193 and 194.

495-2 Traffic Signal Maintenance Inspection Manual

This manual outlines the performance measures for the Organizational Performance Index (OPI) for Traffic Signal Maintenance performed by District forces. A discussion of each of the signal inspection items is also presented. This manual is available from the Office of Traffic Engineering.
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496 FORMS INDEX

496-1 Signal Support Inspection Form

Form 496-1 can be used for inspection of signal supports, as noted in Section 421-2, and is available on-line from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.

496-2 Traffic Signal Stage 3 Check List

Form 496-2 is a sample Traffic Signal Stage 3 Check List, as noted in Section 440-7.

496-3 Traffic Signal Controller Timing Chart for Actuated Signals

Form 496-3 is a sample Traffic Signal Controller Timing Chart for Actuated Signals, as noted in Section 440-7.

496-4 Traffic Signal Detector Chart

Form 496-4 is a sample Traffic Signal Detector Chart, as noted in Section 440-7.

496-5 Coordination Timing Chart

Form 496-5 is a sample Coordination Timing Chart, as noted in Section 440-7.

496-6 Report of Electrical Tests

Form 496-6 is used for reporting the results of the standard electrical tests, as noted in Sections 450-11.2, 450-11.3, 450-11.4, 50-11.5 and 50-11.6.

496-7 Signal Inspection Form

Form 496-7 is the Signal Inspection Form described in Sections 460-9.2 and 460-10.

496-8 Application to Install and Operate a Traffic Control Signal

Form 496-8 is used by village authorities to obtain permission to install and operate Traffic Control Signals as described in Section 401-6, and is available on-line from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.

496-9 Application for Approval of Traffic Control Signal Operation

Form 496-9 is the operation plan for proposed village Traffic Control Signals as described in Section 401-6, and is available on-line from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.

496-10 Permit for Operation of a Traffic Control Signal

Form 496-10 is the Traffic Control Signal Permit as described in Section 401-6, and is available on-line from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.

496-11 Application to Modify Operation of a Traffic Control Signal

Form 496-11 is for proposed modifications to village Traffic Control Signals as described in Section 401-6, and is available on-line from the OTE Forms web page at: www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx.
496-12 Right Turn Factorization Sheet

*Form 496-12* is used in the procedure described in *Section 402-5* for determining how much, if any, right-turning traffic from the minor street to remove from the signal warrant analysis. It is available on-line from the OTE Forms web page at: [www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx](http://www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx).

496-13 Example of a Completed Right Turn Factorization Sheet

*Form 496-13* is a completed example of *Form 496-12*.

496-14 Application for a Permit to Have a Special or Off-Duty Law Enforcement Officer (LEO) to Operate a Traffic Control Signal

*Form 496-14* is the Application for a Permit described in *Section 401-10*, and is available on-line from the OTE Forms web page at: [www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx](http://www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx).

496-15 Permit for a Special or Off-Duty LEO to Operate a Traffic Control Signal

*Form 496-15* is the Permit described in *Section 401-10*, and is available on-line from the OTE Forms web page at: [www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx](http://www.dot.state.oh.us/Divisions/Operations/Traffic/Pages/Forms.aspx).

496-16 Reserved for Future Use

496-17 Reserved for Future Use

496-18 Reserved for Future Use

496-19 Field Wiring Hook-Up Chart

*Form 496-19* is the Field Wiring Hook-Up Chart described in *Section 440-7*.

496-20 Example of Field Wiring Hook-Up Chart

*Form 496-20* is an example of a completed Field Wiring Hook-Up Chart.
Form 496-1. Signal Support Inspection Form

Support Information

Support Identifier: ___________________________       Date: ______________________

Route: ____________________________________            Direction: ____________________

Intersection of: ________________________________and ___________________________

Design No.: _________________________________

Support Type: _____ Strain Pole   ____ Mast Arm  _____ Sign  _____ School

____ Other: ___________________________________________________

Foundation

_____ Concrete Condition   _____ Soil Condition   _____ Anchor Bolts/Nuts

Comments: ___________________________________________________________________

__________________________________________________________________________

Support Condition

_____ Galvanized    _____ Painted    _____ Wood  

_____ Structural Members   _____ Structural Connections   _____ Down Guy

Damage? _____ Yes _____ No        Pitting? _____ Yes _____ No

Surface Rust: _____ Minimal    _____ Moderate    _____ Severe

Comments: ___________________________________________________________________

__________________________________________________________________________

Inspected by: ___________________________________    Date: ______________________

(April 20, 2012)          October 23, 2002          4-129
Form 496-2. Traffic Signal Stage 3 Check List

A. General: *Written justification required (see Section F) (DNA) - Does Not Apply

1. Are the following items being used in the project:
   a. *Optically programmed signal heads __________
   b. Mast arms __________
   c. *Thermoplastic markings (general) __________
   d. *Thermoplastic markings only at intersections __________
   e. Special control equipment
      I. Priority control __________
      II. RR preemption __________
      III. Traffic adjusted master __________
      IV. Interconnection __________: Type __________
   f. Combination supports __________
   g. Overhead lane control supports __________
   h. Are all Stage 2 comments compiled with or otherwise explained? __________
   i. Other (list): __________

2. Who is:
   a. furnishing signs __________
   b. erecting signs __________
   c. applying thermoplastic markings __________
   d. applying painted markings __________
   e. removing existing signs __________
   f. removing existing markings __________
   g. provide, maintain, remove temporary markings __________

B. Warrants

1. Have signal warrants for all intersections been resolved?

2. Are all unwarranted signals being removed? If answer is no, list intersections and agreed action at each intersection.

3. If unwarranted signals are not being removed, who is doing the upgrading and interconnecting of these signals and when will work be done?

4. Are traffic signal permits involved (i.e., is any signal within a village and on a State Route)? (Village is incorporated area with population of less than 5000.)

C. Utilities

1. Have the utility companies reviewed the plans and approved of the work in writing?

2. Are utility poles being used for interconnect?

3. Is power service by flat rate contract or meter?

4. Are disconnect switches required at power service points?

5. Will the power company run power service to the signal poles or will triplex service cable be run from power pole to signal pole as part of this project?
Form 496-2. Traffic Signal Stage 3 Check List  (Continued)

6. Are high voltage lines present in the area? 10 feet minimum clearance may be required. Check with power company for specific requirements.

7. Have proposed support locations been field checked for conflicts with overhead lines and underground facilities?

8. Do any lines go over/under railroad tracks?

D. Right-of-Way

1. Are any work agreements or easements required? (For placement of items such as loop detectors, pavement marking, etc. outside of the right-of-way limits.)

2. Are right-of-way (R/W) lines shown on signal intersection plan sheets for checking pole foundations, conduit runs, etc., and are all items within the R/W? Note: certain procedures require temporary easements, etc., even though actual construction is within the R/W (i.e., jacking conduit usually requires a jacking pit).

E. Equipment Responsibility

1. Existing signal installation - Does anyone besides contractor retain existing equipment? If answer is yes, name other parties involved.

2. Are any equipment items being reused? If yes, are these items clearly defined on plan sheets and has consultant field checked these items?

3. Has ownership of all items to be removed been established (control equipment, poles, luminaires, etc., by city, state, utility companies, etc.)?

4. Is the maintaining agency of each signal clearly discernible on the plans?

F. Justification

1. Is justification needed and who will submit it (refer to Section A)?
   a. Thermoplastic
   b. Optically programmed signal heads
   c. Combination supports (commitment on installment of lighting)
   d. Justification for proprietary items
   e. Other (list)
Form 496-3. Traffic Signal Controller Timing Chart for Actuated Signals

Intersection ________________________________________________________________

Maintaining Agency __________________________________________________________

<table>
<thead>
<tr>
<th>Start Up</th>
<th>Dual Entry O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start In: O y/r flash or O all red</td>
<td>Rest In Red: Ring 1 O</td>
</tr>
<tr>
<td>Time for Flash or All Red: ________</td>
<td>Ring 2 O</td>
</tr>
<tr>
<td>First Phases(s): * ______ &amp; *______</td>
<td>Overlap</td>
</tr>
<tr>
<td>Color Displayed O Green; O Yellow</td>
<td>A B C D</td>
</tr>
<tr>
<td></td>
<td>Phases</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interval or Feature</th>
<th>Controller Movement No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection Movement</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
<tr>
<td>Minimum Green (Initial)</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Added Initial</td>
<td>*(Sec./Actuation)</td>
</tr>
<tr>
<td>Maximum Initial</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Passage Time (Preset Gap)</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Time Before Reduction</td>
<td>*(Sec.)</td>
</tr>
<tr>
<td>Minimum Gap</td>
<td>*(Sec.)</td>
</tr>
<tr>
<td>Time To Reduce</td>
<td>*(Sec.)</td>
</tr>
<tr>
<td>Maximum Green I</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Maximum Green II</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Yellow Change</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>All Red Clearance</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Walk</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Pedestrian Clearance</td>
<td>(Sec.)</td>
</tr>
<tr>
<td>Recall</td>
<td></td>
</tr>
<tr>
<td>Maximum (On/Off)</td>
<td></td>
</tr>
<tr>
<td>Minimum (On/Off)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian (On/Off)</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>(On/Off)</td>
</tr>
<tr>
<td>Call to Non Actuated</td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td></td>
</tr>
</tbody>
</table>

