Chapter 1330  Traffic Control Signals

1330.01 General
Traffic control signals are power-operated traffic control devices that warn or direct motorists to take a specific action. They are used to control the assignment of right of way at locations where conflicts with motorists, bicyclists, and pedestrians exist or where passive devices such as signs and markings do not provide the necessary flexibility of control to move motorists, bicyclists, and pedestrians in an efficient manner.

The decision to install a traffic signal is the result of an Intersection Control Analysis (ICA) that is approved by the region Traffic Engineer or other designated authority.

1330.02 References
The following references are used in the planning, design, construction, and operation of traffic control signals installed on state highways. The RCWs noted are specific state laws concerning traffic control signals, and conformance to these statutes is required.

(1) Federal/State Laws and Codes
Americans with Disabilities Act of 1990 (ADA) (23 CFR Part 36, Appendix A)
Revised Code of Washington (RCW) 35.77, Streets – Planning, establishment, construction, and maintenance
RCW 46.04.450, Railroad sign or signal
RCW 46.04.600, Traffic control signal
RCW 46.04.62250, Signal preemption device
RCW 46.61.050, Obedience to and required traffic control devices
RCW 46.61.055, Traffic control signal legend
RCW 46.61.060, Pedestrian control signals
RCW 46.61.065, Flashing signals
RCW 46.61.070, Lane-direction-control signals
RCW 46.61.072, Special traffic control signals – Legend
RCW 46.61.075, Display of unauthorized signs, signals, or markings
RCW 46.61.080, Interference with official traffic-control devices or railroad signs or signals
RCW 46.61.085, Traffic control signals or devices upon city streets forming part of state highways – Approval by department of transportation

RCW 46.61.340, Approaching train signal

RCW 47.24.020(6) and (13), Jurisdiction, control

RCW 47.36.020, Traffic control signals

RCW 47.36.060, Traffic devices on county roads and city streets

Washington Administrative Code (WAC) 468-18-040, Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings

WAC 468-18-050, Policy on the construction, improvement and maintenance of intersections of state highways and city streets


(2) Design Guidance

A Policy on the Geometric Design of Highways and City Streets (Green Book), AASHTO, 2004


[web link]

Instructions for the Guide for Determining Time Requirements for Signal Preemption at Highway-Rail Grade Crossings, Texas Department of Transportation

Manual on Uniform Traffic Control Devices for Streets and Highways, USDOT, FHWA; as adopted and modified by Chapter 468-95 WAC “Manual on uniform traffic control devices for streets and highways” (MUTCD)

Plans Preparation Manual, M 22-31, WSDOT


Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10, WSDOT

WSDOT Traffic Design Resources

[web link]
1330.03 Definitions

The various types of traffic control signals are defined below. Warning beacons, pedestrian flashing beacons, emergency signals, and ramp meter signals are energized only at specific times of the day or upon detecting a user. All other signals remain in operation at all times.

**accessible pedestrian signal** A device that communicates information about the “WALK” phase in audible and vibrotactile (vibrating surface that communicates information through touch, located on the accessible pedestrian signal button) formats.

**conventional traffic signal** A permanent or temporary installation providing alternating right of way assignments for conflicting traffic movements. At least two identical displays are required for the predominant movement on each approach.

**emergency vehicle signal** A special adaptation of a conventional traffic signal installed to allow for the safe movement of authorized emergency vehicles. Usually, this type of signal is installed on the highway at the entrance into a fire station or other emergency facility. The signal ensures protected entrance onto the highway for the emergency vehicle. When not providing for this movement, the signal either operates continuously (consistent with the requirements for a conventional traffic signal) or displays continuous green, which is allowed at nonintersection locations only. At least two identical displays are required per approach.

**flashing warning assembly** Flashing beacons that are used only to supplement an appropriate warning or regulatory sign or marker. The displays consist of two alternating flashing yellow indications.

**high-speed roadway** A roadway with a posted speed of 45 mph or higher.

**intersection control beacon** (also flashing beacon) A secondary control device, generally suspended over the center of an intersection, that supplements intersection warning signs and stop signs. One display per approach may be used; however, two displays per approach are desirable. Intersection control beacons are installed only at intersections that control two or more directions of travel.

**lane control signal** (reversible lanes) A special overhead signal that permits, prohibits, or warns of impending prohibition of lane use.

**low-speed roadway** A roadway with a posted speed of lower than 45 mph.

**metering signal** A signal used to control the predominant flow rate of traffic at an at-grade facility.

**movable bridge signal** (also drawbridge signal) A signal installed to notify traffic to stop when the bridge is opened for waterborne traffic. Movable bridge signals display continuous green when the roadway is open to vehicular traffic.

**multilane approach** An approach that has two or more lanes, regardless of the lane use designation.

**overlapped displays** Overlapped displays allow a traffic movement to operate with one or more nonconflicting phases. Most commonly, a minor street’s exclusive right-turn phase is overlapped with the nonconflicting major street’s left-turn phase. An overlapped display can be terminated after the parent phase (the main phase the overlap is associated with) terminates. An overlapped display programmed for two or more parent phases continues to display until all of the parent phases have
terminated. An overlap is made up of two or more phases—not one phase controlling two movements.

**pedestrian signal**  An adaptation of a conventional traffic signal installed at established pedestrian crossings. It is used to provide a protected phase for pedestrians by terminating the conflicting vehicular movements to allow for pedestrian crossings.

**portable traffic signal**  A type of conventional traffic signal used in work zones to control traffic. This signal is most commonly used on two-way two-lane highways where one lane has been closed for roadwork. This signal is most commonly operated in pairs, with one signal at each end of the work zone. This eliminates the need for 24-hour flagger control. The traffic signal provides alternating right of way assignments for conflicting traffic movements. The signal has an adjustable vertical support with two three-section signal displays and is mounted on a mobile trailer with its own power source.

**ramp meter signal**  A signal used to control the flow rate of traffic entering a freeway or similar facility. A minimum of two displays is required for each approach. On single-lane ramps, a Type RM signal pole with two three-section signal heads is normally installed. On double-lane ramps, a Type II signal pole with two three-section signal heads is normally installed. When not in use, ramp meter signals are not energized.

**speed limit sign beacon**  A beacon installed with a fixed or variable speed limit sign. The preferred display is two flashing yellow indications.

**stop sign beacon**  A beacon installed above a stop sign. The display is a flashing red indication.

**temporary traffic signal**  A conventional traffic signal used during construction to control traffic at an intersection while a permanent signal system is being constructed. A temporary traffic signal is typically an inexpensive span-wire installation using timber strain poles.

**queue cutter traffic signal**  A traffic signal used at highway-rail grade crossings where the queue from a downstream traffic signal is expected to extend within the Minimum Track Clearance Distance. It is used to keep vehicles from an adjacent signalized intersection from queuing on the railroad tracks.

**warning beacon**  A beacon that supplements a warning or regulatory sign or marking. The display is a flashing yellow indication. These beacons are not used with STOP, YIELD, or DO NOT ENTER signs or at intersections that control two or more lanes of travel. A warning identification beacon is energized only during those times when the warning or regulation is in effect.

### 1330.04 Procedures

**(1) Permit**

State statutes (RCWs) require Washington State Department of Transportation (WSDOT) approval for the design and location of all conventional traffic signals and some types of beacons located on city streets forming parts of state highways. Approval by WSDOT for the design, location, installation, and operation of all other traffic control signals installed on state highways is required by department policy.
The Traffic Signal Permit (DOT Form 242-014 EF) is the formal record of the department’s approval of the installation and type of signal and must be included in the DDP. The permit is completed by the responsible agency and submitted, complete with supporting data, to the Regional Administrator for approval. The Regional Administrator approves or denies the application and sends it to the region Traffic Office. The region Traffic Office retains a record of the approved permit and supporting data and forwards a copy to the State Traffic Engineer at WSDOT Headquarters (HQ). Permits are required for the following types of signal installations:

- Conventional traffic signals
- Emergency vehicle signals
- Intersection control beacons
- Lane control signals
- Movable bridge signals
- Ramp meter signals
- Pedestrian signals
- Temporary traffic signals
- Queue-cutter traffic signals

Emergency vehicle signals require annual permit renewal. The region Traffic Office reviews the installation for compliance with requirements. If satisfactory, the permit is renewed by the Regional Administrator with a letter to the operating agency. A copy of this letter is also sent to the State Traffic Engineer.

Permits are not required for portable traffic signals, speed limit sign beacons, stop sign beacons, or lane assignment signals at toll facilities.

When it is necessary to increase the level of control, such as changing from an intersection control beacon to a conventional traffic signal, a new permit application is required. If the change results in a reduction in the level of control, as in the case of converting a conventional signal to a flashing intersection beacon, or if the change is the removal of the signal, submit the “Report of Change” portion of the traffic signal permit to the Regional Administrator, with a copy to the State Traffic Engineer. If an intersection approach is going to be signalized that was not signalized when the original signal permit was filed, a “Report of Change” is required.

If experimental systems are proposed, region Traffic Engineer review and approval is required. The region Traffic Office will send the approved proposal to the State Traffic Engineer for review, approval, and forwarding to FHWA for approval. The FHWA approval document is to be included in the DDP.

