Traffic Signal Summary
April 2021

Design Manual

- **Section 13A-1 - Traffic Signal General Information**
  - Updated references and removed outdated information

- **Section 13A-2 - Traffic Control Signal Needs Study**
  - Simplified MUTCD references and deleted text that was copied directly from the manual
  - Added a couple of references to new documents

- **Section 13A-3 - Traffic Signal Features**
  - Deleted listings of section titles for chapters within the MUTCD and simply included the chapter hyperlink
  - Expanded listings for potential items designers need to verify with agencies to ensure inclusion in the design plans
  - Updated signal design criteria for types of equipment that may be required by agencies
  - Updated list of additional items beyond typical vehicle and pedestrian signals that may be a part of the project

- **Section 13A-4 - Traffic Signal Design Considerations**
  - Updated references and information on impacts of geometrics to traffic signal design
  - Deleted specific information on determining turn lane and other lane geometrics since they aren’t specific to traffic signal design and are usually completed using software applications
  - Updated references to system design considerations
  - Updated references to traffic signal operations on automated communication methods

- **Section 13A-5 - Traffic Signal Specification Information**
  - Deleted specific listings of information that is contained in Spec Section 8010, including the duplicated figures
  - Updated list of cabinet and controller options to include products currently available
  - Expanded list of items that need to be included in project’s supplemental specifications

Specifications

- **Section 8010**
  - Added submittal of fiber optic wiring diagrams
  - Revised the payment of temporary traffic signal to pay 80% at installation and 20% upon removal (rather than 50/50)
  - Added a bid item and execution language for removal of poles and pole foundations
  - Updated products to include additional materials and equipment
  - Evaluated pole painting requirements so specific manufacturers aren’t eliminated
  - Added the potential for short bolt-on mast arm extensions
  - Added process for post installation testing of fiber optic cables
  - Provided for advance notice of signal turn on
  - Updated figures to reflect new equipment and processes and to ease construction difficulties in steel placement, ground rod placement, and conduit location in the foundation, in addition to other information
  - Added bicycle detector loop detail
Traffic Signal General Information

A. Introduction

The purpose of this chapter is to supplement SUDAS Specifications Section 8010 and to provide general guidance for traffic signal designs on roadways within Iowa. The information is provided as an overview for traffic signals design consideration.

B. Scope

There is no legal requirement to use the information within this chapter by local agencies. This document refers to a number of other resources available for the designer to be considered when designing a traffic control signal. The document loosely follows the format of the MUTCD, as published by The U.S. DOT, FHWA and as adopted or modified by the Iowa DOT. However, no attempt is made to re-print the content of the MUTCD herein. A variety of other technical resources are also noted for consideration by the designer.

By MUTCD definition, a traffic control signal is “any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed” with highway traffic signal being defined as “a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include power-operated signs, illuminated pavement markers, barricade warning lights, or steady-burning electric lamps.” From an application standpoint traffic control signals are used to assign vehicular or pedestrian right-of-way.

The design for traffic control signals shall be in conformance with the current edition of the MUTCD as adopted or modified by the Iowa DOT. The following should be used as design standards as applicable to a project (all accessed October 2012):

- MUTCD Part 4 Highway Traffic Signals
- Jurisdiction Design Standards and Construction Standards
- Iowa DOT and FHWA regarding the design of traffic control signals
- Other standard references such as the National Electrical Code by the National Fire Protection Association (NFPA), and the National Electrical Manufacturers Association (NEMA) Standards Publications.

Other resources to consider and that are referenced within this document include:

- MnDOT Signal Design Manual
- MnDOT Lighting and Signal Certification Field Guide
- MnDOT Signals 101 Course Presentation
- MnDOT Signal Justification Reports
C. Definitions

A resource for traffic signal definitions can be found within MUTCD Section 4A.02 “Definitions Relating to Highway Traffic Signals.”

- FHWA Automated Traffic Signal Performance Measures
- FHWA Adaptive Traffic Signal Control Website
Traffic Control Signal Needs Study

A. General

The MUTCD states that “A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.” The first question that must be answered is whether a traffic control signal is justified or is the most effective treatment option. It is the responsibility of the Engineer or agency to make this determination with serious consideration given to the following MUTCD Section 4B.

Section 4B.01 General
Section 4B.02 Basis of Installation or Removal of Traffic Control Signals
Section 4B.03 Advantages and Disadvantages of Traffic Control Signals
Section 4B.04 Alternatives to Traffic Control Signals
Section 4B.05 Adequate Roadway Capacity

B. Data Collection

The engineering study should be based upon a complete collection of current site and traffic data (vehicle, pedestrian, etc) pertaining to the candidate location. Section 9-4.01 of the Mn/DOT Traffic Engineering Manual notes the studies which will be helpful in assessing and demonstrating the need for a signal as follows:

- Volume studies, including approach volumes, turning movements, and peak hour detail counts
- Pedestrian counts, including any unusual numbers of children, handicapped, and elderly
- Traffic gap studies
- Speed studies
- Crash studies
- Intersection delay studies

Procedures for completing various traffic studies are found in the ITE Manual of Traffic Transportation Engineering Studies.

MUTCD Section 4C.01 provides a detailed description of engineering study data which may be needed to conduct a warrant analysis. These include:

1. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24 hour traffic volume.

2. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public transit vehicles, and, in some locations, bicycles), during each 15 minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.

3. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B above and during hours of highest pedestrian volume. Where young, elderly, and/or
persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.

4. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.

5. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.

6. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.

7. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods specified in item 2 of the preceding paragraph:

1. Vehicle-hours of stopped time delay determined separately for each approach.

2. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.

3. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.

4. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.

5. Queue length on stop-controlled approaches.

It is critical to present the above information in an organized fashion. Mn/DOT makes use of a **Signal Justification Report**, which contains the following information:

1. Intersection Location: Trunk highway cross-street name and county road numbers, municipality, and county. A map should be included that identifies the site.

2. Type of Work: Type of signal or beacon proposed, whether temporary or permanent.

3. Character of Site: Function and importance of roads, number of lanes, existing and proposed geometrics, channelization, grades, presence or absence of parking, bus stops and routes, posted speed limit, 85th-percentile speed if markedly different, and sight-distance restrictions.

4. Land Use: Present land use at the intersection, presence of any special traffic generators, proposed or likely future development.

5. Traffic Control: Existing traffic control, present and planned adjacent signals, and proposed or existing coordinated systems.
6. Actual Traffic Volumes at the Intersection: Volumes must include at least 16 hours of counts on all approaches, turning movement counts for at least a.m. and p.m. peak hours. Unusual numbers of heavy vehicles and unusual percentages of turning movements must be noted. Volumes shall have been counted within two years of the date of submission of the report.

7. Iowa DOT generated or approved volume estimates for a proposed intersection, such as found in an official TAM or SPAR report, and for which warrant estimation methods are acceptable.

8. Pedestrian counts, particularly if the intersection is a school crossing or is used by large numbers of elderly or handicapped pedestrians.

9. Crash Data: Number and general types of crashes which have occurred for a minimum of 12 months before the date of the report. If Warrant 7 for crash experience is addressed, a collision diagram must be included, showing crashes by type, location in the intersection, directions of movement, severity, date, time of day, weather, light, and roadway conditions.

10. Any special site conditions adding to the Engineer’s judgment that signals are necessary.

The above information can be presented in either checklist or narrative form, so long as it is clearly and logically presented. Volumes can be presented in graph or tabular form.

Mn/DOT’s Section 9.4.02.04 signal justification also provides a section on “Signal Removal Justification Criteria.”

C. Warrants

MUTCD Section 4C.01 “Studies and Factors for Justifying Traffic Control Signals” states, “An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

The investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location:

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals
Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume
Section 4C.03 Warrant 2, Four-Hour Vehicular Volume
Section 4C.04 Warrant 3, Peak Hour
Section 4C.05 Warrant 4, Pedestrian Volume
Section 4C.06 Warrant 5, School Crossing
Section 4C.07 Warrant 6, Coordinated Signal System
Section 4C.08 Warrant 7, Crash Experience
Section 4C.09 Warrant 8, Roadway Network
Section 4C.10 Warrant 9, Intersection Near a Grade Crossing

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

Accompanying MUTCD figures and tables for the above warrants include:

Table 4C-1 Warrant 1, Eight-Hour Vehicular Volume
Figure 4C-1 Warrant 2, Four-Hour Vehicular Volume
Ohio DOT’s Traffic Engineering Manual Part 4-Signals provides additional guidance for consideration of the reduction of minor approach right turning volume for traffic signal warrants to account for minor approach lane configurations, the proportion of right turns to other traffic, and the conflicting through volumes on the major street.

Guidelines regarding the installation of pedestrian hybrid beacons (HAWK signals) are provided in MUTCD Chapter 4F. These guidelines consider vehicular and pedestrian crossing volumes, crosswalk length and traffic speeds.

Mn/DOT’s Traffic Signal Design Manual Section 9-4.02.03 provides additional guidance for the following advance warning flashers consideration:

- Section 9-4.02.02 Warrants for Flashing Beacons at Intersections
- Section 9-4.02.03 Advance Warning Flashers Consideration
Traffic Signal Features

A. Traffic Control Signal Features

The MUTCD Chapter 4D Traffic Control Signal Features establishes traffic signal uniformity and serves as a critical resource for checking each traffic signal design. The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in the MUTCD, is especially important for reasonably safe and efficient traffic operations. This chapter includes the following sections:

- Section 4D.01 General
- Section 4D.02 Responsibility for Operation and Maintenance
- Section 4D.03 Provisions for Pedestrians
- Section 4D.04 Meaning of Vehicular Signal Indications
- Section 4D.05 Application of Steady Signal Indications
- Section 4D.06 Application of Steady Signal Indications for Left Turns
- Section 4D.07 Application of Steady Signal Indications for Right Turns
- Section 4D.08 Prohibited Steady Signal Indications
- Section 4D.09 Unexpected Conflicts During Green or Yellow Intervals
- Section 4D.10 Yellow Change and Red Clearance Intervals
- Section 4D.11 Application of Flashing Signal Indications
- Section 4D.12 Flashing Operation of Traffic Control Signals
- Section 4D.13 Preemption and Priority Control of Traffic Control Signals
- Section 4D.14 Coordination of Traffic Control Signals
- Section 4D.15 Size, Number, and Location of Signal Faces by Approach
- Section 4D.16 Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces
- Section 4D.17 Visibility, Shielding, and Positioning of Signal Faces
- Section 4D.18 Design, Illumination, and Color of Signal Sections
- Section 4D.19 Lateral Placement of Signal Supports and Cabinets
- Section 4D.20 Temporary Traffic Control Signals
- Section 4D.21 Traffic Signal Signs, Auxiliary

Accompanying MUTCD figures and tables for signal features include:

- Table 4D-1 Minimum Sight Distance
- Figure 4D-1 Maximum Mounting Height of Signal Faces Located Between 40 Feet and 53 Feet from Stop Line
- Figure 4D-2 Horizontal Location of Signal Faces
- Figure 4D-3 Typical Arrangements of Signal Lenses in Signal Faces
B. Pedestrian Control Features

The MUTCD Chapter 4E Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for checking each traffic signal design. Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DON'T WALK), and a countdown display. This Chapter includes the following sections:

Section 4E.01 Pedestrian Signal Heads
Section 4E.02 Meaning of Pedestrian Signal Head Indications
Section 4E.03 Application of Pedestrian Signal Heads
Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications
Section 4E.05 Location and Height of Pedestrian Signal Heads
Section 4E.06 Accessible Pedestrian Signals
Section 4E.07 Countdown Pedestrian Signals
Section 4E.08 Pedestrian Detectors
Section 4E.09 Accessible Pedestrian Signal Detectors
Section 4E.10 Pedestrian Intervals and Signal Phases

Accompanying MUTCD figures and tables for pedestrian control features include:

Figure 4E-1 Typical Pedestrian Signal Indications
Figure 4E-2 Recommended Pushbutton Locations for Accessible Pedestrian Signals

C. Agency Specific Information

Agencies often have different design requirements that differ or are in addition to those found in the MUTCD. Therefore, one of the first steps in the traffic signal design process is to learn the design requirements by meeting with agency staff and studying agency specific design manuals, and/or studying the MUTCD specifications, and/or standard details. Field observations of existing traffic signals within an agency’s jurisdiction can also provide insight to specific design requirements.

Determining agency specific design requirements prior to design can be challenging. It can be difficult to ask all the right questions, give all the necessary answers, and not overlook any details. More challenges can arise when staff is less experienced or a new working relationship is being established. Most design requirements that are overlooked will be caught during the design process or review process. However, taking steps to prevent design requirements from being overlooked will accelerate the design process and minimize costs by eliminating or reducing change orders. The following are some examples of design requirements that can vary between agencies.

- The 2003 edition of the MUTCD requires a maximum distance of 180 feet from the stop line to the 12 inch signal faces unless a near side supplemental signal face is used. The previous version required a maximum distance of 150 feet and some agencies continue to follow the old requirement.
- Some agencies center mast arm mounted signal heads over the lane line and others center them over the center of the lane.
- Certain agencies elect to install supplemental signal heads on the vertical shaft of the mast arm pole and others elect not to.
- Doghouse style five section heads are used for protected / permissive left turns by some agencies but not others.
• Protected / permissive left turn lane operation can vary. Some agencies configure left turn lane loop detectors to call the protected phase only when all loop detectors are covered by vehicles detection to call the protected phase only when two to three vehicles are queued while other agencies always call the protected phase.
• Detector types, sizes, and layouts vary between agencies.
• The size and number of conduits, handholes, and wiring varies greatly among agencies.
• Some agencies share conduit between signal cable, street light power, and/or interconnect while others keep these cables in separate conduits.
• Some agencies choose to install emergency vehicle preemption.
  • Some agencies choose to install traffic monitoring (PTZ) cameras.
• Signal wiring details vary among agencies.
• Some agencies use the “astro” type brackets to mount all signal heads and others do not use this on side of pole mounted heads. Bracketing and banding of all hardware (typically to the poles) varies greatly among agencies.
• Traffic signal cabinets, cabinet risers, and controller types and preferences vary greatly among agencies.
• Mounting heights for signal heads, street light luminaires, detection cameras, monitoring cameras, etc. vary greatly among agencies.
  • Pedestrian signals may or may not include Assessible Pedestrian Signals (APS), with or without voice messages.
  • Agencies use a variety of signal interconnect and communication systems including fiber optic cable, wireless systems, and GPS timeclocks.
• Pedestrian walking speed for crossing interval timing may vary.

D. Preliminary Signal Design Discussion List Criteria

Signal designers should coordinate with the agency regarding specific traffic signal elements to be included in a project. This is particularly important for a first project with a new agency. A list of memoranda regarding signal design criteria for review by and discussion with the agency early in the project development may meet and confer to agree on preliminary signal design details. Having a list of the basic criteria to be discussed at a preliminary stage can be of significant benefit to both the engineer and agency. The following list is based on Mn/DOT’s Signal Design Manual “Pencil Sketch” review list. The following is a list of possible signal design criteria items to consider:

1. General nature of the signal project - new installation, replacement, minor modifications, or major revisions.

2. Phasing of the intersection, relation of proposed phasing to the traffic volumes and turning movements; use of protected-permissive left-turn phasing rather than protected-only; use of overlaps.

3. Determine design standards based on who will operate the system.

4. Use of four and five section heads and non-standard bracketing.

5. Head type (LED, optically-programmed, etc.).

6. Appropriateness of poles and pedestals for the site.

7. Placement of signal standards to ensure legal placement of all vehicle and pedestrian signal indications.
8. Placement of pedestrian pushbuttons relative to signal standards and in place sidewalks and crosswalks.

9. Need for emergency vehicle pre-emption (EVP) and police door with auto/flash switch, manual/stop-time switch, and on/off power switch for signal heads only, including placement of components.

10. Detector placement and functions. See the Signal Design Manual for loop detector placement diagrams.

11. Placement and type of handholes.
12. Design of equipment pad.
13. Type of service equipment.
14. Discuss needs for combined pad with lighting and/or TMC.
15. Need for intersection geometric improvements.
16. For revised systems, the wording of the signal-pole notes for the revision.
17. Need for AWF's, supplemental heads, etc.
18. House-moving route needs (Mn/DOT uses a mast arm mount that can swivel).
19. Painting of signal.
20. Luminaires metered or unmetered.
21. Source of power (to determine cabinet location).
22. Interconnect (determine need and type, location of master).

2. Signal Phasing:
   a. Phase numbering (Phase 2 southbound or major through movement)
   b. Left turn phasing for each approach (protected-only, protected-permissive, permissive-only, split-phase)
   c. Leading pedestrian interval
   d. Use of overlaps

3. Signal Heads:
   a. Based on proposed left turn phasing
   b. Overhead locations relative to lane lines
   c. Side-of-pole locations
   d. Head configurations, displays, color
   e. Pedestrian signal head type (1-section or 2-section)
   f. Head mounting hardware and bracket types
   g. Backplates, visors

4. Poles:
   a. Pole types (mast arm, combination mast-arm/ lighting, pedestal)
   b. Pole locations considering clear zone, sidewalk, utilities and right-of-way constraints
c. Pole base types (T-base or anchor base)
d. Luminaire mounting height for combination poles
e. Special pole finishes (paint, powdercoat)
f. Special pole handhole needs

5. Detection:
   a. Type of vehicle detection (video, pavement loops, microwave, other)
   b. Advance detection based on approach speeds
   c. Detection to accommodate Automated Traffic Signal Performance Measures
   d. Emergency Vehicle Preemption (EVP) detectors
   e. Pedestrian pushbuttons (APS or non-APS)
   f. Pushbutton locations per ADA and MUTCD guidance
   g. Special detection needs (bicycles)

6. Controller/ Cabinet:
   a. Controller type or model (NEMA, ATC, 2070)
   b. Cabinet type or model (TS1, TS2, ATC, 2070)
   c. Cabinet location
   d. Pad or pole-mounted cabinet
   e. Battery back-up (UPS)
   f. Cabinet riser height
   g. Meter location
   h. Misc. cabinet equipment

7. Conduit and Wiring:
   a. Conduit sizes and types
   b. Separate conduits for lighting, power and/or fiber optic cable
   c. Signal cable configurations (number of conductors)
   d. Lighting cable sizes
   e. Ground wire, tracer wire and pull tape
   f. Fiber optic cable configuration, routing, termination and splicing
   g. Misc. cables (video, EVP, Cat 5/6, etc.)