* Volume Density Controls
Form 496-4. Traffic Signal Detector Chart

<table>
<thead>
<tr>
<th>Loop Designation</th>
<th>Loop Configuration</th>
<th>Size (ft, m)</th>
<th>Pulse or Presence</th>
<th>Delay (sec.)</th>
<th>Extension (sec.)</th>
<th>Override Phase</th>
<th>Connect to Detector Unit (unit-channel)</th>
<th>Associated Controller Phase</th>
<th>Terminal No.</th>
</tr>
</thead>
</table>

1. For 332/336 Cabinet
2. Configurations: Powerhead (P), Quadrupole (Q), Angular Design Detector (ADD), Rectangular (R), or Diamond (D)
### Form 496-5. Coordination Timing Chart

<table>
<thead>
<tr>
<th>Plan (cycle-secs.)</th>
<th>Splits (G+Y+AR) in seconds</th>
<th>Offset From Phase #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

1. Offsets are measured from reference phase(s) numbered “end of green/beginning of yellow”.

2. Coordination timing chart shall be in seconds only (no percentages).

<table>
<thead>
<tr>
<th>(1) TBC Plan Events</th>
<th>(2) Hours</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

1. TBC Plan Event (ex. Plan 1 Mon – Fri)
2. Hours shall be in military time (ex. 0600-0800)
3. Cycle/Split/Offset (ex. 1/1/1) or Coordination Plan Number (ex. 1)
4. Plans should be provided for each weekday for the following peak time periods: AM, Midday, PM, and Off-peak. Plans should also be provided for the weekend.
Form 496-6. Report of Electrical Tests

<table>
<thead>
<tr>
<th>DATE ___ / ___/ ___</th>
<th>SHEET ____ OF ____</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT NO. __________</td>
<td>COUNTY ______</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short Circuit Test 632.28(C)</th>
<th>Circuit Continuity Test 632.28(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Zero or Negligible Ohms Required)</td>
<td></td>
</tr>
<tr>
<td>Pairs Measured</td>
<td>Ohms</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Form 496-6. Report of Electrical Tests (Continued)

<table>
<thead>
<tr>
<th>Cable Insulation (Megger) Test 632.28(E)</th>
<th>Ground Test For Traffic Signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locations</td>
<td>Type of</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Functional Test: 632.28(F)**  OK

- **Incoming AC 120 Volts** .................................................................
- **Cabinet Fan, Thermostat, Convenience Outlet, and Lamp Operation** ........................................
- **Controller timing set as per plan or approved by the Engineer** ...........................................
- **Switches** ............................................................................................
- **Controller functions** ............................................................................
- **Detector Units detect all vehicles, including small motorcycles** ...................
- **Detector Units do not give frequent extraneous calls** ............................
- **Flash Switch Transfer** ........................................................................
- **Monitor is not activated by normal operations** ....................................
- **Monitor is not activated by manipulation of cabinet switches** ..................
- **Monitor activated by artificial conflict** ..............................................
- **Signal transfers to flash when monitor is disconnected** ..........................

*See **TEM Section 450-11.6**.
Form 496-7. Signal Inspection Form

<table>
<thead>
<tr>
<th>TRAFFIC SIGNAL FILE NUMBER:</th>
<th>LOCATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNTY AND ROUTE NUMBER:</td>
<td>ODOT SIGNAL SYSTEM NUMBER:</td>
</tr>
</tbody>
</table>

** Points: **

| DATE INSPECTED: _/__/____ | TIME REQUIRED: ||
|-----------------------------|-----------------|

** Controller Type: **

** ODOT Number:**

** Monitor Model:**

** Coordination Type:**

<table>
<thead>
<tr>
<th>INSPECTED BY:</th>
<th>TITLE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>----------------</td>
<td>-------</td>
</tr>
</tbody>
</table>

### 1 TRAFFIC SIGNAL HEAD

<table>
<thead>
<tr>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
<th>N/A</th>
<th>Repaired</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Alignment **</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Date re-lamp **</td>
<td>Date re-lamped <em>/__/</em>___</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Clearance Height**</td>
<td>Clearance Ft. <em>In.</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Condition including the following:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lens (dirty, burns, holes), lamp orientation, visors, lamps (all burning), signal head cable condition (splices/wear), Prepare to Stop When Flashing sign, above ground detection, water leaks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2 OVERHEAD SIGNAL SUPPORT SYSTEM

| Condition including the following: | |
|------------------------------------| |
| messenger wire for rust, grips, 3-bolt clamps, pole clamp bolts tight, wire entrance and pin wear, span wire signing, pole clamp assembly and clevis pin wear, lashing rods, signal cable |

### 3 CONTROLLER & CABINET

<table>
<thead>
<tr>
<th>Present &amp; Current</th>
<th>Present &amp; Not Current</th>
<th>Not Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Intersection documentation **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Conflict Monitor or MMU (6 mo. inspection) **</td>
<td>Date: <em>/__/</em>___</td>
<td></td>
</tr>
<tr>
<td>3.3 All detection operational**</td>
<td>All working</td>
<td>1 Detector Failed</td>
</tr>
<tr>
<td>3.4 Wires and cables labeled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 Cabinet sealed to foundation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6 Lock condition (including Power Service)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.7 Filter Clean (Size <em>X</em> <em>X</em> <em>X</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8 Cabinet lamp working</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.9 GFCI receptacle (test)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.10 Wire terminations tight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.11 Prepare To Stop When Flashing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.12 Load switch indicators lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.13 Preemption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.14 Cabinet earth ground (___ohms)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.15 Lightning arresters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.16 Housing conduit sealed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.17 Cabinet fan / thermostat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.18 Cabinet clean? need vacuuming?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.19 Cabinet hinges, need lubricated?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** USED IN DISTRICT OPI RATING **
Form 496-7.  Signal Inspection Form (Continued)

<table>
<thead>
<tr>
<th>Item #</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
APPLICATION FOR PERMISSION TO INSTALL/MODIFY AND OPERATE
A TRAFFIC CONTROL SIGNAL

To: District Deputy Director

District ______________

Date: ______________

In accordance with the provisions of Sections 4511.10 and 11, Ohio Revised Code, the incorporated Village of ________________ does hereby request authority to install/modify and operate a traffic control signal at the intersection of ________________ Street (State Route ________________) and ________________ Street (State Route ________________).

The enclosed traffic engineering study performed by ___________________________ and dated ________________ indicates that the proposed signal is justified by warrant(s) ________________.

This application is made with the understanding that, if approved by you, the signal will comply with the requirements as stipulated by law.

Village of ________________

County of ________________

____________________________________
(Signature of Elected Official)

TRAFFIC CONTROL SIGNAL AUTHORIZATION

To: Village of _________________________

You are hereby authorized to install or modify a traffic control signal at this intersection. This is subject to approval, by the Ohio Department of Transportation of the Village-prepared operation plan (sample attached) with the understanding that the traffic control signal will comply with the requirements of the Ohio Manual of Uniform Traffic Control Devices.

The Operations Plan should be submitted as soon as possible because this authorization will automatically expire 180 days from the date issued unless otherwise extended by the Ohio Department of Transportation at the request of the Village.

____________________________________
Date

____________________________________
District Deputy Director

Form 496-8: For a copy of this form, contact the Office of Traffic Engineering, 1980 West Broad Street, Columbus, Ohio 43223
Form 496-9. Application for Approval of Traffic Control Signal Operation

REQUEST FOR APPROVAL OF A TRAFFIC CONTROL SIGNAL OPERATION PLAN

To: District Deputy Director  Date ________________
District ____________________________
_________________________________________________________________

The traffic control signal we have proposed for the intersection of ____________________________
Street (State Route ______) and ____________________________Street (State Route ______)
would function in accordance with the attached operation plan dated ________________

Village of ___________________________
County of ___________________________
_________________________________________________________________
(Signature of Elected Official)

OPERATION PLAN APPROVAL

The operation plan has been approved/approved with modification (see explanation of modification below) and permission is hereby granted to proceed with the installation.

- Explanation of Approval With Modification -

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

__________________________ Date ____________________________
District Deputy Director

CERTIFICATION

Upon completion of the installation/modification as specified in the approved operation plan, fill in the certification below and return the attached copy to the District Deputy Director.

I hereby certify that the Village of ____________________________ has installed/modified, and will operate, the above described traffic control signal in accordance with the approved operation plan and O MUTCD standards. This signal was placed in operation on ________________.

Signed ____________________________
Title ____________________________

Form 496-9: For a copy of this form, contact the Office of Traffic Engineering, 1980 West Broad Street, Columbus, Ohio 43223
Form 496-10. Permit for Operation of a Traffic Control Signal

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
OFFICE OF TRAFFIC ENGINEERING
P.O. BOX 899
COLUMBUS, OHIO 43216-0899

PERMIT
FOR THE OPERATION OF A TRAFFIC CONTROL SIGNAL
ON A STATE HIGHWAY

Under authority of Sections 4511.10 and 11 of the Ohio Revised Code, the Director of Transportation hereby app
subject to the condition(s) and restriction(s) set forth herein, the operation of a traffic control signal
location described below:

I. Location of Signal:

II. Operation:

This traffic control signal shall be operated in accordance with the Ohio Manual of Uniform Traffic Control Devices for Streets and Highways (OMUTCD). Signal phasing and hours of operation as a stop signal or a flashing signal shall be in accordance with the latest approved schedule. Initial settings shall be as submitted with the "Request for Approval of a Traffic Control Signal Operation Plan." (Note: Signals maintained as "School Signals" or "Seasonal Signals," those signals authorized to operate only certain months of each year, shall be hooded or taken down during the period(s) such signals are authorized to operate.)

