Washington State
Department of Transportation

TST: RAMP METERS and DATA STATIONS

STUDENT HANDBOOK

ATMS CODE: CUF

Instructors:
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January 2011

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION COURSE DESCRIPTION

TST Training Program

Course Title: TST: Ramp Meters and Data Stations

Course Code: CUF
Class Size: 10
Hours: 8

Course Description:
To provide TST personnel with the basic knowledge of ramp meters and data stations.

Course Objectives: By the end of this course, you'll be able to:

1. Describe 5 types of vehicle detection; loops, piezos, infrared, radar, camera.
2. Explain the function and layout of the 3 types of installations; ramp meters, weigh-in-motion, and permanent traffic recorder.
3. Explain the 5 methods of data transfer; twisted pair, fiber optics, cellular IP, analog and digital cell.

Attendees: TST A, B, C, and D personnel.

Comments:

Vehicle Detection

WSDOT utilized 5 types of vehicle detection for Ramp Meters and Data Stations.

1. Induction Loops
2. Piezo Sensors
3. RADAR
4. Video
5. Infrared (IR)

Inductive Loop Detectors

A road loop consists of two or more turns of insulated wire wound in a shallow, rectangular or circular slot, sawed in the roadway. A type 2 induction loop has 4 turns of wire and measures 6ft by 6ft square. Some newer installations use a 6ft circle (round loop), type 3. Either can be used depending on installation preference. At curbside the two ends of the wire are carefully spliced to a factory-twisted lead-in cable. This cable is routed to a cabinet housing the detector unit. This unit drives energy through the loop at radio frequencies typically in the range of 20 to 200 KHz.

The detector unit, lead-in wire and loop wire comprise a tuned circuit of which the loop is the inductive element. A vehicle or any metal object entering the loop will absorb some of the radio frequency energy because of eddy currents created in the metal periphery (the Chassis and the body).

The inductance is reduced when disturbed by a vehicle, causing the resonant frequency to increase. At this point, various designs of inductive loop detectors electronics process phase, frequency, amplitude or impedance changes to register a count, perform an output or other action based on the type of detectors purpose. In traffic classification and counting equipment the most common method of detection utilizes the "phase shift" method which the oscillator is automatically adjusted to a null condition in feedback circuits. Any drop in inductance temporarily "de-tunes" the loop, causing a phase shift or amplitude change in the current flowing through the loop. Long-term inductance changes, such as a vehicle parked on part of the loop, are compensated for by the feedback circuit automatically tuning to a new null.

Advanced Detection Details

It is important to note the changes in inductance are very small when sensing presence of a vehicle. The sensitivity in most detectors are measured by how much change is needed to "sense" detection. This is usually calculated in the "percent change" in inductance measured on the loop. The following is the defacto standard example:

Motorcycle: 0.13 percent (ΔL/L) or 0.12 μH (ΔL) inductance change (small motorcycle).

Large Motorcycle: 0.32 percent (ΔL/L) or 0.3 μH (ΔL) inductance change (large motorcycle).

Auto: 3.2 percent (ΔL/L) or 3.0 μH (ΔL) inductance change (automobile).

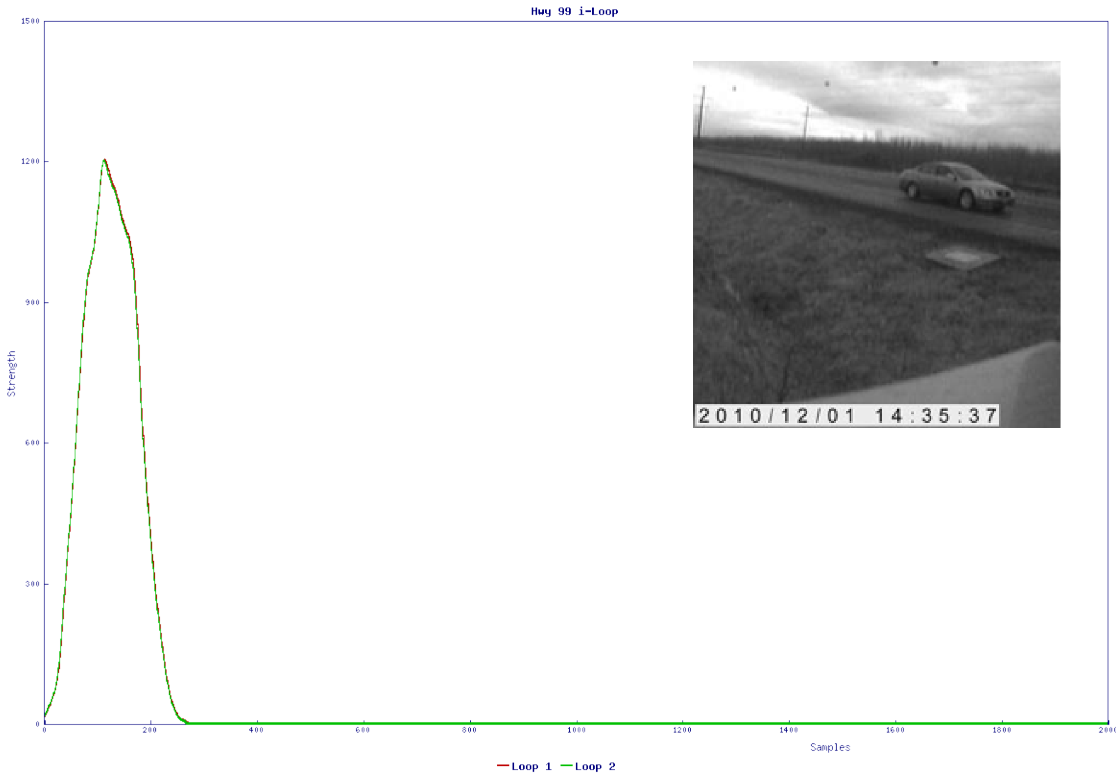
Depending on the detector used, sensitivity can be adjusted along with scan rates (resolution), loop frequency and many other settings the can affect loop accuracy and performance. Although most detectors do not provide a detailed signal analysis, the actual vehicle impact on a loop field can be seen in the following graphs depicting the change in frequency on the loop over time. The following graphs were recorded with a Diamond Traffic Products Phoenix II unit on 6ft round loops with a scan rate of 1000 samples per second to produce the following signature depiction of 4 vehicle classes and how they "look" to a loop.

Motorcycle - (notice the length and low signal strength):

1: 14:35:40.76 58.8mph, 2 Axles, Length= 5.2', A#1 = 4.9'

Passenger Car - (notice how high the signal strength is):

1: 14:35:37.56 59.2mph, 2 Axles, Length= 14.7', A#2= 9.2'



Passenger Bus - (notice the middle being the largest signal):

1: 15:39:24.28 56.0mph, 3 Axles, Length= 49.8', A#4 = 26.6' 3.9'

Truck (class 9) - (notice how weak the signal strength is):

1: 15:00:59.47 58.2mph, 5 Axles, Length= 63.9', A#9 = 15.5' 4.3' 31.7' 4.0'

The graphs represent the different vehicle characteristics such as the vehicle length, vehicle "profile" and the strength of each vehicles signature. The question that is most posed by this is "why does the passenger car have a much higher signal than the truck or even the bus?" The answer to that question is the differences in vehicle heights. The inductive loop field created is most sensitive closest to the sensor and its ability to detect change is not only limited to range (height – typically 2/3 distance of the shortest side of a loop (6ft ~= 4ft detection height)) but the further away from the loop the less sensitive it is as well. Because the passenger car is lower to the roadway it produces a greater change in the field than a high bed truck or other vehicle.

Inductive loop Questions and Answers

1. Inductive loops are used in almost all traffic detection equipment.

2. Very accurate when installed correctly and used with good data collection equipment.

3. Inductive loops can be tested by measuring the inductance of the loop, continuity, the Q of the loop, also resistance or leakage to ground.

4. A single loop can do vehicle counts and lane occupancy. Two loops per lane can do vehicle counts, vehicle lengths, vehicle speeds, and occupancy.

Loop Pros

1. Accuracy (considered the most accurate sensor overall)
2. Long Lifespan (between 10-15 years on average)
3. Low cost (maintenance and calibration are nil after install)

Loop Cons

1. Intrusive technology (up front installation cost and safety)
2. Motorcycles can be missed
3. Static position (cannot adjust for lane shifting)
4. Cross talk on older detectors

PIEZO VEHICLE DETECTION:

The Piezo axle and weight sensors employed by WSDOT data stations use the piezoelectric effect to detect vehicle axles for vehicle classification and the weight of each of those axles. These sensors are relatively inexpensive, fairly accurate +/- 7% for weights, and somewhat durable (3-5 years). They are used in 95% of Washington States historical data collection stations. The Piezo sensors are installed between the inductive loops in most TDO data station installations. They are also used in State Patrol's CVSIN sites in the "sorter" lanes.

The "Piezo" works by producing a positive voltage spike that is relative to the weight of the axle deflecting the sensor. The sensor itself is inserted into a 1 inch deep slot across half of the lane for an axle sensor for vehicle classification only, and the entire lane for a weight and classification sensor. As the tires cross the Piezo, it is deflected downward; the polarized piezoelectric film in the sensor is bent, causing it to produce a voltage spike.

A typical class 9, five axle tractor trailer, will produce an approximate momentary 2 volt spike for the steering axle, and 5 volt for most remaining axles. The typical passenger vehicle will produce around 600 mv spike on each axle.

3.1 Piezoelectric Sensors

The Piezoelectric effect is an effect in which energy is converted between mechanical and electrical forms. It was discovered in the 1880's by the Curie brothers. Specifically, when a pressure (piezo means pressure in Greek) is applied to a polarized crystal, the resulting mechanical deformation results in an electrical charge. Piezoelectric microphones serve as a good example of this phenomenon. Microphones turn an acoustical pressure into a voltage. Alternatively, when an electrical charge is applied to a polarized crystal, the crystal undergoes a mechanical deformation which can in turn create an acoustical pressure. An example of this can be seen in piezoelectric speakers. (These are the cause of those annoying system beeps that are all too common in today's computers).

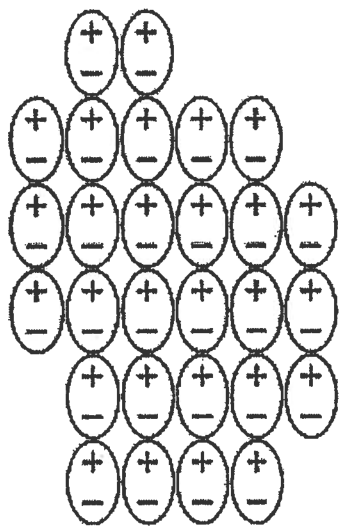


Figure 3: Internal Structure of an electret

Electrets are solids which have a permanent electrical polarization. (These are basically the electrical analogs of magnets, which exhibit a permanent magnetic polarization). Figure 3 shows a diagram of the internal structure of a electret. In general, the alignment of the internal electric dipoles would result in a charge which would be observable on the surface of the solid. In practice, this small charge is quickly dissipated by free charges from the surrounding atmosphere which are attracted by the surface charges. Electrets are commonly used in microphones.

Permanent polarization as in the case of the electrets is also observed in crystals. In these structures, each cell of the crystal has an electric dipole, and the cells are oriented such that the electric dipoles are aligned. Again, this results in excess surface charge which attracts free charges from the surrounding atmosphere making the crystal electrically neutral. If a sufficient force is applied to the piezoelectric crystal, a deformation will take place. This deformation disrupts the orientation of the electrical dipoles and creates a situation in which the charge is not completely canceled. This results in a temporary excess of surface charge, which subsequently is manifested as a voltage which is developed across the crystal.