(2) Responsibility for Funding, Construction, Maintenance, and Operation

Responsibility for the funding, construction, maintenance, and operation of traffic signals on state highways has been defined by legislative action and Transportation Commission resolutions (see Exhibit 1330-1). Responsibilities vary depending on location, jurisdiction, and whether or not limited access control has been established. Limited access as used in this chapter refers to full, partial, or modified limited access control that has been established as identified in the Access Control Tracking System: [www.wsdot.wa.gov/Design/accessandhearings/tracking.htm](http://www.wsdot.wa.gov/Design/accessandhearings/tracking.htm)
Responsibility for Various Types of Facilities on State Highways

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Notes:
[1] ESD refers to the applicable Emergency Service Department.
[2] State highways without established limited access control (see 1330.04(2)(b)).
[3] See 1330.04(2)d.

Responsibility for Facilities

Exhibit 1330-1

(a) **Inside the corporate limits of cities with a population of less than 25,000:**
WSDOT is responsible for funding, construction, maintenance, and operation of traffic signals. Population figures can be found at: "www.ofm.wa.gov/pop/"

(b) **Inside the corporate limits of cities with a population of 25,000 or greater where there is no established limited access control:** The city is responsible for the funding, construction, maintenance, and operation of traffic signals. Population figures can be found at: "www.ofm.wa.gov/pop/"

(c) **Inside the corporate limits of cities with a population of 25,000 or greater where there is established limited access control:** WSDOT is responsible for funding, construction, maintenance, and operation of traffic signals. Population figures can be found at: "www.ofm.wa.gov/pop/"

(d) **Outside the corporate limits of cities and outside established limited access control areas:** WSDOT is responsible for funding, construction, maintenance, and operation of a traffic signal when a new state highway crosses an existing county road. When a new county road intersects an existing state highway,
WSDOT is responsible for only the maintenance and operation of a traffic signal. The county is responsible for the construction costs of the traffic signal and associated illumination. When it is necessary to construct a traffic signal at an existing county road and state highway intersection, the construction cost distribution is based on the volume of traffic entering the intersection from each jurisdiction’s roadway. The county’s share of the cost, however, is limited to a maximum of 50%. The state is responsible for maintenance and operation (WAC 468-18-040).

(e) **Outside the corporate limits of cities and inside established limited access control areas:** WSDOT is responsible for funding, construction, maintenance, and operation of traffic signals.

(f) **Emergency vehicle signals:** The emergency service agency is responsible for all costs associated with emergency vehicle signals.

(g) **Third party agreement signals:** At those locations where WSDOT is responsible for traffic signals and agrees with the alternatives analysis that the proposed traffic signal is justified, but where funding schedules and priorities do not provide for the timely construction of the traffic signal requested by others, the following rules apply:

- The third party agrees to design and construct the traffic signal in conformance with WSDOT’s guidelines and requirements.
- The third party agrees to submit the design and construction documents to WSDOT for review and approval by the region Traffic Engineer.
- The third party obtains a traffic signal permit.
- Third party agreement(s) with incorporated cities will be part of the DDP.

### 1330.05 Signal Warrants

A signal warrant is a minimum condition that is to be met before a signal may be installed. Satisfying a warrant does not mandate the installation of a traffic signal. The warranting condition indicates that an engineering study, including a comprehensive analysis of other traffic conditions or factors, is needed to determine whether the signal or another improvement is justified. This is the Intersection Control Analysis performed during the scoping of the project (see Chapter 1300). For a list of the traffic signal warrants and information on how to use them, see the Manual on Uniform Traffic Control Devices (MUTCD). Include the selected signal warrants in the DDP.

A proposal to install a traffic signal on any state route with a posted speed of 45 mph or higher requires an alternatives analysis, approved by the region Traffic Engineer, with review and comment by the HQ Design Office.

### 1330.06 Conventional Traffic Signal Design

(1) **General**

The goal of any traffic signal design is to assign right of way in the most efficient manner possible and still be consistent with traffic volumes, intersection geometrics, and safety.
(2) **Signal Phasing**

With some exceptions, the fewer the traffic signal phases, the more efficient the operation of the traffic signal. The number of phases required for efficient operation is related to intersection geometrics, traffic volumes, composition of traffic flow, turning movement demands, and desired level of driver comfort. The traffic movements at an intersection have been standardized to provide a consistent system for designing traffic signals. (See Exhibit 1330-2 for standard intersection movements, signal head numbering, and standard phase operation, and see Exhibit 1330-3 for phase diagrams for various traffic signal operations.)

(a) **Left-Turn Phasing**

Left-turn phasing can either be permissive, protected/permissive, or protected. It is not necessary that the left-turn mode for an approach be the same throughout the day. Varying the left-turn mode on an approach among the permissive only, protected/permissive, and protected-only left-turn modes during different periods of the day is acceptable.

1. **Permissive Left-Turn Phasing**

   Permissive left-turn phasing requires the left-turning vehicle to yield to opposing through traffic and pedestrians. Permissive left-turn phasing is used when the turning volume is minor and adequate gaps occur in the opposing through movement. This phasing is more effective on minor streets where providing separate protected turn phasing might cause significant delays to the higher traffic volume on the main street. On high-speed (posted speed of 45 mph or above) single-lane approaches or where sight distance is limited, the preferred channelization would include a separate left-turn storage lane for the permissive movement to reduce the potential for rear-end-type collisions and delay to through movements.

2. **Protected/Permissive Left-Turn Phasing**

   Protected/permissive left-turn phasing provides the left-turn movements with an exclusive nonconflicting phase followed by a secondary phase when vehicles are required to yield to opposing traffic. The traffic signal can also operate with the permissive left-turn phase first followed by the protected left-turn phase. Where left-turn phasing will be installed and conditions do not warrant protected-only operation, consider protected/permissive left-turn phasing. Protected/permissive left-turn phasing can result in increased efficiency at some types of intersections, particularly “T” intersections, ramp terminal intersections, and intersections of a two-way street with a one-way street where there are no opposing left-turn movements.

   Protected/permissive left-turn phasing is not allowed under the following conditions:

   - On the approaches of a signal where Warrant 7 is met and there are five left-turning collisions on that approach included in the warranting collisions.
   - When documentation shows that existing protected left-turn phasing was installed due to left-turn collisions.
Phases 1, 2, 5, & 6 are normally assigned movements to the major street.

**Legend**
- Movement
- Vehicle heads
- Pedestrian head
- EV Emergency vehicle

**Typical Intersection Movements and Head Numbers**

**Typical Eight Phase Operation**

**Standard Intersection Movements and Head Numbers**

*Exhibit 1330-2*
Four-Phase Operation
Permissive lefts

Six-Phase Operation
Main St. protected lefts
Minor St. protected lefts

Minor St. permissive lefts

Eight-Phase Operation
Main St. protected lagging lefts
Minor St. protected lagging lefts

Protected leading lefts and overlapped rights
(A Minus Ped. overlap shall be used for Phases 2, 4, 6, & 8)

Phase Diagrams: Four-Way Intersections
Exhibit 1330-3
• When sight distance for left-turning vehicles, as outlined in AASHTO’s *A Policy on the Geometric Design of Highways and City Streets*, cannot be met.

• On intersection approaches where the opposing approach has three or more lanes (including right-turn lanes) and either the posted speed limit or 85th percentile speeds for the opposing approach are at or above 45 mph.

• On intersection approaches that have dual left-turn lanes.

• At intersections where lead/lag phasing is employed.

A flashing yellow arrow is allowed for protected/permissive left-turn operations under the following conditions:

• The approach has a separate left-turn storage lane.

• At least one separate four-section signal face, in addition to the minimum of two signal faces for the primary traffic movement on the approach, is to be provided for the left-turn movement. The separate left-turn signal face is to display, from top to bottom (or left to right in a horizontally aligned face), the following set of indications: steady left-turn red arrow, steady left-turn yellow arrow, flashing left-turn yellow arrow, and steady left-turn green arrow. If the left-turn movement is always operated in the permissive-only mode, the green arrow signal section is to be omitted.

• During a protected left-turn movement, the left-turn signal face displays only a steady left-turn green arrow signal indication.

• During a permissive left-turn movement, the left-turn signal face displays only a flashing yellow arrow signal indication.

• During a prohibited left-turn movement, the left-turn signal face displays only a steady left-turn red arrow or a steady circular red.

• A steady left-turn yellow arrow signal indication is displayed following every steady left-turn green arrow signal indication.

• A steady left-turn yellow arrow signal indication is displayed following the flashing left-turn yellow arrow signal indication if the permissive left-turn movement is being terminated and the left-turn signal will subsequently display a steady red signal indication. The steady left-turn arrow signal indication and the flashing left-turn yellow arrow signal indication are to be separate displays for permissive left turns.

• When a permissive left-turn movement is changing to a protected left-turn movement, a steady left-turn green arrow signal indication is to be displayed immediately upon termination of the flashing left-turn yellow arrow signal indication. A steady left-turn yellow arrow signal indication is not to be displayed between the display of the flashing left-turn yellow arrow signal indication and the display of the steady left-turn green arrow signal indication.