III. Village authorities are responsible for periodic review of this signal.

The right is reserved to require the timing schedule of the signal, the days upon which it is operated, the hours during which it is operated to meet the approval of the Director of Transportation. Revisi
the interval timing or hours of operation schedules shall be submitted to the District Deputy Director of Transportation. Any other aspect of the traffic control signal operation covered by this permit shall not be modified without the specific approval of the Director of Transportation, after proper application has been made by the permittee.

This permit is revocable upon thirty days notice by the Director of Transportation if in his opinion the signal is not being operated or maintained in a proper manner, or that traffic would be better served by elimination.

__________________________  ________________
Date  Director of Transportation

(April 20, 2012)  October 23, 2002  4-141
APPLICATION
TO MODIFY TIMING OR HOURS OF OPERATION
FOR A TRAFFIC CONTROL SIGNAL

To: DISTRICT DEPUTY DIRECTOR  
Date ________________________

Ref. Permit No. ________________

______________________________

______________________________

The incorporated Village of _______________ hereby requests authority to modify
the □ timing and/or □ hours of operation of the traffic control signal at the intersection of
__________________ Street (State Route ____________ ) and _______________________
Street (State Route ____________ ), as noted on the attached timing chart.

The change(s) is/are requested for the following reasons:

1. ____________________________________________________________

2. ____________________________________________________________

3. ____________________________________________________________

This application is made with the understanding that, if approved, the signal timing and hours of operation
will comply with the timing chart which will be returned with the approved change.

Village of ______________________

County of ______________________

(Signature of Elected Official)

To: Village of ______________________

The attached interval timing and hours of operation dated _____________________ are herewith
approved.

_________________________  ____________________________
DateDistrict Deputy Director

Form 496-11: For a copy of this form, contact the Office of Traffic Engineering, 1980 West Broad Street, Columbus, Ohio 43223
Form 496-12. Right Turn Factorization Sheet

<table>
<thead>
<tr>
<th>Hour</th>
<th>Left</th>
<th>Through</th>
<th>Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00-8:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:00-9:00</td>
<td></td>
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<td>9:00-10:00</td>
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<td>10:00-11:00</td>
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<td>11:00-12:00</td>
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<td>12:00-1:00</td>
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<td>1:00-2:00</td>
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<td>2:00-3:00</td>
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<td>3:00-4:00</td>
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<td>4:00-5:00</td>
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<td>5:00-6:00</td>
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</tbody>
</table>

Any Configuration with an exclusive Right Turn Lane.
Form 496-13. Example of a Completed Right Turn Factorization Sheet

<table>
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<tr>
<th>Intersection</th>
<th>Minor Street</th>
<th>Through Traffic</th>
<th>Right Turn</th>
<th>Total</th>
<th>Adjusted Right Turn</th>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>400</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td></td>
<td>200</td>
<td>10</td>
<td>10</td>
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</tr>
</tbody>
</table>

Diagram:

[Diagram of right turn configuration]
Form 496-14. Application for a Permit to Have a Special or Off-Duty Law Enforcement Officer (LEO) to Operate a Traffic Control Signal

To: District Deputy Director  Date: ______________
District ________

In order to process your application for a Permit to operate a traffic control signal, please provide the following information:

1. _______________________________________________________
   Name of Entity requesting permission to operate the traffic signal.  
   (Permittee)

2. _______________________________________________________________________
   Address

3. ____________________________________________________________
   Telephone Number, Fax Number and E-Mail Address

4. _______________________________________________________________________
   Location of Traffic Signal(s)

5. ____________________________________________________________
   Date(s) and Time(s) of Operation

The following terms and conditions apply to the permit:

1. The permit is revocable at-will and non-assignable.

2. The permit expires upon termination of the event.

3. The Permittee warrants that the traffic control signal will be operated by a special or off duty law enforcement officer with the authority to make an arrest in the jurisdiction where the traffic control signal is located.

4. The Permittee agrees to indemnify and hold harmless the Ohio Department of Transportation (ODOT) and its employees from any and against all suits, costs (including attorneys fees, expenses, and court costs) claims, expenses, liabilities and judgments of every kind and from and against all damages and expenses to which ODOT and its employees may be subject to caused by, resulting from, or arising out of the Permittee’s operation of the traffic control signal. This obligation shall survive the expiration of the permit.

5. Provide a copy of the liability insurance which will cover any damage to ODOT property as a result of operating the traffic control signal.

Signed ________________________________
Form 496-15. Permit for a Special or Off-Duty LEO to Operate a Traffic Control Signal

This permit is issued to ___________________________ (Permittee) for the purpose of operating the traffic control signal located at _____________.

This permit shall be in effect from __________ until ______________.

_______________________________________         ___ ____________
District Deputy Director            Date
Form 496-19. Field Wiring Hook-Up Chart

<table>
<thead>
<tr>
<th>SIGNAL HEAD #</th>
<th>INDICATION</th>
<th>FIELD TERMINAL</th>
<th>FLASH</th>
<th>SIGNAL HEAD #</th>
<th>INDICATION</th>
<th>FIELD TERMINAL</th>
<th>FLASH</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Electronic file available upon request. See Form 496-20 for a completed sample of this chart.
### Field Wiring Hook-Up Chart

<table>
<thead>
<tr>
<th>SIGNAL HEAD</th>
<th>INDICATION</th>
<th>FIELD TERMINAL</th>
<th>FLASH</th>
<th>SIGNAL HEAD</th>
<th>INDICATION</th>
<th>FIELD TERMINAL</th>
<th>FLASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (WBLT)</td>
<td>R</td>
<td>Ø5 R</td>
<td>R</td>
<td>12 (EB)</td>
<td>R</td>
<td>Ø6 R</td>
<td>R</td>
</tr>
<tr>
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<td>Y</td>
<td>Ø5 Y</td>
<td></td>
<td></td>
<td>Y</td>
<td>Ø6 G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>Ø5 G</td>
<td></td>
<td></td>
<td>G</td>
<td>Ø6 G</td>
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</tr>
<tr>
<td>2, 3 (WB)</td>
<td>R</td>
<td>Ø2 R</td>
<td>R</td>
<td>14 (EBRT1)</td>
<td>R</td>
<td>Ø6 R</td>
<td>R</td>
</tr>
<tr>
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<td>Y</td>
<td>Ø2 Y</td>
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<td></td>
<td>Y</td>
<td>Ø6 Y</td>
<td></td>
</tr>
<tr>
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<td>G</td>
<td>Ø2 G</td>
<td></td>
<td></td>
<td>G</td>
<td>Ø6 G</td>
<td></td>
</tr>
<tr>
<td>4 (WBRT)</td>
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<td>Ø2 R</td>
<td>R</td>
<td>15 (NBRT)</td>
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<td>Ø8 R</td>
<td>R</td>
</tr>
<tr>
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<td>Y</td>
<td>Ø2 Y</td>
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<td></td>
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<td>Ø8 Y</td>
<td></td>
</tr>
<tr>
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<td>G</td>
<td>Ø2 G</td>
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<td></td>
<td>G</td>
<td>Ø8 G</td>
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</tr>
<tr>
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<td>Y</td>
<td>Ø7 Y</td>
<td></td>
<td></td>
<td>Y</td>
<td>Ø5 Y</td>
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</tr>
<tr>
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<td>G</td>
<td>Ø7 G</td>
<td></td>
<td></td>
<td>G</td>
<td>Ø5 G</td>
<td></td>
</tr>
<tr>
<td>5 (SBRT)</td>
<td>R</td>
<td>Ø4 R</td>
<td>R</td>
<td>16 (SBLT)</td>
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<td>Ø4 R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Ø4 Y</td>
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<td></td>
<td>G</td>
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<td></td>
<td>Y</td>
<td>Ø7 Y</td>
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</tr>
<tr>
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<td>G</td>
<td>Ø1 G</td>
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<td></td>
<td>G</td>
<td>Ø7 G</td>
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</tr>
<tr>
<td>6 (NBLT)</td>
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<td>Ø3 R</td>
<td>R</td>
<td>17 (SBRT)</td>
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<td>Ø4 R</td>
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<td></td>
<td>Y</td>
<td>Ø4 Y</td>
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<td>Ø3 G</td>
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<td>G</td>
<td>Ø4 C</td>
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<td>Ø8 Y</td>
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<td></td>
<td>Y</td>
<td>Ø1 Y</td>
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<tr>
<td></td>
<td>G</td>
<td>Ø8 G</td>
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<td></td>
<td>G</td>
<td>Ø1 G</td>
<td></td>
</tr>
<tr>
<td>7 (NB)</td>
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<td>18 (NBLT)</td>
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</tr>
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<td>Ø8 G</td>
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<td>Ø3 G</td>
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<td></td>
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</tr>
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<td>G</td>
<td>Ø5 G</td>
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<td></td>
<td>G</td>
<td>Ø5 G</td>
<td></td>
</tr>
<tr>
<td>8 (NBRT)</td>
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<td>Ø4 R</td>
<td>R</td>
<td>AB (EAST)</td>
<td>W</td>
<td>OLD G (Ø8)</td>
<td>OUT</td>
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<tr>
<td></td>
<td>Y</td>
<td>Ø4 Y</td>
<td></td>
<td>CD (SOUTH)</td>
<td>W</td>
<td>OLC G (Ø6)</td>
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</tr>
<tr>
<td></td>
<td>G</td>
<td>Ø4 G</td>
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<td>EF (WEST)</td>
<td>W</td>
<td>OLB G (Ø4)</td>
<td>OUT</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Ø7 Y</td>
<td></td>
<td>DH (NORTH)</td>
<td>W</td>
<td>OLA G (Ø2)</td>
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<td>G</td>
<td>Ø7 G</td>
<td></td>
<td>OLA = LS 9</td>
<td>OLC = LS II</td>
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<td></td>
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<tr>
<td>9 (SBLT)</td>
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<td>Ø1 R</td>
<td>R</td>
<td>OL B = LS 10</td>
<td>OLD = LS 12</td>
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</tr>
<tr>
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<td>Y</td>
<td>Ø1 Y</td>
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</tr>
<tr>
<td></td>
<td>G</td>
<td>Ø1 G</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
497 TABLES INDEX

497-1 Cross Section Area of Conduit, Cable and Wire

Table 497-1 is used as described in Section 450-3.4 to size conduit based on the number and size of the conductors contained in the conduit.