8. Handhole types and locations

9. Interconnect:
   a. Need for coordinated signal operation
   b. Type of interconnect
   c. Modifications needed at adjacent signalized intersections

10. Power Service:
    a. Coordination with utility company
    b. Power source location and type (overhead or pad-mounted transformer)
    c. Meter requirements
    d. Metered or un-metered lighting

11. Signs:
    a. Street name signs
    b. Lane use signs
    c. Traffic signal signs
    d. Pedestrian pushbutton signs
12. Construction Staging:
   a. Potential need for temporary signals and/or detection
   b. Lane closures
   c. Special requirements

13. Miscellaneous:
   a. Potential need for AWF
   b. Construction schedule and anticipated pole and equipment lead times
   c. Supplemental specifications and/or plan notes as needed
   d. Signal turn-on procedure, possible portable dynamic message signs
   e. Luminaires for combination poles

E. Additional Information

The MUTCD Chapter 4E Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for checking each traffic signal design. Pedestrian signal heads provide:

In addition to typical vehicle and pedestrian signals, the MUTCD also provides guidance on the following types of traffic signals:

Chapter 4F Traffic Control Signals for Emergency Vehicle Access
Chapter 4G Traffic Control Signals for One-Lane, Two-Way Facilities
Chapter 4H Traffic Control Signals for Freeway Entrance Ramps
Chapter 4I Traffic Control Signals for Movable Bridges
Chapter 4J Lane-Use Control Signals
Chapter 4K Flashing Beacons
Chapter 4L In-Roadway Lights

Chapter 4F Pedestrian Hybrid Beacons
Chapter 4G Traffic Control Signals and Hybrid Beacons for Emergency-Vehicle Access
Chapter 4H Traffic Control Signals for One-Lane, Two-Way Facilities
Chapter 4I Traffic Control Signals for Freeway Entrance Ramps
Chapter 4J Traffic Control for Movable Bridges
Chapter 4K Highway Traffic Signals at Toll Plazas
Chapter 4L Flashing Beacons
Chapter 4M Lane-Use Control Signals
Chapter 4N In-Roadway Lights
Traffic Signal Design Considerations

In addition to basic MUTCD requirements, the safe and efficient operation of a signalized intersection requires careful attention and balance of a number of design parameters. This section provides some reference resources for the traffic signal designer in consideration of these features.

A. Geometrics

The geometrics of an intersection are a critical consideration given the potential impact on intersection safety and performance. Geometrics directly impact sight distance, vehicle separation, operations, and capacity. As a result, intersection geometrics should always be considered whether dealing with existing, reconstructed, or new signalized intersections.

References are made to Signalized Intersections: Informational Guide, Second Edition, FHWA-HRT-04-091, August 2004 FHWA-SA-13-027, July 2013, which provides a single, comprehensive document with methods for evaluating the safety and operations of signalized intersections and tools to remedy deficiencies. The treatments in this guide range from low-cost measures such as improvements to signal timing and signage, to high-cost measures such as intersection reconstruction or grade separation. While some treatments apply only to higher volume intersections, much of this guide is applicable to signalized intersections of all volume levels.

1. Basic Geometric Considerations: The geometric design section of the Signalized Intersections: Informational Guide provides the following comments:

Geometric design of a signalized intersection involves the functional layout of travel lanes, curb ramps, crosswalks, bike lanes, and transit stops in both the horizontal and vertical dimensions. Geometric design has a profound influence on roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist.

In addition to safety, geometric design influences the operational performance for all road users. Minimizing impediments, eliminating the need for lane changes and merge maneuvers, and minimizing the required distance to traverse an intersection all help improve the operational efficiency of an intersection.

The needs of all possible road users must be considered to achieve optimal safety and operational levels at an intersection. At times, design objectives may conflict between road user groups; the practitioner must carefully examine the needs of each user, identify the tradeoffs associated with each element of geometric design, and make decisions with all road user groups in mind.

Geometric design profoundly influences roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist. In addition to safety, geometric design influences the operational performance for all road users. Minimizing impediments, reducing the need for lane changes and merge maneuvers, and minimizing the required distance to traverse an intersection all improve intersection safety and operational efficiency.
All possible road users’ (Chapter 2 of the guide) needs must be considered to achieve optimal safety and operational levels at an intersection. When road user groups’ design objectives conflict, the practitioner must carefully examine the needs of each user, identify the tradeoffs associated with each element of geometric design, and make decisions with all road user groups in mind. For instance, practitioners may design corner radii to accommodate large vehicles. However, these larger radii could be detrimental to pedestrian safety due to the increase in walking distances and the increase in speed of turning vehicles.

The geometric design section (Chapter 4 of the guide) addresses the following design topics to be considered when designing traffic signal controlled intersections:

- 3.1 Channelization
- 3.2 Number of Intersection Legs
- 3.3 Intersection Angle
- 3.4 Horizontal and Vertical Alignment
- 3.5 Corner Radius and Curb Ramp Design
- 3.6 Sight Distance
- 3.7 Pedestrian Facilities
- 3.8 Bicycle Facilities
- 4.1 Number of Intersection Legs
- 4.2 Channelization
- 4.3 Horizontal and Vertical Alignment
- 4.4 Corner Radius
- 4.5 Sight Distance
- 4.6 Pedestrian Treatments
- 4.7 Bicycle Facilities
- 4.8 Transit Facilities

2. Additional Sight-Distance Considerations:

a. Sight distance is a safety requirement that impacts intersection geometrics as fundamental as horizontal and vertical alignments. It is a design requirement that is discussed in detail as it relates to the visibility of traffic signal indications in the MUTCD. In addition to the sight distance requirements of the MUTCD, the AASHTO “Policy on Geometric Design of Highways and Streets 2001-2018” states that drivers of the first stopped vehicles on all approaches should have adequate sight distance to view one another at signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. It also states that left turning vehicles should have adequate sight distance to select gaps in oncoming traffic and complete turning maneuvers drivers need sufficient site distance to decide when to turn left across the lane(s) used by opposing traffic. This requires consideration of offset left turn lanes for permissive left turns to provide adequate left turn sight distance. If right turns are allowed on a red signal indication, the appropriate departure sight triangle sight distance to the left of the right turning vehicle should be provided. Finally, the policy states that the appropriate departure sight triangles should be provided for left and right turning vehicles on the minor approach for two-way flashing operations. Two-way flashing operations are flashing yellow for the major street and flashing red for the minor street. See Chapter 9 - Intersections in the AASHTO “Policy on Geometric Design of Highways and Streets 2001-2018” for additional sight distance information.

b. One sight distance issue that deserves additional consideration is the sight triangle and the sight obstructions found within it. Certain obstructions are obvious like structures near the street. Other obstructions are not always obvious or are installed after the traffic signal is designed and constructed. These obstructions seem to blend into the background. They are
obstructions like entrance monuments, parked vehicles, special street name signs, business signs, and landscape vegetation that may not be a problem initially but become a problem as the plants reach maturity. Finally, be aware of the signal cabinet size and location including the height of the footing or cabinet riser so it does not become a sight obstruction.

c. Sight distance requirements are less restrictive at signalized intersections as drivers are required by law to obey the signal indications; however, there are instances when drivers do not obey traffic signals. A traffic signal should be designed to exceed minimum sight distance requirements when possible. Drivers are taught to drive defensively and providing additional sight distance will only aid drivers in collision avoidance.

3. Turn Lanes:

a. Traffic volumes, turning movement counts, and crash history are used to complete intersection capacity and accident safety analyses. The results of the analyses determine the need for and length of turn lanes, the number of turn lanes, and the length of the turn lanes. The turn lane information is used to properly design the geometrics of signalized intersection approaches.

b. Turn lane capacity issues often create safety problems. Left or right turning vehicle queues blocking through traffic create increased potential for rear-end accidents crashes. Sideswipe potential also increases as traffic attempts to maneuver out of defacto turn lanes or around left turn queues blocking through lanes. High volumes of turning vehicles combined with high volumes of opposing vehicles significantly reduce the number and size of available gaps needed to complete turning maneuvers increasing the potential for right angle collisions. As a result, properly designed turn lanes improve safety as well as capacity.

c. The need for turn lanes, turn lane storage lengths, and other geometric or traffic control improvements should be determined based on traffic operations analyses or existing and projected design year peak hour traffic. Traffic engineers typically use traffic analysis and/or simulation software for these analyses.

c. Determining turn lane design details when upgrading existing signalized intersections in largely developed areas is relatively straight forward. Capacity problems are recognized through evidence obtained from capacity analyses, visual inspections, and/or citizen comments. Capacity analyses and visual inspections of peak hour traffic often reveal long queues that do not clear after multiple signal cycles. Heavy turning volumes and a lack of turn lanes on multilane facilities often result in shared lanes acting as defacto turn lanes. If turn lanes exist, traffic volumes may exceed the capacity of the turn lanes resulting in vehicle queues spilling out of the turn lanes and into the through lanes.

d. Determining turn lane design details when constructing new signalized intersections in undeveloped or under developed areas experiencing significant growth is a challenge. In many cases, there is no visual evidence of existing capacity or safety problems. The challenge is judging future traffic patterns and the extent of the traffic growth over a given time period, usually twenty years, with no guarantees as to the type, extent, and rate of development. Judgment is improved with information and the information is obtained from capacity analyses that examine existing and proposed development, existing traffic volume data, and future traffic volume data derived from land use maps and the ITE Trip Generation Manuals. This information combined with traffic growth rates obtained from developed areas with similar land use characteristics and engineering judgment are used to arrive at an intersection design that will support existing traffic volumes as well as future growth.
e. Past experience has helped to formulate several design guidelines used to initially determine the number of lanes needed at an intersection. These guidelines are planning-level guidelines and should be confirmed with the results of the operational analysis methods discussed in the Operations section of this chapter. The guidelines can be found in Chapter 10 of the Highway Capacity Manual 2000 (HCM 2000) and are summarized as follows:

1) Exclusive Left Turn Lanes:
   - A single exclusive left turn lane should be considered when the minimum left turn volume is 100 veh/hr.
   - Dual exclusive left turn lanes should be considered when the minimum left turn volume is 300 veh/hr.

2) Exclusive Right Turn Lanes:
   - An exclusive right turn lane should be considered when the right turn volume exceeds 300 veh/hr and the adjacent mainline volume exceeds 300 veh/hr/ln.

3) Number of Lanes:
   - Enough lanes should be provided to prevent the total volume of the approach from exceeding 450 veh/h/ln.

f. Past experience has also helped to formulate several design guidelines used to initially determine turn lane lengths needed at intersections. Like the guidelines used to determine the number of lanes, the guidelines used to determine turn lane lengths are planning-level guidelines and should be confirmed with the results of an operational analysis. Also remember that the lengths discussed here are the actual storage lengths and do not include taper lengths. Taper requirements are discussed in several sources including Chapter 5 - Roadway Design, the Iowa DOT Design Manual, and the AASHTO Policy on Geometric Design of Highways and Streets. The guidelines are as follows:

- Enough storage length should be provided to equal one foot for each vehicle per hour (vph) turning during the peak hour in the horizon year. For example, 250 vph turning during the peak hour in the horizon year would require a 250 foot turn lane.

- Storage length can also be computed using the following equation:

\[
\text{Storage Length} = \frac{h}{s} (v + g) (p)
\]

\(h\) = horizon year peak hour volume (vph)
\(s\) = number of signal cycles per hour
A signal cycle is typically 60 to 120 seconds. Engineering judgment is used to select the cycle length or lengths to use in the equation.

\(v\) = average vehicle length
The average vehicle length often used is 20 feet.

\(g\) = average gap between vehicles
The average vehicle gap often used is 5 feet.

\(p\) = probability factor
The probability factor is based on the Poisson distribution and associated with the probability that enough length is provided to store all vehicles.

<table>
<thead>
<tr>
<th>Probability Factor (p)</th>
<th>Probability of Storing All Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50</td>
<td>0.90</td>
</tr>
<tr>
<td>1.75</td>
<td>0.95</td>
</tr>
<tr>
<td>1.85</td>
<td>0.98</td>
</tr>
</tbody>
</table>
A paper written by the Transportation Research Institute at Oregon State University suggests modifying the average vehicle length plus gap \((v + g)\) based on the percentage of trucks using the turn lane. The paper suggests modifying \(v + g\) as follows:

<table>
<thead>
<tr>
<th>Percent Trucks</th>
<th>(v + g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2%</td>
<td>25'</td>
</tr>
<tr>
<td>5%</td>
<td>27'</td>
</tr>
<tr>
<td>10%</td>
<td>29'</td>
</tr>
</tbody>
</table>

The initial storage length for dual left turn lanes can be found by dividing the storage length found from one of the two methods discussed above by 1.8.

Example:

\[
h = 250 \text{ vph} \\
x = 100 \text{ s/cycle} \\
3600 \text{ s/hr} / 100 \text{ s/cycle} = 36 \text{ cycles/hr} \\
5\% \text{ trucks} \\
v + g = 27' \\
p = 1.85 (95\% \text{ probability})
\]

Single lane storage length = \((250 / 36) \times 27 \times 1.75\) 
Single lane storage length = 328': Say 325'

Determining turn lane length also requires some additional considerations. One consideration is the length of the queues in the through lanes. If the turn lanes are not long enough, through lane queues may prevent turning vehicles from entering the turn lanes leaving the turn lanes nearly empty until the through lane queues begin clearing. This issue could be addressed with lagging lefts but lagging lefts require additional considerations to prevent left turn traps and an operational analysis to determine optimal signal phasing and timing. If through lane queues block the turn lanes, the turn lanes could be lengthened beyond the through lane queues. However, the additional length needed may not be practical.

Another consideration is maximum turn lane length. Once a turn lane becomes too long, the signal cycle cannot serve all the traffic waiting in the turn lane reducing, if not eliminating, the benefits of the extra length. At this point, it may be more practical to add turn lanes or look at other solutions to relieve congestion. When is a turn lane too long? It is difficult to point to an exact number but in the neighborhood of 350 to 400 feet. An operational analysis will provide better evidence regarding the maximum length.

The final consideration that can impact the length of a turn lane is visibility. A turn lane that starts just beyond the crest of a vertical curve may not be visible until a vehicle is at the start of the lane. It may be practical to extend the turn lane to increase its visibility giving drivers more time to react to the lane.

g. Lane balance should be considered when addressing lane geometrics. Left turn lanes should be opposing or offset to one another. If dual left turn lanes are required on one approach, dual left turn lanes or a wide median should be installed on the opposing approach to promote lane balance. Through lanes should be located so they align with one another as the
intersection is traversed. Creating a lane shift through an intersection creates driver confusion.

4. **Agency Geometric Considerations**: The Mn/DOT Traffic Engineering Manual (Section 9-6.00 Traffic Signal Design) provides a good identification of major issues for design consideration and serves as an example of agency specific criteria. Since this is a PDF document, Sections 9-6.02 through 9-6.05 are provided below:

Intersection geometry is an important element of traffic signal design. The design of traffic signal system hardware and operation of the traffic signal system should be preceded by a thorough evaluation and, if necessary, geometric improvement of the existing intersection. Mn/DOT Section 9-6.03 notes the following geometric elements should be considered:

- **Pavement width should be adequate for anticipated traffic movements and future capacity requirements.** Highway capacity analysis should be performed to get a better understanding of the capacity of the intersection.

- **If appropriate islands should be designed and constructed so that the driver has adequate reaction distance to them and they are large enough to install a standard signal foundation. Existing shoulders should always be carried through the intersection; this will usually provide enough reaction distance to the island. However, turning radii should be checked to ensure enough setback for comfortable turns.**

- **Turn lanes must provide adequate storage in order to prevent turning traffic from interfering with other traffic movements and thus causing capacity breakdown.**

- **When a median width is more than 30 feet between opposing through lanes, special signal design considerations are necessary (See MN MUTCD, Section 4H).** Extremely wide medians confuse drivers on the crossing street, prevent them from being comfortable with opposing traffic, and cause them to lose track of their path. Wide medians also cause capacity restrictions because more time is needed for vehicle movements and clearances through the intersection.

- **Sidewalks should be constructed as close to the center of the corner as possible. Pedestrian crosswalks should be in line with the sidewalk and as close to the intersection as practical.**

- **Alignment changes within the intersection should be avoided.** Vehicles approaching the intersection should be directed through the intersection. Vertical alignments approaching signals must allow for proper signal visibility.

- **Driveways within an intersection should be signalized and accommodated by the intersection geometries.** Whenever feasible, the driveways should be located or relocated outside the limits of the intersection.

- **The size of corner radii is an important consideration.** Excessively large corner radii may obscure intersection limits and create a hazard for bicycles and pedestrians, while very small radii may create a hazard for motorists. Corner radii at signalized intersections should not be less than 20 feet nor more than 60 feet. A turning radius guide for 58 foot vehicles should be used to determine proper corner radii. At intersections where bus routes are located, corner radii should be analyzed giving due consideration to bus maneuvers.

- **It may be necessary to relocate utilities such as manholes, catch basins, fire hydrants, overhead power and telephone lines and power poles, to obtain adequate geometries for**
signalization. The existence of these utilities must not get in the way of adequate geometrics.

j. Pedestrian curb ramps should be considered in accordance with Chapter 12 – Sidewalks and Bicycle Facilities if sidewalks are present.

k. Handhole spacing should be based on the following factors:
   • Location of junction points within the signal system
   • Physical features, such as driveways, utilities, etc.
   • Cable pull length based on size of cable and diameter of conduit

B. Operational Characteristics

The behavior of the traffic at an intersection is another highly important element of signal design. The MnDOT Traffic Engineering Manual Section 9.7.03 9.6.03 notes the following various elements that should be considered.

1. Existing 15 minute vehicle volumes, by vehicle class, and pedestrian volumes, are the most basic operational consideration. Data used should represent intersection operation in peak periods. Saturated approaches should have an upstream count taken to determine the demand volume rather than the service volume at the intersection.

2. Intersection capacity should be determined based on the Highway Capacity Manual and other sources.

3. The vehicle approach posted speeds should be determined for the location of advance detection.

4. Adjacent land uses should be evaluated to identify activities which may conflict with intersection operation. Items that should be considered include entrances, advertising devices, and areas of high pedestrian activity (schools, manufacturing plants, shopping centers, etc.).

5. Crashes within the intersection should be studied to determine causes and possible design solutions.

6. Pedestrian volumes and school-crossing activities should be studied to determine pedestrian routes and necessary design treatments. Pedestrian movements in and around signals should be routed into the intersection crosswalks in front of vehicles stopped for the signal. Provide pedestrian refuges in medians 6 feet and wider.

C. System (Arterial) Considerations

In many cases, an individual traffic control signal must be considered as part of a system, either as one of a series of signals along a linear route, or as one signal in a grid network. MnDOT Section 9.7.04 9.6.04 notes the following elements should be considered. In addition, note the following:

Traffic actuated controllers are most often used. The actuated controller tends to reduce the number of stops and does not cut off platoons of vehicles. In the suburban environment, the arterial streets tend to be very wide, and traffic volumes are often significant. At intersections with low volumes of pedestrians crossing such as an arterial, an actuated controller tends to operate much more efficiently, as it is not necessary to time pedestrian intervals except when an actual demand exists.

A split is the relative percentage of green, yellow, and red clearance time allocated to each of the various phases at a single intersection. An offset is a system reference time, usually expressed in
System considerations in signal design should include but are not limited to the following:

1. Adjacent signals should be interconnected whenever they are less than one-half mile apart, when the travel time between adjacent signals is less than the cycle length at each signal, or when platoons leaving one intersection remain intact to the next signal.

2. Properly spaced signalized intersections greatly simplify coordination in planning new signals. Minimum spacing of one-quarter mile is recommended. Irregular signal spacing reduces the overall operational efficiency of the mainline movements and greatly complicates signal coordination.

3. Whenever possible, platoons should be kept intact to allow easier mainline coordination and minimize cross-street delay.

4. New street or roadway construction should anticipate the need for future signals and the need for handholes and conduit, particularly under the roadway.

5. Pretimed controllers are used in built-up urban environments, particularly central business districts. The streets are not excessively wide and the traffic patterns are quite predictable. In this environment, a signal cycle should contain pedestrian movements. Actuated controllers are used in suburban and rural environments. In the rural environment, the actuated controller tends to reduce the number of stops and does not cut off platoons of vehicles. In the suburban environment, the arterial streets tend to be very wide, and the volumes are usually quite high on these arterials. There are not usually many pedestrians crossing such an arterial, so an actuated controller tends to operate much more efficiently, as it is not necessary to time pedestrian intervals except when an actual demand exists.