3. Protected Left-Turn Phasing

Protected left-turn phasing provides the left-turning vehicle a separate phase, and conflicting movements are required to stop.
Protected phasing is always required for multilane left-turn movements.

Use protected left-turn phasing when left-turning-type collisions on any approach equal three per year or five in two consecutive years. This includes left-turning collisions involving pedestrians.

Use protected left-turn phasing when the peak-hour turning volume exceeds the storage capacity of the left-turn lane because of insufficient gaps in the opposing through traffic and where one or more of the following conditions is present:

- Either the posted speed or the 85th percentile speed of the opposing traffic exceeds 45 mph.
- The sight distance to oncoming traffic is less than 250 feet when the 85th percentile speed is 35 mph or below, or less than 400 feet when the 85th percentile speed is above 35 mph.
- The left-turn movement crosses three or more lanes (including right-turn lanes) of opposing traffic.
- Geometry or channelization is confusing.

Typically, an intersection with protected left turns operates with leading left turns. This means that on the major street, the left-turn phases, phase 1 and phase 5, time before the through movement phases, phase 2 and phase 6. On the minor street, the left-turn phases, phase 3 and phase 7, time before phase 4 and phase 8. Lagging left-turn phasing means that the through phases time before the conflicting left-turn phases. In lead-lag left-turn phasing, one of the left-turn phases times before the conflicting through phases and the other left-turn phase times after the conflicting through phases. In all of these cases, the intersection phasing is numbered in the same manner. Leading, lagging, and lead-lag left-turn phasing are accomplished by changing the order in which the phases time internally within the controller. Check that all turning movements provide turning clearance for opposing turn phases. If the opposing left-turning vehicle paths do not have 4-foot minimum—12-foot desirable—separation between them, split or lead lag phasing is to be used.

4. **Multilane Left-Turn Phasing**

Multilane left-turn phasing can be effective in reducing traffic signal delay at locations with high left-turning volumes or where the left-turn storage area is limited longitudinally. At locations with closely spaced intersections, a two-lane left-turn storage area might be the only solution to reduce the potential for the left-turn volume to back up into the adjacent intersection. Consider the turning paths of the vehicles when proposing multilane left turns. If the opposing left-turning vehicle paths do not have 4-foot minimum—12-foot desirable—separation between them, split or lead lag phasing is to be used. At smaller intersections, the opposing single-lane left-turn movement might not be able to turn during the two-lane left-turn phase and it might be necessary to reposition this lane. If the opposing left turns cannot time together, the reduction in delay from the two-lane left-turn phase might be nullified by the requirement for a separate opposing left-turn phase. Exhibit 1330-4 shows two examples of two-lane left turns with opposing single-left arrangements.
Two receiving lanes are required for two-lane left-turn movements. In addition, these receiving lanes are to extend well beyond the intersection before reducing to one lane. A lane reduction immediately beyond the intersection can cause delays and backups into the intersection because the left-turning vehicles usually move in dense platoons, which may make lane changes difficult. (See Chapter 1310 for guidance on lane reductions on intersection exits.)

Left-Turn Lane Configuration With Concurrent Phasing

Left-Turn Lane Configuration Preventing Concurrent Phasing

Left-Turn Lane Configuration Examples

Exhibit 1330-4
(b) **Right-Turn Phasing**

1. **Right-Turn Overlapped Phasing**

   Consider right-turn overlapped phasing at locations with a dedicated right-turn lane where the intersecting street has a complementary protected left-turn movement and U-turns are prohibited. Several right-turn overlaps are shown in the Phase Diagrams in Exhibit 1330-3. The display for this movement is dependent on whether or not a pedestrian movement is allowed to time concurrently with the through movement adjacent to the right-turn movement.

   For locations with a concurrent pedestrian movement, use a five-section signal head consisting of circular red, yellow, and green displays with yellow and green arrow displays. Connect the circular displays to the through phase adjacent to the right-turn movement and connect the arrow displays to an overlap using an auxiliary output file. The right-turn overlap is to be programmed so that the green arrow will not be shown during a conflicting pedestrian phase or emergency vehicle preemption. The capabilities of the signal controller software will determine how the right-turn overlap is to be set up. Some signal software allows use of a negative pedestrian overlap, which prevents the green arrow from being displayed when the conflicting pedestrian phase is being served, and it allows the green arrow when the conflicting pedestrian movement is not being served. If the negative pedestrian overlap can be used, the overlap for the right-turn arrows is driven by both the adjacent through phase and the associated side street left turn. If the software does not have this feature, the overlap for the right-turn arrows is to be driven by the associated side street left-turn phase only. Coordinate with the region Signal Operations Engineer regarding the software features.

   For locations without a concurrent pedestrian movement, use a three-section signal head with all arrow displays or visibility-limiting displays (either optically programmed sections or louvered visors) with circular red, yellow arrow, and green arrow displays. This display is in addition to the adjacent through movement displays. Program this display as an overlap to both the complementary left-turn phase and the adjacent through phase.

2. **Two-Lane Right-Turn Phasing**

   Two-lane right-turn phasing can be used for an extraordinarily heavy right-turn movement. It can cause operational challenges when “right turn on red” is permitted at the intersection. Verify that there is adequate sight distance and the correct exit lane selections are made to minimize the possibility of collisions. In most cases, a single unrestricted “right-turn-only” lane approach with a separate exit lane (auxiliary lane) will have a similar capacity as the two-lane right-turn phasing.

(c) **Phasing at Railroad Crossings**

   Refer to 1330.06(12), Signal Design and Operation Near Railroad Crossings, for more information on phasing at railroad crossings.
(3) Intersection Design Considerations

Intersection design can have a considerable effect on how a traffic signal will operate, and careful consideration is to be given to this aspect of the design. (See Chapter 1310 for further guidance.)

Left-turning traffic can be better accommodated when the opposing left-turn lanes are directly opposite each other. When a left-turn lane is offset into the path of the approaching through lane, the left-turning driver might assume the approaching vehicles are also in a left-turn lane and fail to yield. To prevent this occurrence, less efficient split phasing may be necessary. (See Chapter 1310 for guidance on opposing left-turn clearance.)

Where a railroad crossing is within 88 feet of a signalized intersection, consider installing turn pockets for the movements leading to the leg of the intersection with the railroad crossing. This greatly improves the efficiency of the signal during railroad preemption when turns are restricted. Also consider providing a left-turn pocket for the minor leg opposing the railroad crossing. This will allow limited service during long periods of railroad preemption.

Consider providing an unrestricted through lane on the major street of a T intersection. This design allows for one traffic movement to flow without restriction. At high-speed intersections where this is used, the through lane is to be separated by a physical barrier or the through movement must also be signalized.

Skewed intersections, because of their geometry, are challenging to signalize and delineate. Where feasible, modify the skew angle to provide more normal approaches and exits. In many cases, the large paved areas for curb return radii at skewed intersections can be reduced when the skew angle is reduced. (See Chapter 1310 for requirements and design options.)

If roadway approaches and driveways are located too close to an intersection, the traffic from these facilities can affect signal operations. Consider eliminating the accesses or restricting them to “right in/right out.” This should be determined early so it can be considered and addressed in the design. (See Chapters 530 and 540 for further guidance.) Consider shifting the location of the advance loops upstream to clear an access point so that vehicles entering from the access point will not affect the loops.

Transit stop and pullout locations can affect signal operation. (See Chapter 1430 for transit stop and pullout designs.) When feasible, locate these stops and pullouts on the far side of the intersection to:

- Minimize overall intersection conflict, particularly the right-turn conflict.
- Minimize impact to the signal operation when buses use preemption to pull out at a traffic signal with transit preemption.
- Provide extra pavement area where U-turn maneuvers are allowed.
- Eliminate sight distance obstructions for drivers attempting to turn right on red.
- Eliminate conflict with right-turn pockets.

Large right-turn curb radii at intersections sometimes have impacts on traffic signal operation. Larger radii allow faster turning speeds and might move the pedestrian entrance point farther away from the intersection area. Pedestrian crossing times are increased because of the longer crossing, thereby reducing the amount of time available for vehicular traffic. (See Chapter 1310 for guidance on determining these radii.)
At intersections with large right-turn radii, consider locating signal standards on raised traffic islands to reduce mast arm lengths. These islands are primarily designed as pedestrian refuge areas. (See Chapter 1510 for pedestrian refuge islands and traffic island designs.) Locating signal standards on islands may decrease the required pedestrian clearance intervals; however, large radii and raised traffic islands may make it difficult for pedestrians to navigate the intersection. Place stop bars so they are out of the path of conflicting left turns. Check the geometric layout by using the turning path templates in Chapter 1310 or a computerized vehicle turning path program to determine whether the proposed layout and phasing can accommodate the design vehicles. Also, check the turning paths of opposing left-turn movements. In many cases, the phase analysis might recommend allowing opposing left turns to run concurrently, but the intersection geometrics are such that this operation cannot occur.

Coordinate with all stakeholders (Maintenance, Signal Operations, Civil Design Engineer, Drainage Engineer, and so on) in the placement of signal equipment to avoid any possible conflicts. Arrange field reviews with the appropriate stakeholders as necessary.