497-2 Cable and Wire Identification

Table 497-2 is referenced in Section 450-10.3 and is a reproduction of CMS Table 632.05-1.

497-3 Minimum Sight Distance

Table 497-3 is referenced in Section 450-10.4 and is a reproduction of Table 4D.1 from OMUTCD, Section 4D.12.

497-4 Types of Overhead Signal Supports

Table 497-4 depicts various types of overhead signal supports and is referenced in Sections 440-3, 440-4 and 450-6.1.

497-5 Areas for Signal Heads

Table 497-5 presents areas used in Sections 440-3 and 440-4 in designing overhead signal supports.

497-6 Height from Bottom of Signal Head to Messenger Wire or Mast Arm

Table 497-6 presents the height (in feet) from the bottom of the signal head to the messenger wire or mast arm and is referenced in Section 440-5.

497-7 Minor Street Analysis Parameters – Minor Leg Lane Configurations and Right Turn Reductions

Table 498-7 presents parameters used in the procedure described in Section 402-5 for determining how many right-turning vehicles to remove from the minor street traffic in a signal warrant analysis.

497-8 Minor Street Analysis Parameters – Mainline Congestion Factors for Limiting Right Turn Reductions

Table 497-8 presents mainline congestion factors used in the procedure described in Section 402-5 for determining how many right-turning vehicles to remove from the minor street traffic in a signal warrant analysis.

497-9 Village Signal Permit Number Assignments

Table 497-9 assigns numbers to be used by Districts for Village Signal Permits (see Section 401-6).
Intentionally blank.
Table 497-1. Cross Section Area of Conduit, Cable and Wire

<table>
<thead>
<tr>
<th>Specification or Material</th>
<th>No. of Conductors AWG</th>
<th>Cross Section Area, Sq. In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMSA</td>
<td>2/C # 14</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>3/C # 14</td>
<td>.13</td>
</tr>
<tr>
<td></td>
<td>4/C # 14</td>
<td>.16</td>
</tr>
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<td>5/C # 14</td>
<td>.19</td>
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<td></td>
<td>7/C # 14</td>
<td>.22</td>
</tr>
<tr>
<td></td>
<td>9/C # 14</td>
<td>.33</td>
</tr>
<tr>
<td></td>
<td>12/C # 14</td>
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</tr>
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<td></td>
<td>18/C # 14</td>
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<td>25/C # 14</td>
<td>.82</td>
</tr>
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<td></td>
<td>2/C # 12</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>3/C # 12</td>
<td>.16</td>
</tr>
<tr>
<td></td>
<td>4/C # 12</td>
<td>.19</td>
</tr>
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<td></td>
<td>5/C # 12</td>
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<td>25/C # 12</td>
<td>1.00</td>
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<td>UL: RHH/RHW/USE</td>
<td>1/C # 14</td>
<td>.053</td>
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<td></td>
<td>1/C # 12</td>
<td>.061</td>
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<td></td>
<td>1/C # 10</td>
<td>.075</td>
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<td>1/C # 8</td>
<td>.107</td>
</tr>
<tr>
<td></td>
<td>1/C # 6</td>
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<td>.173</td>
</tr>
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<td></td>
<td>1/C # 2</td>
<td>.229</td>
</tr>
<tr>
<td>Belden</td>
<td>2/C # 14</td>
<td>.08</td>
</tr>
<tr>
<td>PE Jacket, Shielded</td>
<td>2/C # 14</td>
<td>.11</td>
</tr>
<tr>
<td>RG-6/V (COAX)</td>
<td>1/C # 18</td>
<td>.06</td>
</tr>
<tr>
<td>RG-6/V With Power (COAX)</td>
<td>1/C # 18 (COAX)</td>
<td>.16</td>
</tr>
<tr>
<td></td>
<td>2/C # 16 (Power)</td>
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</tr>
<tr>
<td>RG-8/V (Antenna Cable)</td>
<td>1/C # 10</td>
<td>.14</td>
</tr>
<tr>
<td>LDF 4-50 A (Antenna Cable)</td>
<td>1/C 0.189 in.</td>
<td>.32</td>
</tr>
</tbody>
</table>

Conduit Cross Section Area

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>1/2</th>
<th>3/4</th>
<th>1</th>
<th>1 1/4</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Diameter, in.</td>
<td>.622</td>
<td>.824</td>
<td>1.049</td>
<td>1.380</td>
<td>1.610</td>
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<tr>
<td>Inside Area, sq. in.</td>
<td>.30</td>
<td>.53</td>
<td>.86</td>
<td>1.50</td>
<td>2.04</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>2</th>
<th>2 1/2</th>
<th>3</th>
<th>3 1/2</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Diameter, in.</td>
<td>2.067</td>
<td>2.469</td>
<td>3.068</td>
<td>3.548</td>
<td>4.026</td>
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<tr>
<td>Inside Area, sq. in.</td>
<td>3.36</td>
<td>4.79</td>
<td>7.38</td>
<td>9.90</td>
<td>12.72</td>
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### Table 497-2. Cable Wire and Identification

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<th>Cable</th>
<th>Tag</th>
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<tbody>
<tr>
<td>Ground Power (2 wire) 1 120 volt</td>
<td>GND AC+ AC- or ACN</td>
</tr>
<tr>
<td>Power (3 wire) 1 120/240 volt Neutral wire</td>
<td>AC+1 AC+2 AC- or ACN</td>
</tr>
<tr>
<td>Phase A</td>
<td>φ A</td>
</tr>
<tr>
<td>Phase 1</td>
<td>φ 1</td>
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<tr>
<td>Phase 1 northbound left turn lanes</td>
<td>φ 1 NBLT</td>
</tr>
<tr>
<td>Phase A, pedestrian signal</td>
<td>φ A PD</td>
</tr>
<tr>
<td>Overlap, phase A + C</td>
<td>φ A + C</td>
</tr>
<tr>
<td>Overlap, phase 1 + 6</td>
<td>φ 1 + 6</td>
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<tr>
<td>Detector lead-in, phase A</td>
<td>DET A</td>
</tr>
<tr>
<td>Detector lead-in, phase 1</td>
<td>DET 1 NBLT</td>
</tr>
<tr>
<td>Detector lead-in, phase 1 northbound left</td>
<td>DET A CALL</td>
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<tr>
<td>Detector lead-in, phase 1 (call type)</td>
<td>DET 1 CALL</td>
</tr>
<tr>
<td>Detector lead-in, phase 1 (call type)</td>
<td>NB-THRU</td>
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<tr>
<td>Detector harness *</td>
<td>DET A</td>
</tr>
<tr>
<td>Interconnect</td>
<td>IC</td>
</tr>
<tr>
<td>Preemption, fire</td>
<td>PE FIRE</td>
</tr>
<tr>
<td>Preemption, railroad</td>
<td>PE RR</td>
</tr>
</tbody>
</table>

* For the detector harness, the tag shall be placed next to the MS plug at the detector amplifier.
Table 497-3. Minimum Sight Distance

<table>
<thead>
<tr>
<th>85th-Percentile Speed (mph)</th>
<th>Minimum Sight Distance (feet)</th>
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<tr>
<td>20</td>
<td>175</td>
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<tr>
<td>25</td>
<td>215</td>
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<td>55</td>
<td>625</td>
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Table 497-4. Types of Overhead Signal Supports

<table>
<thead>
<tr>
<th>Support Type</th>
<th>Allowable Sign Area, Sq. Ft.</th>
<th>Span or Arm Length, Ft.</th>
<th>Configuration</th>
<th>Notes</th>
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<tbody>
<tr>
<td>TC-81.21 Signal Support Single Arm</td>
<td>(Small signs may be mounted.)</td>
<td>25 to 70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC-81.21 Combination Signal Support</td>
<td>---------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC-81.10 Strain Pole &amp; Messenger Wire Supported Signals</td>
<td>(Small signs may be mounted.)</td>
<td>---------</td>
<td></td>
<td>May be used to add a highway lighting and/or signing function to TC-81.21.</td>
</tr>
<tr>
<td>TC-81.10 Combination Strain Pole</td>
<td>(Small signs may be mounted.)</td>
<td>---------</td>
<td></td>
<td>May be used to add highway lighting and/or signing function to TC-81.10.</td>
</tr>
</tbody>
</table>
Table 497-5. Areas for Signal Heads