3.1 Piezoelectric Sensors

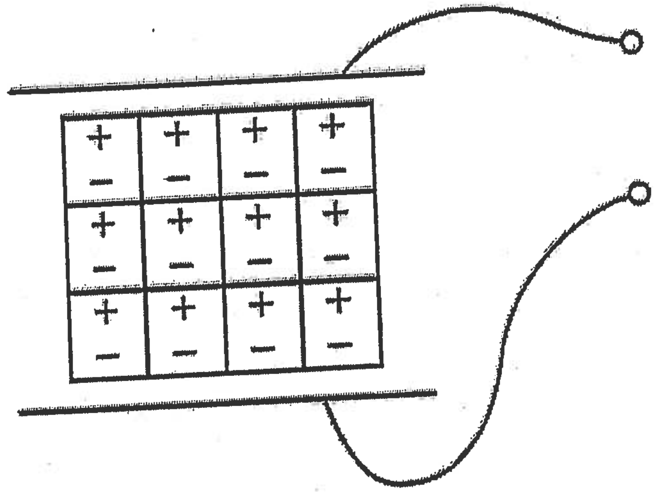


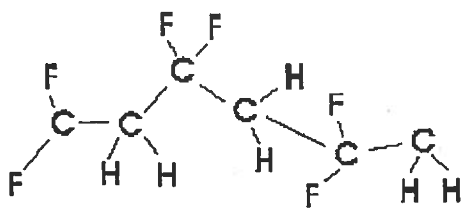
Figure 4: A sensor based on the piezoelectric effect

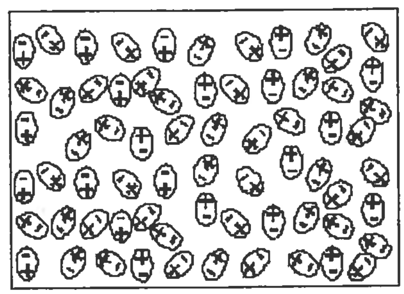
In order to utilize this physical principle to make a sensor to measure force, we must be able to measure the surface charge on the crystal. Figure 4 shows a common method of using a piezoelectric crystal to make a force sensor. Two metal plates are used to sandwich the crystal making a capacitor. As mentioned previously, an external force cause a deformation of the crystal results in a charge which is a function of the applied force. In its operating region, a greater force will result in more surface charge. This charge results in a voltage $V = \frac{Q_f}{C}$, where Q_f is the charge resulting from a force *f*, and *C* is the capacitance of the device.

In the manner described above, piezoelectric crystals act as transducers which turn force, or mechanical stress into electrical charge which in turn can be converted into a voltage. Alternatively, if one was to apply a voltage to the plates of the system described above, the resultant electric field would cause the internal electric dipoles to re-align which would cause a deformation of the material. An example of this is the fact that piezoelectric transducers find use both as speakers (voltage to mechanical) and microphones (mechanical to electrical).

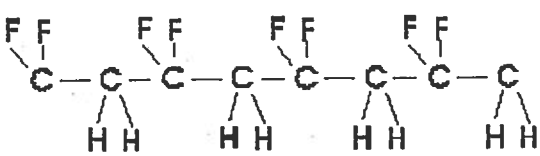
Manufacturing Piezoelectric Materials

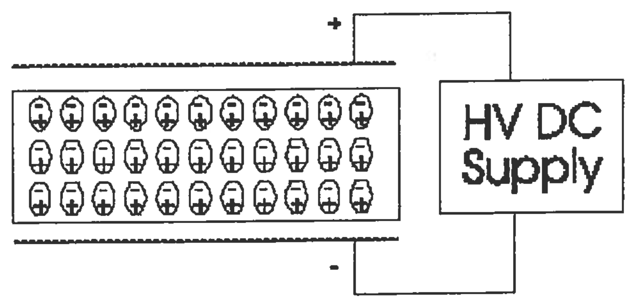
Researchers continued to look for and manufacture better piezo-electric materials. Ceramic materials are made piezo-electric by applying a very high polarizing voltage during its manufacturing. This technique has been found to work effectively on polyvinylidine fluoride (PVDF), a plastic polymer.





Random Orientation





Polarized orientation Induced by stretching and high voltage poling voltage

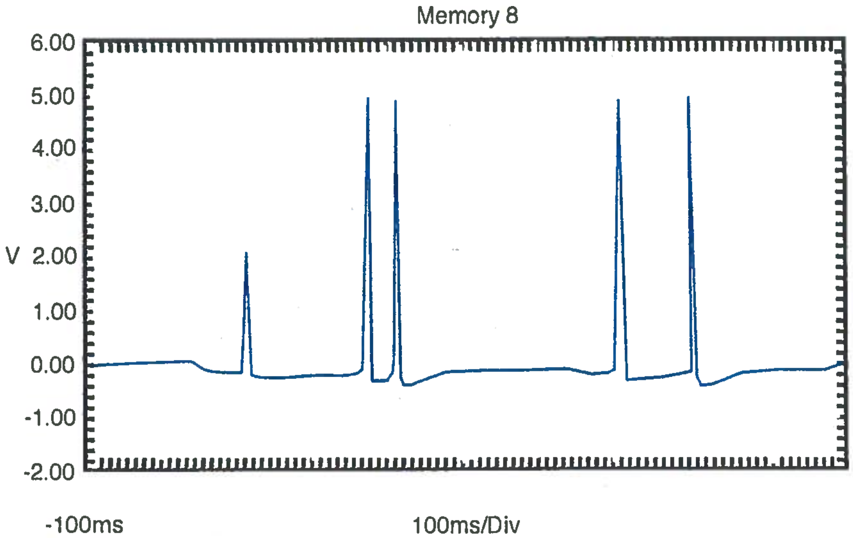
Figure 5

PVDF is the material in piezo-electric film. The high poling voltage polarizes and aligns the dipole molecules, which the PVDF material is stretched, see Figure 5. This molecular alignment creates the piezo-electric effect.

Piezoelectric Film

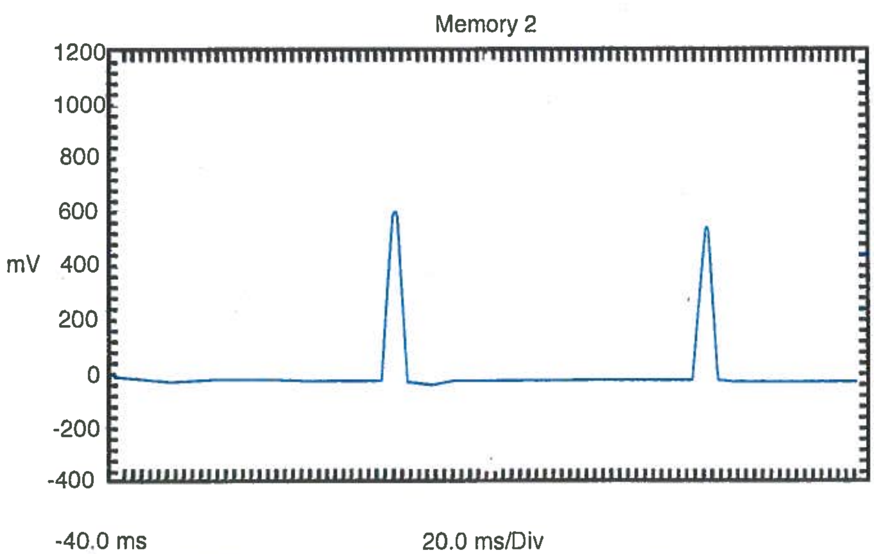
The PVDF piezoelectric material is a relatively new class of piezo-electric sensors. The PVDF material is a thin plastic polymer sheet that has a thin electrically conductive nickel copper alloy deposited on each side. This material is called piezo film. The material resembles aluminum foil, with the exception that it is more resilient, (doesn't crinkle as easily).

To use piezo film one makes an electrical connection to the electrically conductive coating on each side of the PVDF material. Most of the piezo-film sensors have wire connections. If one needs to attach electrical connections to raw piezo film this is accomplished using either copper tape or a conductive epoxy. Soldering directly to the film is not possible because the heat would destroy the underlying plastic PVDF material.



Datablock

Name	= Memory 8
Date	= 5/20/97
Time	= 8:55:43 PM
Y Scale	= 1.00 V/Div
Y At 50%	= 1.00 V
X Scale	= 100 ms/Div
X At 0%	= -100 ms
X Size	= 250 (256)
Maximum	= 5.60 V
Minimum	= -0.44V



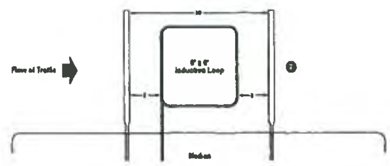
Datablock

Name	= Memory 2
Date	= 6/14/97
Time	= 9:13:37 AM
Y Scale	= 200 mV/Div
Y At 50%	= 400 mV
X Scale	= 20.0 ms/Div
X At 0%	= -40.0 ms
X Size	= 250 (256)
Maximum	= 608 mV
Minimum	= -40 mV

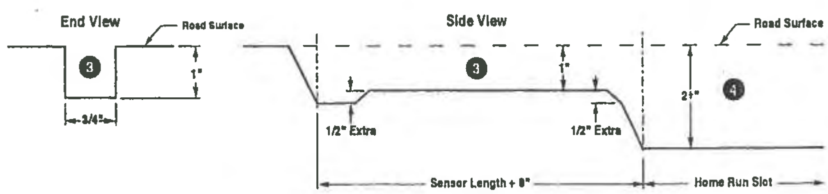
BL Piezoelectric Traffic Sensor Installation Instructions

1) Ensure that the road is safely closed, as per local regulations.

2) Using pavement crayons, paint, tape measure and cord, carefully mark the layout of the sensor installation. Ensure sensors are emplaced exactly perpendicular to the flow of traffic and that all lines are straight. Verify that the passive cable length is enough to reach the cabinet. DO NOT SPLICE CABLE IF IT IS TOO SHORT. Typical WIM/Classification site layout with 11' (3.5 m) sensors is shown below.



3) Using a 3/4" (20 mm) Diamond Blade, wet cut slot for sensor. Slot must be 3/4"(20 mm) wide (±1/16" or ±2 mm) by 1" (25 mm) minimum deep. Cut slot 8" (200 mm) longer than sensor length (including lead attachment). Drop blade an extra 1/2" (12 mm) down on both ends. Repeat for all sensors.



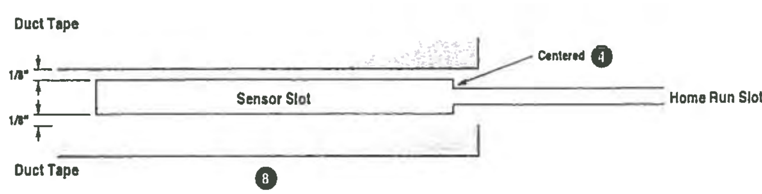
4) Cut home run slots for BL sensors. Center the home run slot on the sensor slot. Home run slots are typically cut the depth of the loop home run slots. The minimum width of the slot needs to be 1/4" (6 mm). Cut it wider if you are using conduit or tubing.

5) Cut all inductive loops sets (if applicable) Note: If inductive loops and home run slots are being dry cut, dry cut these slots and clean the area before wet cutting the BL sensor slots.

6) Power wash and sweep all slots. All slots must be very clean.

7) Dry all slots with compressed air. All slots and the pavement 1' (300 mm) on either side must be completely dry.

8) Place duct tape along length of both sides of the sensor slot. Tape must be 1/8"(3 mm) away from the slot. Repeat for all sensors.



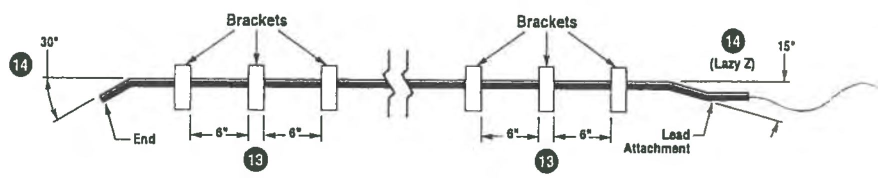
9) Remove BL sensor from box. Visually inspect sensor to ensure it is straight without any twists or curls. Check passive cable for bare wire. Check lead attachment for cracks or gaps. Look at data sheet to ensure the correct sensor is being installed, Class I versus Class II. Again, verify that there is sufficient passive cable to reach the cabinet.

10) Connect sensor up to LCR Meter. Test capacitance and dissipation factor. Test the resistance on the 20M setting. Capacitance and dissipation should be within ±20% of the enclosed data sheet. Resistance should be infinite. Record all results on the data sheet.

11) Place sensor on tape next to the slot. From this point forward, handle the sensor with latex (or equivalent) gloves.