6. Splits and offsets should be carefully estimated to determine their impact on arterial flow. A split is the relative percentage of green, yellow, and red clearance time allocated to each of the various phases at a single intersection. An offset is a system reference time, usually expressed in percent of cycle length.

7. Minimum pedestrian walk and clearance timings should be anticipated when designing coordinated signal systems.

D. Signal Design Elements

MnDOT Section 9.6.05 notes the following elements should be considered:

1. The most efficient operation of a signal system is attained with the fewest phases that are enough to move traffic without hazardous conflicts. Procedures exist to determine the optimum number of phases for an intersection.

2. The primary consideration in signal head placement is clear visibility. Drivers approaching an intersection shall be given a clear and unmistakable indication of their right-of-way assignment. The number and placement of signal faces shall conform to the requirements of the MUTCD. Overheads should be located as near as practicable to the line of the driver’s normal view. When an overhead is to control two lanes, it should be installed over the lane line dividing the two lanes. An overhead should be used over each lane when speeds are above 40 mph. The size of lenses shall be as stated in the MUTCD. See the signal head placement charts in the Signal Design Manual. In general, vehicle signal faces should be placed and aimed to have maximum
effectiveness for an approaching driver located a distance from the stop line equal to the distance traveled while reacting to the signal and bringing the vehicle to a stop at an average approach speed. Visors, shields, or visual delimiting should be used to help in directing the signal indication to the approaching traffic, and to reduce sun-phantom resulting from external light entering a signal lens.

3. Vehicle detectors should be placed according to the detector spacing chart and the loop placement diagrams.

4. At locations where pedestrians are expected, provisions must be made to control pedestrian activity in and around the signalized intersection. At locations where pedestrians are expected, pedestrian indications shall be provided if minimum pedestrian crossing time exceeds minimum vehicular green time, or if any of the conditions set out in section 4E.3 of the MN MUTCD are met. Pedestrian push buttons should be installed at locations with pedestrian activity where it is not operationally efficient to provide pedestrian timing on every cycle. Pedestrian signal indications shall be mounted, positioned, and aimed so as to be in the line of pedestrians' vision, and to provide maximum visibility at the beginning of the controlled crossing.

5. If it is determined to prohibit pedestrian movement across any approach, that prohibition must be clearly visible to pedestrians by use of Standard Sign R9-3a on each side of the prohibited crosswalk. See part 4 of the MN MUTCD for further information.

6. Street lighting should normally be installed with traffic signals and flashing beacons. The luminaires are generally 250-watt high-pressure sodium vapor luminaires, mounted in the far-right quadrants of the major street. Larger intersections may require additional luminaires. Forty-foot mounting heights provide even light distribution. Street lights installed on Type A signal mast arm poles should be mounted at approximately 350 degrees clockwise from the mast arm in order to provide frontal illumination of any signs mounted on the mast arm.

Signal design must take into account the existing adjacent lighting systems and the equipment available to provide access to the luminaires for relamping and maintenance. The presence of overhead power lines must also be taken into account. These must be designed around or moved.

The following publications provide a wide range of guidance in the design of traffic signals:

Traffic signal designs should be based on project and intersection-specific design criteria (Section 13A-3, D). Key elements to consider and include in the design, as appropriate, include the following:

1. **Signal Layout**:
   a. Pole locations considering clear zone requirements, existing and proposed utilities, signal head locations, mast arm lengths, lighting needs, elevation differences, pedestrian pushbutton locations, and right-of-way constraints.
   b. Cabinet location considering proposed power service, signal interconnect, sight distance, and cabinet accessibility.
   c. Signal head locations and configurations considering visibility and proposed phasing.
d. Handhole locations and conduit layout to minimize lengths of conduit runs.


e. Signing needs.

f. Stop line and advance detection.

g. Miscellaneous equipment (EVP, traffic monitoring camera, etc.)

2. Conduit and Wiring:

a. Conduit sizes considering conduit fill percentage.

b. Wiring quantities and configurations based on equipment needs.

c. Fiber optic cable configuration, terminations, and splicing.

3. Phasing and Timing:

a. Type of left turn phasing (protected-only, protected-permissive, permissive-only) for each approach.

b. Possible right turn overlap for right turn lanes.

c. Phasing sequence diagram.

d. Recommended initial timings.

4. Miscellaneous Items:

a. Traffic signal notes and supplemental specifications, as needed.

b. Estimated traffic signal quantities.

c. Specific equipment or materials requirements.

d. Reference or include applicable SUDAS Specifications Section 8010 figures and/or special details needed.

E. Traffic Signal Operations

The MnDOT Traffic Engineering Manual provides an exceptional discussion on basic traffic signal operations and design considerations. These are not reprinted within this document but these references are noted below:

- Traffic Engineering Manual, Chapter 9
  o Chapter 2. Traffic Signal Phasing and Operations
  o Chapter 3. Head Placement Charts
  o Chapter 4. Detection
- MnDOT Lighting and Signal Certification Field Guide

The following publications provide guidance regarding traffic signal timings and operations:

Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, NCHRP Report 731

Traditionally, protected-only left turn phasing has been used for dual left turn lanes, due to safety concerns with permissive operation. However, protected-only left turn phasing can be inefficient, particularly during off-peak times. If protected-permissive or permissive-only left turn phasing is being considered, a traffic engineering study should be performed, including evaluation of the following:

- Operating speeds
- Possible sight distance obstructions (vehicles in opposing left turn lane(s), horizontal/vertical roadway geometry)
- Left turn and opposing through traffic volumes (vehicle mix - trucks)
- Left turn crossing distance
- Crash history
- Vehicle delays and queuing
- Potential pedestrian crossing conflicts
- Controller, cabinet and equipment flexibility and limitations

If protected-permissive or permissive-only operation is determined to be acceptable, flashing yellow arrow signal heads are required for separate signal faces per the MUTCD. Consideration should be given to providing this type of operation only during off-peak times.

To help jurisdictions better manage the variations in traffic volumes and operating speeds along signalized corridors, the use of Automated Traffic Signal Performance Measures (ATSPMs) and/or Adaptive Traffic Signal Control (ATSC) could be considered.

The use of ATSPMs give agencies a better idea of how signal timing plans are performing throughout the day / week / month / year and provide the information needed to make adjustments to fine tune timing plans and coordination plans. New traffic signal controllers, or third party equipment added to existing traffic signal controllers, collect the real-time data needed to produce the performance reports. More information can be found on the FHWA ATSPM Website.

The data produced through the ATSPMs can be used to determine the potential need for an ATSC system, which utilizes much of the same data collected for ATSPMs and adjusts traffic signal plans or coordination plans automatically. ATSC systems can be useful for corridors in which traffic is more variable or unpredictable than what could be addressed with specific time-of-day timing and coordination plans. More information can be found on the FHWA ATSC Website.

F. Pedestrian Considerations

1. Geometrics:

   a. Geometrics have a significant impact on pedestrian operations and safety at signalized intersections as alluded to in the previous section. Intersection skew, number of lanes, lane width, medians, islands, and curb returns all impact the distance pedestrians must travel to cross an intersection. As the distance to traverse an intersection approach increases, so does the signal timing that must be allocated to the pedestrian clearance interval. Long pedestrian clearance intervals have a negative impact on traffic capacity and operations. A pedestrian actuation will disrupt traffic signal coordination and require several cycles to bring a corridor back into coordination. However, large pedestrian volumes may dictate signal timing resulting in less than optimal conditions for vehicles. A traffic engineer must balance the
priorities and safety of vehicles and pedestrians with no calculations or answers that clearly define a solution but do provide guidance at signalized intersections.

b. Right turns present challenges for pedestrians. A driver of a vehicle turning right on red will be looking left for a gap in traffic. A pedestrian approaching from the right may have a walk indication. If the driver sees a gap but does not look back to the right, the pedestrian may not be seen by the driver resulting in a collision. As a result, a traffic engineer must decide whether to allow right turns on red.

c. Right turn lanes can present additional challenges for pedestrians, especially if the returns are large and channelize traffic with an island. The islands can channelize right turning vehicles away from the traffic signal indications creating difficulties signalizing the right turn movement. Using a stop sign instead of a supplemental signal indication for the channelized right turning movement is not an option. It creates a confusing message when all movements on the approach see green indications, including right turning vehicles, until they are partially through the turning maneuver and see a stop sign. Some agencies assign the right turning vehicles a yield sign but it creates an issue protecting pedestrians. If a pedestrian push button is used at the back of curb and pedestrians must cross a right turn lane controlled by a yield sign, it may give pedestrians a false sense of security when crossing in front of right turning vehicles. Drivers of right turning vehicles see a yield sign and look left, away from the pedestrians stepping off the curb, for a gap in traffic. In fact, drivers of right turning vehicles would be looking even farther left due to the channelization and orientation of the vehicles making it even more difficult for drivers to see pedestrians approaching from the right. Consequently, pedestrian volume and safety are important considerations when considering and designing right turn lanes.

d. The final additional geometric consideration as it relates to pedestrians is the pedestrian refuge. Right turn islands and medians often double as pedestrian refuges. If islands and medians are intended to be used as pedestrian refuges, they must be large enough to hold pedestrians and be ADA compliant. A traffic engineer must consider the likelihood that pedestrians will stop and get stranded in an island or median. On large approaches, it may be intended that pedestrians only cross a portion of the approach and stop in a median or island. As a result, a traffic engineer must decide whether to install supplemental push buttons in the right turn island or median. If islands and medians are not intended to function as pedestrian refuges, they must be located so they do not obstruct the path of pedestrians.

2. Visibility: Visibility is important to the safe operation of the pedestrian indications. Pedestrian indications as well as the push buttons should be easily located by pedestrians. Consider where vehicles, especially large trucks, may stop so they do not obstruct the view of the pedestrian indications. This will require careful location of median noses, stop bars, crosswalks, and the pedestrian heads. Finally, make sure there are no obstructions in the returns that may prevent drivers and pedestrians from seeing one another such as the signal cabinet or vegetation.

3. Special Considerations: Circumstances often arise that require special considerations. For example, children may have difficulty understanding the meaning of pedestrian indications. Count down pedestrian heads may be easier for children to understand; therefore, have increased value in school zones. Count down pedestrian heads may also have added value on wide approaches. The flashing numbers can attract a person’s eye and the numbers tell a pedestrian how much time they have to cross which has added value on very wide approaches. There may be a particular area within a city that has a high concentration of visually impaired. In this case, audible pedestrian indications may have added benefit. In many cases, some extra thought and minimal dollars can change a design from adequate to desirable.
4. **Americans with Disabilities Act**: The Americans with Disabilities Act (ADA) addresses several design requirements relating to pedestrians. ADA addresses design requirements for items such as sidewalk ramps, truncated domes, and pedestrian push buttons. These topics are addressed in detail in Chapter 12 - Sidewalks and Bicycle Facilities and other design manuals guides such as the MUTCD and the AASHTO Policy on Geometric Design of Highways and Streets.

a. **Accessible Pedestrian Signals (APS)**: Evaluate each traffic signal project location to determine the need for accessible pedestrian signals, especially if the project location presents difficulties for individuals with visual disabilities. Some jurisdictions elect to provide APS for all new or modified signal installations. An engineering study should be completed that determines the needs for pedestrians with visual disabilities to safely cross the street. The study should consider the following factors:

- Potential demand for accessible pedestrian signals
- Requests for accessible pedestrian signals by individuals with visual disabilities
- Traffic volumes when pedestrians are present, including low volumes or high right turn on red volumes
- The complexity of the signal phasing, such as split phasing, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases
- The complexity of the intersection geometry

One tool that is available for evaluation of the need for APS and also prioritizing the order for installing APS equipment on crosswalks can be found at www.apsguide.org developed by the National Cooperative Highway Research Program (NCHRP).

If APS are warranted, it is necessary to provide information to the pedestrian in non-visual formats. This will include audible tones and vibrotactile surfaces. Pedestrian push buttons should have locator tones for the visually impaired individual to be able to access the signal. Consistency throughout the pedestrian system is very important. Contact the Jurisdictional Engineer regarding the standards and equipment types that should be incorporated into the design of the accessible pedestrian signal system. New tones such as clicks, ticks, and other electronic sounds have replaced the cuckoos and chirping tones of past systems.

b. **APS Design Elements**: Refer to MUTCD Sections 4E.08 through 4E.13 and the following information.

1) **Push Button Stations**: An APS push button station is a weather-tight housing with a 2 inch diameter push button, a speaker, and a pedestrian sign. Braille signing, raised print or a tactile map of the crosswalk may also be provided. The push button has a vibrotactile arrow pointing in the direction of the crossing.

2) **Location of Pedestrian Push Buttons**: Push buttons (APS and non-APS) should be located adjacent to the sidewalk, between 1.5 and 6 feet from the edge of curb, shoulder, or pavement and no more than 5 feet from the outside crosswalk line (extended). Where physical constraints make the 6 feet maximum impractical, push buttons should be located no more than 10 feet from the edge of curb, shoulder, or pavement. Where two push buttons are provided on the same corner of the intersection, they should be separated by at least 10 feet. If the 10 feet separation is not feasible, audible speech walk messages are required for APS. Supplemental push button poles or posts will typically be needed to meet the above criteria. The MUTCD requires a pedestrian push button mounting height of approximately 3.5 feet above the sidewalk; keep in mind that the 3.5 feet is above the grade where the pedestrian would be when accessing the button. The push button should be located so pedestrians using the audible or vibrotactile indication can align themselves and prepare for the crossing while waiting close to the push button station and the crossing departure point.
It is common to see a narrow grass strip between the sidewalk and pole used to mount the push buttons or to only see sidewalk on one side of a pole containing multiple push buttons. It is difficult to impossible for a person in a wheelchair to reach the push button in cases like these since it often requires the person to struggle with one wheel in the grass and one on the sidewalk. As a result, sidewalks must be paved up to the pole used to mount the push buttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a push button.

3) **Locator Tone:** APS push buttons have a locator tone to allow visually impaired individuals to access the signal. The locator tone should be audible 6 to 12 feet from the push button. The locator tone is active during the pedestrian clearance and “DON’T WALK” intervals.

4) **Walk Indications:**
   - In addition to visual indications, APS include audible and vibrotactile walk indications. When at least 10 feet separation is provided between pedestrian push button stations, the audible walk indication is a percussive tone. If 10 feet separation is not provided, speech messages are required. The speech message should name the street to be crossed and indicate that the walk sign is on. For example: “Main. Walk sign is on to cross Main.” Other audible messages may be developed, including counting down the pedestrian clearance time, depending on the needs of the particular crosswalk or intersection. Designations such as “Street” or “Avenue” should not be used unless necessary to avoid ambiguity at a particular location. If the traffic signal rests in WALK, the tone/message should be limited to 7 seconds and be repeated with each actuation recalled by a button press during the WALK interval, provided that the crossing time remaining is greater than the pedestrian change interval.
   - The vibrotactile walk indication is provided by a high visual contrast tactile arrow on the push button that vibrates during the walk interval. The vibrotactile indication is particularly useful to individuals who have both visual and hearing impairments. The pedestrian must be able to stand with place a hand on the device while being aligned and waiting to begin the crossing. The arrow should be aligned parallel to the direction of travel on the associated crosswalk.

c. **APS System Options:**
   - Products currently in the marketplace involve use of 2-wire or 4-wire systems, indicating the number of wires between the push button station and the control unit (CU). The 2-wire system uses a central CU mounted in the controller cabinet, and may provide Ethernet connectivity. Advantages of this system include minimal field wiring required on retrofit applications and central control of multiple crossings.
   - The 4-wire system requires a separate CU mounted in the applicable pedestrian signal head for each push button station. In addition to the typical two wires between the push button and the controller cabinet, a 4-wire cable must be provided between the push button station and the CU. This system may be more cost effective for installations with only one or two crossings.

d. **APS Compliant Equipment:** The following equipment currently meets 2009 MUTCD and 2011 proposed public right of way accessibility guidelines (PROWAG) for accessible pedestrian signals. Other compliant equipment may also be available.
   - Advisor Guide and Advisor Advanced Pedestrian Stations (AGPS and AAPS) manufactured by Campbell Company.
   - EZ Communicator Navigator APS manufactured by Polara.

e. **Location of Pedestrian Push Buttons:** It is common to see a narrow grass strip between the sidewalk and pole used to mount the push buttons or to only see sidewalk on one side of a
pole containing multiple push buttons. It is difficult to impossible for a person in a wheelchair to reach the push button in cases like these since it often requires the person to struggle with one wheel in the grass and one on the sidewalk. As a result, sidewalks must be paved up to the pole used to mount the push buttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a push button. The MUTCD requires a pedestrian push button mounting height of approximately 3.5 feet above the sidewalk; keep in mind that the 3.5 feet is above the grade where the pedestrian would be when accessing the button. Often times pole foundation elevations end up above grade and installing a push button based on the foundation elevation and not the ground elevation where the pedestrian accesses the button results in a mounting height that is too high. Finally, consider the proximity of the push buttons to the street. If the poles used to mount the push buttons are too far from the street, pedestrians will not use the push buttons. Consider installing supplemental poles closer to the street for mounting the push buttons.

G. Driver and Pedestrian Expectations

Other traffic signal design considerations involve driver and pedestrian expectancy. A traffic engineer must look beyond the traffic signal being designed and consider the characteristics of the corridor and the attributes of the existing traffic signals along the corridor. For example, left turn phasing should be applied consistently and not switch between protected only and protected/permissive without legitimate reasons. If pedestrian signal heads are used, they should be used consistently and not sporadically where one intersection uses the heads and the next intersection relies on vehicular signal heads to guide pedestrians. Traffic signal head style, placement, and orientation should be consistent along a corridor as well as sign type, size, and location. Intersections should not randomly switch between doghouse and vertical five section heads, center of lane and lane line placement, or vertical and horizontal signal head orientation. Consistently applied design criteria improve driver and pedestrian expectations which typically promote improved safety and operations. However, circumstances exist that may, at times, require changes to design criteria to increase vehicle and pedestrian safety and operations.

H. Future Development and Improvements

One of the biggest traffic signal design challenges is designing a traffic signal in an area that is under development or being redeveloped. Under these circumstances, much of the data needed for design is either unknown or unstable. Land uses are often modified and business prospects continually change often having significant impacts on existing and future traffic volumes. In addition, the rate at which traffic volumes will increase is difficult to determine. In such cases, the traffic signal designer must work closely with adjacent area land use planning agencies to work towards reasonable expectations for future travel demands and overall operations. Future phases can be accommodated for within the design to significantly reduce the need to replace signal poles, mast arms, and foundations locations, adjust mast arm lengths, or add additional functionality to the traffic signal. These simple steps can build credibility with the public and add considerable efficiency to the traffic signal design and overall engineering process.
Traffic Signal Specifications Information

This section provides design information that complements and is organized similar to SUDAS Specifications Section 8010, which includes:

Part 1 – General

Part 1 provides direction on general items such as submittals; substitutions; delivery, storage, and handling; scheduling and conflicts; and measurement and payment.

Part 2 – Products

Part 2 describes the products to be provided and is arranged as follows:

2.01 Underground
2.02 Detection
2.03 Communications
2.04 Cabinet and Controller
2.05 Poles, Heads, and Signs

Part 3 – Execution

Part 3 describes how these products should be installed and matches the arrangement described in Part 2, with the following additions:

3.06 Temporary Traffic Signal
3.07 Surface Restoration
3.08 Testing
3.09 Documentation

The information below provides selective guidance on the specifications.