<table>
<thead>
<tr>
<th>Signal Head Type</th>
<th>Area (Sq. Ft.)^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>1 Section</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>3 Sections</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>8.7</td>
</tr>
<tr>
<td>4 Sections</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>11.0</td>
</tr>
<tr>
<td>5 Sections - Vertical</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>13.3</td>
</tr>
<tr>
<td>5 Sections - Cluster</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>12.4</td>
</tr>
<tr>
<td>5 Sections - Mixed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.4</td>
</tr>
</tbody>
</table>

Note 1. Area includes 5-inch backplate.
Table 497-6. Height from Bottom of Signal Head to Messenger Wire or Mast Arm

### FREE SWINGING

<table>
<thead>
<tr>
<th>Signal Head Type</th>
<th>Height (Feet)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 in. Sections</td>
<td>12 in. Sections</td>
<td>12 in. Sections with Backplates</td>
</tr>
<tr>
<td>1 Section</td>
<td>1.7</td>
<td>1.9</td>
<td>-</td>
</tr>
<tr>
<td>3 Sections</td>
<td>3.7</td>
<td>4.2</td>
<td>4.7</td>
</tr>
<tr>
<td>4 Sections</td>
<td>4.7</td>
<td>5.4</td>
<td>5.9</td>
</tr>
<tr>
<td>5 Sections - Vertical</td>
<td>5.7</td>
<td>6.5</td>
<td>7</td>
</tr>
<tr>
<td>5 Sections - Cluster</td>
<td>-</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>5 Sections - Mixed</td>
<td>-</td>
<td>4.5</td>
<td>5</td>
</tr>
</tbody>
</table>

### RIGID MOUNT, CENTERED ON RED LENS

<table>
<thead>
<tr>
<th>Signal Head Type</th>
<th>Height (Feet) to Red Lens Center</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 in. Sections</td>
<td>12 in. Sections with Backplates</td>
<td></td>
</tr>
<tr>
<td>1 Section</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3 Sections</td>
<td>2.9</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>4 Sections</td>
<td>4.1</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>5 Sections - Vertical</td>
<td>5.3</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>5 Sections - Cluster</td>
<td>3.2</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>5 Sections - Mixed</td>
<td>3.2</td>
<td>3.7</td>
<td></td>
</tr>
</tbody>
</table>
Table 497-7. Minor Street Analysis Parameters – Minor Leg Lane Configurations and Right Turn Reductions

<table>
<thead>
<tr>
<th></th>
<th>IF</th>
<th>THEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IF</td>
<td>THEN</td>
</tr>
<tr>
<td></td>
<td>R &gt; 0.7A</td>
<td>Reduce R by 60%</td>
</tr>
<tr>
<td></td>
<td>0.7A ≥ R &gt; 0.35A</td>
<td>Reduce R by 40%</td>
</tr>
<tr>
<td></td>
<td>R ≤ 0.35A</td>
<td>Reduce R by 20%</td>
</tr>
<tr>
<td>2</td>
<td>IF</td>
<td>THEN</td>
</tr>
<tr>
<td></td>
<td>R &gt; 3T</td>
<td>Reduce R by 60%</td>
</tr>
<tr>
<td></td>
<td>3T ≥ R &gt; T/3</td>
<td>Reduce R by 40%</td>
</tr>
<tr>
<td></td>
<td>R ≤ T/3</td>
<td>Reduce R by 20%</td>
</tr>
<tr>
<td>3</td>
<td>IF</td>
<td>THEN</td>
</tr>
<tr>
<td></td>
<td>Any configuration with an exclusive right turn lane (usually ≥ to 600 ft. long)</td>
<td>Reduce R by 75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In all classes</td>
</tr>
<tr>
<td>4</td>
<td>IF</td>
<td>THEN</td>
</tr>
<tr>
<td></td>
<td>R &gt; (T + L)</td>
<td>Reduce R by 65%</td>
</tr>
<tr>
<td></td>
<td>L &gt; (T + R)</td>
<td>Use situation 2.</td>
</tr>
<tr>
<td></td>
<td>L = T ≈ R (± 10 veh)</td>
<td>Reduce R by 40%</td>
</tr>
<tr>
<td></td>
<td>L = T &gt; 3R</td>
<td>Reduce R by 20%</td>
</tr>
<tr>
<td></td>
<td>R = T &gt; 3L</td>
<td>Reduce R by 50%</td>
</tr>
<tr>
<td></td>
<td>All other classes</td>
<td>Reduce R by 30%</td>
</tr>
<tr>
<td>5</td>
<td>IF</td>
<td>THEN</td>
</tr>
<tr>
<td></td>
<td>R &gt; T</td>
<td>Reduce R by 75%</td>
</tr>
<tr>
<td></td>
<td>T ≥ R &gt; T/2</td>
<td>Reduce R by 50%</td>
</tr>
<tr>
<td></td>
<td>T/2 ≥ R &gt; T/4</td>
<td>Reduce R by 30%</td>
</tr>
<tr>
<td></td>
<td>R &lt; T/4</td>
<td>Reduce R by 15%</td>
</tr>
</tbody>
</table>

Legend:
L = number of left-turning vehicles
R = number of right-turning vehicles
T = number of through vehicles
A = (L + T + R)
Table 497-8. Minor Street Analysis Parameters – Mainline Congestion Factors for Limiting Right Turn Reductions

<table>
<thead>
<tr>
<th>Volumes per Lane</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 399</td>
<td>0%</td>
</tr>
<tr>
<td>400 – 499</td>
<td>5%</td>
</tr>
<tr>
<td>500 – 599</td>
<td>10%</td>
</tr>
<tr>
<td>600 – 699</td>
<td>15%</td>
</tr>
<tr>
<td>700 – 799</td>
<td>20%</td>
</tr>
<tr>
<td>800 – 899</td>
<td>25%</td>
</tr>
<tr>
<td>900 – 999</td>
<td>30%</td>
</tr>
<tr>
<td>1000 – 1099</td>
<td>35%</td>
</tr>
<tr>
<td>1100 – 1199</td>
<td>40%</td>
</tr>
<tr>
<td>1200 – 1299</td>
<td>45%</td>
</tr>
<tr>
<td>1300 – 1399</td>
<td>50%</td>
</tr>
<tr>
<td>1400 – 1499</td>
<td>55%</td>
</tr>
<tr>
<td>1500 – 1599</td>
<td>60%</td>
</tr>
<tr>
<td>etc.</td>
<td>etc.</td>
</tr>
</tbody>
</table>

*Mainline = Approach with right-turns turn into
Table 497-9. Village Signal Permit Number Assignments

<table>
<thead>
<tr>
<th>Districts</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>District 1</td>
<td>1200 - 1699</td>
</tr>
<tr>
<td>District 2</td>
<td>1700 - 2199</td>
</tr>
<tr>
<td>District 3</td>
<td>2200 - 2699</td>
</tr>
<tr>
<td>District 4</td>
<td>2700 - 3199</td>
</tr>
<tr>
<td>District 5</td>
<td>3200 - 3699</td>
</tr>
<tr>
<td>District 6</td>
<td>3700 - 4199</td>
</tr>
<tr>
<td>District 7</td>
<td>4200 - 4699</td>
</tr>
<tr>
<td>District 8</td>
<td>4700 - 5199</td>
</tr>
<tr>
<td>District 9</td>
<td>5200 - 5699</td>
</tr>
<tr>
<td>District 10</td>
<td>5700 - 6199</td>
</tr>
<tr>
<td>District 11</td>
<td>6200 - 6699</td>
</tr>
<tr>
<td>District 12</td>
<td>7000 - 7499</td>
</tr>
</tbody>
</table>
Intentionally blank.
498 FIGURES INDEX

498-1 Emergency Traffic Signal Guidelines

*Figure 498-1* illustrates the cross-corner sight distance criteria suggested for use in reviewing requests for Emergency Traffic Signals, as described in *Section 406-3*.

498-2 Local Government Agency/Utility Force Account Work

*Figure 498-2* illustrates the process for administering force account work by a local government agency or utility to an active construction project.

498-3 Suggested Loop Placement for High-Speed Mainline vs. Large-Volume Side Street

*Figure 498-3* illustrates suggested loop detector placements as described in *Section 420-5* for the intersection of a high-speed mainline with a large-volume side street.

498-4 Suggested Loop Placement for High-Speed Mainline vs. Ramp/T Intersection

*Figure 498-4* illustrates suggested loop detector placements as described in *Section 420-5* for the intersection of a high-speed mainline with a ramp or T intersection.

498-5 Suggested Loop Placement for High-Speed Mainline vs. Low-Speed Side Street

*Figure 498-5* illustrates suggested loop detector placements as described in *Section 420-5* for the intersection of a high-speed mainline with a low-speed side street.

498-6 Concrete Pull Box

*Figure 498-6* illustrates a concrete pull box as described in *Section 450-3.2*.

498-7 Trench Details

*Figure 498-7* illustrates details of the different types of trench that are described in *Section 450-3.3*.

498-8 Exothermic Weld

*Figure 498-8* illustrates the equipment used for an exothermic weld as described in *Section 450-3.6*.

498-9 Power Service

*Figure 498-9* illustrates the mounting details for the power service components as described in *Sections 440-2 and 450-4*.

498-10 Strain Pole Supports

*Figure 498-10* illustrates details for signal strain poles as described in *Section 450-6.2*.