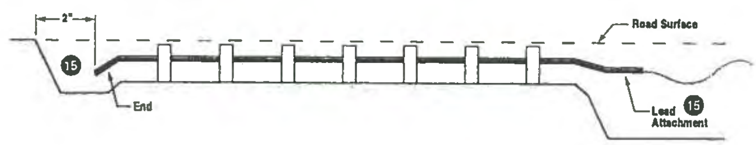
12) Clean sensor with steel wool or emery pad. Wipe down with alcohol and clean lint-free cloth.

13) Place installation brackets on sensor every 6" (150 mm) for the length of the sensor, use the 3/4" (20 mm) (small) brackets

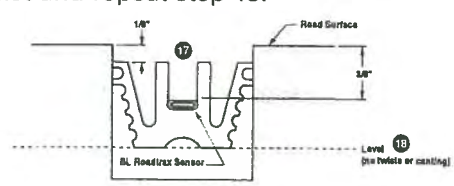


14) Bend the end of the sensor downward at a 30° angle. Bend the lead attachment end down at a 15° angle and then 15° back up until level (forming a lazy Z).

15) Emplace sensor in the slot in the road. The end of the sensor should be at least 2" (50 mm) from the end of the slot, and the tip should not touch the bottom of the slot. The lead attachment should also not touch the bottom or the sides of the slot.



16) If any of the 3/4" (20 mm) (small) brackets do not fit snugly against the sides of the slot or are loose, replace with a 1" (25 mm) (large) bracket and repeat step 15.



17) Starting at the lead attachment end, use the installation depth gauge to position the sensor so that it is 3/8" (9mm) below the surface of the road by pressing the depth gauge against the top of the sensor. At this point, the installation bracket is 1/8" (3mm) below the surface of the road.

18) Visually inspect the length of the sensor to ensure it is at uniform depth along its length and it is level (not twisted, canted or bent).

RADAR VEHICLE DETECTION

The RADAR based systems in use by WSDOT data stations include RTMS G4 by EIS Inc., and Wavetronix systems. Both systems operate similarly by transmitting and receiving microwave signals to determine the presence of vehicles. Both Radar solutions are non-intrusive, resulting in low impact to drivers during installation and maintenance, and are zero impact on the longevity of the roadway. These units are also a great option on for use during construction times where traffic lanes are shifted, or road pavement grinding is taking place.

Both the RTMS G4 unit and the Wavetronics HD unit operate in the transmit frequency range of 24 GHz. The Wavetronics HD unit operates at 8watts of power and the G4 units operate at 3 watts of power.

The Wavetronix unit will give vehicle speeds and lengths by emitting dual radar beams that emulate two inductive loops on the roadway. Timing is measured by the device to determine speed and length of vehicles passing between the two radar beams. The G4 unit will also measure vehicle speed and output vehicle length data.

Occlusion is still a potential problem with radar units. This happens when a large vehicle blocks the radar beams from “seeing” a smaller vehicle traveling at the same speed in an adjacent lane to the large vehicle. Detector setback and mounting height can greatly affect the accuracy of radar detectors. Stick with manufacturers suggesting mounting specs when installing these units.

Both the Wavetronix HD and the RTMS G4 output occupancy switch closures that can be used to trigger the 170, 2070, 1060 and 1068’s (WIM) and PTR counters. Both units can also run as independent data collection devices to collect and store data captured by the radar units.

VIDEO VEHICLE DETECTION

The only video based vehicle detection system tested by the Transportation Data Office today is the Iteris Vantage One system. This system uses video cameras positioned directly above the roadway to detect the passage of vehicles. The advantage of a video detection system is its non-intrusive characteristics over an inductive loop and axle sensor installation. Camera software is also easily reprogrammable in the event that the lanes are moved to provide for roadwork. It will also not be affected by any asphalt grinding, which would eliminate surface mounted sensors. However, installation of any unit above open lanes still requires the closing of lanes under which the camera is to be mounted.

The Iteris system requires considerably less maintenance than an inductive loop site. However, the disadvantages of a video based vehicle detection systems include the limitation of vehicle counts only, no accurate speed or length data. Weather and lightning are also factors limiting video detection. It should be noted that the overall operation of the Iteris video detection system has an accuracy of +/- 11%, which may work for certain ITS and data collection needs, but is outside of the acceptable limits for accurate historical trend calculations.


3
2
4
Add Dtl Mov Del Lod Cam Dia Mod Clk Cal Q
1 Camera
Panasonic
Video Monitor WV-BM990
POWER
ON
OFF
V.HOLD
BRIGHT
CONTRAST

INFRARED VEHICLE DETECTION:

The only infrared vehicle detection system in use by WSDOT today, is The Infrared Traffic Logger or "TIRTL". This system is deployed in tandem, with a transmitter unit and a receiver unit placed on opposite sides of the roadway (up to 330 feet apart). The transmitter unit emits four beams, two parallel and two crossed beams. The receiver detects the disturbances in these beams (break beam events and make beam events) and uses intelligent software to produce vehicle classification based on the timing of these events.

The system can classify vehicles based on direction, lane, speed, axle count, and wheel size and wheel ratio. This is done by an intricate evaluation of beam event timing that is accurate with speeds up to 155 mph within +/- 1%.

The units are battery powered, with support for AC power, external battery power and solar charging. They have several communication options, including RS 232, internal fixed line or GSM/GPRS modems, or optional external satellite modem. The TIRTL is web capable, with support for SMS text, fax and email transfers.

A fully functioning classification site can be installed in less than an hour by two technicians. The TIRTL units are one of the newest and most advanced traffic counting and classification units available to transportation industry today.

3 Theory of Operation

A TIRTL installation consists of a transmitter and receiver pair. The transmitter is the source of infra-red beams used to detect traffic. The receiver detects disturbances in the infra-red beams caused by passing wheels, and uses intelligent software to produce vehicle classifications based upon the relative timing of those events.

3.1 Vehicle Detection using "Beam Events"

The transmitter emits a beam of infra-red light from each forward facing lens. These light beams overlap at the receiver, such that the light from each falls over both of the receiver's lenses. This beam overlap yields four different paths of light from the transmitter to the lenses of the receiver, two parallel beams and two crossed beams as illustrated in Figure 2. As a vehicle passes between the receiver and transmitter, each wheel interrupts each of the four beam pathways.

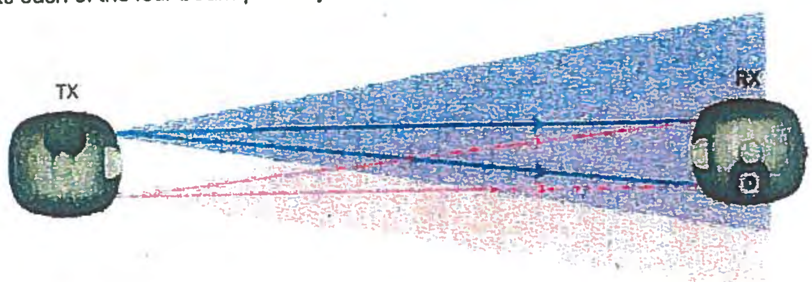


Figure 2 – TIRTL beam configuration.

Breaking of a beam is known as a "Break Beam Event" while the re-establishment of a given beam's continuity is defined as a "Make Beam Event". In this way with passing of each vehicle wheel a set of 8, time-stamped, Beam Events are generated from the 4 beam pathways at the TIRTL receiver. Detecting the precise time of each Beam Event allows the receiver to compute for example the velocity and lane of each vehicle wheel as it passes.

It is important to note that the alignment of the transmitter and receiver units is critical and that the beams traversing the roadway are set at as low a point as possible. This allows effective detection without interference from mud-flaps and other features hanging from the main body of the vehicles. By use of the specialized TIRTL Optical Sights and in the intelligent setup software accurate alignment during the day or night is easily achieved.

3.2 Speed and Vehicle Direction Detection

Figure 3 illustrates a TIRTL installation on a bi-directional roadway as viewed from above. As the wheels of the vehicles interact with the 4 beam pathways, "Make and Break" Beam Events are generated. The speed of a vehicle is determined by the time interval measured (t1 or t2) between like Beam Events on the parallel beam pathways, A and B.

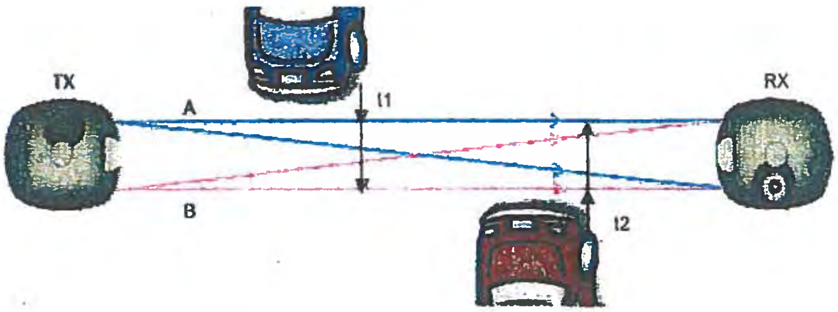


Figure 3 - Speed and Vehicle Direction Detection

The direction of travel of a vehicle on the monitored roadway is determined by the order in which Beam Events occur. In Figure 3, A to B represents South bound traffic and B to A represents North bound traffic.

A number of redundant Beam Events are recorded in TIRTL installations. The redundant information is used to discard invalid measurements in multi-lane installations where passing traffic obscures or distorts a Beam Event associated with the target vehicle.

3.3 Vehicle Direction Convention

The convention for vehicle direction movement is:

When viewed from the rear of the TIRTL receiver positive velocity signed traffic always moves from left to the right of the unit (Figure 4).

This is only true if the correct installation information is entered into the *Site Information* details (see reference [1]). The *Site Information* must accurately reflect the non-inverted or inverted installation of the units. Non-inverted operation is defined as when the TIRTL is mounted underneath a tripod. Inverted operation is typical for permanent installations.

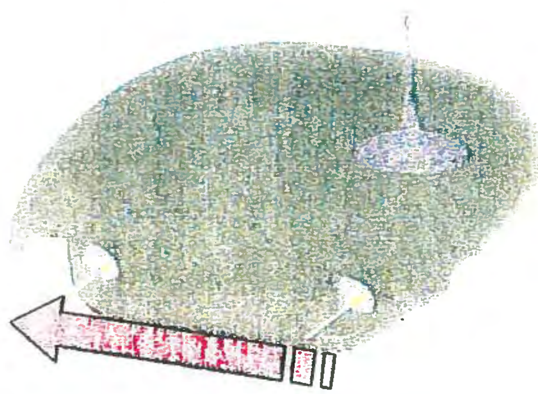


Figure 4 – Positive velocity polarity for left side of the road driving

Important Note: When using the TIRTL system in countries that drive on the *__right hand side of the road__* the sign of the vehicle velocity is reversed. That is, positive velocity implies right to left movement in front of the unit.

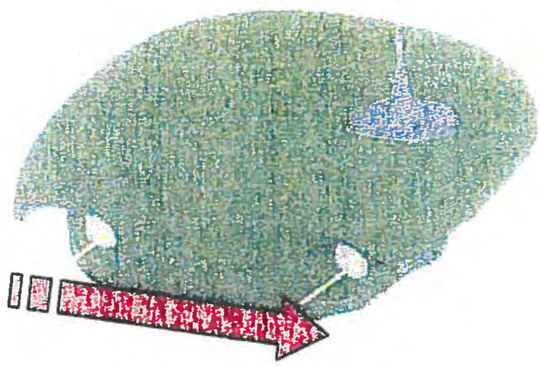


Figure 5 – Positive velocity polarity for right side of the road driving

3.4 Lane Detection

Figure 6 illustrates the principles of lane detection as implemented in TIRTL. As each wheel of the vehicle interacts with infra-red light pathway A, Ax, B and Bx, "Beam Events" are generated. For each class of Beam Event, Make or Break, time intervals are measured. "t1" and "t2" are defined as the time interval between Beam Events on beams "A" and "Ax". "t3" and "t4" are similarly defined as the time interval between Beam Events on beam "A" and "Bx". Figure 6 illustrates that there exists a quantized time difference between time interval "t1" and "t2" used by the intelligent software of the TIRTL receiver to learn the lane positions of the installation. The measured time intervals are normalized to the vehicle speed to provide a ratio metric measurement of vehicle position. Time Intervals "t3" and "t4" represent an example of redundant measurement information which may be employed to verify vehicle information on a multi-lane installation.