(4) Crosswalks and Pedestrians

When designing pedestrian signals, consider the needs of all pedestrians, including older pedestrians and pedestrians with disabilities who might walk at a significantly slower pace than the average pedestrian. Determine whether there are pedestrian generators in the project vicinity that might attract older people and pedestrians with disabilities, and adjust signal timing accordingly. Include accessible pedestrian pushbuttons and countdown pedestrian displays at all locations and crossings unless a specific crossing is prohibited. Consult with region and city maintenance personnel regarding maintenance requirements for these devices. (See Chapter 1510 for more information on accessible pedestrian routes.)

- Locate pedestrian push buttons in accordance with the most current edition of the Public Rights-of-Way Accessibility Guidelines (PROWAG) and the MUTCD.
- Clearly identify which crossing is controlled by the push button.
- Provide a level clear space (maximum 2% slope in any direction, 48 inches minimum by 30 inches minimum) within reach range at each push button for wheelchair users. The level clear space must be connected to the crosswalk it serves by a pedestrian access route.
- Mount push button at a maximum height of 3 feet 6 inches and a maximum horizontal distance of 2 feet from the level clear space surface.
(a) **Accessible Pedestrian Signals (APS)**

At all locations where pedestrian signals are newly installed, replaced, or significantly modified, the installation of accessible pedestrian signals (APS) and countdown pedestrian displays is required. (Note: Simply moving existing pedestrian push buttons to satellite poles to improve accessibility is not by itself considered a significant modification of the pedestrian signal.) When APS and countdown pedestrian display improvements are made, they shall be made for all locations associated with the system being modified. APS includes audible and vibrotactile indications of the WALK interval. Installation of these devices may require improvements to existing sidewalks and curb ramps to meet ADA compliance regulations (see Chapter 1510).

Refer to the MUTCD and the most current edition of the PROWAG for design requirements. Also, consult with region Traffic Office, HQ Traffic Operations, the HQ Design Office, and region and city maintenance personnel for current equipment specifications and additional design and maintenance requirements.

Crosswalks, whether marked or not, exist on all legs of a signalized intersection. For closing a crossing at a signalized intersection, see Chapter 1510.

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</table>

*Exhibit 1330-5*
If a crosswalk is installed across the leg where right-turning or left-turning traffic enters, the vehicle display cannot have a green turn arrow indication during the pedestrian WALK phase. If this cannot be accomplished through a negative ped overlap, provide a separate pedestrian or vehicle turn phase. Use of exclusive pedestrian phases should be avoided because of the negative effect they can have on efficient traffic signal operations.

(5) Control Equipment

Controller assemblies can be Type 170, Type 2070, or National Electrical Manufacturers Association (NEMA) controllers with dual ring, eight vehicle phases, four pedestrian phases, four overlaps, emergency vehicle preemption, railroad preemption, transit preemption, and start and end daylight savings time dates operational capabilities. From a design perspective, identical operation can be obtained from each controller. Specify Type 2070 unless region policy is to use 170 or NEMA controllers. The local controller software can impact the brand and model of the control equipment installed. Contact the region Signal Operations Engineer for software and controller specifications. The designer needs to specify the type of controller and the operating software to be installed. Include documentation of selected control equipment in the Project File.

Intersections within ½ mile of each other on low-speed state highways should be interconnected. Intersections within 1 mile of each other on high-speed state highways should be interconnected. The preferred method for interconnection is fiber optic cable, but other methods such as IP over copper or wireless interconnect may be considered after discussion with the region Signal Operations Engineer and approval by the region Traffic Engineer. Add a construction note in the plans stating to coil additional cable in the adjacent junction box, not the controller cabinet. Consider using a separate vault or junction box for coiling the fiber optic interconnect cable to allow for the large-bend radii. This will save on space in the controller cabinet and also allow additional cable in case the cabinet is hit by an errant vehicle. In situations where it is necessary to coordinate the traffic movements with another agency, it is important that the agencies work together.
Vacant

Exhibit 1330-6a
Vacant

Exhibit 1330-6b
It is often beneficial for one of the agencies to assume responsibility for the operation of the traffic signals. This is accomplished by negotiating an agreement with the other agency. The designer needs to check region policy and make sure someone initiates the process for setting up an operational agreement with the other agency or modifying an existing agreement when applicable. (See the Agreements Manual for more information on signal systems and maintenance agreements.) At a new intersection, where the state owns the signal, but WSDOT has agreed to let another agency operate the signal, the controller should be compatible with that agency’s system. When installing a new controller in an existing interconnected corridor, the controller should be capable of operating with the existing controllers in the corridor.

When it is necessary to install a NEMA controller in a 332 cabinet, this can be done by using a “C1” plug to NEMA “A” “B” “C” “D” adapters.

The model 210 conflict monitor in the Type 332 cabinet can be used with a NEMA controller by changing a switch setting. The NEMA conflict monitor is not used in this configuration. It does not fit in a Type 332 cabinet and the operation is not compatible. When a NEMA cabinet is used, specify rack mountings for the loop detector amplifiers and the preemption discriminators. Specify a power supply for the loop detectors. Coordinate with the region Signal Operations Engineer when selecting controller cabinets, controller, and controller assembly appurtenances.

Coordinate with the region Signal Operations Engineer and Transportation Systems Technician to determine the optimum controller cabinet location and the cabinet door orientation. The controller cabinet is positioned to provide maintenance personnel access. At this location, a clear view of the intersection, while facing the front of the controller, is desirable. The location is to have adequate room for a maintenance vehicle to park by the cabinet. Avoid placing the controller at locations where it might block the view of approaching traffic for a motorist turning right on red. Avoid locating the controller where flooding might occur or where the cabinet might be hit by errant vehicles. If possible, position the controller where it will not be affected by future highway construction.

If a telephone line, fiber optic, wireless, or other connection is desired for remote signal monitoring and timing adjustments by signal operations personnel, provide the appropriate equipment in the controller cabinet and/or nearby junction box or cable vault with separate conduits and junction boxes for the remote communications equipment.

Vehicle and pedestrian movements are standardized to provide uniformity in signal phase numbering, signal display numbering, preemption channel identification, detection numbering, and circuit identification. The following are general guidelines for the numbering system:

- Assign phases 2 and 6 to the major street through movements, orienting phase 2 to the northbound or eastbound direction of the major street, thereby aligning phase 2 with the direction of increasing mileposts.
- Phasing on new signals installed within an already signalized corridor should match the existing corridor phasing.
- Assign phases 1 and 5 to the major street protected left-turn movements.
- Assign phases 4 and 8 to the minor street through movements.
- Assign phases 3 and 7 to the minor street protected left-turn movements.
• At T intersections, the movement on the stem of the T is normally assigned to either phase 4 or phase 8.

• At intersections with four approaches using split phasing on the minor streets, where each minor street times separately, the minor streets are normally assigned as phases 4 and 8, and a note is added with the phase diagram to indicate that these phases time exclusively.

• Signal displays are numbered as follows: the first number indicates the signal phase and the second number is the number of the signal head counting from centerline to fog stripe. For example, signal displays for phase 2 are numbered 21, 22, 23, and so on. If the display is an overlap, the designation is the letter assigned to that overlap. For example, signal displays for overlap A are number A1, A2, A3, and so on. If the display is protected/permissional, the display is numbered with the phase number of the through display followed by the phase number of the left-turn phase. For example, a protected/permissional signal display for phase 1 (the left-turn movement) and phase 6 (the compatible through movement) is numbered 61/11. With a conventional protected/permissional left-turn display, the circular red, yellow, and green displays are connected to the phase 6 controller output and the steady yellow and green arrow displays are connected to the phase 1 controller output. When a flashing yellow arrow display is used, coordinate with the Signal Operations Engineer and signal maintenance group to determine appropriate wiring. When using flashing yellow operation, ensure an auxiliary output rack is specified in the controller cabinet.

• Pedestrian displays and detectors are numbered with the first number indicating the signal phase and the second number as either an 8 or 9. For example, pedestrian displays and detectors 28 and 29 are assigned to phase 2.

• Detection is numbered with the first number representing the phase. The second number represents the lane number from centerline out. The third number represents the loop number counting from the stop line back. Detection loops for phase 2 detectors are numbered 211, 212, 213 for lane 1; 221, 222, 223 for lane 2; and so on. (See Exhibit 1330-8 for standard detector numbering.)

• Emergency vehicle detectors are designated by letters: phase 2 plus phase 5 operation uses the letter “A,” phase 4 plus phase 7 uses the letter “B,” phase 1 plus phase 6 uses the letter “C,” and phase 3 plus phase 8 uses the letter “D.”

(6) Detection Systems

The detection system at a traffic-actuated signal installation provides the control unit with information regarding the presence or movement of vehicles, bicycles, and pedestrians. Vehicle detection systems perform two basic functions: queue clearance and the termination of phases. Depending on the specific intersection characteristics, either of these functions can take priority. The merits of each function are considered and a compromise might be necessary.

The following vehicle detection requirements vary depending on the speeds of the approaching vehicles:

• When the posted speed is below 35 mph, provide stop bar detection from the stop bar to a point 30 to 40 feet in advance of that location. Stop bar detection is usually assigned to detection input “extension/call” channels. Coordinate with the Signal Operations Engineer on detection assignments. When queue/advance loops are installed, calculate the distance traveled by a vehicle in two seconds.
at the 85th percentile speed and position the advance loops at this distance in advance of the stop bar.