498-11 Strain Pole Attachment Details

*Figure 498-11* illustrates details for the attachment of span wires to a signal strain pole as described in *Sections 450-6.2 and 450-8*. 
498-12 Single Arm Support

*Figure 498-12* illustrates a mast arm signal support as described in *Sections 440-3 and 450-6.3*.

498-13 Sag and Vertical Clearance Diagram

*Figure 498-13* illustrates sag and vertical clearance and is referenced in *Section 450-7*.

498-14 Cable Support Assembly

*Figure 498-14* illustrates the use of a cable support assembly to relieve cable strain inside of a pole as described in *Sections 450-8.2 and 450-8.7*.

498-15 Aerial Interconnect Cable

*Figure 498-15* illustrates attachment details for aerial interconnect cable as described in *Section 450-8.8*.

498-16 Method of Measurement for Signal Cable

*Figure 498-16* illustrates the calculation method for the measurement of signal cables as described in *Sections 450-8.5 and 450-9*.

498-17 Method of Measurement for Interconnect Cable

*Figure 498-17* illustrates the calculation method for the measurement of interconnect cable as described in *Sections 450-8.5, 450-8.8 and 450-9*.

498-18 Method of Measurement for Detector Lead-In Cable

*Figure 498-18* illustrates the calculation method for the measurement of detector lead-in cables as described in *Sections 450-8.5, 450-9 and 450-10.8*.

498-19 Method of Measurement for Power Cable

*Figure 498-19* illustrates the calculation method for the measurement of power cable as described in *Sections 450-8.5 and 450-9*.

498-20 Method of Measurement for Service Cable

*Figure 498-20* illustrates the calculation method for the measurement of service cable as described in *Sections 450-8.5 and 450-9*.

498-21 Vehicular Signal Heads

*Figure 498-21* illustrates the hardware and wiring for signal heads as described in *Section 450-10.4*.

498-22 Pedestrian Signal Heads

*Figure 498-22* illustrates the mounting of pedestrian signal heads as described in *Section 450-10.6*.

498-23 Loop Detector Placement and Installation

*Figure 498-23* illustrates the installation details for loop detectors as described in *Section 450-10.7*. 
498-24 Loop Detector Slots and Wiring

*Figure 498-24* illustrates the installation details for loop detectors as described in *Section 450-10.7*.

498-25 Loop Detector Wiring

*Figure 498-25* illustrates miscellaneous wiring details for loop detector wiring as described in *Section 450-10.8*.

498-26 Magnetometer Probes and Lead-In

*Figure 498-26* illustrates installation details for magnetometer probes as described in *Section 450-10.9*.

498-27 Vehicle Loop Test Targets

*Figure 498-27* illustrates the test targets described in *Sections 420-5 and 450-11.6*.

498-28 Short-Circuit Test

*Figure 498-28* illustrates the connections for the short-circuit test as described in *Section 450-11.3*.

498-29 Circuit Continuity Test of Loop Wire (Before Splice to Lead-In Cable)

*Figure 498-29* illustrates the connections for the continuity circuit test on loop detector wire as described in *Section 450-11.4*.

498-30 Circuit Continuity Test of Loop Wire and Lead-In Cable

*Figure 498-30* illustrates the connections for the continuity circuit test for the entire loop wire and lead-in cable installation after splicing as described in *Section 450-11.4*.

498-31 Circuit Continuity Test of Signal Cable Disconnected from Heads or Other Cable

*Figure 498-31* illustrates the connections for the continuity circuit test for signal cable disconnected from the signal heads and other cables as described in *Section 450-11.4*.

498-32 Circuit Continuity Test of Signal Cable With Cable Connected to the Signal Heads and Lamps Installed

*Figure 498-32* illustrates the connections for the continuity circuit test for signal cable connected to the signal heads with lamps installed as described in *Section 450-11.4*.

498-33 Cable Insulation Test (Loop Detector Wire)

*Figure 498-33* illustrates the connections for the cable insulation test for loop detector wire as described in *Section 450-11.5*.

498-34 Cable Insulation Test (Signal Cable)

*Figure 498-34* illustrates the connections for the cable insulation test for signal cable as described in *Section 450-11.5*.

498-35 Reserved for Future Use
498-36 Plan Details for Strain Poles

*Figure 498-36* presents a sample angle orientation chart for signal strain pole (SCD TC-81.10) appurtenances as described in *Section 441-8*.

498-37 Plan Details for Signal Supports - Arm Lengths

*Figure 498-37* presents a sample chart for mast arm signal supports (SCD TC-81.21) appurtenances as described in *Section 441-8*.

498-38 Plan Details for Signal Supports - Mast Arm Orientation

*Figure 498-38* presents a sample angle orientation chart for mast arm signal support (SCD TC-81.21) appurtenances as described in *Section 441-8*.

498-39 Example of Wire Size for Equipment Grounding Conductor – PTSWF with Pedestrian Indications

*Figure 498-39* presents an example of wire size for equipment grounding conductor as described in *Section 442-32*.

498-40 Example of Wire Size for Equipment Grounding Conductor – PTSWF without Pedestrian Indications

*Figure 498-40* presents an example of wire size for equipment grounding conductor as described in *Section 442-32*.

498-41 Example of Wire Size for Equipment Grounding Conductor – Mast Arms

*Figure 498-41* presents an example of wire size for equipment grounding conductor as described in *Section 442-32*.

498-42 Example of Wire Size for Equipment Grounding Conductor – Span Wire

*Figure 498-42* presents an example of wire size for equipment grounding conductor as described in *Section 442-32*.

498-43 Dilemma Zone Graph

*Figure 498-43* presents a graphical representation of the dilemma zone drivers face when approaching a signalized intersection.
### Figure 498-1. Emergency Traffic Signal Guidelines

#### Minimum Cross Corner Sight Distance

<table>
<thead>
<tr>
<th>Approach Speed (MPH)</th>
<th>Distance “S”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 ft</td>
</tr>
<tr>
<td>25</td>
<td>230</td>
</tr>
<tr>
<td>30</td>
<td>280</td>
</tr>
<tr>
<td>35</td>
<td>330</td>
</tr>
<tr>
<td>40</td>
<td>370</td>
</tr>
<tr>
<td>45</td>
<td>420</td>
</tr>
<tr>
<td>50</td>
<td>460</td>
</tr>
<tr>
<td>55</td>
<td>510</td>
</tr>
<tr>
<td>60</td>
<td>560</td>
</tr>
</tbody>
</table>
Figure 498-2. Local Government Agency/Utility Force Account Work

1. Submission to District
2. Evaluate
3. Draft Agreement and Send to Agency for Signature
   - If Required, Send to FHWA for Approval.
4. Send to Contract Sales for Director’s Signature and Encumberance No.
5. Return Copy of Signed Agreement and Formal Approval to Local Agency or Utility
6. Work Performed
7. Billings Submitted to District
8. Reviewed by District
9. Submit to Business & Human Services Administrator for Payment
Figure 498-3. Suggested Loop Placement for High-Speed Mainline vs. Large-Volume Side Street (1 of 4)
(For better legibility, portions of this sample layout have also been shown separately.)

Sample Page Layout
Figure 498-3. Suggested Loop Placement for High-Speed Mainline vs. Large-Volume Side Street (2 of 4)
**Figure 498-3.  Suggested Loop Placement for High-Speed Mainline vs. Large-Volume Side Street (3 of 4)**

**LOOP DETECTOR CHART**

<table>
<thead>
<tr>
<th>LOOP</th>
<th>CONFIGURATION</th>
<th>SIZE (FT (m))</th>
<th>Ø</th>
<th>AM NO.</th>
<th>DELAY (SEC)</th>
<th>MODE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-2</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-3</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-4</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-5</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-6</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-7</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-8</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-9</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>5</td>
<td>3 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-10</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>6</td>
<td>presence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-11</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>7</td>
<td>10 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-12</td>
<td>ADD/QUAD¹</td>
<td>variable</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-13</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>8</td>
<td>3 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-14</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>9</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-15</td>
<td>ADD¹</td>
<td>SEE BELOW²</td>
<td>10</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-16</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>11</td>
<td>3 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-17</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>12</td>
<td>10 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-18</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8)²</td>
<td>13</td>
<td>3 presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Configuration Terms: ADD= Angular Design Detection; QUAD= Quadrupole
2. For size information see Standard Construction Drawing TC-82.10. (L)=Length, variable as needed, maximum 35 feet.

<table>
<thead>
<tr>
<th>X FT (m)</th>
<th>SPEED (MPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450 (135)</td>
<td>60</td>
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<tr>
<td>400 (120)</td>
<td>55</td>
</tr>
<tr>
<td>350 (105)</td>
<td>50</td>
</tr>
<tr>
<td>300 (90)</td>
<td>45</td>
</tr>
<tr>
<td>250 (75)</td>
<td>40</td>
</tr>
</tbody>
</table>
Figure 498-3. Suggested Loop Placement for High-Speed Mainline vs. Large-Volume Side Street (4 of 4)

**MAIN LINE LOOP NOTES**

(A) L1 through L8 are used to extend main-line green. L1, L2, L7 and L8 are placed to mitigate high-speed dilemma zone conflicts. L3, L4, L5, L6 and L15 are used to mitigate lower speed dilemma zone conflicts.

(B) For permitted phasing, L13, L15 and L16 can be used to extend mainline green. The designer should look at turn volumes, capacity analysis and traffic patterns to determine if it is desirable to extend mainline green with left-turn traffic. If it is not desirable, L13 and L16 can be omitted.