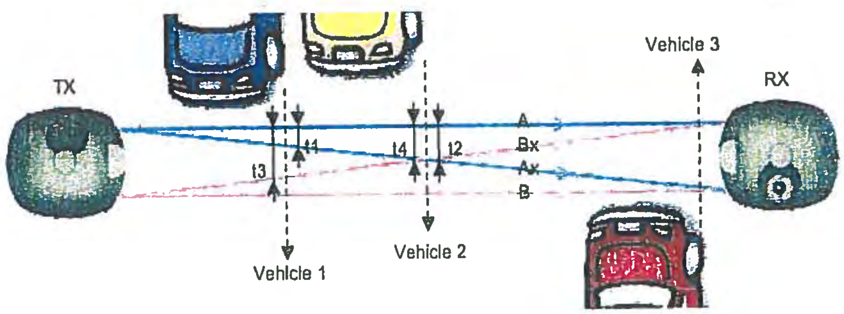


Figure 6 - Lane Detection

3.5 Axle, Axle Groups, Vehicle Detection and Wheel Size Measurement

Figure 7 illustrates in more detail the process of Make and Break Beam Events. The combination of a Break Beam Event followed by Make Beam Event of the same beam occurring within a single vehicle lane constitutes the detection of an axle. Detection of axles is the first stage in the important process of vehicle classification.

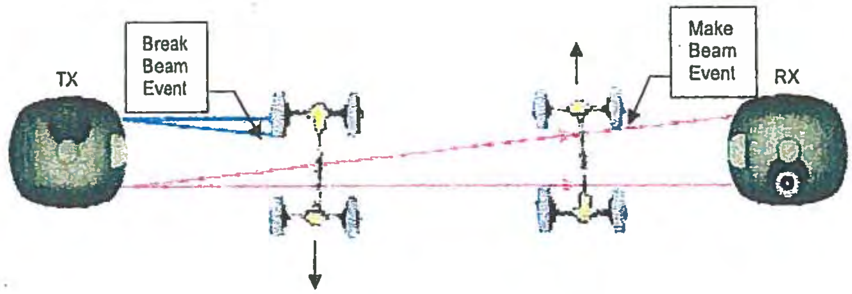


Figure 7 – Axle, Axle Groups and Vehicle Detection

An "Axle Group" is defined by TIRTL as a collection of axles separated by a user defined maximum distance. The distance between axles is measured by knowing the speed of the vehicle, the vehicles lane location and the time taken to traverse the 4 beam pathways. For example, the maximum distance between axles for a vehicle type is user defined as 2.1m. If a distance between 2 axles was measured at less than 2.1m TIRTL would consider a vehicle had been detected. In the vehicles illustrated in Figure 7 each of the Axle Groups consists of 1 axle. However, for multi-wheel vehicles such as semi-trailers Axle Groups can consist of more than one axle (see Figure 9).

A vehicle is detected when the number of axles and the distance between Axle Groups are within user defined limits.

The Wheel Size of a particular vehicle class is necessarily a TIRTL learned parameter. It is necessary that this parameter is learned as the height of the beams above the road varies between TIRTL installations. Each of the infra-red beam pathways between the transmitter and receiver effectively scribes a chord across the circle of the passing wheel (see Figure 8). With the speed measurement of the vehicle, the time between the Break and Make Beam Event and the travelling lane a measure of the wheel width is obtained. This measurement may be ratio metrically used to discriminate between vehicle classes where the vehicles have very similar wheel bases based upon percentage wheel size variances.

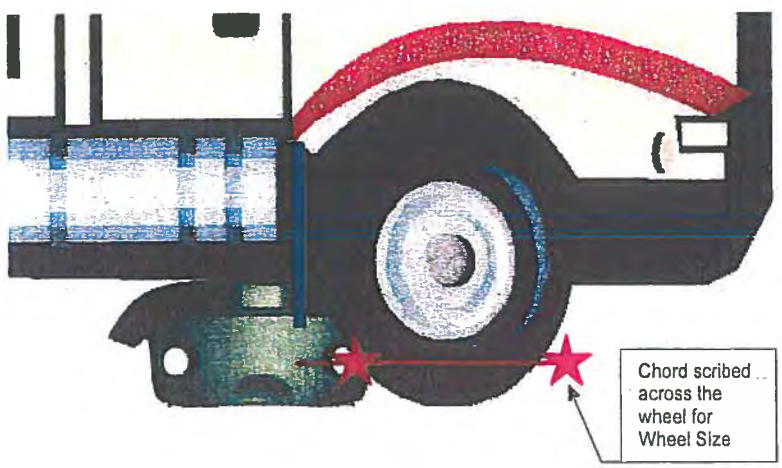


Figure 8 - Wheel Size Measurement

3.6 Classification of Vehicles

There are a number of different features of the wheel base of road vehicles which may be used by the intelligent TIRTL software to classify vehicles. Figure 9 illustrates these features. Classification Schemes based upon these features are built up by the user using the *Classification Editor* function of the TIRTL*soft* GUI

A Classification Scheme contains a series of patterns based upon parameters associated with vehicle axles. Each pattern contains a number of parameters that uniquely describe a vehicle class. Generally the Classification Scheme moves toward finer and finer detail for the parameters of a particular vehicle class.

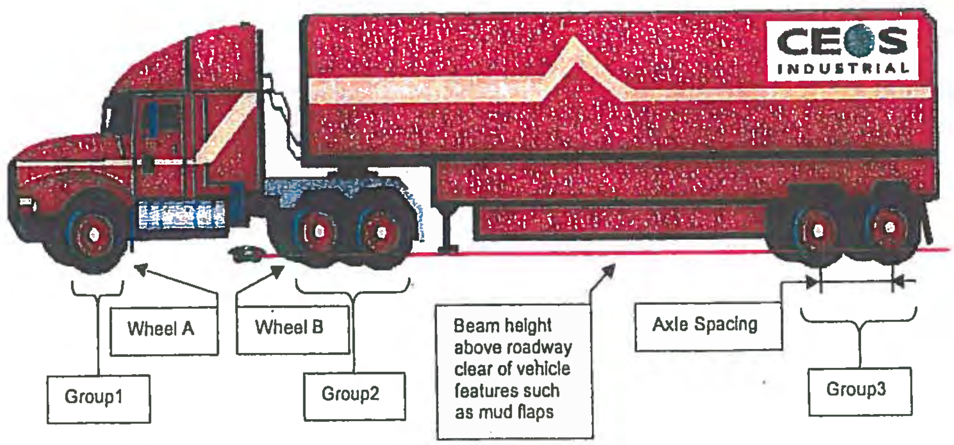


Figure 9 – Features of road vehicles.

A definition of the parameters associated with a user defined Classification Scheme is provided in the following paragraphs.

Axle Count – The number of Beam Events allows a count of the number of axles in a given vehicle. This is useful for discriminating between standard cars and trucks.

Axle Groups – The frequency of beam events allows an assessment of groups of axles. This is useful for discriminating between vehicles with the same axle count. Figure 9 illustrates 3 axle groups, the first group includes a single axle while groups 2 and 3 include double axles.

Axle Spacing – The duration between beam events allows a measurement of axle spacing providing discrimination between vehicles with the same axle count.

Wheel Size – This is a fine discrimination that allows vehicles with very similar axle profiles to be further categorized by ratio metric wheel size variations. The absolute wheel size within TIRTL is a learned parameter, the average of which is normalized to 1 within the current wheel base class. This modifiable parameter gives the user the ability of differentiating wheel sizes measurably outside the average for this wheel base. For example, by specifying a minimum normalized wheel size of 0.97 and a maximum of 1.03 all vehicles with a wheel size greater than ±3% will not be classified within this class.

Wheel Ratio – A ratio metric measurement of the leading wheel size measurement (wheel A in Figure 9) divided by the trailing wheel size measurement (wheel B in Figure 9). This is a fine discrimination that allows vehicles with different wheels front and back to be categorized.

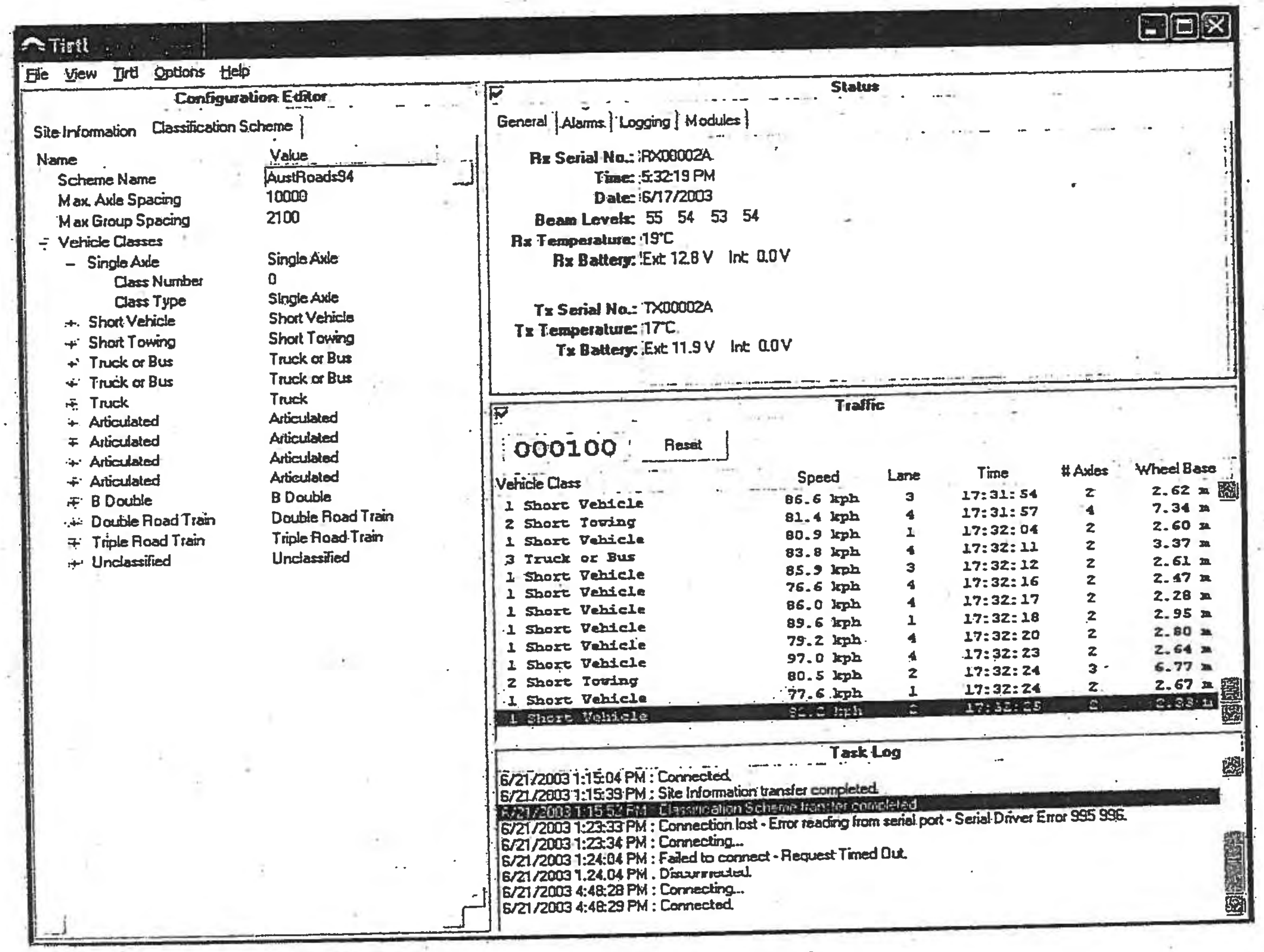


Figure 10 – Broad view of TIRTL*soft*

A Specifications

Speed measurement accuracy:	±1% (0 - 125miles/hr)
Maximum number left bound lanes:	9
Maximum number left bound lanes:	9
Max. Tx/Rx separation distance:	330ft
Max Tx/Rx separation (long range optic)	660ft
Operating temperature range:	-40 to +185°F
Environmental rating:	IP67 (Main body) IP66 (Battery compartment)
Internal C-cell battery operating time:	7 days (alkaline)
External power input:	10V to 16V dc
Avg Rx Power Consumption at 77°F:	680 mW (no traffic) 770 mW (dense traffic)
Peak Rx Power Consumption 77°F:	1800 mW
Avg Tx Power Consumption at 77°F:	640 mW
Processor:	x486, 33 MHz
Operating System:	Linux (kernel 2.2)
On Board RAM:	8MB - 16MB
On Board ROM:	8MB - 64MB
Compact Flash Storage (log storage):	16MB - 1,024MB (~ 100,000 – 7M vehicles)
Communication Interfaces:	2 x RS232 serial ports PSTN modem (optional) GSM/GPRS modem (optional)

Index

Training Purpose: To provide TST personnel with the basic knowledge of ramp meters and data stations.