A. Part 1 - General

1. Submittals: There are several key submittals required of the contractor following award of the project. These are described below.

   a. Schedule of Unit Prices:
      1) Document: Prepared by the traffic signal designer and included within the contract documents (generally attached to the back of the traffic signal specifications) or provided to the contractor prior to construction.
      2) Purpose: Contracting authority approval of the unit pricing for all major traffic signal items. Establish unit pricing for change order work if needed. Used to estimate partial payments.
      3) Includes: Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (unit price, and unit extension).
      4) Contractor Action: Within 30 days after award, the contractor is required to submit a completed schedule of unit prices to the contracting authority for engineer approval.
5) **Engineer Action:** Review the schedule in a timely manner. Check the appropriateness of each unit price, the accuracy of each unit extension calculation, and ensure that the grand total for all unit extensions matches the lump sum bid item for traffic signalization. Upon acceptance, sign and date the document and provide a copy to the contractor.

b. **Material and Equipment List:**
   1) **Document:** Prepared by the traffic signal designer and included within the contract documents (generally attached to the back of the traffic signal specifications) or contractor.
   2) **Purpose:** Contracting authority approval of the make and model numbers, materials and equipment for all major traffic signal items.
   3) **Includes:** Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (manufacturers name and each item’s model number).
   4) **Contractor Action:** Within 30 days after award, the contractor is required to submit a completed list of materials and equipment to the contracting authority for engineer approval.
   5) **Engineer Action:** Review the schedule list in a timely manner. Check the appropriateness of each identified manufacturer and model number. Upon acceptance, sign and date the schedule list and provide a copy to the contractor.

c. **Contractor Certification:**
   1) **Document:** Prepared by the contractor on company letterhead.
   2) **Purpose:** Contracting authority approval of key project personnel verification of contractor qualifications.
   3) **Includes:** Name, contact information, and certification of the Level II International Municipal Signal Association (IMSA) Certified Traffic Signal Technician(s) working on the project, along with a copy of their IMSA certificate.
   4) **Contractor Action:** Within 30 days after award, the contractor is required to submit the contractor certification to the contracting authority for engineer approval.
   5) **Engineer Action:** Review the appropriateness of the information and on acceptance, sign and date the document, and provide a copy to the contractor provided.

d. **Shop Drawings:**
   1) **Document:** Prepared by the traffic signal pole supplier for the contractor.
   2) **Purpose:** Contracting authority approval review of traffic signal poles, supports, and related hardware.
   3) **Includes:** Shop drawing information detailing each traffic signal pole, accompanying parts, and necessary hardware.
   4) **Contractor Action:** Within 30 days after award, submit shop drawings to the contracting authority for engineer approval review.
   5) **Engineer Action:** Review the shop drawings in a timely manner. Check the appropriateness of each detail. Upon acceptance completion of the review, sign initial and date the shop drawings and provide a copy to the contractor.

e. **Catalog Cuts:**
   1) **Document:** Prepared by the traffic signal equipment supplier for the contractor.
   2) **Purpose:** Contracting authority approval review of all items within the equipment and materials list as well as for supporting components.
   3) **Includes:** Catalog cut information detailing the make, model number, manufacturer, and specific details for all traffic signal equipment.
   4) **Contractor Action:** Within 30 days after award, submit catalog cuts to the contracting authority for engineer approval review.
5) **Engineer Action:** Review the catalog cuts in a timely manner. Check the appropriateness of each item. Upon acceptance of the review, sign and date the catalog cut documents and provide a copy to the contractor.

2. **Substitutions:** Comply with SUDAS Specifications Division 1—General Provisions and Covenants.

3. **Delivery, Storage, and Handling:** Comply with SUDAS Specifications Division 1—General Provisions and Covenants.

4. **Scheduling and Conflicts:** Comply with SUDAS Specifications Division 1—General Provisions and Covenants.

5. **Special Requirements:** Comply with the current edition of the MUTCD as adopted by the Iowa DOT.

2. **Measurement and Payment:** Traffic signal work is typically bid as a lump sum item of which no measurements are made. However, partial payments to the contractor are established through measuring or estimating installed quantities and applying these quantities to the appropriate approved unit price (see Schedule of Unit Prices above).

**B. Part 2 - Products**

1. **Underground:**

   a. **Handhole:** Handholes are a critical component to traffic signal design. The standard precast concrete handhole shown in Figure 13A-5.01 is typically used at all locations except where fiber optic cables are used and adjacent to the controller cabinet. The designer should verify with the jurisdiction how handhole lids are to be labeled and whether cable hooks should be included in handholes (sometimes not included in fiber optic handholes).

   Composite Handholes can come in all shapes and sizes (see Quazite example table SUDAS Specifications Figure 8010.103) and must be specified by the Engineer. These are typically made of a polymer concrete. Polymer concrete is made from selectively graded aggregates in combination with a polymer resin system. When combined through a process of mixing, molding and curing, an extremely powerful cross-linked bond is formed. Precast polymer concrete is reinforced with fiberglass for strength and rigidity.

   The designer should ensure that the contract documents clearly distinguish between handhole types, sizes, and desired locations. Handholes are typically uniquely numbered on the contract documents.

   An online resource can be found through Chapter 12—Handholes, Pulling Vaults, and Junction Boxes from Mn/DOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for considering handhole features and functions along with execution issues such as installation, inspection, and key points to remember.
b. **Conduit:** The SUDAS Specifications allow both steel and PVC flexible conduit. Steel conduit is typically used on all service risers and plastic PVC or HDPE is used at all other locations. A typical signal installation will use a variety of conduit sizes. Some jurisdictions may request a specific color for fiber optic conduit. When connecting HDPE conduit to PVC conduit, the designer should work with the Contractor to clarify the method or materials to be used.

A conduit check list from Mn/DOT Signal Design Documents, Checklists, and Worksheets is noted below: The designer should ensure the following: The following is a conduit checklist to consider during signal design:

- Conduit size and cables listed.
- Correct symbol for in-place conduit.
- Correct symbol for proposed conduit.
- Check for conflict with in place underground utilities.
- Check if conduit fill is less than 40% (Check).
- 3 inch RSC minimum typical size conduit under all public traveled roadways.
- Spare Possible spare 4 inches of conduit stub out of controller cabinet for future use, threaded and capped.
- Conduit runs for interconnect should be as straight as possible.
- No PVC above ground (for example: bridge crossings and wood pole systems).
- All conduits except those within pads shall drain.
- Primary power shall be in a separate conduit run and separate hand holes.
- Size of bends and elbows in conduit according to National Electrical Code or UL guidelines.
- If conduit is suspended under a bridge, does the distance between supports conform to code, is a hanger detail given in plan, and are expansion fittings called for?
- Conduit placed under in-place pavement does not need to be labeled (bored or pushed).

An online resource can be found through Chapter 11 - Conduits and Fittings from MnDOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for considering conduit installation and features.

c. **Wiring and Cable:** Signalized intersections require a variety of standard wires and cables; however, the number, size, and quantity of extra conductors pulled can vary by agency. The designer should include sufficient details to ensure the clear identification of cable runs by conduit. The inspector should make sure all wires are terminated neatly and in an organized fashion. With the exception of detector lead-in wires, no signal cable splices are allowed within underground handholes. Cables for vehicle and pedestrian signal heads should be continuous from the pole base to the controller cabinet without splices in underground handholes. Video and emergency vehicle preemption cables should be continuous without splices from the unit to the controller cabinet. All plan terminology should be consistent for example:

- Cable callouts/symbols correct (3/C #12, 2/C #14, 3/C #20 5/C #14, 2/C #14, 1/C #10 all different, for example) identifying the number of cables and the number and size of conductors (for example 1-12C#14, 2-5C#14, 2-2C#14, 1-1C#6 Ground, 1-1C#10 Tracer, etc.).
- Ped indications on different phases shall have separate 3/C #12 5/C #14 cables.
- Separate 2/C #14 detector lead-in cable for each group of loop detectors.
- Provide spares for future expansion of system, if necessary, and label them.
An online resource can be found through Chapter 15–Wiring from Mn/DOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for labeling and training wires (very Mn/DOT specific though).

d. **Foundations:** Signalized intersections require footings or foundations for all poles, pad-mounted controller pads, cabinets, and other service cabinets such as fiber optic hubs or electrical service panels. Controller Cabinet footing details are included for NEMA controller cabinets as shown in Figure 13A-5.02 shown on SUDAS Specifications Figure 8010.101. The designer should ensure that the plans reflect any desired future use spare conduit stubs out of the foundation.

![Figure 13A-5.02: Cabinet Footing Details](SUDAS Specifications Figure 8010.101)
Foundation size and depths vary according to pole style, mast-arm length, and pole loadings. The SUDAS Specifications provide figures for both pedestal poles and for mast-arm poles (Figure 13A-5.04 8010.102). SUDAS standard Type A mast arm pole foundation in soil designs (Figure 8010.102 and Table 13A-5.01 and Figure 13A-5.04) are based on the following guidelines, parameters, and assumptions:

- Broms’ method for lateral resistance (moment/shear design) per AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals, 6th Edition, 2013 (AASHTO LTS-6), with a safety factor of 2.86, which accounts for the possible under capacity of the soil strength (0.7) and the overload factor for the loadings (2.0).
- Alpha method for torsion design per FHWA-NHI-10-016 Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010, with a safety factor of 1.0.
- Disturbed soil due to frost: 2.5 feet for moment/shear design, 5.0 feet for torsion design. Broms’ method as presented in AASHTO LTS-6 includes an additional 1.5 diameters of foundation length to be added to the minimum foundation length required. The maximum value of 1.5 diameters or 2.5 feet shall be used when determining the disturbed soil for moment/shear design.
- Groundwater is present for moment/shear and torsion designs.
- Pole loadings as shown in Figure 13A-5.03, with poles designed per AASHTO LTS-6 specifications. Basic wind speed equals 90 mph with a 50 year mean recurrence interval and gust effect factor of 1.14 for strength design. Use Category II for fatigue design. Apply only natural wind gust loads (i.e. do not apply galloping loads, vortex shedding loads, or truck-induced gust loads) for fatigue design. Install vibration mitigation devices on all traffic signal pole mast arms over 60 feet in length as shown in the figures.
- Cohesive soils along the length of the foundation with an average blow count (N60) greater than or equal to 8, which equates to an average unconfined compressive strength (Qu) greater than or equal to 2.0 kips per square foot.
- Reinforced concrete design per AASHTO LTS-6 specifications.

For pole loading conditions greater than shown in Figure 13A-5.03, granular soils, or lower strength soils, special foundation designs will be required. Soil boring testing should be performed prior to construction to verify soil types and strengths if non-typical soils are suspected. If rock is anticipated at the project site and the designer intends to utilize the Type C mast arm pole foundation in rock or a Type B foundation (see Figure 13A-5.04 8010.102), determine rock quality through a subsurface investigation completed by a geotechnical engineer licensed in Iowa. If rock is encountered unexpectedly, the contractor may undertake a subsurface evaluation conducted by a geotechnical engineer licensed in Iowa to determine the quality of the rocks encountered. Based on that investigation, the Engineer may approve the use of a Type B or Type C foundation in rock if requested by the contractor.

**Table 13A-5.01: Standard Mast Arm Pole Foundation Designs**

<table>
<thead>
<tr>
<th>Loading Type (Figure 13A-5.03)</th>
<th>Maximum Mast Arm Length (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
</tbody>
</table>
**Figure 13A-5.031**: Mast Arm Pole Loadings for Standard Foundation Designs

<table>
<thead>
<tr>
<th>Loading Type</th>
<th>Mast-Arm Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20-35'</td>
</tr>
<tr>
<td>2</td>
<td>36-45'</td>
</tr>
<tr>
<td>3</td>
<td>46-60'</td>
</tr>
<tr>
<td>4</td>
<td>61-100'</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12&quot; five section signal head with backplate</td>
</tr>
<tr>
<td>2</td>
<td>12&quot; three section signal head with backplate</td>
</tr>
<tr>
<td>3</td>
<td>30&quot; X 36&quot; sign</td>
</tr>
<tr>
<td>4</td>
<td>24&quot; X 120&quot; sign</td>
</tr>
<tr>
<td>5</td>
<td>Video camera</td>
</tr>
<tr>
<td>6</td>
<td>Video camera with 6' extension</td>
</tr>
<tr>
<td>7</td>
<td>Wind damper (18&quot; X 48&quot; sign black)</td>
</tr>
</tbody>
</table>

20' max. arm length

12' 12' 12' 12' 6'

3' 3' 3' 3' 3' 3'

12' 12' 12' 6'

40' max. luminaire mounting height

15 min.

210.0 - 258.0

10 min.
The Type A Foundation is the normally required foundation for construction. Where rock is encountered, the Engineer may approve the use of the Type B or C Foundation, prior to installing a foundation in rock, obtain a subsurface investigation certified by a geotechnical engineer licensed in the State of Iowa.

1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rod, edge, or non-shrink grout with weep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedded end.

### Pole Foundation Details

<table>
<thead>
<tr>
<th>Max. Mast Arm Length</th>
<th>Foundation</th>
<th>&quot;V&quot; Bars</th>
<th>Tie Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Count</td>
<td>Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#8</td>
</tr>
<tr>
<td>45'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#8</td>
</tr>
<tr>
<td>55'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#8</td>
</tr>
<tr>
<td>65'-0&quot;</td>
<td>3'-0&quot;</td>
<td>13</td>
<td>#8</td>
</tr>
<tr>
<td>70'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#10</td>
</tr>
<tr>
<td>80'-0&quot;</td>
<td>3'-0&quot;</td>
<td>14</td>
<td>#10</td>
</tr>
<tr>
<td>90'-0&quot;</td>
<td>4'-0&quot;</td>
<td>16</td>
<td>#10</td>
</tr>
<tr>
<td>100'-0&quot;</td>
<td>4'-0&quot;</td>
<td>20</td>
<td>#10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upper Spacing</th>
<th>Lower Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td># Spaces S1</td>
<td># Spaces S2</td>
</tr>
</tbody>
</table>

| 9"           | 12"          |
| N/A          | N/A          |
| N/A          | N/A          |
| 6"           | 8"           |
| 5 12"        | 5 12"        |
| 6"           | 8"           |
| 5 12"        | 5 12"        |
| 6"           | 8"           |
| 10 8"        | 8"           |
| 10 8"        | 8"           |
| 7 8"         | 7 8"         |

**Note:** All dimensions are out to out.
Type B Foundation is applicable for traffic signal poles with mast arm lengths up to 60 feet.

If the excavation for a Type B Foundation is not open for more than 1 calendar day, install temporary barrier rail if any part of the excavation is located within the clear zone. Temporary barrier rail layout requires the Engineer's approval.

Competent rock has an average unconfined compressive strength (f_s) of at least 2,000 psi and rock quality designation of at least 90% RQD. Conditions not meeting minimum requirements will require:
- A site-specific design, or
- Using the parameters for Mast Arm Pole Foundation in Soil.

1. Install rodent guard or non-shrink grout with weep hole.
2. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedded end.
3. Place 13 equally spaced #6 vertical bars.
4. Cast foundation concrete against competent rock. If foundation is formed, place backfill with concrete cast against rock.
5. When in contact with rock, place ground rods as specified in National Electrical Code, current edition.
6. #6 bars spaced at 8 inch maximum. Ties may be welded to vertical bars.
Figure 13A-5.04 (Continued): Pole Foundation Details

**MAST ARM POLE FOUNDATION IN ROCK TYPE C FOUNDATION**

1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rodent guard or non-shrink grout within deep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedment strand.
4. When in contact with rock, place ground rods as specified in National Electrical Code, current edition.

<table>
<thead>
<tr>
<th>Max, Mast Arm Length</th>
<th>Foundation Depth (W)</th>
<th>'S' Bars (L)</th>
<th>Tie Bars</th>
<th>'V' Bars</th>
<th>Count</th>
<th>Size</th>
<th>Length</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>35'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>45'-0&quot;</td>
<td>3'-6&quot;</td>
<td>2'-6&quot;</td>
<td>4'-6&quot;</td>
<td>3'-0&quot;</td>
<td>12</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>55'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>4'-6&quot;</td>
<td>3'-0&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>60'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>4'-6&quot;</td>
<td>3'-0&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>70'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-6&quot;</td>
<td>5'-6&quot;</td>
<td>3'-6&quot;</td>
<td>14</td>
<td>#9</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>80'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-0&quot;</td>
<td>5'-6&quot;</td>
<td>3'-6&quot;</td>
<td>14</td>
<td>#9</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
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<td>90'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>6'-0&quot;</td>
<td>4'-0&quot;</td>
<td>15</td>
<td>#10</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>100'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>6'-0&quot;</td>
<td>4'-0&quot;</td>
<td>15</td>
<td>#10</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
</tbody>
</table>

*Broken rock has an average unconfined compressive strength (f_u) of at least 1.0 ksi and rock quality designation of at least 20%.

*Competent rock has an average unconfined compressive strength (f_u) of at least 2.0 ksi and rock quality designation of at least 90%.

***Foundation length L must be sufficient to provide a 3 inch clearance between the bottom of the traffic signal pole anchor bolts and the bottom of the rock socket.

****The Rock Socket Length L can be decreased if the total length of the shaft is L, as shown in the table.

Conditions not meeting minimum requirements will require site specific designs or shall use the Type A Foundation bolt parameters.
1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rodent guard or non-shrink grout withweep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedment end.

PEDESTAL POLE FOUNDATION IN SOIL OR ROCK

DETAIL 'A'

11" Shape with Forms (Square or Circular)
The designer should ensure that all foundations:
- Are located in compliance with applicable clear zone requirements (unless breakaway pedestal poles)
- Do not conflict with pedestrian walkways or ramps
- Are at the proper finish grade elevation
- Avoid or minimize conflicts with existing or proposed utilities
- Provide acceptable pedestrian pushbutton locations per MUTCD guidance
- Are located to provide adequate visibility of signal heads

An online resource can be found through Chapter 10 - Foundations and Equipment Pads from MnDOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for foundation types and installation details.

e. Bonding and Grounding: All traffic signal installations must be bonded and grounded according to the National Electrical Code.

Bonding is defined in the Code Book as the permanent joining of metallic parts required to be electrically connected. In a traffic signal, the term is used to describe the electrical and mechanical connection of conduit, metal poles, cabinets, and service equipment.

Grounding is defined in the Code as a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conductive body that serves in place of earth.

The designer should ensure that the contract documents include sufficient notation for the traffic signalized intersection to be properly bonded and grounded. This includes placing ground rods at each traffic signal pole and at the controller as well as through use of bonding and grounding jumpers within the handholes.

An online resource can be found through Chapter 13 - Grounding and Bonding from MnDOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for bonding and grounding details.

2. Detection: Detectors provide vehicle and pedestrian inputs to the traffic signal controller. Proper detector installation, operation, and maintenance is critical to the safe and efficient operation of any signalized intersection. An online resource to learn more about detection styles, modes, and typical layouts can be found within Chapter 9 - Traffic Signals from MnDOT’s Traffic Engineering Manual. Since this document is a PDF, some of the information from this source is provided below.

Detector sizes and locations vary by agency and by location. SUDAS provides a standard drawings for a typical modified diamond and rectangular detector loops (Figure 13A-5.05 8010.104).

An online resource can be found through Chapter 15 - Vehicle Detection from Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for installation and mounting details.

a. Inductive Loop Vehicle Detector: The most common type of vehicle detection device in use today is the inductive loop. This is a loop of wire imbedded in the pavement (saw cut in existing concrete or NMC loop in new concrete) carrying a small electrical current. When a large mass of ferrous metal passes over the loop, the magnetic field is disturbed and
generates, or induces, a change in resonant frequency in the wire. This change in frequency is then recognized by the detector amplifier and signals the controller that a vehicle is present.