- When the posted speed is at or above 35 mph, provide advance detection based on the “decision zone detection design.” When stop bar detection is installed, it should extend from the stop bar to a point 30 to 40 feet in advance of that location. Stop bar detection is required on minor streets. Stop bar detection is usually assigned to detection input “call” channels, and advance detection is usually assigned to detection input “extension/call” channels. Coordinate with the Signal Operations Engineer on detection assignments.

A decision zone is a location along the intersection approach where a motorist is forced to make a decision between two alternatives. As applied to vehicle detection design, this situation can occur when two vehicles are approaching a traffic signal and the signal indication turns yellow. The motorist in each vehicle must decide whether to continue through the intersection or stop prior to the intersection. If the lead vehicle decides to brake and the following vehicle does not, there may be a rear-end collision. Decision zone detection design has been developed to reduce the chances of this occurrence. This design increases the opportunity for a range of vehicles from the 90th percentile speed vehicle to the 10th percentile speed vehicle to either clear the intersection safely or decelerate to a complete stop before reaching the intersection. The method of calculating the decision zone and the required detection loops is shown in Exhibit 1330-7. Include the calculations in the Project File.

A study of the approach speeds at the intersection is necessary to design the decision zone detection. Speed study data is obtained at the approximate location or just upstream of the decision zone. Only the speed of the lead vehicle in each platoon is considered. Speed study data is gathered during off-peak hours in free-flow and favorable weather conditions. It is important that the person conducting the speed study remain inconspicuous so they do not influence drivers to slow down. Normal driving patterns are needed for proper speed studies. Prior speed-study information obtained at this location can be used if it is less than 18 months old and driving conditions have not changed significantly in the area.

When permissive left-turn phasing is installed on the major street with left-turn channelization, include provisions for switching the detector input for future protected left-turn phasing. Assign the detector a left-turn detector number and connect to the appropriate left-turn detector amplifier. Most controller software can do this internally. If the controller being specified cannot do this internally, then specify a jumper connector between that amplifier output and the extension input channel for the adjacent through movement detector. The jumper is removed when the left-turn phasing is changed to protected left-turn phasing in the future. Check with the Signal Operations Engineer to see whether this is available with the software being used.
Where:
\( V_{90} = 90^{th} \) percentile speed in ft per second
\( V_{10} = 10^{th} \) percentile speed in ft per second
UDZ\(_{90}\) = Upstream end of decision zone for 90\(^{th}\) percentile speed
DDZ\(_{10}\) = Downstream end of decision zone for 10\(^{th}\) percentile speed

\( LC_1 = V_{10} \) travel time to downstream DDZ\(_{10}\)
\( LC_2 = V_{10} \) travel time from 1\(^{st}\) loop to 2\(^{nd}\) loop
\( LC_3 = V_{10} \) travel time from 3\(^{rd}\) loop to DDZ\(_{10}\)

G = Grade of roadway in decimal form
(Include + or -) Example: -4% = -0.04

Use with grades less than +/- 4%:
\[
UDZ_{90} = \frac{(V_{90})^2}{16} + V_{90}
\]
\[
DDZ_{10} = \frac{(V_{10})^2}{40} + V_{10}
\]
\[
LC_1 = \frac{UDZ_{90} - DDZ_{10}}{V_{10}}
\]

Use with grades +/- 4% or steeper:
\[
UDZ_{90} = \frac{(V_{90})^2}{2(8 + 32.2G)} + V_{90}
\]
\[
DDZ_{10} = \frac{(V_{10})^2}{2(20 + 32.2G)} + V_{10}
\]
\[
LC_1 = \frac{UDZ_{90} - DDZ_{10}}{V_{10}}
\]

Single Advance Loop Design
Use when \( LC_1 \) is less than or equal to 3 seconds.

Double Advance Loop Design
Use when \( LC_2 \) is less than or equal to 3 seconds.

Triple Advance Loop Design
Use when \( LC_3 \) is less than or equal to 3 seconds.

Decision Zone Loop Placement
Exhibit 1330-7
In most cases, electromagnetic induction loops provide the most reliable method of vehicle detection. Details of the construction of these loops are shown in the Standard Plans. Video detection should be used only for temporary or portable traffic signals or locations with undesirable pavement conditions unless approved for other usage by the region Traffic Engineer. Other types of vehicle detection, such as in-pavement wireless magnetometers, may be used with approval from the region Traffic Engineer. Consider video detection systems for projects at the following locations: projects that have extensive stage construction with numerous alignment changes; on a private leg of an intersection where an easement is not available; and on existing bridge deck where loops or other types of in-pavement detection cannot be placed into the bridge deck.

Video detection functions best when the detectors (cameras) are positioned high above the intersection. In this position, the maximum effective detection area can be about ten times the mounting height in advance of the camera. (Contact the appropriate video detection equipment manufacturer for specific installation requirements.) When video detection is proposed, installation of the cameras on the luminaire mast arms can often provide good detection coverage. However, high wind can adversely affect the video equipment by inducing vibration in the luminaire mast arms. Also, areas that experience frequent high winds are not always suitable for video detection. Snow, fog, and rain can also adversely affect the operation of video detection equipment.

Provide temporary decision zone detection on projects where the decision zone detection will be disconnected for more than 48 hours, unless the designer concurs with the Signal Operations Engineer that the temporary detection is not necessary. The designer needs to find out whether there is a speed reduction during construction and place the temporary decision zone detection accordingly.

For loop numbering, see Exhibit 1330-8.

### (7) Preemption Systems

#### (a) Emergency Vehicle Preemption

Emergency vehicle preemption is required for all traffic signals unless approved otherwise by the region Traffic Engineer. WSDOT is responsible for the preemption equipment that is permanently installed at the intersection for new construction or rebuild projects. The emergency service agency is responsible for preemption emitters in all cases. If the emergency agency requests additional preemption equipment at an existing signal, that agency is responsible for all installation costs for equipment installed permanently at the intersection. The standard emergency vehicle system is optically activated to be compatible with all area emergency service agency emitters. Approval by the State Traffic Engineer is required for the installation of any other type of emergency vehicle preemption system. Include emergency service vehicle preemption system documentation in the Project File.
Round Loop Layout Example

Square Loop Layout Example

Numbering Legend

Loop# X X X

First number denotes phase number
Second number denotes lane number
(counting from centerline out)
Third number denotes loop number
(counting from stop line back)

(Phases 2 and 5 shown)

Loop Numbering Layout

Exhibit 1330-8
Optically activated preemption detectors are positioned for each approach to the intersection. These detectors function best when the approach is straight and relatively level. When the approach is in a curve, either horizontal or vertical, it might be necessary to install additional detectors in or in advance of the curve to provide continuous coverage of that approach, as recommended by the region Operations Engineer. Consider the approximate speed of the approaching emergency vehicle and the amount of time necessary for phase termination and the beginning of the preemption phase when positioning these detectors.

(b) **Railroad Preemption**

The Railroad Crossing Evaluation Team will determine the level of preemption required at signalized intersections. (See 1330.06(12) for more information.)

(c) **Transit Priority Preemption**

Signal preemption is sometimes provided at intersections to give priority to transit vehicles. This can be included in mobility projects, but the transit company assumes all costs for providing, installing, and maintaining this preemption equipment. The department’s role is limited to approving preemption operational strategies (phasing, timing, software, and so on) and verifying the compatibility of the transit company’s equipment with the traffic signal control equipment. Transit priority preemption documentation is part of the Project File.

(8) **Signal Displays**

Signal displays are the devices used to convey right of way assignments and warnings from the signal controller to the motorists and pedestrians. When selecting display configurations and locations, the most important objective is the need to present these assignments and warnings to the motorists and pedestrians in a clear, concise, and uniform manner. Typical vehicle signal displays are shown in Exhibits 1330-14a through 14f. In addition to the display requirements contained in the MUTCD, the following also apply:

- Always provide a minimum of two identical indications for the through movement if one exists at an intersection, even if it is not the primary (predominant) movement. Provide a minimum of two indications for the major signalized turn movement of an intersection if no through movement exists, such as on the stem of a T intersection. These signal faces are to be spaced a minimum of 8 feet apart when viewed from the center of the approach. At a T intersection, select the higher-volume movement as the primary movement and provide displays accordingly. A green left-turn arrow on a primary display and a green ball on the other primary display do not comply with this rule.
- All displays of a phase on an approach are to be a minimum of 8 feet apart. Displays for different phases on an approach should be a minimum of 8 feet apart.
- Use steady arrow indications only when the associated movement is completely protected from conflict with other vehicular and pedestrian movements. This includes conflict with a permissive left-turn movement.
- Whenever possible, locate displays directly overhead and in line with the path of the applicable vehicular traffic as it moves through the intersection. (See Exhibits 1330-14a through 14f for signal head locations.)
• Locate displays a minimum of 40 feet and a maximum of 180 feet from the stop line. The preferred location of the signal heads is between 60 and 120 feet from the stop bar. When the nearest signal face is located between 150 and 180 feet beyond the stop line, engineering judgment of conditions, including worst-case visibility conditions, is to be used to determine whether the provision of a supplemental or near-side signal face would be beneficial.