Learning Outcome

The student will be able to explain the layout and function of a ramp meter site.

Purpose of Ramp Meters

Regulates the flow of traffic on the mainline

Decreases the mainline congestion

Maximizes freeway capacity by prolonging free flow movement on the ramp

Prevents stop and go merging at the gore point

Ramp Meters Have:

8 and 12 inch signal heads

Type 1 or 2 RM Pole

334 cabinet

170 controller

Loop amps

Load packs

Advanced Warning Sign

Display Panel

Modem

Monitor Unit/WDT

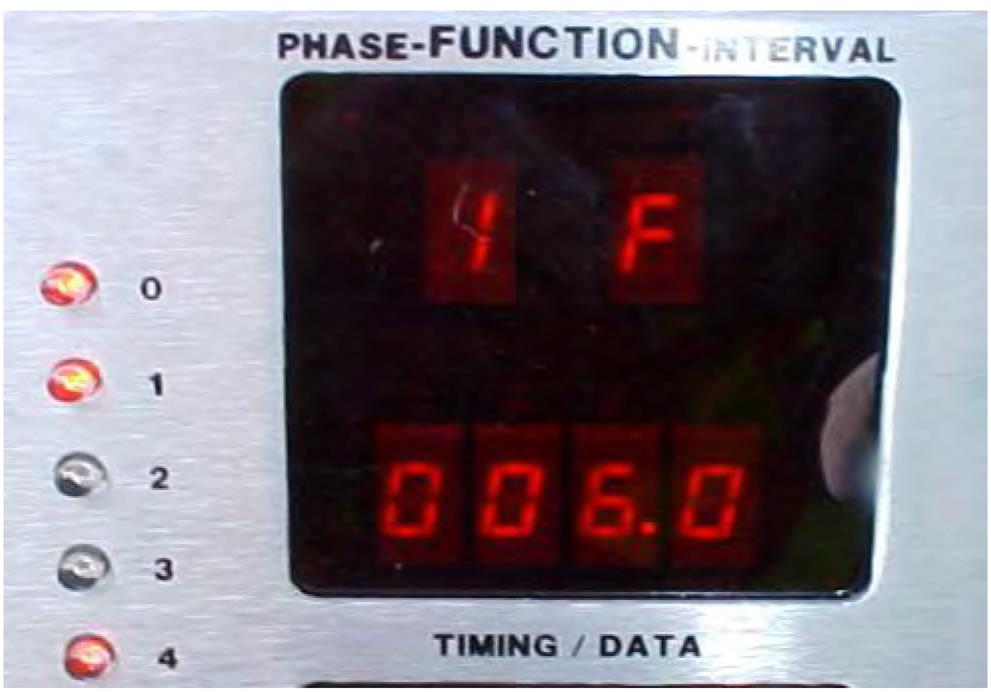
TYPE 1 RM POLE

TYPE 2 RM POLE

334 CABINET

170 CONTROLLER

DISPLAY ON 170 CONTROLLER



LOOP AMPS


DET
FLT
ON
222
CHAN 1
MODE
CHAN 2
SENS
CALL 1
FREQ
ALL CHAN
EDI

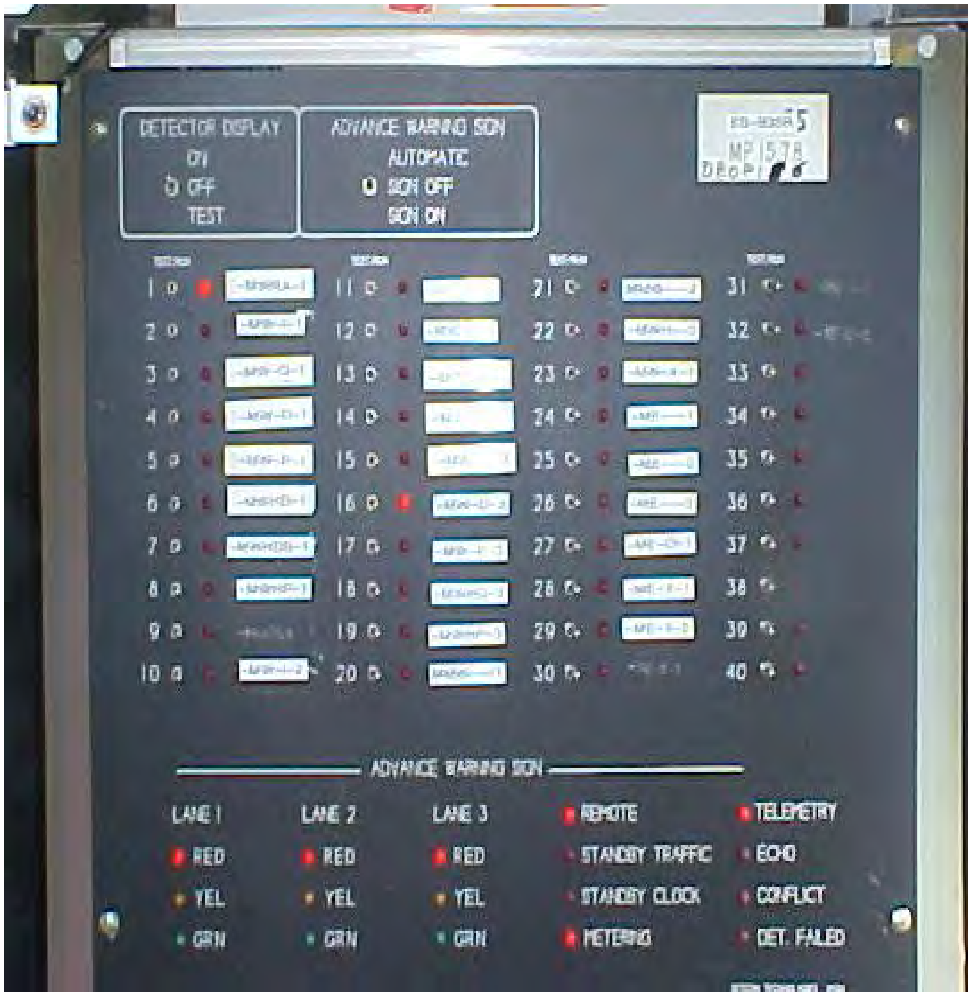

222
CALL
FAULT
SENSE LEVEL
PRES PUL NOT USED
FREQ
DISABLE
MODEL C

LOAD PACKS


200
RED
YEL
GRN
Intersection Developm
MODEL
200
RED
YEL
GRN
P
D
C

ADVANCED WARNING SIGN

DISPLAY PANEL



DEFINITIONS

Advanced Loop: Located at the beginning of the ramp; used with Fuzzy Logic.

(A common use for the queue loop is to measure the backup on the ramp and to adjust the meter rate when the line of cars becomes too long. This same job is given to the intermediate queue loop (present on long ramps) as well as advance queue loops.)

Queue Loop: The loop that lets the controller know that a vehicle is moving towards the ramp meter.

Demand Loop: Tells the controller that a vehicle is sitting at the ramp meter stop bar.

Pass Loop: Tells the controller that the vehicle has left the ramp stop bar.

High-Occupancy Vehicle Bypass Loop: A loop in the H.O.V. lane of the ramp that is used to add time to the Red signal indication of the METERED LANE for the car currently waiting at the stop bar. This allows the vehicle using the H.O.V. lane opportunity to bypass the car at the meter and safely merge with traffic. The HOV demand loop is normally located 300 feet before the stop bar in the HOV lane (accompanied by a speed loop).

Ramp Design

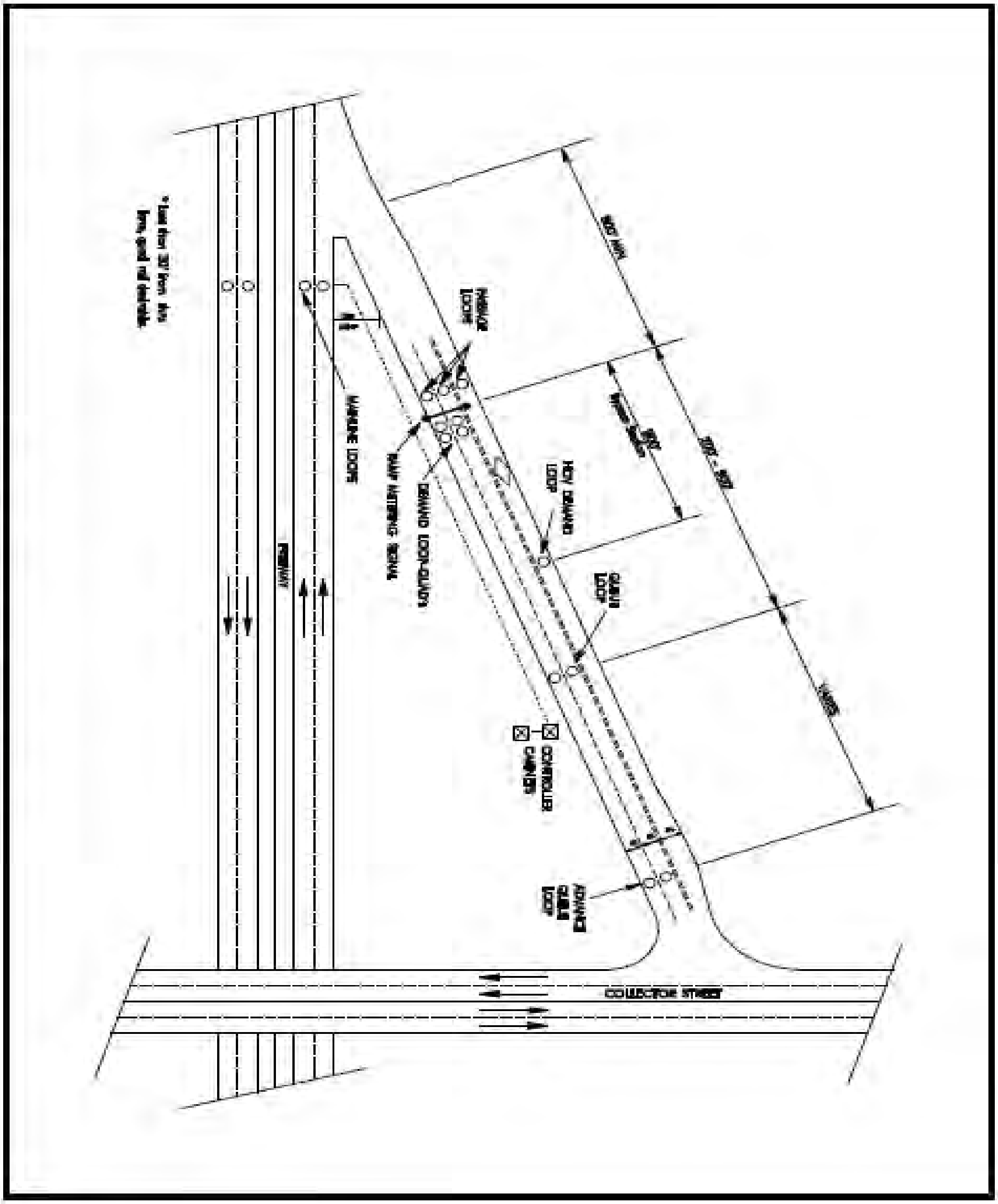
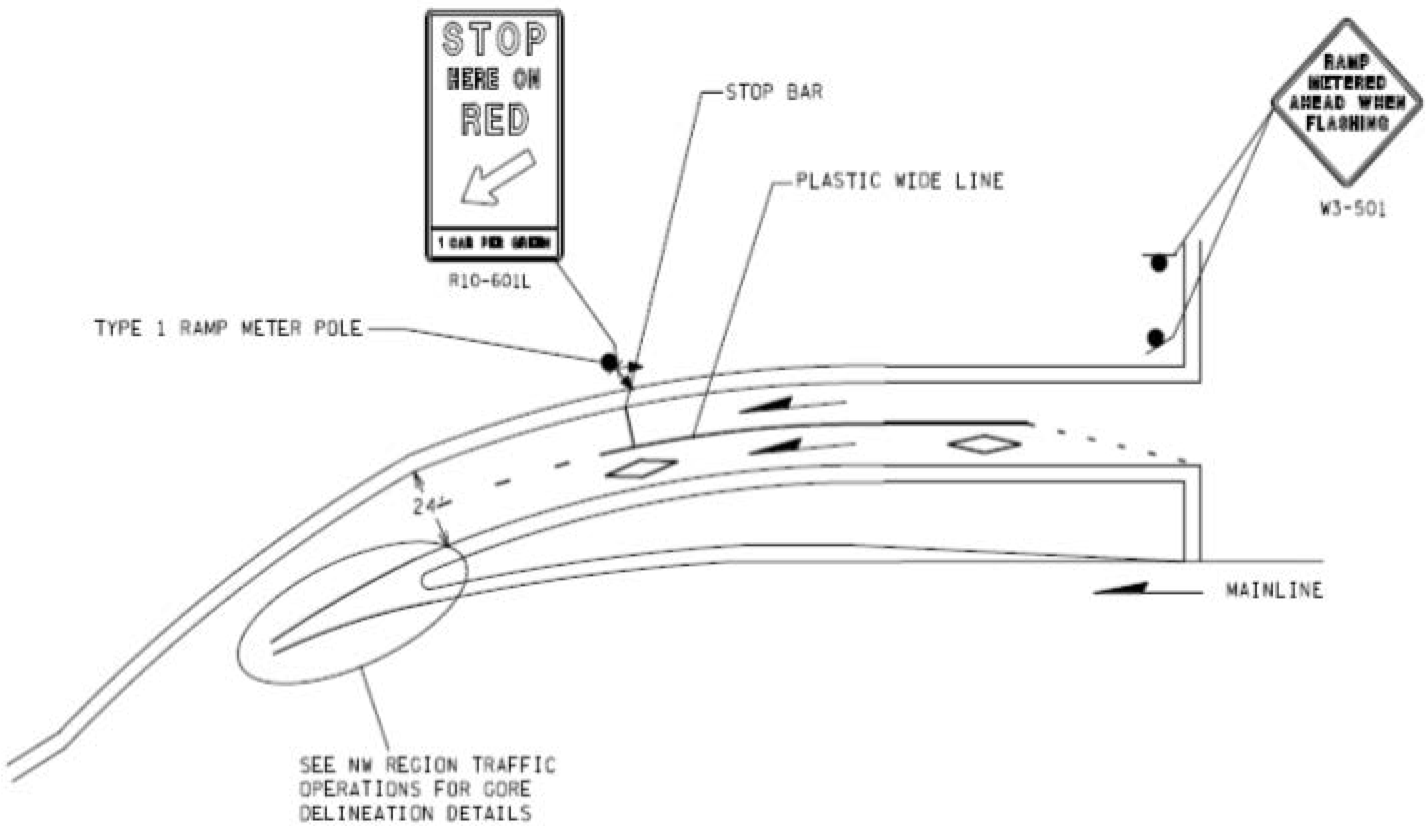