**Figure 13A-5.05:** Inductive Loop Vehicle Detectors

(SUDAS Specifications Figure 8010.104)
b. **Pedestrian Push Button Detector:** There are a number of ways to provide pedestrian actuation at a signalized intersection. The most common equipment used by far is the pedestrian pushbutton detector. Pressing the button provides a contact closure that actuates the call. There are plenty of examples of good and bad pedestrian pushbutton placement; however, part of the problem is getting the pedestrian to use the button. Specific information regarding pedestrian detectors can be found in the MUTCD [Section 4E.08 Pedestrian Detectors](#).

An online resource can be found through [Chapter 18 - Accessible Pedestrian Signal Push Buttons](#) from MnDOT’s [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

c. **Video Detection Camera System:** Vehicle detection by video cameras is a popular form of vehicle detection within Iowa. The rapid processing of video images provides the detection outputs to the controller. The designer should carefully consider the type of equipment necessary to provide video detection, the maintenance needs of this equipment, and the specific installation and mounting requirements necessary.

Designers should consider relevant manufacturer recommendations and other online resources such as the [Guidelines for Using Video Detection at Intersections and Interchanges](#) by Bonneson at Texas Transportation Institute.

d. **Microwave/Radar Vehicle Detector:** Microwave/radar detection is often used within Iowa during temporary signal control to provide simple, non-intrusive vehicle detection. A variety of styles and levels of sophistication exist in the market today.

3. **Communications:** The designer may be required to provide supplemental specifications for these items given the highly proprietary nature of this equipment and the needs of the contracting agency. Generic specifications have been provided in the SUDAS Specifications.

4. **Cabinet and Controller:** The designer may be required to provide supplemental specifications for the controller, cabinet, and emergency vehicle pre-emption system given the highly proprietary nature of this equipment. Cabinet and controller options include TS1, TS2, ATC, and 2070. The need for controllers to collect high definition data should be considered. Generic specifications have been provided in the SUDAS Specifications; this section also includes references to UPS battery backup system and emergency vehicle preemption system. New information was added to the specifications regarding uninterruptable power supply battery back-up system. The designer should carefully consider the cabinet and mounting requirements of the battery back-up system.

An online resource can be found through [Chapter 21 - Traffic Control Signal Cabinets](#) from MnDOT’s [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

5. **Poles, Heads, and Signs:**

a. **Vehicle Traffic Signal Head Assembly:** Vehicle signal heads must comply with the following MUTCD sections [Chapter 4D](#).

   - [Section 4D.16](#) Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces
   - [Section 4D.17](#) Visibility, Shielding, and Positioning of Signal Faces
   - [Section 4D.18](#) Design, Illumination, and Color of Signal Sections
b. **Pedestrian Signal Head Assembly**: Pedestrian vehicle signal heads must comply with the following MUTCD sections: Chapter 4E of the MUTCD.

   - **Section 4E.01** Pedestrian Signal Heads
   - **Section 4E.02** Meaning of Pedestrian Signal Head Indications
   - **Section 4E.03** Application of Pedestrian Signal Heads
   - **Section 4E.04** Size, Design, and Illumination of Pedestrian Signal Head Indications
   - **Section 4E.05** Location and Height of Pedestrian Signal Heads
   - **Section 4E.06** Accessible Pedestrian Signals
   - **Section 4E.07** Countdown Pedestrian Signals

c. **Traffic Signal Poles and Mast Arms**: Signalized intersections require poles and mast arms to achieve proper traffic signal and pedestrian head placement. Mast arm details and typical loadings are shown on Figure 13A-5.03; additional mast arm details are shown on Figure 13A-5.06 SUDAS Specifications Figure 8010.105. The designer should ensure that the plan locations comply with all clear zone, sight restriction, and pedestrian flow criteria. Vertical clearance to overhead utility lines is a constant issue that designers should take note of during pre-design field activities. Although the minimum height from the pavement to the bottom of the signal housing is 15 feet, the designer should consider the street classification and the volume of large trucks in establishing the signal height above the pavement. However, the top of the signal housing cannot exceed 25.6 feet above the pavement. If the project being designed has specific requirements relative to the elevation of the end of the mast arm in relation to the connecting point on the vertical pole, include those requirements in the plans or special provisions of the contract documents.

   An online resource can be found through Chapter 16 - Signal and Light Poles from MnDOT’s Lighting and Signal Certification Field Guide, which provides the designer with a photographic resource for style, installation, and mounting details.

d. **Traffic Signal Pedestal Poles**: Pedestal poles provide alternate mounting heights for signal and pedestrian heads, are often used for pedestrian signals and pushbuttons, and are much easier to locate within a tight right-of-way. Pedestal pole details and typical head mounting information are shown in Figure 13A-5.07 on SUDAS Specifications Figure 8010.106.

e. **Traffic Signs**: The designer must ensure that all signs comply with Iowa DOT standards and the MUTCD.
Figure 13A-5.06: Mast Arm Pole Details
(SUDAS Specifications Figure 8010.105)
Figure 13A-5.07: Pedestal Pole and Pedestrian Post Details
(SUDAS Specifications Figure 8010.106)
C. Items Requiring Supplemental Specifications

A summary listing of items within SUDAS Specifications Section 8010 requiring supplemental specifications to be provided by the designer includes, but is not limited to, the following:

- Composite handhole and cover - specify materials and dimensions. Handholes - specify types, sizes, and lettering.
- Foundations - specify dimensions and any conduit stubs needed for future use.
- Communications - specify all traffic monitoring equipment along with any fiber optic equipment and materials.
- Cabinet, controller, battery backup, vehicle detection, pedestrian detection, PTZ camera, and emergency vehicle preemption - specify all relevant equipment.
- Traffic signal poles and mast arms - specify specialty finish for pole if necessary.
- Traffic signs - specify sheeting, sign dimensions, street name sign letter series and sizes, and mounting requirements.
TRAFFIC SIGNALS

PART 1 - GENERAL

1.01 SECTION INCLUDES
A. Underground
B. Detection
C. Communications
D. Cabinet and Controller
E. Poles, Heads, and Signs

1.02 DESCRIPTION OF WORK
This part of the specifications includes the furnishing of all material and equipment necessary to complete, in place and operational, traffic control signal(s) as described in the project plans.

1.03 SUBMITTALS
Comply with Division 1 - General Provisions and Covenants, as well as the additional requirements listed below. All of the following must be submitted within 30 days after awarding of the contract for the project. Verify the method of submittal with the Jurisdiction.

A. Schedule of Unit Prices: Submit a completed schedule of unit prices. Estimates of the work performed on the project will be made by the Jurisdiction and the unit costs will be used to prepare progress payments to the Contractor.

B. Material and Equipment List: Submit a completed list of materials and equipment to the Jurisdiction for written approval before any equipment or materials are ordered.

C. Contractor Certification: Submit the name(s) and contact information of the International Municipal Signal Association (IMSA) Level II Certified Traffic Signal Technician(s) working on the project and a copy of their IMSA certificate.

D. Shop Drawings/Catalog Cuts: Submit PDF shop drawings file for traffic signal poles and structures to be furnished on the project. Submit single PDF of catalog cuts files and list manufacturer's specifications for all items in the equipment list project documents.

E. Fiber Optic Cable: Submit a splicing diagram.

1.04 SUBSTITUTIONS
Comply with Division 1 - General Provisions and Covenants.

1.05 DELIVERY, STORAGE, AND HANDLING
Comply with Division 1 - General Provisions and Covenants.

1.06 SCHEDULING AND CONFLICTS
Comply with Division 1 - General Provisions and Covenants.
1.07 SPECIAL REQUIREMENTS

A. Comply with the current edition of the MUTCD as adopted by the Iowa DOT.

B. Electrical equipment complying with current NEMA requirements.

C. Ensure materials and work conform to current NEC and IMSA requirements.

1.08 MEASUREMENT AND PAYMENT

A. Traffic Signal:

1. Measurement: Lump sum item; no measurement will be made.

2. Payment: Payment will be at the lump sum price for traffic signal installation. Partial payment will be made according to the approved schedule of unit prices for those materials installed.

B. Temporary Traffic Signal:

1. Measurement: Lump sum item; no measurement will be made.

2. Payment: Payment will be at the lump sum price for temporary traffic signal. 50% of the lump sum bid amount will be paid upon completion of the installation and successful initial operation of the signal; the final 50% will be paid upon removal of the temporary traffic signal and cleanup of the site.

3. Includes: Lump sum price includes, but is not limited to, furnishing, installing, maintaining, and removing poles; wiring; traffic signal control equipment including pedestrian equipment if specified; implement all modifications of signal timing, signal placement and display due to changes in construction staging; relocation of trailer mounted temporary traffic signal systems; placement in another physical location to address changes in construction staging; and all appurtenances.

C. Traffic Signal Removal:

1. Measurement: Lump sum item; no measurement will be made.

2. Payment: Payment will be at the lump sum price for traffic signal removal.

3. Includes: Lump sum price includes, but is not limited to, removal of poles, concrete pads, foundations, wiring, traffic signal cabinet and equipment, pedestrian signal equipment, and handholes; delivery of removed materials to the location specified in the contract documents; furnishing, placing, and compacting backfill in all excavations; and restoring disturbed surfaces.
PART 2 - PRODUCTS

2.01 UNDERGROUND

A. Handhole:

1. General:
   a. **Cable Hooks**: Unless otherwise specified, provide four galvanized steel cable hooks with a minimum diameter of 3/8 inch and a minimum length of 5 inches.
   
   b. **Granular Base**: Comply with the following gradations; however, the Engineer may authorize a change in gradation, subject to materials available locally at the time of construction.

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<tr>
<th>Sieve</th>
<th>Percent Passing</th>
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<tr>
<td>2&quot;</td>
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<td>1 1/2&quot;</td>
<td>80 to 90</td>
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<td>15 to 20</td>
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<td>3/4&quot;</td>
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   c. **Cover**: Include “TRAFFIC SIGNAL” as a message on the cover. Alternate messages may be required as specified in the contract documents.

2. Precast Concrete Handhole:
   a. **Pipe**: Comply with ASTM C 76. Minimum Class III, Wall B (Iowa DOT Class 2000D). Four, 8 inch knockouts (conduit entrance points) equally spaced around the handhole.
   
   b. **Casting**: Gray cast iron and certified according to requirements of AASHTO M 306 for a 16,000 pound proof-load (HS-20).

3. Composite Handhole and Cover: Composed of mortar consisting of sand, gravel, and polyester resin reinforced by a woven glass fiber mat or of resin mortar and fiberglass. Ensure the handhole and cover withstands a load of 20,000 pounds has a minimum ANSI/SCTE 77 2017 TIER 15 rating. Provide a skid resistant surface on the cover. Provide two 3/8-16 UNC stainless steel hex head bolts with washers.

4. HDPE Handhole and Cover:
   a. **Size**: Provide handhole and cover with a minimum inside diameter of 24 inches and a minimum of 24 inches in depth. Handhole to be conical in shape with the taper from bottom to top.
   
   b. **Loading**: Ensure handhole, any extensions, and cover comply as a complete unit with ANSI 77 with a minimum 20,000 pound load.
   
   c. **Resin**: HDPE resin to comply with ASTM D 790 for minimum flexural modulus of 142,000 psi and ASTM D 638 for minimum yield strength of 3,100 psi when using a Type IV specimen, 2 inch per minute test speed, and 0.075 inch thick molded sample.
   
   d. **Cover**: Ensure cover has a skid resistant surface meeting PROWAG requirements with stainless steel bolts meeting manufacturer’s requirements. Ensure cover fits handhole to meet PROWAG vertical surface discontinuity requirements when placed in pedestrian walkways.

B. Conduit:

1. General:
   a. Furnish weatherproof fittings of identical or compatible material to the conduit. Use standard factory elbows, couplings, and other fittings.
   
   b. Use a manufactured conduit sealing compound that is readily workable material at temperatures as low as 30°F and will not melt or run at temperatures as high as 300°F.
2.01 UNDERGROUND (Continued)

c. Furnish flat polyester pull tape with a minimum pulling strength of 1,250 pounds and permanent sequential footage markings.

2. Steel Conduit and Fittings:
   a. Comply with ANSI C80.1.
   b. Use weatherproof expansion fittings with galvanized, malleable iron, fixed and expansion heads jointed by rigid steel conduit sleeves. As an option, the fixed head may be integral with the sleeve, forming a one piece body of galvanized malleable iron.
   c. Provide steel bushings.

3. Plastic Conduit and Fittings:
   a. PVC:
      1) PVC Schedule 40 plastic conduit and fittings complying with NEMA TC-2 (pipe), NEMA TC-3 (fittings), and UL 651 for Schedule 40 heavy wall type.
      2) Solvent welded, socket type fittings, except where otherwise specified in the contract documents.
      3) Threaded adaptors for jointing plastic conduit to rigid metal ducts.
      4) Provide bell end fittings or bushings.
   b. HDPE:
      1) Comply with ASTM F 2160 (conduit) and ASTM D 3350 (HDPE material), SDR 13.5.
      2) Use orange colored conduit. Use the color specified in the latest NEC or approved by the owner.
      3) Continuous reel or straight pieces to minimize splicing.
      4) For dissimilar conduit connections, provide an adhesive compatible with both materials.

C. Wiring and Cable: Provide wire that is plainly marked on the outside of the sheath with the manufacturer’s name and identification of the type of the cable.

1. Power Cable: Comply with Iowa DOT Article 4185.11.

2. Signal Cable: Comply with IMSA Specifications 19-1 (PVC jacket) or 20-1 (polyethylene jacket) for polyethylene insulated, 600 volt, solid, multi-conductor copper wire, #14 American Wire Gauge (AWG).

3. Tracer Wire: Comply with #10 AWG, single conductor, stranded copper, type thermoplastic heat and water resistant, nylon-coated (THWN), with UL approval, and an orange colored jacket.


5. Category 5E (Cat5E) Ethernet Cable: Provide outdoor use rated cable. Provide either Category 5E (CAT5e) or Category 6 (CAT6) cable.

6. Fiber Optic Cable and Accessories:
   a. Furnish fiber optic cable of the mode type, size, and number of fibers specified in the contract documents, and all associated accessories.
   b. Meet the latest applicable standard specifications by ANSI, Electronics Industries Association (EIA), and Telecommunications Industries Association (TIA).
2.01 UNDERGROUND (Continued)

c. Multimode Fiber:
Core Diameter:  62.5 μm ± 1.0 μm
Cladding Diameter:  125.0 μm ± 0.20 μm
Core Concentricity:  ± 1%
Max. Attenuation:  3.50 dB/km @ 850 nm

d. Single-Mode Fiber:
Typical Core Diameter:  8.3 μm ± 1.0 μm
Cladding Diameter:  125.0 μm ± 0.7 μm
Core Concentricity:  ± 1%
Attenuation Uniformity:  No point discontinuity greater than 0.1 dB at either 1310 nm or 1550 nm
Max. Attenuation:  0.25 to 0.30 dB/km @ 1550 nm, 0.35 to 0.40 dB/km @ 1310 nm

e. Dual layer UV cured acrylate coating applied by the fiber manufacturer, mechanically or chemically strip-able without damage to the fiber.
f. Glass reinforced plastic rod central member designed to prevent the buckling of the cable. Cable core interstices filled with water blocking tape to prevent water infiltration. Dielectric fillers may be included in the cable core where needed to lend symmetry to the cable cross-section.
g. Buffer tubes of dual layer construction with a polycarbonate inner layer and polyester outer layer. Each buffer tube filled with a water-swellable yarn or tape. Buffer tubes stranded around the central member using reverse oscillation or “SZ” stranding process. Gel-free cable and buffer tubes.
i. Cable tensile strength provided by a high tensile strength aramid yarn and/or fiber glass.
j. All dielectric cables, without armoring, sheathed with medium density polyethylene (1.4 mm minimum nominal jacket thickness). Outer jacket of medium density polyethylene with minimum nominal thickness of 1.3 mm applied over corrugated steel taper armor. Inner jacketing material applied directly over the tensile strength members and flooding compound. Jacket or sheath marked in a contrasting color with the manufacturer’s name and the words “Optical Cable,” the year of manufacture, and sequential meter or feet marks. Additionally, provide a durable weather proof label on the cable jacket showing the actual attenuation of each fiber expressed in dB/km.
k. Cable fabricated to withstand a maximum pulling tension of 600 pounds during installation (short term) and 135 pounds upon installation (long term).
l. Shipping, storing, and operating temperature range of the cable: -40° C to + 70° C. Installation temperature range of cable: -10° C to + 60° C.
m. Each fiber of all fiber optic cable tested by manufacturer at the 100% level for the following tests:
   • Proof tested at a minimum load of 50 kpsi (350 Mpa)
   • Attenuation
n. Meet the appropriate standard Fiber Optic Test Procedure for the following measurements:
   • Fluid Penetration
   • Compound Drip
   • Compressive Loading Resistance
   • Cyclic Flexing
   • Cyclic Impact
   • Tensile Loading and Bending
o. Make cable ends available for testing. Seal cable ends to prevent moisture impregnation.
p. Fiber Distribution Panel: Provide a fiber distribution panel capable of terminating a minimum of 24 fibers, or the number of fibers as specified in the contract documents.
2.01 UNDERGROUND (Continued)

q. Fiber Optic Connectors:
   1) ST type connectors of ceramic ferrule and physical contact end finish to
terminate multi-mode fibers to equipment.
   2) SC type connectors of ceramic ferrule and physical contact end finish to
terminate single-mode fibers to equipment.
   3) ST or mechanical connectors not allowed for cable splices.
   4) Maximum attenuation per connector: 0.75 dB.

r. Fiber Optic Jumpers/Patch Cords: For connections in the cabinet, provide factory-
   assembled duplex pigtail jumpers with dielectric strength member, durable outer
   jacket and ST or SC compatible connectors. Provide adequate length for
   connections and 2 feet minimum slack.

s. Fiber Optic Breakout Kits: Provide breakout kits for separation and protection of
   individual fibers, with buffering tube and jacketing materials suitable for termination of
   the fiber and fiber optic connector.

t. Splices/Splice Enclosures: Fusion splice continuous fiber runs or branch circuit
   connections in splice enclosures as allowed or specified in the contract documents.
   Provide environmentally protected outside plant splice enclosures with adequate
   number of trays to splice all fibers. **Do not splice continuous fibers unless physical**
   **restraints require all fibers to be cut, unless approved by the Jurisdiction.**
   Maximum attenuation per splice: 0.3 dB.

D. Footings and Foundations:

1. Use Class C structural concrete complying with Iowa DOT Section 2403.

2. Use uncoated reinforcing steel complying with Iowa DOT Section 4151.

E. Bonding and Grounding:

1. **Ground Rods:** Provide 5/8 inch by 8 foot copper clad, steel ground rod.

2. **Bonding Jumper or Connecting Wire:** Provide #6 AWG bare conductor, copper wire.

2.02 DETECTION

A. Inductive Loop Vehicle Detector: A detector consists of a conductor loop or series of loops
   installed in the roadway, lead-in (feeder) cable, and a sensor (amplifier) unit with power
   supply installed in a traffic signal controller cabinet.

1. **Cables:** All cables must be UL approved.
   a. **Tube Loop Detector Cable:** Comply with IMSA Specifications 51-5.
   b. **Prefomed Loop Detector Cable:** As approved by the Engineer.
   c. **Loop Detector Lead-in Cable:** Comply with IMSA Specifications 50-2.