• Installation of a near-side supplemental display is required when the visibility requirements of 1330.06(8) and the MUTCD cannot be met.

• Use vertical vehicle-signal display configurations. Horizontal displays are not allowed unless clearance requirements cannot be achieved with vertical displays or unless they are being installed at an intersection to match other displays in the intersection. Approval by the State Traffic Engineer is required for the installation of horizontal displays.

• Use 12-inch signal sections for all vehicle displays except the lower display for a post-mounted ramp meter signal.

• Use all arrow displays for protected left turns when the left turn operates independently from the adjacent through movement.

• The preferred layout is all arrow displays for protected left turns when the left turn operates independently from the adjacent through movement. When green and yellow arrows are used in combination with circular red for protected left turns operating independently from the adjacent through movement, use visibility-limiting displays (either optically programmed sections or louvered visors that are programmable for visibility angle and distance) for the circular red display. Contact the local Signal Maintenance Superintendent, Signal Operations Office, or Traffic Engineer to ensure correct programming of the head.

• Use a five-section cluster arrangement (dog house) or the four-section flashing yellow arrow signal head for protected/permitted operations.

• Use either Type M or Type N mountings for vehicle display mountings on mast arms. Provide only one type of mounting for each signal system. Mixing mounting types at an intersection is not acceptable except for supplemental displays mounted on the signal standard shaft.

• Use backplates for all overhead-mounted displays for new, updated, or rebuilt signal faces. Backplates are to have a 1-inch-wide to 3-inch-wide yellow stripe of retroreflective, Type IV, prismatic sheeting around the perimeter to project a rectangular image at night. The 3-inch-wide sheeting is the preferred width and should only be decreased to avoid overlapping the back plate louvers.

• With some exceptions, Type E mountings are to be used for pedestrian displays mounted on signal standard shafts.

• Supplemental signal displays are to be installed when the approach is in a horizontal or vertical curve and the intersection visibility requirements cannot be met unless approved otherwise by the region Traffic Engineer.

The minimum mounting height for cantilevered mast arm signal supports and span wire installations is 16.5 feet from the roadway surface to the bottom of the signal housing. There is also a maximum height for signal displays. The roof of a vehicle can obstruct the motorist’s view of a signal display. The maximum heights from the roadway surface to the bottom of the signal housing with 12-inch sections are shown in Exhibit 1330-9.
<table>
<thead>
<tr>
<th>Distance</th>
<th>Signal Display</th>
<th>Maximum Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal displays 40 feet from the stop bar</td>
<td>Vertical 3-section</td>
<td>17.5 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 4-section</td>
<td>17.0 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 5-section*</td>
<td>17.0 ft</td>
</tr>
<tr>
<td>Signal displays 45 feet from the stop bar</td>
<td>Vertical 3-section</td>
<td>19.2 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 4-section</td>
<td>18.0 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 5-section*</td>
<td>17.5 ft</td>
</tr>
<tr>
<td>Signal displays 50 feet from the stop bar</td>
<td>Vertical 3-section</td>
<td>20.9 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 4-section</td>
<td>19.7 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 5-section*</td>
<td>18.5 ft</td>
</tr>
<tr>
<td>Signal displays 53 to 180 feet from the stop bar</td>
<td>Vertical 3-section</td>
<td>22.0 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 4-section</td>
<td>20.8 ft</td>
</tr>
<tr>
<td></td>
<td>Vertical 5-section*</td>
<td>19.6 ft</td>
</tr>
</tbody>
</table>

*The 5-section cluster display is the same height as a vertical 3-section signal display.

**Signal Display Maximum Heights**

Exhibit 1330-9

An advanced signalized intersection warning sign assembly to warn motorists of a signalized intersection should be installed when either of the two following conditions exists:

- The visibility requirements in the MUTCD are not achievable.
- The 85th percentile speed is 55 mph or higher and the nearest signalized intersection is more than 2 miles away; this does not apply to freeway off-ramps.

This warning sign assembly consists of a W3-3 sign with Type IV reflective sheeting and two continuously flashing beacons. Locate the sign in advance of the intersection in accordance with Table 2C-4 (Condition A) of the MUTCD. Approval from the region Traffic Engineer is required if the sign is not installed.

**9) Signal Supports**

Signal supports for vehicle displays consist of metal vertical shaft standards (Type I), cantilevered mast arm standards (Type II, Type III, and Type SD Signal Standards), metal strain poles (Type IV and Type V Signal Standards), or timber strain poles (see the Standard Plans). Vertical shaft signal standards are generally used for supplemental signal displays to meet visibility requirements. Mast arm installations are preferred because they generally provide better placement of the signal displays, greater stability for signal displays in high-wind areas, and reduced maintenance costs. The maximum length for mast arms on signal standards is 65 feet. Mast arm lengths over 65 feet are not allowed, so metal strain poles or a signal bridge will need to be considered. Contact the HQ Bridge and Structures Office for design of a signal bridge. The maximum attachment height for a signal mast arm on preapproved plans is 20 feet. Special design poles are required for a mast arm attachment height over...
20 feet. Use mast arm signal standards for permanent installations unless display requirements cannot be met. Metal strain poles are allowed when signal display requirements cannot be achieved with mast arm signal standards or the installation is expected to be in place less than five years. Timber strain pole supports are generally used for temporary installations that will be in place less than two years.

Pedestrian displays can be mounted on the shafts of vehicle display supports or on individual vertical shaft standards (Type PS). The push buttons used for the pedestrian detection system can also be mounted on the shafts of other display supports or on individual pedestrian push button posts. Do not place the signal standard at a location that blocks pedestrian or wheelchair activities. Locate the pedestrian push buttons such that they are accessible to all.

Terminal cabinets mounted on the shafts of mast arm signal standards and steel strain poles are required. The cabinet provides electrical conductor termination points between the controller cabinet and signal displays that allow for easier construction and maintenance. Terminal cabinets are located on the back side of the pole and at a height that reduces the potential for conflicts with pedestrians and bicyclists.

(a) **Signal Standard Placement Considerations**

In the placement of signal standards, the primary consideration is the visibility of signal faces. Place the signal supports as far as feasible from the edge of the traveled way without adversely affecting signal visibility. (The MUTCD provides additional guidance on locating signal supports.) Initially, lay out the location for supports for vehicle display systems, pedestrian detection systems, and pedestrian display systems independently to determine the optimal location for each type of support. Consider the need for future right-turn lanes or intersection widening when choosing the final location of the signal standards. If conditions allow and optimal locations are not compromised, pedestrian displays and pedestrian detectors can be installed on the vehicular display supports.

Another important consideration that can influence the position of signal standards is the presence of overhead and underground utilities. Verify the location of these lines during the preliminary design stage to avoid costly changes during construction. After the underground utilities are located in the field, if they are within 10 feet of equipment being installed, consider potholing for the utility to find its actual location. Field locates are not always accurate and must be verified if a potential conflict exists. Verify aerial clearances. A minimum 10-foot circumferential clearance is required from all overhead power lines rated at 50Kv or below, including the neutral. For lines rated over 50Kv, the minimum clearance is 10 feet plus 0.4 inches for each Kv over 50Kv.

(b) **Mast Arm Signal Standards**

Mast arm signal standards are designed based on the total wind load moment on the mast arm. The moment is a function of the XYZ value, and this value is used to select the appropriate mast arm fabrication plan. The preapproved mast arm fabrication plans are listed in the contract special provisions. To determine the XYZ value for a signal standard, the cross-sectional area for each component mounted on the mast arm is determined. Each of these values is multiplied by its distance from the vertical shaft. These values are then totaled to determine the XYZ value. When determining the XYZ values, the worst-case scenarios on head and sign placements are to be used. All signal displays and mast arm-mounted
signs, including street name signs, are included in this calculation. The effects of emergency preemption detectors and any required preemption indicator lights are negligible and can be excluded. For mast arm-mounted signs, use the actual sign area to determine the XYZ value. Cross-sectional areas for vehicle displays are shown in Exhibit 1330-10. Include traffic signal support calculations in the DDP.

<table>
<thead>
<tr>
<th>Signal Display</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical 3-section</td>
<td>9.2 sq ft</td>
</tr>
<tr>
<td>Vertical 4-section</td>
<td>11.6 sq ft</td>
</tr>
<tr>
<td>Vertical 5-section</td>
<td>14.1 sq ft</td>
</tr>
<tr>
<td>5-section cluster</td>
<td>14.4 sq ft</td>
</tr>
</tbody>
</table>

Signal Display Areas

Exhibit 1330-10

(c) Foundation Design

Foundation design is a critical component of the signal support. A soils investigation is required to determine the lateral bearing pressure, the friction angle of the soil, and whether groundwater may be encountered. The XYZ value is used in determining the foundation depth for the signal standard. A special foundation design for a mast arm signal standard is required if the lateral bearing pressure is less than 1,000 psf or the friction angle is less than 26°. The region materials group determines whether these unusual soil conditions are present and a special foundation design will be required. The region materials group then sends this information to the HQ Materials Laboratory for confirmation. The HQ Materials Laboratory forwards the findings to the HQ Bridge and Structures Office and requests the special foundation design. The HQ Bridge and Structures Office designs foundations for the regions and reviews designs submitted by others.