Figure 10 - DOUBLE LANE METERED RAMP WITH HOV BYPASS

RAMP WITH TYPE 1 METER POLE

(SIGNS AND SCHEMATIC–NOT TO SCALE)

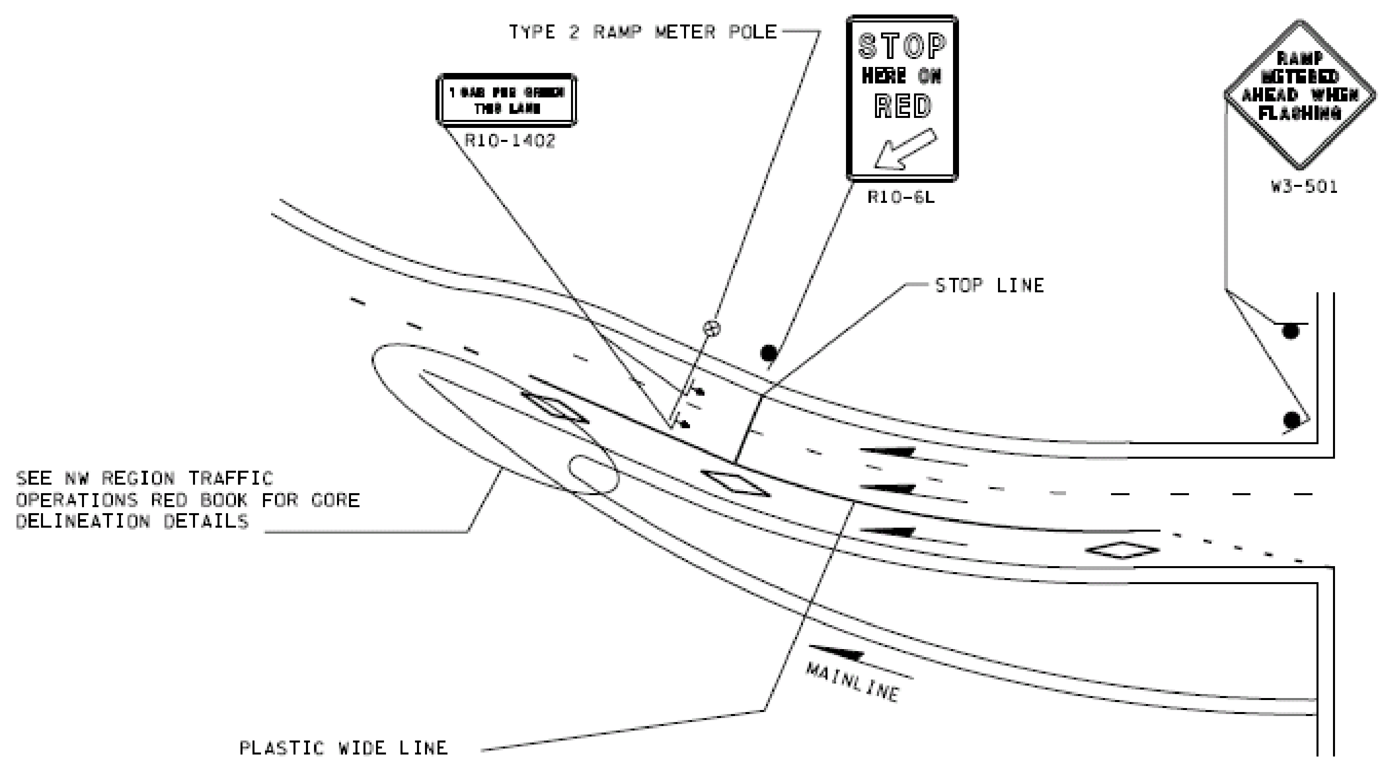


NOTES:

1) DETAIL FOR REQIRED ITS SIGNING ONLY. NOT ALL REQUIRED RAMP SIGNING IS SHOWN.

RAMP WITH TYPE 2 METER POLE

(SIGNS AND SCHEMATIC--NOT TO SCALE)



NOTES:

1) DETAIL FOR REQIRED ITS SIGNING ONLY. NOT ALL REQUIRED RAMP SIGNING IS SHOWN.

How loops are named

Can contain up to 7 characters: the 1st is the roadway, 2nd is the direction, 3rd is the lane type, and 4th is lane number.

LOOP NAMING SCHEME

A loop name contains exactly seven characters. The underscores are considered characters and are therefore necessary. A loop name is found by selecting one item from each column in table #1 (Roadway, Direction, Lane Type, and Lane Number). These items are then concatenated into a loop name. The correct item is found by following the conventions in the list of rules below. Special loops that need to be identified to the 170 are shown in table #2.

Speed loops must also be identified to the 170. These loops are identified by XXXXXSX. To find the corresponding loop for the trap, match each X in XXXXXSX to each X in XXXXX_X.

Table #3 shows some loop name examples from Figure 16.

TABLE #1

ROADWAY	DIRECTION	LANE TYPE	LANE NUMBER
_M - Mainline	S - Southbound (SB)	_X - Exit Ramp	_1
_C - Collector/Distributor	N NB	_O - On-Ramp	_2
_R - Reversible	E - EB	RA - Right Advanced Queue	_3
AM - Auxiliary Mainline	W - WB	LA - Left Advanced Queue	_4
AC - Auxiliary C/D		_Q - Queue Loop	_5
AR - Auxiliary Reversible		_I - Intermediate Queue Loop	_6
MM Metering Mainline		_D - Demand Loop	_7
MC - Metering C/D		_P - Passage Loop	_8
MR - Metering Reversible		HX - HOV Exit Ramp	_9
		HO - HOV On-Ramp	S1 Speed Loop L-1
		HD - HOV Demand Loop	S2 Speed Loop L-2
		HP - HOV Passage Loop	S3 Speed Loop L-3
		H_ - HOV Mainline	S4 Speed Loop L-4
		__ - Mainline	S5 Speed Loop L-5
			S6 Speed Loop L-6
			S7 Speed Loop L-7
			S8 Speed Loop L-8
			S9 Speed Loop L-9