2. **Detector Loop Sealant:**
   a. Use a rapid cure, high viscosity, liquid epoxy sealant formulated for use in sealing
      inductive wire loops and leads embedded in pavement. Ensure the cured sealer is
      unaffected by oils, gasoline, grease, acids, and most alkalis.
   b. Use a sealant complying with Iowa DOT Materials I.M. 491.18.

3. **Sensor (Amplifier) Unit:**
   a. Use a sensor unit that is solid state, digital, providing detection channel(s) with an
      inductance range of 0 to 2,000 micro-henries. Output circuits of the sensor unit will
      be provided by relays. Vehicle presence will result in a continuous call indication.
2.02 DETECTION (Continued)

b. Provide a sensor unit with the following qualities:
   1) Sensitivity adjustment to allow as a minimum the selection of high, medium, or low sensitivity.
   2) Be capable of providing reliable detection of all licensed motor vehicles.
   3) Provide an indicator light for visual indication of each vehicle detection.
   4) Will not require external equipment for tuning or adjustment.
   5) Provide operation in the pulse mode or presence mode. Ensure mode switch is readily accessible.
   6) Provide a self tuning system that is activated automatically with each application of power. Provide automatic and continuous fine tuning to correct for environmental drift of loop impedance.
   7) Provide for fail-safe operation (continuous call) in the event of detector loop failure.
   8) Ensure each detector channel will respond to a frequency shift in an increasing or decreasing value as occurs with temperature shifts in the pavement without requiring a locked call.
   9) Use detector units with delay and extension timing. The delay feature is selected and adjusted externally on the sensor unit housing. Digitally derived timing is selectable in 1 second increments from 0 to 30 seconds. Ensure delay timing inhibits detector output until presence has been maintained for the time selected. Restart delay timer at each new detection.
  10) Use a sensor unit capable of normal operation without interference and false calls between sensor units ("crosstalk") when installed in the physical environment of the controller cabinet and the electrical environment of the associated electronic equipment installed therein, including other detectors.

B. Pedestrian Push Button Detectors:

1. Assembly:
   a. Ensure the entire assembly is weather tight, secure against electrical shock, withstands continuous hard usage.
   b. Provide a removable contact assembly mounted in a die cast aluminum case.
   c. Ensure contacts are normally open with no current flowing except at the moment of actuation.
   d. Ensure the contacts are entirely insulated from the housing and operating button with terminals for making connections.
   e. Provide housing with one outlet for 1/2 inch pipe.

2. Accessible Pedestrian Signals (APS) Push Button Stations:
   a. Housing: Die cast aluminum, weather tight, secure against electrical shock and withstands continuous hard usage.
   b. Audible and Vibrotactile Features: Audible walk indication tone, vibrotactile arrow, and locator tone complying with MUTCD.
   c. Voice Messages: As specified in the contract documents and per MUTCD.
   d. Speaker: Weatherproof with automatic volume adjustment to 5 dBA over ambient sound. Maximum volume 100 dB at 3 feet.
   e. Push Button: Nonrusting metal alloy, ADA compliant, 2 inch diameter with tactile arrow and 3 pounds maximum operational force.
   f. Switch: Solid state rated at 20 million operations minimum.
   g. Program and Audio File Updates: USB or Ethernet.
   h. Operating Temperature: -30 to + 165°F.
2.02 DETECTION (Continued)

   a. Housing: Die cast aluminum, weather tight, secure against electrical shock and withstands continuous hard usage.
   b. Push Button: Nonrusting metal alloy, ADA compliant, 2 inch diameter with 3 pounds maximum operational force, with momentary LED visual confirmation and audible tone confirmation.
   c. Switch: Solid state piezo-driven, rated at 20 million operations minimum.
   d. Operating Temperature: -30 to + 165°F.

4. Signs: Furnish signs complying with MUTCD.

C. Video Detection Camera System: Detects vehicles by processing video images and providing detection outputs to the traffic signal controller.

1. Video Detection System and Processors:
   a. Processor to be card rack mounted, shelf mounted, or located within camera. Compatible with NEMA TS-1, TS-2, ITE ATC, and Type 170 and 2070 controllers and cabinets.
   b. Must be capable of the following:
      1) Shadow rejection without special hardware.
      2) Non-impaired operation under light intensity changes.
      3) Maintained operation during various weather conditions (e.g. rain, fog, snow).
      4) Anti-vibration, 5% rejection based on image change.
      5) Ability to select direction of flow parameters.
      6) Ability to properly detect directionally.
      7) Operate in presence mode with less than 4% error.
   c. Provide user-defined detection zone programming via a graphical user interface (GUI) and any necessary equipment for future programming. Store detection zones in non-volatile memory.
   d. Comply with NEMA TS-1 and TS-2 environmental and physical standards with an operating temperature of -34°C to +60°C, and 0% to 95% relative humidity.
   e. Ensure a factory certified representative from the supplier provides on-site VDS programming and testing.

2. Video Cameras:
   a. Meet NEMA-4 or NEMA-6P environmental standards.
   b. Use camera cable(s) meeting the manufacturer’s recommendations. Provide a continuous run, without splices, from the camera to the controller cabinet.
   c. Camera per Approach or Advance Detection Camera:
      a. 1) Provide a charge-coupled device (CCD) image sensor with variable focus color or black and white lens providing a minimum of 4 to at least a 40 degree horizontal field of view.
      b. 2) Equipped with internal thermostatically controlled heater and external sunshield.
   d. Single Stop Line Detection Camera:
      1) Provide a minimum 5 MP image sensor with power over ethernet and a fisheye lens capable of detecting multiple approaches from a single mounting location.
      2) Include the ability to count traffic.
      3) Provide necessary internal thermostatically controlled heater as needed.

D. Microwave/Radar Vehicle Detectors: Detects all vehicles moving within the field of detection at speeds from 2 to 80 mph.
2.02 DETECTION (Continued)

1. Must be capable of the following:
   a. Minimum detection range from 3 to 200 feet for all vehicles.
   b. Pattern spread of the detection field no more than 16 degrees.
   c. Self-tuning and capable of continuous operation over a temperature range of -35°F to 165°F.
   d. Side-fire mount or overhead mount.
   e. Detecting directional traffic and the direction user selectable.

2. Microprocessor based using Doppler microwave at an operating frequency of 10.525 GHz.

3. FCC certification and tested to the applicable FCC specifications.

4. Enclosure constructed of aluminum or stainless steel and water resistant.

5. All user operated controls and adjustments must be clearly marked and easily accessible.

6. Relay detection output to the controller with a minimum 5 amp rating and designed to place a constant call to the controller in the event of any failure.

7. Easily accessible indicator showing activation of detection relay.

8. Required wiring as recommended by the manufacturer.

9. Provide mounting hardware for the type of mounting specified in the contract documents and power supply equipment as recommended by the manufacturer.

E. Wireless Magnetic Sensors (Pod/Puck): Provide as specified in the contract documents in pavement sensors, access points, base stations, and repeaters, if necessary.

2.03 COMMUNICATIONS

A. Traffic Monitoring System: Provide as specified in the contract documents including, video camera in dome, dome mounting bracket and hardware, camera controller, cabling from camera to controller cabinet, and all accessories, software, and hardware necessary for a complete and operational system.

1. Pan/tilt/zoom (PTZ) color camera with automatic conversion to monochrome during low light levels, auto focus, auto-iris control, electronic image stabilization, privacy masking and high resolution 1/4 inch CCD imager progressive CMOS sensor. Minimum 1920 x 1080 maximum resolution. Minimum optical zoom: 25X. Minimum digital zoom: 12X.

2. Camera system provided in a NEMA 4X or IP66 certified rugged weather-resistant package.

3. Provide all required lightning protection for electronics control, power, and coax video outputs.

4. Operating temperature range: -40°C to +50°C.

5. Maximum cable length as specified by camera manufacturer.

6. Provide full 360 degree endless pan and 220 degree tilt under PTZ control.
2.03 COMMUNICATIONS (Continued)

7. Dome electronics capable of programming a minimum of 64 preset views and nine preprogrammed pattern sequences of preset views. All views selectable by the central office computer or a remote control device.

8. Provide encoder and decoder devices as needed to transmit video over existing or proposed communication systems at 30 frames per second (or more).

9. Provide all necessary rack support devices for video viewing and PTZ control.

10. Provide ability to control PTZ and view video remotely. Includes installing necessary software/programming needed for agency to operate system.

B. Fiber Optic Hub Cabinet: As specified in the contract documents.

C. Wireless Interconnect Network: Provides two-way data communication between the on-street master controller and local traffic signal controllers.

1. Data Transceiver:
   a. Utilize a license-free spread spectrum radio frequency (902-928 MHZ) with frequency hopping technology.
   b. Completely programmable by software. Furnish software to the Jurisdiction.
   c. Built-in diagnostics capabilities.
   d. Configurable as master, slave, or repeater with store and forward capability.
   e. Maintains user selectable power output levels between 0.1 and 1 watt.
   f. Operates with input voltages between 6 VDC and 30 VDC.
   g. RS-232 interface with 115.2 kbps capability.
   h. Operating temperature of -40°C to +75°C.
   i. Receiver sensitivity of -108 to -110 dBm at 10^-6 BER.
   j. Protected from power surges.
   k. Rack or shelf mounted in controller cabinet and connections for antenna, power, and controller.

2. Antenna:
   a. Capable of transmitting and receiving data between intersections.
   b. Mount near the top of the signal pole nearest the controller cabinet or as specified in the contract documents. Provide engineer-approved mounting hardware.
   c. Connect to transceiver via appropriate cable from pole to signal cabinet in same conduit as traffic signal cable. Conceal cable within a watertight connection at antenna.

2.04 CABINET AND CONTROLLER

A. NEMA-Controller, Cabinet, and Auxiliary Equipment: Comply with the latest edition of NEMA TS1 or TS2, CalTrans model 2070, or ITE advanced transportation controller (ATC) standards.

1. Controller:
   a. Solid state modular design with digital timing and capable of accommodating at least eight phases.
   b. Fully prompted, front panel keyboard with menu driven programmability.
   c. Local time base scheduler including automatic accommodation for daylight savings time.
   d. Local coordination control.
   e. Local preemption control with at least four programmable internal preemption sequences.
   f. Current software and documentation.
   g. Data retained in a memory medium that does not require battery backup.
2.04 CABINET AND CONTROLLER (Continued)

2. Cabinet:
   a. Unpainted aluminum cabinet according to NEMA standards.
   b. Aluminum cabinet riser with same dimensions as cabinet and 12 to 18 inch height, as specified in the contract documents.
   c. ATC cabinet voltage category as specified in the contract documents.
   d. Police door with auto/flash switch, manual/stop time switch, and on/off power switch for signal heads only. Controller to remain in full operation regardless of switch positions.
   e. Maintenance panel on inside of the main door containing the following test switches.
      1) Controller power switch.
      2) Detector test switches.
      3) Stop time switch.
      4) Signal flash switch.
   f. Heavy-duty clear plastic envelope attached to inside wall of cabinet or cabinet door, for cabinet wiring diagrams, 12 inches by 18 inches minimum.
   g. GFI electrical outlet and lamp in accessible location near the front of the cabinet. GFI outlet fused separately from main AC circuit breaker.  Fluorescent or LED cabinet lamp connected and fused with GFI outlet.
   h. Back panel positions to accommodate phasing and expansibility specified in the contract documents.
   i. Power protection devices including AC power circuit breakers, radio interference suppressors, and lightning and surge protectors.
      1) AC field service single pole, nonadjustable, magnetic breaker rated for 117 VAC operation, NEC approved.
      2) Radio interference suppressors (RIS) as required to minimize interference in all broadcast transmission and aircraft frequency bands.
      3) Lightning arrestor/surge protector capable of withstanding repeated (minimum of 25) 30,000 ampere surges.
   j. Neatly train wiring throughout the cabinet and riser. Bundle and attach wiring to interior panels using nonconductive clamps or tie-wraps.

3. Auxiliary Equipment: Conflict monitor/malfunction management unit, flasher, load switches, terminals and facilities, and miscellaneous equipment and materials according to NEMA standards. For ATC cabinets, use serial interface unit, high density switch pack/flasher unit, cabinet monitor unit, cabinet power supply requirements, auxiliary display unit, sensor unit, and miscellaneous equipment materials meeting ITE standards.

B. Uninterruptible Power Supply Battery Backup System: Monitors 120VAC input from the electric utility source and automatically switches to/from a system consisting of batteries and electronics.

1. Include a maintenance bypass switch to allow operation of the traffic signal system while repairs are made to the battery backup system.
2. Designed to provide a minimum of 4 hours of normal operation.
3. Use cabinet equipment that is plug connected and shelf mounted.
4. Designed to cover a temperature range from -30°F to +165°F and include a surge suppressor.

2.05  POLES, HEADS, AND SIGNS

A. Vehicle Traffic Signal Head Assembly: Comply with current MUTCD and ITE standards.

1. Housing:
   b. Self-contained unit capable of separate mounting or inclusion in a signal face containing two or more signal sections rigidly and securely fastened together.
   c. Equipped with openings and positive locking devices in the top and bottom so that it may be rotated between waterproof supporting brackets capable of being directed and secured at any angle in the horizontal plane.
   d. Doors and lenses with suitable watertight gaskets and doors that are suitably hinged and held securely to the body of the housing by simple locking devices of non-corrosive material. Doors are to be easily removed and reinstalled without use of special tools.

2. Optical System: Designed to prevent any objectionable reflection of sun rays even at times of the day when the sun may shine directly into the lens.

3. Lenses: 12 inch diameter polycarbonate. Do not use glass lenses.

4. Visors:
   a. Standard Installation:
      1) Each signal lens is to have a visor with the bottom 25% open.
      2) Minimum 0.1 inch in thickness and black in color.
      3) Fits tightly against the housing door with no filtration of light between the visor and door.
      4) Minimum length of 9 1/2 inches. Ensure the visor angle is slightly downward.
   b. Optically Programmed Sections: Make sure the optical unit and visor are designed as a whole to eliminate the return of outside rays entering the unit from above the horizontal.

5. Terminal Block:
   a. Three-section signal equipped with a six position terminal block.
   b. Four- and five-section signal equipped with an eight position terminal block.

6. Backplate:
   a. Manufactured one-piece, durable, black plastic or aluminum capable of withstanding 100 mph winds.
   b. Provides 5 inches of black field around the assembly.
   c. If specified, provide high visibility reflective tape with a minimum width of 1 inch.

7. Mounting Hardware:
   a. Fixed Rigid: 1 1/2 inch aluminum pipe and fittings, natural aluminum finish for galvanized poles or match the pole color if specified in the contract documents. Secure to pole with a minimum 5/8 inch wide stainless steel banding material.
   b. Universally Adjustable: Rigid mounted, consisting of both top and bottom brackets and easily adjustable in both horizontal and vertical planes. Provide galvanized steel cable material per manufacturer’s recommendation.

8. LED Modules: Comply with current ITE standards and consistent with cabinet voltage requirements.
2.05 POLES, HEADS, AND SIGNS (Continued)

B. Pedestrian Traffic Signal Head Assembly: Comply with current MUTCD and ITE standards.

1. Housing:
   b. Self-contained unit capable of separate mounting or inclusion in a signal face containing one or more signal sections rigidly and securely fastened together.
   c. Equipped with openings and positive locking devices in the top and bottom so that it may be rotated between waterproof supporting brackets capable of being directed and secured at any angle in the horizontal plane.
   d. Doors and lenses with suitable watertight gaskets and doors that are suitably hinged and held securely to the body of the housing by simple locking devices of non-corrosive material. Doors are to be easily removed and reinstalled without use of special tools.

2. Visor:
   a. Egg crate or tunnel type visor**, as specified in the contract documents, attached to the housing door by stainless steel screws or according to manufacturer's requirements.
   b. Fit tightly against the housing door to prevent any filtration of light between the door and the visor.
   c. Ensure the visor angle is slightly downward.

3. LED Module:
   a. Provide a LED unit(s) for the filled upraised hand symbol, walking person symbol, and countdown timer.
   b. Ensure immediate blank out of the countdown timer display upon recognizing a shortened "Walk" or a shortened "Flashing Don’t Walk" interval.
   c. Comply with current ITE standards and consistent with cabinet voltage requirements.

C. Traffic Signal Poles and Mast Arms:

1. General:
   a. Use mast arm length and vertical pole height as specified in the contract documents.
   b. Ensure the mast arms, poles, and supporting bases are galvanized on both interior and exterior surfaces according to ASTM A 123.
   c. Use continuously tapered, round, steel poles of the transformer base type for poles with mast arms 60 feet or less. Fabricate poles from low carbon (maximum carbon 0.30%) steel of U.S. standard gauge.
   d. For poles with mast arms greater than 60 feet or when a transformer base is not specified, provide a 6 inch by 16 inch handhole in the pole shaft for cable access. Provide a cover for the handhole. Secure the cover to the base with simple tools. Use corrosion resistant hardware.
   e. Ensure minimum yield strength of 48,000 psi after manufacture. Supply base and flange plates of structural steel complying with ASTM A 36 and cast steel complying with ASTM A 27, Grade 65-35 or better.
   f. Where a combination street lighting/signal pole is specified in the contract documents, ensure the luminaire arm is mounted in the same vertical plane as the signal arm unless otherwise specified. Use a luminaire arm of the single member tapered type. Fabricate the pole with a minimum 4 inch by 6 inch handhole and cover located opposite the signal mast arm.
2.05 POLES, HEADS, AND SIGNS (Continued)

g. If allowed by the Engineer, poles and mast arms may be fabricated by shop welding two sections together, resulting in a smooth joint as follows:
1) Ensure a minimum of 60% penetration for longitudinal butt welds in plates 3/8 inch and less in thickness, except within 1 foot of a transverse butt-welded joint. Ensure a minimum of 80% penetration for longitudinal butt welds in plates over 3/8 inch in thickness.
2) Ensure 100% penetration for longitudinal butt welds in poles and arms within 1 foot of a transverse butt-welded joint.
3) Ensure 100% penetration for transverse butt welds by using a back-up ring or bar to connect the sections.
4) Examine the full length of all transverse butt welds and 100% penetration longitudinal butt welds by ultrasonic inspection according to the requirements of ANSI/AWS D1.1.
5) Comply with ANSI/AWS D1.1 except as modified by Iowa DOT Article 2408.03, B.

h. Provide non-shrink grout (complying with Iowa DOT Materials I.M. 491.13) or a rodent guard (complying with Iowa DOT Materials I.M. 443.01) for placement between the pole base and the foundation per the manufacturer's requirements.

2. Pole Design: Comply with AASHTO 2013 Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. Use a 90 mph basic wind speed with a 50 year mean recurrence interval for strength design. Use Category II for fatigue design. Apply only natural wind gust loads (i.e. do not apply galloping loads, vortex shedding loads, or truck-induced gust loads) for fatigue design. Install vibration mitigation devices on all traffic signal pole mast arms over 60 feet in length as shown on the figures.