(d) Steel Strain Poles

Steel strain poles are used in span wire installations and are available in a range of pole classes. A pole class denotes the strength of the pole. The loads and resultant forces imposed on strain poles are calculated and a pole class greater than that load is specified. Exhibits 1330-11a and 1330-11b show the procedure for determining the metal strain pole class and foundation. Exhibit 1330-12 shows an example of the method of calculation. The foundation depth is a function of the pole class and the soil conditions. A special design is required for metal strain pole or timber strain pole support systems if the span exceeds 150 feet, the tension on the span exceeds 7,200 pounds, or the span wire attachment point exceeds 29 feet in height. Contact the HQ Bridge and Structures Office for assistance.
Selection Procedure

1. Determine span length.
2. Calculate the total dead load (P) per span. Use 40 pounds per signal section and 6.25 pounds per square ft of sign area.
3. Calculate the average load (G) per span. 
   \[ G = \frac{P}{n} \]
   where (n) is the number of signal head assemblies plus the number of signs.
4. Determine cable tension (T) per span. Enter the proper chart with the average load (G) and the number of loads (n). If (n) is less than minimum (n) allowed on chart, use minimum (n) on chart (see Exhibit 1330-11b).
5. Calculate the pole load (PL) per pole. If only one cable is attached to the pole, the pole load (PL) equals the cable tension (T). If more than one cable is attached, (PL) is obtained by computing the vector resultant of the (T) values.
6. Select the pole class from the “Foundation Design Table.” Choose the pole class closest to but greater than the (PL) value.
7. Calculate the required foundation depth (D). Use the formula:
   \[ D = a \frac{DT}{\sqrt{S}} \]
   Select the foundation depth (DT) from the “Foundation Design Table.” Lateral soil bearing pressure (S) is measured in pounds per square ft (psf). The formula value (a) is a variable for the cross-sectional shape of the foundation. The values for these shapes are:
   - a = 50 for a 3-ft round foundation
   - a = 43 for a 4-ft round foundation
   - a = 41 for a 3-ft square foundation
   Round (D) upward to nearest whole number if 0.10 ft or greater.
8. Check vertical clearance (16.5 ft minimum) assuming 29 ft maximum cable attachment height and 5% minimum span sag.

Notes:

A special design by the HQ Bridge and Structures Office is required if:
- The span length exceeds 150 ft.
- The (PL) value exceeds 7,200 lbs.
- The vertical distance between the base plate and the first cable attachment exceeds 29 ft.

1. Charts (see Exhibit 1330-11b) are based on a cable weight of 3 pounds per ft (1.25 lbs/ft for cable and conductors and 1.75 lbs/ft for ice load).
2. On timber strain pole designs, specify two down guy anchors when the (PL) value exceeds 4,500 lbs.

<table>
<thead>
<tr>
<th>Pole Class (Pounds)</th>
<th>Foundation Depth (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,900</td>
<td>6'-0&quot;</td>
</tr>
<tr>
<td>2,700</td>
<td>7'-0&quot;</td>
</tr>
<tr>
<td>3,700</td>
<td>8'-0&quot;</td>
</tr>
<tr>
<td>4,800</td>
<td>9'-6&quot;</td>
</tr>
<tr>
<td>5,600</td>
<td>10'-0&quot;</td>
</tr>
<tr>
<td>6,300</td>
<td>11'-0&quot;</td>
</tr>
<tr>
<td>7,200</td>
<td>12'-0&quot;</td>
</tr>
</tbody>
</table>

DT = initial foundation depth off chart
D = calculated foundation depth for use in contract

Strain Pole and Foundation Selection Procedure

Exhibit 1330-11a
Strain Pole and Foundation Selection Procedure

Exhibit 1330-11b
Given: Exhibits 1330-11a and 11b, and the following diagram:

Determine the following:
- Cable Tensions (T)
- Pole Loads (PL)
- Pole Classes
- Foundation Depths (D)

Step 1. Span lengths given above.

Step 2. Calculate (P) and (G) values.

- Span 1-2, n = 3
  - 7 sections x 40 lbs/sec = 280 lbs
  - 6 s.f. sign x 6.25 lbs/s.f. = 38 lbs
  - Total (P) = 318 lbs
  - G = P/n = 318/3 = 106 lbs
- Span 2-3, n = 4
  - 9 sections x 40 lbs/sec = 360 lbs
  - 6 s.f. sign x 6.25 lbs/s.f. = 38 lbs
  - Total (P) = 398 lbs
  - G = P/n = 398/4 = 100 lbs
- Span 3-4, n = 2
  - 7 sections x 40 lbs/sec = 280 lbs
  - Total (P) = 280 lbs
  - G = P/n = 280/2 = 140 lbs
- Span 4-1, n = 3
  - 9 sections x 40 lbs/sec = 360 lbs
  - Total (P) = 360 lbs
  - G = P/n = 360/3 = 120 lbs

Step 3. Determine Cable Tensions (T) values.

<table>
<thead>
<tr>
<th>Span</th>
<th>Length</th>
<th>G</th>
<th>Chart</th>
<th>n</th>
<th>min</th>
<th>n</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>140'</td>
<td>106</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3,000 lbs</td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td>150'</td>
<td>100</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2,900 lbs</td>
<td></td>
</tr>
<tr>
<td>3-4</td>
<td>100'</td>
<td>140</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2,800 lbs</td>
<td></td>
</tr>
<tr>
<td>4-1</td>
<td>120'</td>
<td>120</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2,500 lbs</td>
<td></td>
</tr>
</tbody>
</table>

Step 4. Calculate (PL) values by computing the vector resultant of the (T) values.

\[ a = \sqrt{b^2 + c^2 - 2bc \cos A} \]

Step 5. Select the pole class from the Foundation Design Table (see Exhibit 1330-11a).

<table>
<thead>
<tr>
<th>Pole Number</th>
<th>(PL)</th>
<th>Pole Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,556 lbs</td>
<td>3,700 lbs</td>
</tr>
<tr>
<td>2</td>
<td>4,976 lbs</td>
<td>5,600 lbs</td>
</tr>
<tr>
<td>3</td>
<td>3,471 lbs</td>
<td>3,700 lbs</td>
</tr>
<tr>
<td>4</td>
<td>3,754 lbs</td>
<td>4,800 lbs</td>
</tr>
</tbody>
</table>

Step 6. Calculate the required foundation depths.

Given: (S) = 1,000 psf

\[ D = \frac{a \cdot DT}{\sqrt{S}} \]

<table>
<thead>
<tr>
<th>Pole No.</th>
<th>Pole Class</th>
<th>DT</th>
<th>3’ Rd</th>
<th>4’ Rd</th>
<th>3’ Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,700 lbs</td>
<td>8’</td>
<td>13’</td>
<td>11’</td>
<td>11’</td>
</tr>
<tr>
<td>2</td>
<td>5,600 lbs</td>
<td>10’</td>
<td>16’</td>
<td>14’</td>
<td>13’</td>
</tr>
<tr>
<td>3</td>
<td>3,700 lbs</td>
<td>8’</td>
<td>13’</td>
<td>11’</td>
<td>11’</td>
</tr>
<tr>
<td>4</td>
<td>4,800 lbs</td>
<td>9’-6”</td>
<td>15’</td>
<td>13’</td>
<td>13’</td>
</tr>
</tbody>
</table>

Strain Pole and Foundation Selection Example

*Exhibit 1330-12*
(10) Preliminary Signal Plan

Develop a preliminary signal plan for the Project File. Include a discussion of the issue that is being addressed by the project. Provide sufficient level of detail on the preliminary signal plan to describe all aspects of the signal installation, including proposed channelization modifications. Use a plan scale of “1 inch = 20 feet” and include:

- Stop bars.
- Crosswalks.
- Sidewalks locations, including curb ramps.
- Guardrail locations.
- Drainage items.
- Left-turn radii, including beginning and ending points.
- Corner radii, including beginning and ending points.
- Vehicle detector locations and proposed detector types.
- Pedestrian detector locations.
- Signal standard types and locations.
- Vehicle signal displays.
- Pedestrian signal displays.
- Phase diagram, including pedestrian movements.
- Emergency vehicle preemption requirements.
- Railroad preemption requirements.
- Illumination treatment, including a calculation summary showing the average light level, average/minimum uniformity ratio, and maximum veiling luminance ratio. (See Chapter 1040 for more information on illumination design requirements.)
- Cabinet locations with door orientations.
- Traffic counts, including left-turn movements.
- Speed study information indicating 90th and 10th percentile speeds for all approaches.
- Utilities information.

Submit a copy of the preliminary signal plan to the State Traffic Engineer for review and comment. Allow two to three weeks for review of the preliminary signal plan. After addressing all review comments, finalize the plan and preserve as noted in 1330.07, Documentation. Prepare the contract plans in accordance with the Plans Preparation Manual.