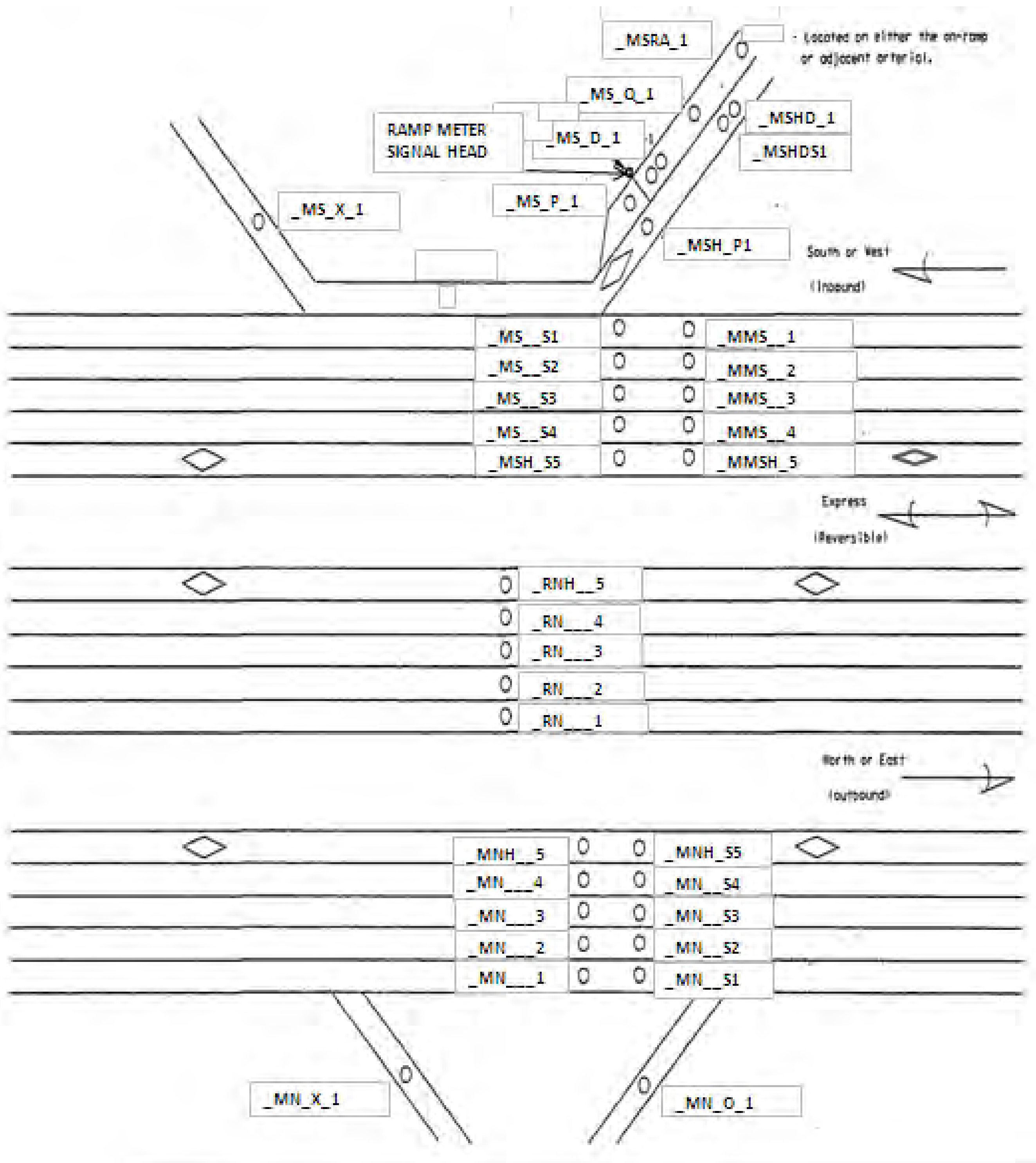


FIGURE 16 LOOP NAMING EXAMPLE

Reversible Loop Names

A loop can only have one name, so the direction of increasing milepost is used for all reversible loops. There are a few exceptions to this rule: one is when there is a ramp that is only open in the decreasing milepost direction (such as a westbound on-ramp to the express lanes that does not operate as an eastbound off-ramp - a loop on this ramp would be called "-RW-O-1" - if the ramp was also used as an eastbound exit, it would be called "-RE-X-1"). Because the express lanes have different uses depending on the direction of the roadway, some loops seem to be “mirrored” in the cabinet. For example, on the I-5 express lanes, there could be "-Reversible NB" loops as well as "-Reversible SB" loops. When the lanes are open southbound, only two of the three lanes are open to traffic (the westernmost lane is closed to allow for Lake City Way to add). When the lanes are open northbound, the westernmost lane is an HOV lane. At all other locations, all of the reversible mainline loops are named "-Reversible NB".

Loop placement in the cabinet is as follows:

Data Stations:
North comes before South
East comes before West

Ordering:
- Mainline loops
- Speed loops
- On-ramps
- Off-ramps

EXAMPLE:

TB2-1,2 :	_ME___1
TB2-3,4 :	_ME___2
TB2-5,6 :	_ME__S1
TB2-7,8 :	_ME__S2
TB2-9,10 :	_ME_O_1
TB2-11,12 :	_MW___1
TB3-1,2 :	_MW___2
TB3-3,4 :	_MW__S1
TB3-5,6 :	_MW__S2
TB3-7,8 :	_MW_O_1
TB3-9,10 :	_MW_X_1
TB3-11,12 :	_MW_X_2

Ramp meters:

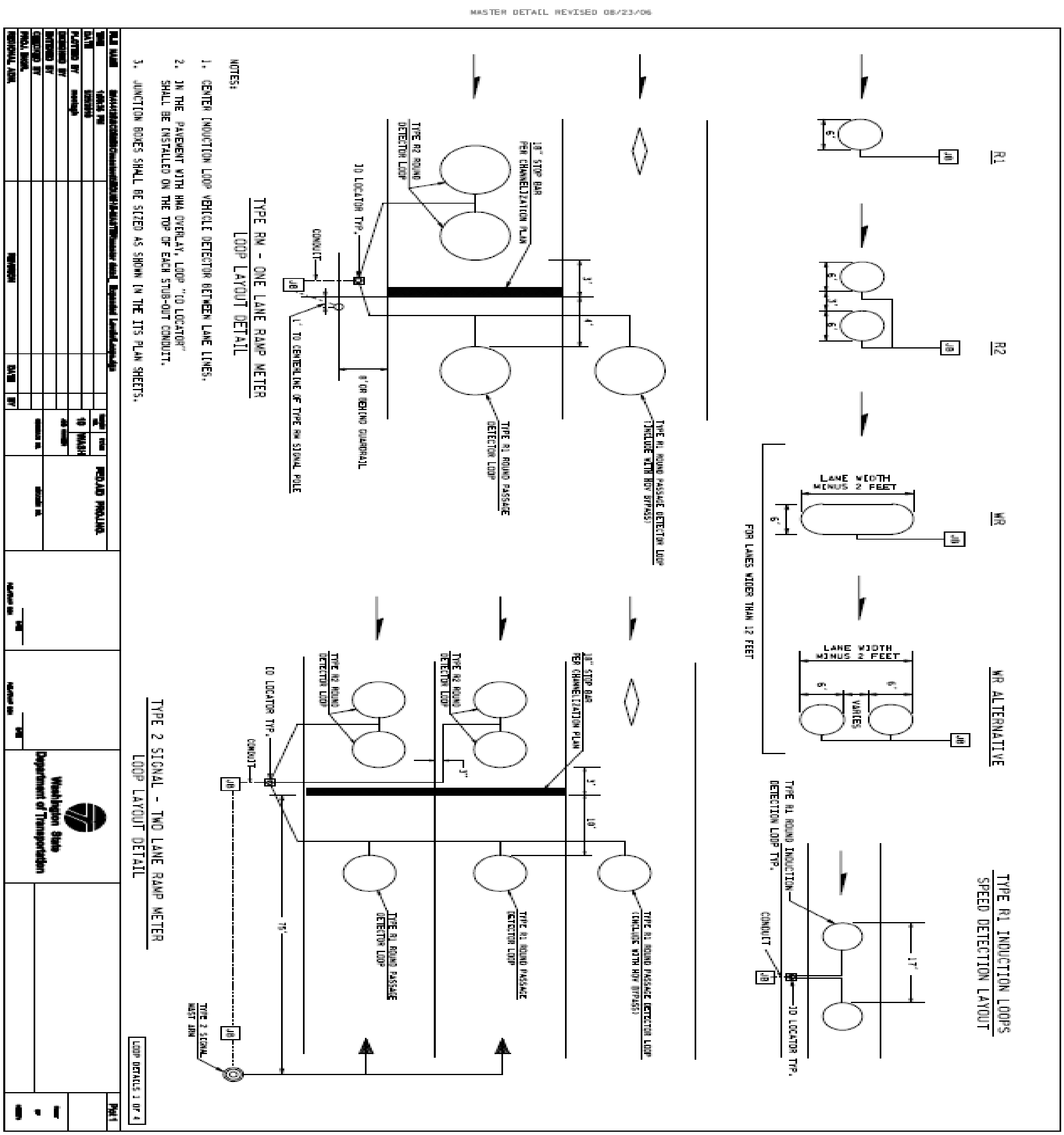
Ramp meter loops first (regardless if it is North/South/East/West).
Ordering:
The loops are ordered beginning with the advanced queue loops and continue in order down the ramp (advanced queue through passage / lane 1 to lane ? (note: HOV bypass will fit in next to the lane that it bypasses i.e. _*MSH*?_2 loops would go between the lane 2 loops and lane 3 loops))
Mainline loops for the metered direction
Speed loops for the metered direction
Any other on-ramps for the metered direction
Off-ramps for the metered direction
Mainline loops for the non-metered direction
Speed loops for the non-metered direction
On-ramps for the non-metered direction
Off-ramps for the non-metered direction

EXAMPLE:

TB2	1-2	_MSRA_1
	3-4	_MS_Q_1
	5-6	_MS_D_1
	7-8	_MS_P_1
	9-10	_MSHD_1
	11-12	_MSHDS1
TB3	1-2	_MSHP_1
	3-4	MMS___1
	5-6	MMS___2
	7-8	MMS___3
	9-10	MMS___4
	11-12	_MSH__5
TB4	1-2	_MSHO_1
	3-4	_MSHX-1
	5-6	_MS_X_1
	7-8	_MS_X_2
	9-10	_MS_X_3
	11-12	_MN___1
TB5	1-2	_MN___2
	3-4	_MN___3
	5-6	_MN___4
	7-8	_MNH__5
	9-10	_MN__S1
	11-12	_MN__S2
TB6	1-2	_MN__S3
	3-4	_MN__S4
	5-6	_MNH_S5
	7-8	_MNHO_1
	9-10	_MNHX_1
	11-12	

Loop Placement in the Roadway

We use a type R2 loop for the demand loop. It is effectively two round loops connected together to act as a single loop. These two loops are spaced 9 feet apart, center to center. The distance between the trailing edge of the demand loop and the leading edge of the passage loop depends on the application. It is 7 feet for a type 1 (shoulder-mount), and 13 feet for a type 2 (mast arm) layout. Speed loops are placed 17’ apart leading edge to edge in each lane.



Definitions

Local station: mainline station near the merge point

Down Stream station: immediate location that is prone to congestion
"Downstream Station" can refer to one or more stations that the drivers entering the on-ramp will encounter. These stations are between .5 and 5 miles away.

Upstream station: next mainline station upstream of the local station

Red Signal Violations: A red signal violation occurs each time the passage loop is actuated while there is a red signal indication. When a violation occurs, the red cycle length is increased.

High-Occupancy Vehicle Bypass Meter Rate Adjustment: For each actuation of the HOV demand speed loop (or demand loop) while the metered lane signal is red, the red cycle length is extended to give the HOV the opportunity to bypass the meter and safely merge with metered traffic.

Queue Adjusted Metering Rate: If in 20-seconds the queue loop exceeds its maximum occupancy, the cycle length is decreased to allow more cars to get through the signal quicker.

For Example: *If the ramp is at minimum storage capacity, a 12 second cycle length with a 1 second red signal indication will be used. Then only 5 vehicles will go through the meter per minute. But, if the ramp is at maximum storage capacity, a 3 second cycle length with a 1 second red signal indication will be used. Then 12 vehicles will go through the meter per minute.*

Volume Adjustment: The ramp volume equation adjusts the queue-adjusted meter rate to compensate for red signal violations and HOV bypass traffic on the ramp.

Advanced Queue Override: Each metered ramp may have more than one advanced queue loop. The loops are designated as right or left. If both of the advanced queue loops indicate that the ramp is at maximum occupancy, the advanced queue override value will adjust the queue meter rate. This adjustment will remain in effect until the advance queue loops indicate that the ramp is below the maximum occupancy limit.

<u>How a Ramp Meter Works : Guided Notes</u>

Operates a 170 controller.
Can meter up to <u>3 different</u> Ramps.
Accumulates data on: vehicle speed and length, ramp occupancy, & communicates with a <u>central</u> computer.

A typical ramp meter is designed to be controlled by a central computer at TSMC. This occurs through the use of phone lines and a modem at 1200 Baud and a 25 pair mainline carrier, a fiber optic line connected directly at the cabinet or a phone 'drop'. Multiple modems can been connected to the same circuit and are then given their own address. This is what we call a <u>Drop Address</u>. A list (which may be provided by your engineer or can be found in SIMMS) will contain all of the addresses for ES stations and associated equipment within your area. This list contains not only the drop address, but also the <u>name</u> of the circuit the equipment is on, the field location, and the cabinet number. Every controller on the circuit receives every message sent out by the central computer, but only the controller with the <u>matching address</u> will respond to the specified command.

The central computer sends a series of messages to set the date, time and specific controller parameters. The central computer will then POLL the controller every <u>20</u> seconds to see if it is responding. Operational parameters are sent to the 170 controller on how to adjust for certain mainline traffic conditions using equations we will discuss later.

Ramp Meter Control

The decision to **activate the ramp meter** is based on the "Flow" operator's judgment as to whether or not it will benefit traffic conditions. The operator activates the meter by sending a <u>Start Metering</u> command to the controller via the central computer. At this time, the Advanced Warning Sign beacons (at the beginning of the ramp) will begin <u>flashing</u>. Then the 170 controller starts the 20 second lead-in green interval. When 20 seconds has passed, the controller begins looking for a gap in traffic crossing the <u>queue</u> loop. When the lead in time is expired and a gap is detected, the signal will change from green to start-up yellow and then red. The yellow signal indication lasts from 3-5 seconds.