3. Hardware:
   a. General:
      1) Equip poles and mast arms with all necessary hardware and anchor bolts to provide for a complete installation without additional parts.
      2) Furnish each anchor bolt with one leveling nut, one anchoring nut, and one jam nut (if required) on the exposed end and one of the following on the embedded end: nut, nut and plate, or nut and anchor bolt assembly ring plate. Use anchor bolts, nuts, and washers that comply with Iowa DOT Materials I.M. 453.08.
   b. Anchor Bolts:
      1) Use straight full-length galvanized bolts.
      2) Comply with ASTM F 1554, Grade 105, S4 (-20°F).
      3) Threads are to comply with ANSI/ASME B1.1 for UNC thread series, Class 2A tolerance.
      4) The end of each anchor bolt intended to project from the concrete is to be color coded to identify the grade.
      5) Do not bend or weld anchor bolts.
   c. Nuts:
      1) Comply with ASTM A 563, Grade DH or ASTM A 194, Grade 2H.
      2) Use heavy hex.
      3) Use ANSI/ASME B1.1 for UNC thread series, Class 2B tolerance.
      4) Nuts may be over-tapped according to the allowance requirements of ASTM A 563.
      5) Refer to Section 8010, 3.05, B, 2 for tightening procedure and requirements.
   d. Washers: Comply with ASTM F 436 Type 1.
   e. Galvanizing: Galvanize entire anchor bolt assembly consisting of anchor bolts, nuts, and washers (and plates or anchor bolt assembly ring plate, if used) according to the requirements of ASTM B 695, Class 55 Type 1 or ASTM F 2329 with zinc bath temperature limited to 850°F. Galvanize entire assembly by the same zinc-coating process, with no mixed processes in a lot of fastener assemblies.
2.05 POLES, HEADS, AND SIGNS (Continued)

D. Traffic Signal Pedestal Poles:

1. Materials:
   a. Pedestal: The height from the bottom of the base to the top of the shaft as specified in the contract documents.
   b. Pedestal Shaft: Schedule 80 with satin brush or spun finish aluminum tubing. Top of the shaft outer diameter to be 4 1/2 inches and provided with a pole cap. Supply base collar for poles with shaft lengths greater than 10 feet. Provide brackets to mount pedestrian signal on side of pole.
   c. Pedestal Base: Cast aluminum, square in shape, with a handhole.
      1) Handhole: Minimum of 6 3 1/2 inches by 6 5 1/2 inches and equipped with a cast aluminum cover that can be securely fastened to the base with the use of simple tools.
      2) Base: Minimum weight of 20 pounds. A breakaway base with a four bolt pattern uniformly spaced on a 12 1/2 inch minimum of 6 inch diameter bolt circle. Meet or exceed AASHTO breakaway requirements.

2. Anchor Bolts: Four 3/4 inch by 15 7 1/2 inch steel (minimum), hot dip galvanized anchor bolts complying with ASTM F 1554, Grade 36, with right angle bend at the bottom and meeting pole manufacturer requirements for installation, complete with all hardware required for installation.

E. Pedestrian Push Button Post:

1. Material:
   a. Post: Standard weight (Schedule 40) pipe complying with ASTM F 1083, galvanized inside and out; 2 1/2 inches in diameter.
   b. Cap: Waterproof cap complying with ASTM F 626.
   c. Anchor Bolts: Four 1/2 inch by 24 inch steel, hot dip galvanized anchor bolts complete with all hardware required for installation.
   d. Non-shrink Grout: Comply with Iowa DOT Materials I.M. 491.3 or a rodent guard (complying with Iowa DOT Materials I.M. 443.01) for placement between the post and the foundation.
   e. Base Plate: Provide a 5 inch square, 1/2 inch thick galvanized steel base plate with a 4 1/2 inch bolt circle.

E. Traffic Signs:

1. Comply Sheet aluminum and retroreflective sheeting complying with Iowa DOT Section 4186.

2. Use a universally adjustable mast arm mounted sign bracket.

3. Comply with MUTCD and the contract documents for the street name sign dimensions, letter height, and font, and sheeting.
PART 3 - EXECUTION

3.01 UNDERGROUND

A. Handhole:

1. Locations:
   a. Do not construct in ditch bottoms, low areas where ponding of water may occur, or where they will be subject to normal vehicular traffic.
   b. With Engineer approval, additional handholes may be placed, at no additional cost to the Contracting Authority, to facilitate the work.

2. Excavation: Excavate as necessary to accommodate the handhole and granular base.

3. Granular Base: Install 8 inch thick granular base extending a minimum of 6 inches beyond the outside walls of the handhole.

4. Placement:
   a. In paved areas, install the handhole at an elevation so the casting is level and flush with the pavement. In unpaved areas, install the handhole approximately 1 inch above the final grade.
   b. Verify ring placement. Invert rings when installed in paved areas.

5. Conduit:
   a. Remove knockouts as necessary to facilitate conduit entrance.
   b. Extend conduit into the handhole, through a knockout, approximately 2 inches beyond the inside wall. Conduit to slope down and away from the handhole.
   c. Place non-shrink grout (complying with Iowa DOT Materials I.M. 491.13) in the opening of the knockout area after placement of conduit.

6. Cable Hooks:
   a. Install cable hooks centered between the knockouts and the top of the handhole anchored within the handhole wall.
   b. Place non-shrink grout (complying with Iowa DOT Materials I.M. 491.13) in the opening around the hook after placement of the hook.

7. Backfill: Place suitable backfill material according to Section 3010.

8. Casting: Place the casting on the handhole. Ensure the final elevation meets the handhole placement requirements.

B. Conduit:

1. General:
   a. Place conduit to a minimum depth of 30 inches and a maximum depth of 60 inches below the gutterline, unless utility conflicts require deeper placement. When conduit is placed behind the curb, place to a minimum depth of 24 inches and a maximum depth of 48 inches below top of curb.
   b. Change direction at handholes or by bending, such that the conduit will not be damaged or its internal diameter changed. Ensure bends are uniform in curvature and the inside radius of curvature of any bend is no less than six times the internal diameter of the conduit.
   c. On the exposed ends of conduit, place bell-end fittings on PVC or HDPE conduit and bushings on steel conduit prior to installing cable. Extend all conduits a minimum of 2 inches and a maximum of 4 inches above the finished surface of any foundation, footing, or structural base.
3.01 UNDERGROUND (Continued)

d. When it is necessary to cut and thread steel conduit, do not allow exposed threads. Ensure conduits and fittings are free from burrs and rough places. Clean, swab, and ream conduit runs before cables are installed. Use nipples to eliminate cutting and threading where short lengths of conduit are required. Coat damaged galvanized finish on conduit with zinc rich paint. Use only galvanized steel fittings with steel conduit.

e. Install duct plugs in conduit ends or pack conduit ends with a conduit sealing compound.

f. Install pull tape in each conduit segment, including empty conduits, and secure to duct plugs at each end.

2. Trenched Installation:
   a. Place backfill in layers not to exceed 12 inches in depth with each layer thoroughly compacted before the next layer is placed. Ensure backfill material is free of cinders, broken concrete, or other hard or abrasive materials.
   b. Remove all surplus material from the public right-of-way as soon as possible.

3. Trenchless Installation:
   a. When placing conduit under pavements, use the trenchless installation methods described in Section 3020.
   b. If trenchless methods that compact soils in the bore path are used, provide sufficient cover to prevent heaving of overlying paved surfaces.
   c. Do not allow pits for boring to be closer than 2 feet to the back of curb, unless otherwise specified in the contract documents.

C. Wiring and Cable:

1. Where practical, follow color codes so that the red insulated conductor connects to the red indication terminal, yellow to yellow, and green to green. Ensure cables are properly labeled at the controller by durable labels, or other appropriate methods, attached to the cables. Label home runs for cables as follows: northwest corner is red, southeast corner is blue, northeast corner is green, and southwest corner is orange.

2. Install continuous runs of vehicle and pedestrian signal cables from the vehicle or pedestrian signal head to the handhole compartment of the signal pole base. Install continuous runs of vehicle and pedestrian signal cables from the handhole compartment of the signal pole base to the terminal compartment in the controller cabinet. Do not splice signal cables in underground handholes.

3. Install continuous runs for video detection and emergency vehicle preemption cables from the unit to the controller cabinet.

4. Install continuous runs of power lead-in cables from the service point to the meter socket and from the meter socket to the controller cabinet.

5. Install continuous detector cable from each detector loop to the first handhole adjacent to the loop. Ensure cables are properly labeled at the controller by durable labels, or other appropriate methods, attached to the cables. Install continuous homerun cable from the splice made in the first handhole to the terminal compartment in the controller cabinet. Attach the drain wire of the shielded cable to the ground in the controller cabinet.

6. Provide a minimum of 4 feet of additional cable at each handhole and loosely coil the extra cable on the handhole cable hooks. Provide a minimum of 2 feet of additional cable at each signal pole (measured from the handhole compartment in the pole to the end of the cable). Provide a minimum of 10 feet of additional cable at each controller base. For fiber optic cable, coil the specified length in a wheel shape and hang vertically.
3.01 UNDERGROUND (Continued)

7. Pull cables through conduit using a cable grip designed to provide a firm hold upon the exterior covering of the cable or cables, and minimize dragging on the ground or pavement.

8. Install a tracer wire in all conduits with the exception of conduits between detector loops and handholes. Use a silicon-filled wire nut to splice the tracer wire in each handhole and at the controller to form a continuous run.

9. Fiber Optic Cable and Accessories:
   a. Use a suitable cable feeder guide between the cable reel and the face of the conduit to protect the cable and guide the cable directly into the conduit off the reel. During the installation, carefully inspect cable jacket for defects. If defects are found, notify the Engineer prior to any additional cable being installed. Take care when pulling the cable to ensure the cable does not become kinked, crushed, twisted, snapped, etc.
   b. Attach a pulling eye to the cable and use to pull the cable through the conduit. Use a pulling swivel to preclude twisting of the cable. Lubricate cable prior to entering the conduit with a lubricant recommended by the manufacturer. Use dynamometer or break away pulling swing to ensure the pulling tension does not exceed the specified force of 600 pounds or the cable manufacturer’s recommendations, whichever is less. Do not allow the cable to twist, stretch, become crushed, or forced around sharp turns that exceed the bend radius or scar or damage the jacket. Manually assist the pulling of the cable at each pull point.
   c. Do not pull cable through any intermediate junction box, handhole, pull box, pole base, or any other opening in the conduit unless specified in the contract documents. Install cable by pulling from handhole or controller cabinet to the immediate next downstream handhole or cabinet. Carefully store the remaining length of cable to be installed in the next conduit run(s) in a manner that is not hazardous to pedestrian or vehicular traffic, yet ensures that no damage to the cable occurs. Storage methods are subject to Engineer approval.
   d. At each handhole, visibly mark or tag cable, “CITY (or COUNTY) FIBER OPTIC”
   e. Secure cables inside controller cabinet so that no load is applied to exposed fiber strands.
   f. Ensure the radius of the bend for static storage is no less than 10 times the outside diameter of the cable, or as recommended by the manufacturer. Ensure the radius of the bend during installation is no less than 15 times the outside diameter of the cable, or as recommended by the manufacturer.
   g. Provide cable slack in each handhole, junction box, and cabinet as specified in the contract documents. Where handholes or junction boxes lack sufficient area for cable storage or bend radius requirements, provide equivalent additional slack in adjacent facilities. Coil and bind slack cable at three points around the cable perimeter and support in its static storage position.
   h. Install fiber optic accessories according to the manufacturer’s recommendations and as specified in the contract documents.

10. Fiber Optic Cable Field Testing: Provide for each fiber strand both on-reel testing prior to installation and final testing after installation using a high-resolution optical time domain reflectometer (OTDR). Conduct measurements for single-mode fibers at 1310 ± 30 nanometer wavelengths. Conduct measurements for multimode fibers at 850 ±30 nanometer wavelength. Record the identification, location, length, and attenuation measurements of each fiber, and furnish test reports to the Engineer. Replace any cable that fails testing, at no additional cost to the Contracting Authority.
   a. On-reel Testing: Perform testing for attenuation and continuity using OTDR and a pigtail splice. Complete testing in one direction only. Acceptable test results will be within ± 3% of factory-supplied attenuation measurements. Except for access to and test preparation of one end of the newly furnished cable, preserve the cable in its originally-shipped condition. Furnish test reports to the Engineer prior to installation.
3.01 UNDERGROUND (Continued)

b. Cable Segment Testing: Perform an end-to-end attenuation test of each terminated fiber of each fiber optic cable. Perform testing using hand-held optical test sets. Include test results in documentation package provided to the Engineer at the conclusion of the project. Acceptable test results will not exceed the cumulative specified losses of the components. For example, at 850 nanometers, a one kilometer multimode fiber link with two splices and a connector on each end will not exceed 5.6 dB:

\[
\begin{align*}
1.0 \text{ km} & \times 3.5 \text{ dB/km}: & 3.5 \text{ dB} \\
0.3 \text{ dB per splice} \times 2: & 0.6 \text{ dB} \\
0.75 \text{ dB per connector} \times 2: & 1.5 \text{ dB} \\
\text{Maximum allowable loss:} & 5.6 \text{ dB}
\end{align*}
\]

Repair or replace any cable segment that fails testing. Retest any repaired or replaced cable. Submit complete documentation of test results to the Engineer (hard copy or electronically).

c. Final System Testing: After complete fiber optic system is installed and terminated, but prior to capping unused fibers, perform OTDR readings on all cables to ensure that each section is in compliance with the specifications. Provide copies of OTDR trace signatures for all fibers for all cable sections to the Engineer. Also provide test results for attenuation test for the installed fibers using the insertion loss procedure and the transmitter/receiver power level test and the continuity test.

b. Post installation, test 100% of the new cables’ fiber count bi-directionally with an optical time domain reflectometer (OTDR) at 1310 nm and 1550 nm; in addition, use an optical loss test set (OLTS) to test all fibers at both wavelengths. Also test existing fibers that are spliced to or re-spliced as part of this contract in both directions and at both wavelengths. Provide the Engineer with up to five copies of any software required for viewing electronic files of the OLTS and OTDR traces. Use test equipment equal to EXFO FTB-500 OTDR meter, and Fluke DTX-CLT OLTS meter.

c. Ensure all test equipment has been factory certified within the last year. Provide copies of the certification 10 days prior to testing.

d. Record test results through the meter manufacturer’s software with data compiled in a PDF. Additional alteration using software beyond the meter manufacturer’s software will not be allowed. Submit test results in a format approved by the Engineer. Provide completed test forms on each fiber to the Engineer. Also provide native test (electronic version) with no alterations and meter software for viewing of fiber traces. At a minimum, ensure test results show the following:

- Cable and fiber identification (as approved by the Engineer)
- Operator name
- Date and time
- Setup and test parameters including wavelength, pulse width, range, scale, and ambient temperature.
- Test results for OTDR test in both directions for total fiber trace, splice loss/gain (dB), connector loss (dB), all events greater than 0.05 dB, measured length from cable markings, and total length from OTDR.
- Test results for attenuation test including measured cable length (cable marking), total length (from OTDR test), number of splices (from as-built) and total link end-to-end attenuation in each direction, and the bidirectional average.

e. Ensure OTDR testing uses launch and receiving cables minimum 3,300 feet or greater than the dead zone for the OTDR used for this test.
3.01 UNDERGROUND (Continued)

f. Ensure all fiber connectors are cleaned and checked for dirt, scratches, or chips before installed in adapters and testing. Install all dust covers after testing is complete.
  • Ensure the fiber optic cable has a maximum attenuation of 0.4 dB/km at 1310 nm and 0.3 dB/km at 1550 nm when measured with an OLTS.
  • Ensure each connector has an averaged loss value of 0.25 dB or less when measured bi-directionally with an OTDR at 1310 nm and 1550 nm.
  • Ensure each splice has an averaged loss value of 0.08 dB or less when measured bi-directionally with an OTDR at 1310 nm and 1550 nm.

D. Footings and Foundations:

1. Excavation: Excavate to the size, shape, and depth specified in the contract documents. Ensure the bottom of all foundations rest securely on firm undisturbed soil. Minimize over-excavation to ensure support and stability of the foundation. Notify the Jurisdiction and Engineer immediately if high water and/or poor soils are encountered during excavation. Provide circular forms if needed at no additional cost to the Contracting Authority.

2. Foundation: Provide a means for holding all of the following elements rigidly in place while the concrete is being placed.
   a. Forms:
      1) Set the forms level or sloped to meet the adjacent paved areas.
      2) When adjacent to paved areas, shape the top 11 inches of the foundation to be square and flush with the surrounding paved area. Provide preformed expansion material between the foundation and paved areas.
      3) When installed in an unpaved area, set the top of the foundation 2 inches above the surface of the ground.
   b. Reinforcing Steel: Install reinforcing steel.
   c. Conduit: Install conduit.
   d. Anchor Bolts:
      1) Set anchor bolts using a template constructed to accommodate the specified elevation, orientation, and spacing according to the pole and controller manufacturer’s requirements.
      2) Center the pole anchor bolts within the concrete foundation.
      3) Protect the anchor bolts until poles are erected.
      4) Orient controller footing with the back of the cabinet toward the intersection such that the signal heads can be viewed while facing the controller, unless otherwise directed by the Engineer.
   e. Concrete:
      1) Place concrete to form a monolithic foundation. Consolidate concrete by vibration methods.
      2) Finish the top of the base level and round the top edges with an edging tool having a radius of 1/2 inch. Provide a rubbed surface finish on the exposed surface of the footing or foundation.
      3) Allow the foundation to cure a minimum of 4 days prior to erecting the poles and 7 days prior to installing the mast arms. Times may be shortened if supported by strength test results.

3. Backfill: Place suitable backfill material according to Section 3010.

E. Bonding and Grounding:

1. Ensure the traffic signal installation is grounded as required by the National Electric Safety Code.

2. Install a ground rod at each signal pole foundation and controller footing.
3.01 UNDERGROUND (Continued)

3. Use PVC conduit within the foundation or footing to accommodate the connection between the top of the concrete and the ground rod.

4. Bond poles to ground rods with copper wire. Connect ground wires to ground rods with approved mechanical connectors.

5. Bond rigid steel conduit ends in handholes with copper wire and approved fittings.

3.02 DETECTION

A. Detector Loop Cable Installation:

1. Coordinate the location of the detector loop with the Engineer. Obtain the Engineer’s approval prior to cutting the pavement.

2. Saw to ensure proper depth and alignment of the slot. Make a 2 inch deep clean, straight, well-defined 3/8 inch wide saw cut without damage to adjacent areas. Overlap the saw cuts where the detector loop changes direction to provide full depth at all corners. Do not use right angle or corners less than 90 degrees. Minimize crossing the number of pavement joints where possible. Route the sawcut from the loop to the edge of pavement perpendicular to the flow of traffic, maintaining at least 1 foot of clearance from parallel joints.

3. Before installing the detector loop cable, check the saw cuts for the presence of jagged edges or protrusions and remove if present. Clean and dry the saw cuts to remove cutting dust, grit, oil, moisture, or other contaminants. Clean by flushing with a stream of water under pressure. Use oil-free compressed air to dry the saw cuts.

4. Install detector loop cable without damage. Place three turns of the detector loop cable into the saw cut. Seal the ends of the tubing at the time of placement to prevent entrance of moisture.

5. Ensure the detector loop cables are in the bottom of the saw cut. Place detector loop sealant within the saw cut area. Comply with the manufacturer’s instructions for mixing and using the detector loop sealant.

6. Install preformed loop detector according to the manufacturer’s recommendations.

7. Identify each detector loop cable in the handhole by phase and location. Wind loops that are physically adjacent in an individual lane or adjacent lanes with opposite rotation (i.e. #1 clockwise, #2 counter-clockwise, #3 clockwise, etc.). Rotation reversal can be accomplished by reversing leads at the handhole.