If HQ Traffic Design is preparing the contract Plans, Specifications, and Estimates (PS&E) for the project, submit the above preliminary signal plan with the following additional items:

- Contact person.
- Charge numbers.
- Critical project schedule dates.
- Existing and proposed utilities, both underground and overhead.
• Existing intersection layout, if different from the proposed intersection.
• Turning movement traffic counts (peak hour for isolated intersections) and a.m., midday, and p.m. peak-hour counts if there is another intersection within 500 feet.
• Electrical service location, source of power, and utility company connection requirements.

After the PS&E is prepared, the entire package is transmitted to the region for incorporation into its contract documents.

(11) Electrical Design

(a) Circuitry Layout

Consider cost, flexibility, construction requirements, and ease of maintenance when laying out the electrical circuits for the traffic signal system. Consolidate roadway crossings (signal, illumination, ITS conduits, and so on) whenever possible to minimize the number of crossings. Include all electrical design calculations in the Project File.

(b) Junction Boxes

Provide junction boxes at each end of a roadway crossing, where the conduit changes size, where detection circuit splices are required, and at locations where the sum of the bends for the conduit run is equal to or exceeds 360°. Signal standard or strain pole bases are not to be used as junction boxes. Where possible, locate junction boxes out of paved areas and sidewalks. Junction boxes are not to be placed in the pedestrian curb ramp of a sidewalk or where it will impact the ADA requirements found in Chapter 1510. Placing the junction boxes within the traveled way is rarely an effective solution and will present long-term maintenance problems. Make every effort to locate new junction boxes and to relocate existing junction boxes outside the travel lane or paved shoulder. If there is no way to avoid locating the junction box in the traveled way or paved shoulder, use heavy-duty junction boxes. Avoid placing junction boxes in areas of poor drainage. Do not place junction boxes within 2 feet of ditch bottoms or drainage areas. The maximum conduit capacities for various types of junction boxes are shown in the Standard Plans. Consider using a pull box or cable vault instead of multiple Type 8 junction boxes by the controller cabinet.

(c) Conduit

Refer to the Standard Specifications for conduit installation requirements. At existing intersections, where roadway reconstruction is not proposed, conduits are to be placed beyond the paved shoulder or behind existing sidewalks to reduce installation costs. With the exception of the ½-inch conduit for the service grounding electrode conductor, the minimum-size conduit is as follows:

• For installations under a roadway in rural areas, 1½ inches on the legs of the intersection and 3 inches minimum for installations under a roadway near and around the intersection perimeter.
• For installations under a roadway inside urban boundaries, 2 inches on the legs of the intersection and 3 inches minimum for installations under a roadway near and around the intersection perimeter.
The minimum size conduit for installations under a roadway at all other locations is 2 inches.

A 2-inch spare conduit is to be installed for all conduit crossings outside the core of the intersection. A 3-inch spare conduit is to be installed for all conduit crossings around the intersection perimeter. At least one 3-inch spare conduit is to be installed from the controller to the adjacent junction box to provide for future capacity. Size all conduits to provide 26% maximum conductor fill for new signal installations. A 40% fill area can be used when installing conductors in existing conduits. (See Exhibit 1330-13 for conduit and signal conductor sizes.)

### Conduit Sizing Table

<table>
<thead>
<tr>
<th>Trade Size</th>
<th>Inside Diam. (inches)</th>
<th>Maximum Fill (inch²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>26%</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>0.632</td>
<td>0.08</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>0.836</td>
<td>0.14</td>
</tr>
<tr>
<td>1&quot;</td>
<td>1.063</td>
<td>0.23</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>1.394</td>
<td>0.40</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>1.624</td>
<td>0.54</td>
</tr>
<tr>
<td>2&quot;</td>
<td>2.083</td>
<td>0.89</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>2.489</td>
<td>1.27</td>
</tr>
<tr>
<td>3&quot;</td>
<td>3.09</td>
<td>1.95</td>
</tr>
<tr>
<td>3 1/2&quot;</td>
<td>3.57</td>
<td>2.60</td>
</tr>
<tr>
<td>4&quot;</td>
<td>4.05</td>
<td>3.35</td>
</tr>
</tbody>
</table>

### Conductor Size Table

<table>
<thead>
<tr>
<th>Size (AWG)</th>
<th>Area (inch²)</th>
<th>Size (AWG)</th>
<th>Area (inch²)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 14 USE</td>
<td>0.021</td>
<td>2cs (# 14)</td>
<td>0.090</td>
</tr>
<tr>
<td># 12 USE</td>
<td>0.026</td>
<td>3cs (# 20)</td>
<td>0.070</td>
</tr>
<tr>
<td># 10 USE</td>
<td>0.033</td>
<td>4cs (# 18)</td>
<td>0.060</td>
</tr>
<tr>
<td># 8 USE</td>
<td>0.056</td>
<td>5c (# 14)</td>
<td>0.140</td>
</tr>
<tr>
<td># 6 USE</td>
<td>0.073</td>
<td>7c (# 14)</td>
<td>0.170</td>
</tr>
<tr>
<td># 4 USE</td>
<td>0.097</td>
<td>10c (# 14)</td>
<td>0.290</td>
</tr>
<tr>
<td># 3 USE</td>
<td>0.113</td>
<td>6pcc (# 19)</td>
<td>0.320</td>
</tr>
<tr>
<td># 2 USE</td>
<td>0.133</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conduit and Conductor Sizes**

*Exhibit 1330-13*
(d) **Electrical Service and Other Components**

Refer to Chapter 1040 for electrical service types, overcurrent protection, and descriptions and requirements for other components.

(e) **Roadway Conduit Crossings**

Minimize roadway crossings whenever possible; usually only three crossings are needed for a four-leg intersection and only two roadway crossings are needed for a T intersection. In most cases, the conduit should cross both the main line and side street from the corner where the controller is located. Directional boring is the method of choice when crossing the state route (main line). One main line crossing is usually sufficient; open cut trenching is acceptable on minor approaches. Open cut trenching to install conduits is allowed on existing roadways where substantial obstacles under the roadway will be encountered or where there is insufficient room for jacking or boring pits at the edges of the roadway. Open cut trenching is not permitted across limited access roadways unless the entire pavement surface is being replaced. Do not use sign or signal bridges for roadway crossings.

**(12) Signal Design and Operation Near Railroad Crossings**

If railroad tracks are within 500 feet of a signalized intersection, then a Railroad Crossing Evaluation Team is formed to determine the need (if any) for railroad preemption, interconnection, simultaneous preemption, advanced preemption, and so on. The Railroad Crossing Evaluation Team should consist of region and HQ Signal Design Engineers, region and HQ Signal Operations Engineers, HQ Railroad Liaison, region Utilities Engineer, region Traffic Design Engineer, region Maintenance Superintendent, and the affected railroad representative.

The Railroad Crossing Evaluation Team will determine what design considerations are needed at all signalized intersections near railroad crossings. A memo with each team member’s concurrence with the PS&E documents is required for the DDP and is to be preserved as noted in 1330.07, Documentation. If railroad tracks are located within ¼ mile and are in excess of 500 feet from a signalized intersection, the same procedure will apply unless the region can demonstrate that 95% maximum queue lengths will not extend to within an area 200 feet from the tracks. Such demonstration is to be documented in the DDP and approved by the Railroad Crossing Evaluation Team.

The Railroad Crossing Evaluation Team has final review and approval authority for all PS&E documents for signal design and operation at all signalized intersections near railroad crossings.

Railroad preemption and interconnection are recommended when any of the following conditions occurs:

- The distance from the stop bar to the nearest rail is less than or equal to 200 feet.
- The 95% maximum queue lengths from the intersection stop bar are projected to cross the tracks. (Use a queue arrival/departure study or a traffic analysis “micro-simulation model” to determine 95% maximum queue lengths.)
• The 95% maximum queue lengths from the railroad are projected to affect an upstream traffic signal. (Use a queue arrival/departure study or a traffic analysis “micro-simulation model” to determine 95% maximum queue lengths.)

Railroad preemption, interconnection, and a presignal are recommended when any of the following conditions occurs:

• The distance from the stop bar to the nearest rail is less than 88 feet; the longest design vehicle permitted by statute is 75 feet, with 3 feet for front overhang, 4 feet for rear overhang, and 6 feet for downstream clear storage.
• The distance from the stop bar to the nearest rail is > 88 feet and < 120 feet and there are no gates for the railroad crossing.
• The sight distance triangle in Chapter 1350, Exhibit 1350-2, cannot be met, and the railroad crossing does not have active control (lights or gates).

Use the Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings to determine the amount of railroad preemption required at an intersection with a traffic signal.

1330.07 Documentation

For the list of documents required to be preserved in the Design Documentation Package and the Project File, see the Design Documentation Checklist:

www.wsdot.wa.gov/design/projectdev/
Traffic Signal Display Placements

Exhibit 1330-14a

Note:
Include signal display calculations in the Project File.
Traffic Signal Display Placements

Exhibit 1330-14b
Traffic Control Signals

Chapter 1330

Traffic Signal Display Placements

Exhibit 1330-14c
Note:

[1] The “Left-Turn Yield on Green Ball” sign is used for protected/permitted phasing, or permissive phasing, if a demonstrable problem of left-turning vehicles not yielding exists.
Traffic Signal Display Placements

Exhibit 1330-14e
Chapter 1330   Traffic Control Signals

Traffic Signal Display Placements

Exhibit 1330-14f