(C) For protected turn phasing, L13, L15 and L16 are used to call and extend protected (turn arrow) phases. NOTE: It is possible to switch detector outputs (detector switching) in order to use L13 and L16 to extend the mainline green phase (permitted) after the protected turn phase has terminated.

(D) L13 and L16 can be placed 30 to 50 feet behind the stop line if protected/permitted phasing is used (3rd vehicle detection).

**SIDE STREET LOOP NOTES**

(A) L9, L10, L11, L17 and L18 are used to call and extend the side street green phases.

(B) L9 and L18 can be used to call and extend both the protected and permitted phases as described in (B) and (C) under mainline loop notes.

(C) L9 and L18 can be placed 30 to 50 feet behind the stop line if protected/permitted phasing is used (3rd vehicle detection).
Figure 498-4. Suggested Loop Placement for Mainline vs. Ramp/T Intersection (1 of 4)
(For better legibility, portions of this sample layout have also been shown separately.)

Sample Page Layout
Figure 498-4. Suggested Loop Placement for Mainline vs. Ramp/T Intersection (2 of 4)
Figure 498-4. Suggested Loop Placement for Mainline vs. Ramp/T Intersection (3 of 4)

**LOOP DETECTOR CHART**

<table>
<thead>
<tr>
<th>LOOP</th>
<th>CONFIGURATION</th>
<th>SIZE FT (m)</th>
<th>Ø</th>
<th>AMP NO.</th>
<th>DELAY (SEC)</th>
<th>MODE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-2</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-3</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-4</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-5</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-6</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-7</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-8</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-9</td>
<td>POWERHEAD (L)x6 (6.1x1.8 )²</td>
<td>5</td>
<td>3</td>
<td>presence</td>
<td>NOT delay inhibited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-10</td>
<td>POWERHEAD (L)x6 (6.1x1.8 )²</td>
<td>6</td>
<td>10</td>
<td>presence</td>
<td>NOT delay inhibited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-11</td>
<td>ADD †</td>
<td>SEE BELOW²</td>
<td>7</td>
<td>3</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-12</td>
<td>POWERHEAD (L)x6 (6.1x1.8 )²</td>
<td>8</td>
<td>3</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Configuration Terms: ADD = Angular Design Detection
2. For size information see Standard Construction Drawing TC-82.10. (L)=Length, variable as needed, maximum 35 feet.

<table>
<thead>
<tr>
<th>SPEED (MPH)</th>
<th>X FT</th>
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<td>60</td>
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<td>45</td>
<td>300</td>
</tr>
<tr>
<td>40</td>
<td>250</td>
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</table>
Figure 498-4. Suggested Loop Placement for Mainline vs. Ramp/T Intersection (4 of 4)

MAIN LINE LOOP NOTES

(A) L1 through L8 are used to extend main-line green. L1, L2, L7 and L8 are placed to mitigate high-speed dilemma zone conflicts. L3, L4, L5 and L6 are used to mitigate lower speed dilemma zone conflicts.

(B) For permitted phasing, L12 can be used to extend mainline green. The designer should look at turn volumes, capacity analysis and traffic patterns to determine if it is desirable to extend mainline green with left-turn traffic. If it is not desirable, L12 can be omitted.

(C) For protected turn phasing, L12 is used to call and extend protected (turn arrow) phases. NOTE: It is possible to switch detector outputs (detector switching) in order to use L12 to extend the mainline green phase (permitted) after the protected turn phase has terminated.

(D) L12 can be placed 30 to 50 feet behind the stop line if protected/permitted phasing is used (3rd vehicle detection).

RAMP/T INTERSECTION LOOP NOTES

(A) L11 is located at the designer’s discretion. Typical placement is for a 35 mph design speed. This reflects the slowing conditions at a ramp/T intersection.

(B) L9 and L10 are placed on delay. After the delay time has expired, these loops call the ramp/"T" intersection green phase. The delay time for these loops is not inhibited. This keeps L9 and L10 from extending the green phase.

(C) L11 is on delay. This prevents the loop from calling the green phase. Once the green phase arrives (called in by L9 and L10), the loop is delay inhibited. This allows L11 to extend the ramp/"T" intersection green phase.
Figure 498-5.  Suggested Loop Placement for High-Speed Mainline vs. Low-Speed Side Street (1 of 4)
(For better legibility, portions of this sample layout have also been shown separately.)

Sample Page Layout
Figure 498-5. Suggested Loop Placement for High-Speed Mainline vs. Low-Speed Side Street (2 of 4)
Figure 498-5. Suggested Loop Placement for High-Speed Mainline vs. Low-Speed Side Street (3 of 4)

**LOOP DETECTOR CHART**

<table>
<thead>
<tr>
<th>LOOP</th>
<th>CONFIGURATION</th>
<th>SIZE FT (m)</th>
<th>Ø</th>
<th>AMP NO.</th>
<th>DELAY (SEC)</th>
<th>MODE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-2</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>1</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-3</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-4</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>2</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-5</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-6</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>3</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-7</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-8</td>
<td>ADD³</td>
<td>SEE BELOW⁴</td>
<td></td>
<td>4</td>
<td>pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-9</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>5</td>
<td>10¹</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-10</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>6</td>
<td>3²</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-11</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>7</td>
<td>3²</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-12</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>8</td>
<td>10¹</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-13</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>9</td>
<td>3²</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
<tr>
<td>L-14</td>
<td>POWERHEAD</td>
<td>(L)x6 (6.1x1.8 )⁴</td>
<td>10</td>
<td>3²</td>
<td>presence</td>
<td>delay inhibited during green phase</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Large delay used to give vehicles a chance to turn right on red.
2. Small delay used to keep left turning vehicles from other street crossing/clipping loop and putting in errant calls.
3. ADD= Angular Design Detection
4. (L)= length, variable as needed, maximum 35 feet.

<table>
<thead>
<tr>
<th>X FT</th>
<th>SPEED (MPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>60</td>
</tr>
<tr>
<td>400</td>
<td>55</td>
</tr>
<tr>
<td>350</td>
<td>50</td>
</tr>
<tr>
<td>300</td>
<td>45</td>
</tr>
<tr>
<td>250</td>
<td>40</td>
</tr>
</tbody>
</table>
Figure 498-5. Suggested Loop Placement for High-Speed Mainline vs. Low-Speed Side Street (4 of 4)

MAIN LINE LOOP NOTES

(A) L1 through L8 are used to extend main-line green. L1, L2, L7 and L8 are placed to mitigate high-speed dilemma zone conflicts. L3, L4, L5 and L6 are used to mitigate lower speed dilemma zone conflicts.

(B) For permitted phasing, L13 and L14 can be used to extend mainline green. The designer should look at turn volumes, capacity analysis and traffic patterns to determine if it is desirable to extend mainline green with left-turn traffic. If it is not desirable, L13 and L14 can be omitted.

(C) For protected turn phasing, L13 and L14 are used to call and extend protected (turn arrow) phases. NOTE: It is possible to switch detector outputs (detector switching) in order to use L13 and L14 to extend the mainline green phase (permitted) after the protected turn phase has terminated.

(D) L13 and L14 can be placed 30 to 50 feet behind the stop line if protected/permitted phasing is used (3rd vehicle detection).

SIDE STREET LOOP NOTES

(A) L9 through L12 are used to call and extend the side street green phases.

(B) L10 and L11 can be used to call and extend both the protected and permitted phases as described in (B) and (C) under the mainline loop notes.

(C) L10 and L11 can be placed 30 to 50 feet behind the stop line if protected/permitted phasing is used (3rd vehicle detection).
Figure 498-6. Concrete Pull Box
Figure 498-7. Trench Details
Figure 498-8. Exothermic Weld
Figure 498-9. Power Service
Figure 498-10. Strain Pole Supports
Figure 498-11. Strain Pole Attachment Details
Figure 498-12. Single Arm Support
Figure 498-13. Sag and Vertical Clearance Diagram

PERCENT SAG = \( \frac{SAG}{SPAN} \times 100 \)

ALLOWABLE SAG IS 3 TO 5 PERCENT OF SPAN

CLEARANCE
18 FT. (5.5 m) MAX.,
16 FT. (4.9 m) MIN.