8. Twist, with at least five turns per foot, all lengths of loop wires and tubing that are not embedded in the pavement.

9. Identify all detector loop lead-in cables with appropriate detector numbers.

10. Use a detector loop cable splice kit for the electrical splice between the detector loop cable and the detector loop lead-in cable to the controller.
   a. Ensure splice kit provides a watertight protective covering for the spliced wire, the shielding on the detector loop lead-in cable, and the end of the tubing containing the detector loop cable.
   b. Use a manufactured electrical splice kit approved by the Engineer.
3.02 DETECTION (Continued)

11. Test all loops and document by using the following procedures:
   a. Determine the insulation resistance of the loop wire using a “megger” with 500V applied to either loop wire to earth ground. The resistance is to be greater than 100 megohms.
   b. Determine the inductance of the loop using a loop inductance meter.

B. Pedestrian Push Button Detectors:

   1. Install according to the manufacturer’s recommendations.
   2. Seal the wire entrance into the pedestrian push button assembly.

C. Video Detection Camera System: Install according to the manufacturer’s recommendations and as specified in the contract documents.

D. Wireless Magnetic Sensors (Pod/Puck): Install according to the manufacturer’s recommendations.

3.03 COMMUNICATIONS

A. Traffic Monitoring System: Install according to the manufacturer’s recommendations and as specified in the contract documents, as well as the following:

   1. Position camera dome on the pole as directed by the Engineer.
   2. Test installed system under the supervision of the Engineer, and certify as fully-functional.

B. Fiber Optic Hub Cabinet: Install according to the manufacturer’s recommendations and as specified in the contract documents.

3.04 CABINET AND CONTROLLER

A. Controller, Cabinet, and Auxiliary Equipment:

   1. Install according to the manufacturer's recommendations and as specified in the contract documents.
   2. Install on pre-placed caulking material on the concrete base. After the cabinet is installed in place, place caulking material around the base of the cabinet.

B. Controller and Auxiliary Equipment: Install according to the manufacturer’s recommendations and as specified in the contract documents.

C. UPS Battery Backup System: Install according to the manufacturer’s recommendations and as specified in the contract documents. Provide service outlet that is not connected to the battery backup system.

D. Emergency Vehicle Preemption System: Install according to the manufacturer’s recommendations and as specified in the contract documents.
3.05 **POLES, HEADS, AND SIGNS**

**A. Vehicle and Pedestrian Traffic Signal Heads:**

1. Inspect each signal head assembly while still on the ground for the following:
   a. Physical defects
   b. Visor type
   c. LED wattage
   d. Lens orientation
   e. Wiring connections

2. Attach signal head mounting hardware according to the manufacturer’s recommendations. Apply anti-seize compound to all mechanical fasteners.

3. Adjust each signal head both vertically and horizontally to approximate a uniform grade of all like signal heads.

4. During the course of construction and until the signals are placed in operation, cover signal faces or turn away from approaching traffic. **When ready for operation,** plumb and aim the heads. Confirm placement of signal heads with the Engineer.

**B. Traffic Signal and Pedestal Poles and Pedestrian Push Button Posts:**

1. Erect all poles and posts vertically under normal load.

2. Securely bolt the bases to the cast-in-place concrete foundations using the following procedures. Perform this work only on days with winds less than 15 mph. Tighten all of the nuts in the presence of the inspector. Once the tightening procedure is started, complete on all of the base plate nuts without pause or delay.
   a. Use properly sized wrenches or sockets, or both, designed for tightening nuts or bolts, or both, to avoid rounding or other damage to the nuts. Do not use adjustable end or pipe wrenches.
   b. Ensure base plates, anchor rods, and nuts are free of all dirt or debris.
   c. Apply stick wax or bees wax to the threads and bearing surfaces of the anchor bolt, nuts, and washers.
   d. Tighten top nuts so they fully contact the base plate. Tighten leveling nuts to snug tight condition. Snug tight is defined as the full effort of one person on a wrench with a length equal to 14 times the bolt diameter but not less than 18 inches. Apply full effort as close to the end of the wrench as possible. Perform tightening by leaning back and using entire body weight to pull firmly on the end of the wrench until the nut stops rotating. Perform a minimum of two separate passes of tightening. Sequence tightening in each pass so that the nut on the opposite side, to the extent possible, is subsequently tightened until all of the nuts in that pass have been tightened.
   e. Tighten top nuts to snug tight as described for the leveling nuts.
   f. Match-mark the top nuts and base plate using paint, crayon, or other approved means to provide a reference for determining the relative rotation of the nut and base plate during tightening. Further tighten the top nuts tightened in two passes, as listed in Table 8010.01, using a striking or hydraulic wrench. Follow a sequence of tightening in each pass so that the nut on the opposite side, to the extent possible, is subsequently tightened until all nuts in that pass have been turned. Do not allow the leveling nut to rotate during the top nut tightening.
   g. Lubricate the jam nuts, place, and tighten to snug tight.
3.05 POLES, HEADS, AND SIGNS (Continued)

Table 8010.01: Bolt Tightening

<table>
<thead>
<tr>
<th>Anchor Bolt Size</th>
<th>First Pass</th>
<th>Second Pass</th>
<th>Total Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than or equal to 1 1/2 inch diameter</td>
<td>1/6 turn</td>
<td>1/6 turn</td>
<td>1/3 turn</td>
</tr>
<tr>
<td>Greater than 1 1/2 inch diameter</td>
<td>1/12 turn</td>
<td>1/12 turn</td>
<td>1/6 turn</td>
</tr>
</tbody>
</table>

3. A torque wrench should be used to verify that a torque at least equal to the computed verification torque, $T_v$, according to paragraph 6.9 of FHWA Guidelines for the Installation, Inspection, Maintenance, and Repair of Structural Supports for Highway Signs, Luminaires, and Traffic Signals, is required to additionally tighten the top nuts. An inability to achieve this torque should be interpreted to indicate that the threads have stripped and should be reported to the Engineer.

4. After leveling the poles, use non-shrink grout or a rodent guard between the pole base and the foundation. When non-shrink grout is used, neatly finish exposed edges of grout to present a pleasing appearance, and place a weep hole in the grout.

5. Apply anti-seize compound to all mechanical fasteners on pole access doors.

6. Install pedestrian push button post caps with tamper-proof set screws per manufacturer’s direction or by driving the cap a minimum of 1/2 inch onto the post.

C. Traffic Signs: Install signs using universally adjustable sign brackets banded to the pole. Apply anti-seize compound to all mechanical fasteners.

3.06 TEMPORARY TRAFFIC SIGNAL

Construct according to Figure 8010.107 and to the configuration specified in the contract documents. Remove the temporary traffic signal as directed by the Engineer.

3.07 SURFACE RESTORATION

A. Replace or reconstruct features removed as a part of the work, such as sidewalks, driveways, curbs, roadway pavement, unpaved areas, or any other items.

B. Complete restoration according the applicable sections of the SUDAS Standard Specifications or as directed by the Engineer.

3.08 SIGNAL TURN ON

Six days in advance of the scheduled signal turn on, place static signs or portable dynamic message signs (PDMS) on at least each of the major street approaches indicating day of week when the traffic signals will be active. If required, special Traffic Signal Ahead signs or PDMS with “Signal Active” message may be left in place for up to 7 days following activation.

3.09 TESTING

A. Notify the Engineer 48 hours 2 working days in advance of the time and date the signal or signal system will be ready for turn on. Do not turn on the signal or signal system without authorization of the Engineer.

B. Ensure a representative from the manufacturer and/or supplier of signal controller or other authorized person is at the project site when the signal controllers are ready to be turned on to provide technical assistance including, as a minimum, programming of all necessary input data.
3.09 TESTING (Continued)

C. All required signal timing data will be provided by the Engineer.

D. A test period of 30 calendar days will start upon confirmation from the Engineer that the signal or signal system is operating consistent with the project requirements. Any failure or malfunction of the equipment furnished by the Contractor, occurring during the test period will be corrected by the Contractor at no additional cost to the Contracting Authority. Upon confirmation by the Engineer that any failure or malfunction has been corrected, a new test period of 30 calendar days will start, exclusive of minor malfunctions such as lamp burnouts. Repeat this procedure until the signal equipment has operated satisfactorily for 30 consecutive calendar days.

E. After signal turn on and prior to completion of the 30 calendar day test period, respond, within 24 hours, to perform maintenance or repair of any failure or malfunction reported.

3.10 DOCUMENTATION

A. Provide file documentation packages with each signal system, consisting of the following:

1. Complete cabinet wiring diagram.

2. Complete physical description of the equipment.

3. Controller printout or equal documentation of initial controller settings installed in the field or in the office.

4. Product manuals for all cabinet equipment.

5. Standard industry warranties on equipment supplied.

6. Documentation of field cable labeling scheme.

7. Diagram of phasing and detector locations.

8. One set of as-built construction plans indicating changes from the original contract documents.

B. Supply two complete sets of documentation. One set to be placed in the controller cabinet and the other set (less construction plan) to be delivered to the Engineer. Electronic (PDF) submittal of the documentation is acceptable, if allowed by the Engineer.

3.11 TRAFFIC SIGNAL REMOVAL

A. Remove and salvage traffic signal and pedestrian poles and posts, including mast arms, signal heads, wiring, mounting hardware, and associated equipment.

B. Remove and salvage controller cabinet and controller, including associated equipment.

C. Remove and salvage handholes.

D. Remove concrete pads and foundations, including reinforcing steel to a depth of 4 feet below established grade. Furnish, place, and compact backfill according to Section 3010.

E. Restore disturbed surfaces to match adjacent areas.

F. Deliver salvaged materials to the location specified in the contract documents.
1. Shape top 11 inches with forms.
2. Bolt spacing and conduit locations as specified by the manufacturer.
3. Provide apron on three sides of cabinet if cabinet has front and back doors.
The Type A Foundation is the normally required foundation construction. Where rock is encountered, the Engineer may approve the use of the Type B or C Foundation. Prior to installing a foundation in rock, obtain a subsurface investigation certified by a geotechnical engineer licensed in the State of Iowa.

1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rodent guard or non-shrink grout with weep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedded end.
4. Provide conduits as per plans.
5. Install ground rod adjacent to foundation or in adjacent handhole.

### TABLE

<table>
<thead>
<tr>
<th>Max. Mast Arm Length</th>
<th>Foundation</th>
<th>&quot;V&quot; Bars</th>
<th>Tie Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W</td>
<td>L</td>
<td>Count</td>
</tr>
<tr>
<td>35'-0&quot;</td>
<td>3'-0&quot;</td>
<td>12'</td>
<td>12</td>
</tr>
<tr>
<td>45'-0&quot;</td>
<td>3'-0&quot;</td>
<td>14'-0&quot;</td>
<td>12</td>
</tr>
<tr>
<td>55'-0&quot;</td>
<td>3'-0&quot;</td>
<td>16'-0&quot;</td>
<td>12</td>
</tr>
<tr>
<td>60'-0&quot;</td>
<td>3'-0&quot;</td>
<td>18'-0&quot;</td>
<td>13</td>
</tr>
<tr>
<td>70'-0&quot;</td>
<td>3'-6&quot;</td>
<td>18'-0&quot;</td>
<td>12</td>
</tr>
<tr>
<td>80'-0&quot;</td>
<td>3'-6&quot;</td>
<td>21'-0&quot;</td>
<td>14</td>
</tr>
<tr>
<td>90'-0&quot;</td>
<td>4'-0&quot;</td>
<td>22'-0&quot;</td>
<td>16</td>
</tr>
<tr>
<td>100'-0&quot;</td>
<td>4'-0&quot;</td>
<td>24'-0&quot;</td>
<td>18</td>
</tr>
</tbody>
</table>
Type B Foundation is applicable for traffic signal poles with mast arm lengths up to 60 feet.

If the excavation for a Type B Foundation is left open for more than 1 calendar day, install temporary barrier rail if any part of the excavation is located within the clear zone. Temporary barrier rail layout requires the Engineer's approval.

Competent rock has an average unconfined compressive strength (q_u) of at least 2.0 ksi and rock quality designation of at least 90%. Conditions not meeting minimum requirements will require either:

- A site specific design, or
- Using the parameters for Mast Arm Pole Foundation in Soil.

2. Install rodent guard or non-shrink grout with weep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedded end.
4. Provide conduits as per plans.
5. When in contact with rock, place ground rods as specified in National Electrical Code, current edition, adjacent to foundation or in adjacent handhole.
6. Cast foundation concrete against competent rock. If foundation is formed, place backfill with concrete cast against rock.
7. Place 13 equally spaced #8 vertical bars.
8. #6 bars spaced at 8 inch maximum. Ties may be welded to vertical bars.

**Plan View**

**Figure 8010.102**

**Traffic Signal Pole Foundation**
FIGURE 8010.102

SHEET 3 OF 4

TYPE C FOUNDATION

MAST ARM POLE FOUNDATION IN ROCK

**TABLE 8010.102**

<table>
<thead>
<tr>
<th>Max. Mast Arm Length</th>
<th>W</th>
<th>W</th>
<th>L***</th>
<th>W</th>
<th>L***</th>
<th>Count</th>
<th>Size</th>
<th>Length</th>
<th>S Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>35'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>12'-0&quot;</td>
<td>3'-0&quot;</td>
<td>3'-6&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>45'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>14'-0&quot;</td>
<td>3'-0&quot;</td>
<td>3'-6&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>55'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>16'-0&quot;</td>
<td>3'-0&quot;</td>
<td>3'-6&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>60'-0&quot;</td>
<td>3'-0&quot;</td>
<td>2'-6&quot;</td>
<td>18'-0&quot;</td>
<td>3'-0&quot;</td>
<td>3'-6&quot;</td>
<td>13</td>
<td>#8</td>
<td>L - 6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>70'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-0&quot;</td>
<td>18'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-6&quot;</td>
<td>14</td>
<td>#9</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>80'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-0&quot;</td>
<td>21'-0&quot;</td>
<td>3'-6&quot;</td>
<td>3'-6&quot;</td>
<td>14</td>
<td>#9</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>90'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>22'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>15</td>
<td>#10</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>100'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>24'-0&quot;</td>
<td>4'-0&quot;</td>
<td>3'-6&quot;</td>
<td>15</td>
<td>#10</td>
<td>L - 6&quot;</td>
<td>5½&quot;</td>
</tr>
</tbody>
</table>

*Broken rock has an average unconfined compressive strength (\(q_u\)) of at least 1.0 ksi and rock quality designation of at least 20%.

**Competent rock has an average unconfined compressive strength (\(q_u\)) of at least 2.0 ksi and rock quality designation of at least 90%.

***Total foundation length \(L\) must be sufficient to provide a 3 inch clearance between the bottom of the traffic signal pole anchor bolts and the bottom of the rock socket.

****The Rock Socket Length \(L_s\) can be decreased if the total length of the shaft is \(L\) long as shown in the table.

Conditions not meeting minimum requirements will require site specific designs or shall use the Type A Foundation Soil parameters.

1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rodent guard or non-shrink grout with weep hole.
3. Furnish nut, nut and plate, or nut and anchor bolt assembly ring plate on embedded end.
4. Provide conduits as per plans.
5. When in contact with rock, place ground rods as specified in National Electrical Code, current edition, adjacent to foundation or in adjacent handhole.

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**Details:***

- **Plan View:**
  - Top of Rock
  - 6" Clear Cover Drilled Shaft
  - 3" Clear Cover Rock Socket (Typ.)
  - #6 Ties
  - "V" Bars
  - Pole Base

- **Detail 'A':**
  - Shape with Forms (Square or Circular)

- **Foundation:**
  - 1" Dia. Ground Wire Duct
  - Expansion Material
  - Drilled Shaft Tie Bars
  - Rock Socket Tie Bars

- **Ground Rod:**
  - 3" Clearance

- **Anchor Bolts:**
  - 2'-6" Min.
  - 4'-0" Max.

- **Conduits:**
  - 6 Spaces at 4" O.C.

- **Ground Rod Clamp:**
  - 3" Clearance

- **Rock:**
  - Broken Rock
  - Competent Rock

- **Spacing:**
  - 4'-6" Width x 5½" Spacing

---

SUDAS DIRECTOR
DESIGN METHODS ENGINEER
PEDESTAL POLE FOUNDATION IN SOIL OR ROCK

1. Shape top 11 inches with forms. See Detail 'A'.
2. Install rodent guard or non-shrink grout with weep hole.
3. When in contact with rock, place ground rods as specified in National Electrical Code, current edition, adjacent to foundation or in adjacent handhole.

12 to 24 inch diameter as shown in contract documents.
PRECAST CONCRETE HANDHOLE (TYPE I)

HDPE HANDHOLE (TYPE V)

Potential conduit entry through bottom of handhole.

Cable Hooks (4) (if required)

Finished Pavement Grade

HDPE Frame

Composite Lid

Extend 6" granular base 6" beyond walls of handhole.

Revised: 10-19-21

CONDUIT AND PRECAST HANDHOLES
**HANDHOLE DIMENSIONS TABLE (NOMINAL)**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>L</th>
<th>W</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>30&quot;</td>
<td>17&quot;</td>
<td>24&quot;</td>
</tr>
<tr>
<td>III</td>
<td>36&quot;</td>
<td>24&quot;</td>
<td>30&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>48&quot;</td>
<td>30&quot;</td>
<td>36&quot;</td>
</tr>
</tbody>
</table>

For conduit behind curb, place 24 to 48 inches below top of curb. For conduit under roadway, place 30 to 60 inches below the gutterline.

Ensure compacted backfill material is free of cinders, concrete, or other rubble.

Extend granular base 8" beyond walls of handhole.

PRECAST CONCRETE COMPOSITE HANDHOLE
Length (L) as specified in the contract documents.

Continuous loop leads to handhole.

Detector Conduit Entry

No Curb

Rectangular Detector Loop

Sections A-A
BICYCLE QUADRUPOLE LOOP DETECTOR

WINDING PATTERN
(Number of turns is 3-6-3)

Drill separate hole for each loop.

Edge of Pavement or Back of Curb
1. Ensure the top of the signal housing is no more than 25.6 feet above the pavement. Ensure the bottom of the signal housing and related attachments are at least 15 feet above the pavement.

2. Ensure the bottom of the signal housing (including brackets) that is not located over a roadway is a minimum of 8 feet and a maximum of 19 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.

3. Mount pedestrian signal heads with the bottom of the signal housing (including brackets) no less than 7 feet or more than 10 feet above the sidewalk level. Position and adjust heads to provide maximum visibility at the beginning of the controlled crosswalk.

4. Possible video camera location.

Typical placement of traffic control and street name signs.
PEDESTAL POLE DETAILS

- Adjustable Mounting Brackets
- Fixed or Universally Adjustable Mounting Brackets
- Pedestrian Traffic Signal Head Assembly
- Pedestrian Push Button Sign
- Pedestrian Push Button

Dimensions:
- 7'-0" min.
- 10'-0" max.
- 8'-0" min.
- 10'-0" max.
- 3'-6" above sidewalk
- 7'-0" min.
- 10'-0" max.
Sag Distance: 5% of Span

Multi-Conductor Tether
Bottom Signal and Backplates

Class 4 Wood Pole
Pole or Pad Mounted Controller Cabinet

Guy Guard

2.5" Galvanized Steel Pipe
Galvanized Guy Connector End Fitting
Galvanized Post Plate
8" Guy Guard

18" min. Anchor

Sidewalk
Roadway

Cable Straps

2.5" Galvanized Steel Pipe

Galvanized Thimble Eye Angle Bolt

Double Galvanized Steel Messenger Wire; 7 Strand (Utilities Grade)

Conduit Entry Cap

Galvanized Thimble Eye Nut

Message Wire; 7 Strand (Utilities Grade)

Controller Cabinet

Guy Guard

Anchors

18" min.

15'-0" max. per MUTCD

3'-0"