SAG FOR SIMPLE SPANS
Figure 498-14. Cable Support Assembly
Figure 498-15. Aerial Interconnect Cable

- Drill and tap for a grounding bolt with two washers.
- 3-bolt clamp, messenger vise or preformed dead end may be used.
- Ground clamp.
- Thimble.
- Box type splice enclosure.
- Interconnect or loop detector lead-in cable.
- Interconnect or loop detector lead-in cable.
- Strain relief type cable connectors, all entries made thru bottom of box.
- Cable to controller by conduit riser or by elbow to the inside of pole.
- No.4 AWG insulated ground wire.
- Messenger wire.
- Weathertight splice enclosure.
- Ground clamp.
- Serve or clamp messenger.
- Pole clamp.
- Clip or band cable.
- Staple to pole, cover with wire moulding or place the wire in EMT from the ground line to 10 ft. (3.1 m) above the ground line.
- Integral messenger interconnect or loop detector lead-in cable.
- Messenger wire.
- Ground clamp, type for bare messenger wire.
- No.4 AWG insulated ground or bonding wire.
- Clamp assembly.
- Square nuts.
- Locknut.
- Lashing wire clamp.
- Spinning or lashing rods.
Figure 498-16. Method of Measurement for Signal Cable

Calculation for Pole Mounted Cabinet:
LENGTH = 5 FT. (1.5 m) + A + 10 FT. (3 m) + B + C1 + 5 FT. (1.5 m)

Calculation for Ground Mounted Cabinet:
LENGTH = 5 FT. (1.5 m) + A + 10 FT. (3 m) + B + C2 + D + E + 5 FT. (1.5 m)
Figure 498-17. Method of Measurement for Interconnect Cable

![Diagram of interconnect cable measurement method]

**Calculation for Pole Mounted Cabinet**:  
Length = 5 ft, 0.5 m + C1 + D + E + F + G + H1 + 5 ft, 0.5 m

**Calculation for Ground Mounted Cabinet**:  
Length = 5 ft, 0.5 m + A + B + C2 + D + E + F + G + H2 + I + J + 5 ft, 0.5 m
Figure 498-18. Method of Measurement for Detector Lead-In Cable

**Calculation for Pole Mounted Cabinet**:
LENGTH = 5 FT. (1.5 m) + A + B + C + D1 + 5 FT. (1.5 m)

**Calculation for Ground Mounted Cabinet**:
LENGTH = 5 FT. (1.5 m) + A + B + C + D2 + E + F + 5 FT. (1.5 m)
Figure 498-19. Method of Measurement for Power Cable

Calculation for Pole Mounted Cabinet:
LENGTH = 5 FT. (1.5 m) + A1 + 5 FT. (1.5 m)

Calculation for Ground Mounted Cabinet:
LENGTH = 5 FT. (1.5 m) + A2 + B + C + 5 FT. (1.5 m)
Figure 498-20. Method of Measurement for Service Cable

EXAMPLE WITH 3 SERVICE POLES

CALCULATION:
LENGTH = 5 FT. (1.5 m) + A + B + C + 5 FT. (1.5 m)
Figure 498-21. Vehicular Signal Heads

Cutaway
Open Bottom Tunnel
Tunnel
Louversed

Hangers for Signal Heads

Visors for Signal Heads

Wiring a Signal Head

Strip Length:
Cable jacket must extend into the signal enclosure.

150 mm (6") min.
Figure 498-22. Pedestrian Signal Heads
Figure 498-23. Loop Detector Placement and Installation

### Width Table

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Rectangular and Powerhead</th>
<th>Quadrupole</th>
<th>Angular Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 FT (3.35 m) and Larger</td>
<td>6 FT (1.83 m) Width</td>
<td>6 FT (1.83 m) Width</td>
<td>A = 4.5 FT (1.37 m)</td>
</tr>
<tr>
<td>Less Than 11 FT (3.35 m)</td>
<td>5 FT (1.52 m) Width</td>
<td>6 FT (1.83 m) Width</td>
<td>A = 4.0 FT (1.22 m)</td>
</tr>
</tbody>
</table>
Figure 498-24. Loop Detector Slots and Wiring

**Technique A**

- Cut out pavement and joint material to depth of sawcut approximately 3 in (75 mm) square or 3 in (75 mm) diam.
- Lay wires in "S" shape.
- Fill with elastic joint material or asphalt.

**Technique B**

- Use soft-setting utility rubber type sealer injected in deep section of groove over wire.
- Epoxy

**Technique C**

- Use 0.75 in (19 mm) rigid plastic conduit.
- Fill with filler compound.
Figure 498-25. Loop Detector Wiring

CONDUIT DRILLED HOLE DETAIL

SPlice ENCLOSURE DETAIL
Figure 498-26. Magnetometer Probes and Lead-In
1. Two turns, ends shorted. Simulates a small motorcycle.
2. One turn, ends shorted. Simulates a bicycle.
3. Set vertically on or just above pavement to test detection areas and adjust sensitivity accordingly (see Section 450-11.6).
Figure 498-28. Short-Circuit Test

Testing is to be done with all electrical loads, power sources, equipment grounds and earth grounds disconnected.

Connect to chosen conductor.

Connect to different connector; repeat test until each conductor pair is measured.

<table>
<thead>
<tr>
<th>Wire Connected</th>
<th>Pairs Measured</th>
</tr>
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<tbody>
<tr>
<td>White</td>
<td>White/Red</td>
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<tr>
<td></td>
<td>White/Orange</td>
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<tr>
<td></td>
<td>White/Green</td>
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<tr>
<td></td>
<td>White/Black</td>
</tr>
<tr>
<td>Red</td>
<td>Red/Orange</td>
</tr>
<tr>
<td></td>
<td>Red/Green</td>
</tr>
<tr>
<td></td>
<td>Red/Black</td>
</tr>
<tr>
<td>Orange</td>
<td>Orange/Green</td>
</tr>
<tr>
<td></td>
<td>Orange/Black</td>
</tr>
<tr>
<td>Green</td>
<td>Green/Black</td>
</tr>
</tbody>
</table>

Turn function selector to resistance, if meter shows infinitive or very high resistance the conductors are acceptable, if the meter reads low or zero the conductors are unacceptable.

Conductors may be jumped together for testing to ground, if a short is revealed, individual conductors may then be tested to ground to isolate the faulty conductor.
Figure 498-29. Circuit Continuity Test of Loop Wire
(Before Splice to Lead-In Cable)

TURN FUNCTION SELECTOR TO RESISTANCE. A RESISTANCE OF ZERO OHMS SHOULD BE INDICATED. IF A HIGH RESISTANCE IS FOUND THE LOOP INSTALLATION IS UNACCEPTABLE.
Figure 498-30. Circuit Continuity Test of Loop Wire and Lead-In Cable
Figure 498-31. Circuit Continuity Test of Signal Cable Disconnected from Heads or Other Cables Such as Interconnect and Loop or Magnetometer Lead-In
Figure 498-32. Circuit Continuity Test of Signal Cable With Cable Connected to the Signal Heads and Lamps Installed

- Red lights only should be illuminated when 120 volts is connected to the white and red wires, yellow lights when white and orange wires are connected, and green lights when white and green wires are connected.

- Connect to red conductor, repeat test for other colored conductors.

- Connect to white conductor.

- The black conductor is usually a spare and is not checked if this procedure is followed.

- Convenience outlet in cabinet (120 volts)
Figure 498-33. Cable Insulation Test (Loop Detector Wire)
Figure 498-34. Cable Insulation Test (Signal Cable)

LEDS/LAMPS LEFT IN

CONNECT OTHER LEAD TO WIRES

WHITE/BLACK
RED
YELLOW
BLUE
BLACK
WHITE

GREEN

MUST READ MORE THAN 10 MEGOHMS

MEGGER

CONNECT ONE LEAD TO CABINET GROUND

SOME MODELS INCORPORATE A GROUND OR DRAIN TERMINAL (SEE MANUFACTURERS INSTRUCTIONS)
Figure 498-35. Reserved for Future Use
### Figure 498-36. Plan Details for Strain Poles

<table>
<thead>
<tr>
<th>From Sheet No.*</th>
<th>Reference Sheet*</th>
<th>Station &amp; Offset*</th>
<th>Pole No.</th>
<th>Design No.</th>
<th>Pole Height ft (m)</th>
<th>Foundation Elev. *</th>
<th>Span Wire Attached, Ht. *</th>
<th>Index Line Angle (Deg.)</th>
<th>Angles (Deg.) from Index Line</th>
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</thead>
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</tr>
</tbody>
</table>

* See *Section 441-8*.

**Notes:**
1. All angles are measured clockwise.
2. The index line goes through the center of the handhole.
Table 498-37. Plan Details for Signal Supports - Arm Lengths
(table is continued in Figure 498-38)

<table>
<thead>
<tr>
<th>Support No.</th>
<th>Design No.</th>
<th>Pole Height ft. (m)</th>
<th>L  ft. (m)</th>
<th>L1  ft. (m)</th>
<th>L2  ft. (m)</th>
<th>L3  ft. (m)</th>
<th>L4  ft. (m)</th>
<th>Elevation</th>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>
Figure 498-38. Plan Details for Signal Supports - Mast Arm Orientation (table continued from Figure 498-37)

Notes:
1. All angles are measured clockwise.
2. Base plate is oriented square to Mast Arm A (largest arm) even if the support has two arms.

<table>
<thead>
<tr>
<th>Mast Arm A Angle (Deg.)</th>
<th>Mast Arm B</th>
<th>Pedestrian Signal</th>
<th>Pedestrian Button</th>
<th>Power Service</th>
<th>Controller</th>
<th>Luminaire Bracket</th>
<th>Handhole</th>
<th>Cable Entrance 12&quot; (0.3m) from top</th>
</tr>
</thead>
</table>
Figure 498-39. Example of Wire Size for Equipment Grounding Conductor – PTSWF with Pedestrian Indications
Figure 498-40. Example of Wire Size for Equipment Grounding Conductor – PTSWF without Pedestrian Indications
Figure 498-41. Example of Wire Size for Equipment Grounding Conductor – Mast Arms
Figure 498-42. Example of Wire Size for Equipment Grounding Conductor – Span Wire
Figure 498-43. Dilemma Zone Graph

Mathematical Description of Dilemma Zone:
\[ d_{go} = 6.3v - 125 \approx d_{stop} - 200 \]
\[ d_{stop} = 7.2v \]

\[ v > 30 \text{ mph} \]

(Source: Adapted from Missouri DOT)