The signal will remain **RED** until all of the following occurs:

1. The demand loop has a vehicle located on it.
2. The passage loop is clear
3. The Red Signal has been on for a minimum of 1.0 second.
4. The Cycle timer has expired; which includes any delays added because of the H.O.V. lane receiving vehicles.

When it is no longer useful to have the ramp metered, the operator sends the Stop Metering command. The controller will continue to meter until a specific gap length is detected across the demand loop. The gap length is reduced by 1/10th of a second every 6 seconds. A 10 second gap will be reduced to zero in 10 minutes if the traffic on the ramp is heavy and does not allow a sufficient break between vehicles to meet the gap reduction rate. Then the 60-second green signal end of meter phase begins.

The gap reduction rate is used so that a large number of vehicles are not dumped onto the freeway when the meter is shut off. If a gap is found, the controller knows that the large number of cars behind the meter is gone.

NOTE:
The 20-second green interval at startup is fixed and cannot be changed. The controller looks for a gap on the queue detector - typically 3.0 seconds. The operators at TSMC can change the size of the queue loop gap for startup if 3.0 seconds is too large. During startup, the green timer will be reset to 2.9 seconds each time the queue detector is actuated. There is no time limit on the gap search in startup. The controller will continue to search for a gap until one is found, or the TOD window closes or the Central computer commands the end of metering.

Ramp Meter Pre-emption

There are 2 types of ramp metering pre-emption: locally by using the cabinet police switch and remotely via the pre-empt parameter. The police panel switch and the pre-empt parameter work separately from each other. But both will cause pre-emption. The meter will not return to normal operation until each one it turned off.

The status of the police switch is checked every 1/10 second. If the police switch is turned on at the cabinet, an alarm is sent to the Central Computer. If the pre-empt parameter or the police panel switch is turned on, the controller places a steady green indication on all ramp signals. When the switch or the pre-empt parameter is turned off, the controller will resume normal operation. If the controller is supposed to be metering, the start meter phase will begin. If the controller should not be metering, the controller goes through the end of meter phase.

Local and Fuzzy Logic Equation Metering: Guided Notes

There are two sources for ramp meter control: **local equations** using local data and the central computer equation (**fuzzy logic**). The Fuzzy Logic equation is what we generally use. The local equation can be used at a "free standing" site or when a communication failure between the 170 controller and the central computer occurs.

The **Local Equation** is based on a time of day plan and is used for special circumstances or when there is a communication failure. The time of day plan is activated at a specific hour, minute, and day of the week. In essence, the individual station uses the local equation to determine a metering rate. It does so by looking at the time-of-day plan, congestion on the ramp (queue loop and advance queue loop), and congestion on the freeway (mainline loops at the merge point). Then, the local meter will increase or decrease its metering rate based on the information gathered from these inputs.

The **Fuzzy Logic Equation** is similar to human thought and reasoning. It utilizes volume, speed and occupancy data that is typical of the metered area; and it can consider imprecise data. When the equation is written, specific detectors or loops and stations are used to determine the meter rate. Ramp meters can process information from as many as 34 loops. The stations (other ramp meters or data stations) specified in the equation (either upstream/downstream) of the desired ramp to be metered are typically ones that have a lot of re-occurring congestion and represent mainline traffic conditions.

The 170 controller takes numerical data from each of the specified equation stations and the queue detector data from each of the ramps at the site you are looking at to formulate a metering rate. This information is then sent to the central computer. Specific ramp conditions (red signal violations, HOV bypass traffic, queue occupancy, and advanced queue detector occupancy) also help determine and optimize an adjusted meter rate. The adjusted meter rate (AMR) is the basic meter rate used to run the ramp meter.

Optimizing example: using the ramp to hold a certain number of cars slows down the number of cars merging. This could effect how traffic is handled on the mainline due to an accident.

Summary

The local equation uses ramp and mainline loops that directly affect the traffic metering rate. This information is the basis for how the ramp meter will operate. The fuzzy logic equation uses loop inputs (from both the mainline and the ramps) to gather data. The gathered data is then applied to specific parameters set forth by the Central Computer. The fuzzy logic parameters can then be adjusted as needed to optimize a meter rate for less-than-ideal freeway conditions.

Basic Troubleshooting for Ramp Meter Failures: Guided Notes

Circuit Failures**:** occur, because a controller on the circuit is locked up.
All controllers on the same circuit are daisy chained together and if one is locked up, the data carrier tone will be directed through to the transmit pair of wires. Most likely the cabinet that is farthest away from the HUB is the problem.

Watch Dog Timer Trip**:** occurs, because the Monitor Unit asks the 170 controller for a response 10 times a second. If the 170 takes a full second or more to respond, the signal heads will go to a green indication. This is the safe indication for traffic on the ramp to enter the freeway.

*To reset the watch dog timer press the button on the WDT card.

WHEN A 170 IS IN A FAILED STATUS, LOOK FOR A:

Locked Controller: its display will be all zeros, eights, blank, or you won't be able to input data through the key pad on the front of the 170 controller. NOTE: Sometimes the controller will show no sign of being locked up. If the unit is communicating via a T-1 line, check the communications wires on the punch down block at the back of the cabinet. Remove the C-2 connector on the back of the controller while listening to the transmit pair of wires. If the carrier tone is "gone," this is your problem. Re-set the controller. If the unit is communicating on fiber optics, then verify that the bi-directional receiver has not locked up, or lost power.

Broken Communication Lines: The left side of the punch down block (back of cabinet) is the source tx/rx signal. The right side is the tx/rx signal going to the C-2 connector. The bridge clips connect the two together. Check that the bridge clips are secure and making good contact. Check the left side for good tones, and then the right. If the left source side is not giving the correct tones, then the problem is outside of the cabinet. Look for the nearest terminal cabinet. This will be a good starting point to look for broken communication wires. If the terminal cabinet has good tones, then the problem is between it and the cabinet that you already visited. Check all cabinets for good comm.'s and all JB's that fall between the terminal cabinet and the ramp meter cabinet you checked. If you have good tones on the source side of the punch down block, follow the wires from the right side down to Terminal Block Nine on the left side of the cabinet. NOTE: This is just a "pigtail" from the punch down block to the terminal block. Check the tones again. The C-2 connector is wired to this TB and goes to the back of the controller. You can also check the audio in and audio out on the back of the 170 controller or take the C-2 connector off and check pins A to B and C to E for tone. If the lines are "good" then you have a bad controller.

HUB/NETWORK Failure: this is usually a power problem, because the cameras, data stations, and ramp meters are all on the same circuit and will be without power or in a "failed" status.

A LOOP Failure or a COMMUNICATION Failure**:**

Both have the ability to cause a similar symptom: a white segment being painted on the Webflow or Internet map. White segments are a product of some logic in a computer program that looks for bad data. A failed cabinet creates nothing but bad data - so if all of the segments being painted by a single cabinet (ES-XXX) are white, there is a good chance that the communication is failed (for whatever reason). However, if even a single segment for a cabinet is being painted green, yellow, red, or black, then it is a loop problem. "Bad data" is in reference to the quality of the data. Each 170 is running a basic quality check on the data it collects. Certain anomalies in the data generate flags that are sent back to the central computer for further analysis. Typically, in each cabinet, a loop from each lane (in each direction) are averaged together to create a single volume/occupancy value for all the lanes. If enough loops in a single direction have these flags on the data they create, the segment's data is considered bad and is painted white. This is often the case when loops break, are out of tune, or are beginning to fail.

170 Controller Reset

1. Turn the ‘Stop Timing Switch’ to **ON**.

2. Turn the 170 Controller OFF. For data stations, skip to step 4.

3. Ramp Meters: turn ‘MU’ switch to OFF.

4. Wait 30 seconds to make sure that the controller misses one communications interval (ensuring that the controller status at TSMC will show failed).
   NOTE: Resetting the controller while it is still ‘active’ can cause problems that may not be evident at the cabinet.

5. Depress and hold key 5. Turn the 170 to ON and then release the key.

6. Turn the ‘Stop Timing Switch’ to **OFF**.

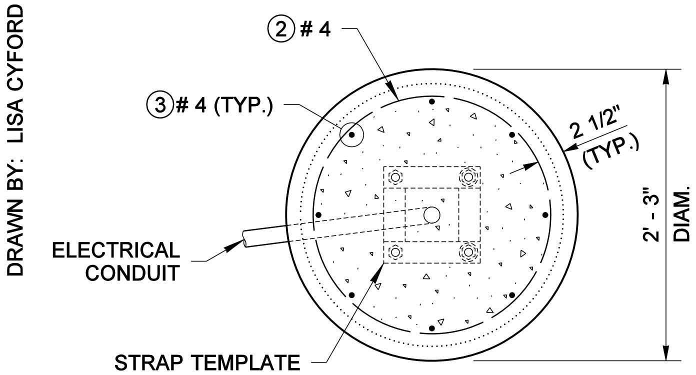
7. For Ramp Meter: turn the MU switch to ON and reset the Watch Dog Timer Card.

8. Enter the drop address using the circuit list provided by your engineer. Do this by pressing C-0-0 then the one or two digit number and E (which is enter). Press B key to get to the base page display. Then press 8-0.

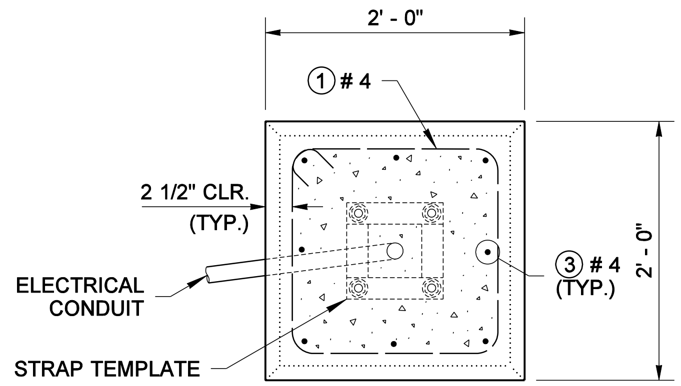
9. The timing/data window will display all zeros and the phase interval window will count the time in hexadecimal. When communication between the controller and the central computer is re-established, the current time will be indicated in the timing/data window.

Note: 8-0 = Time in hours, minutes, seconds & day of week.

DRAWN BY: LISA CYFORD



SECTION A



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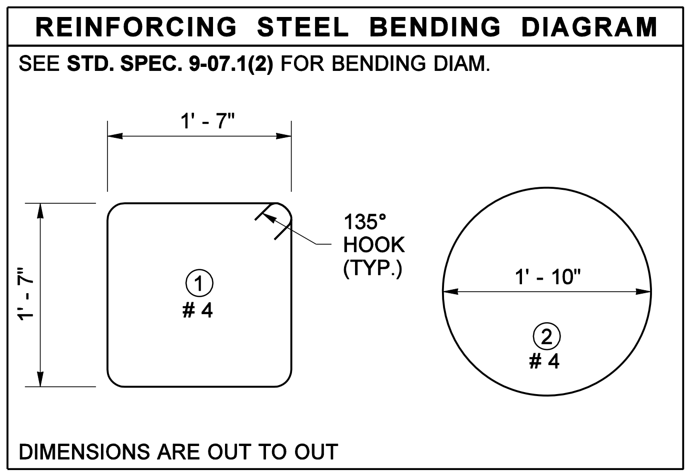
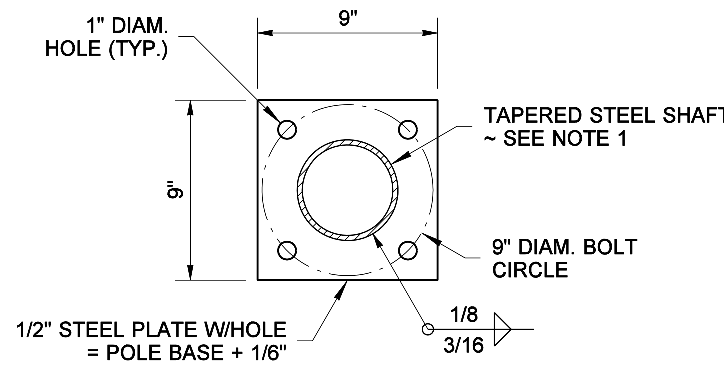
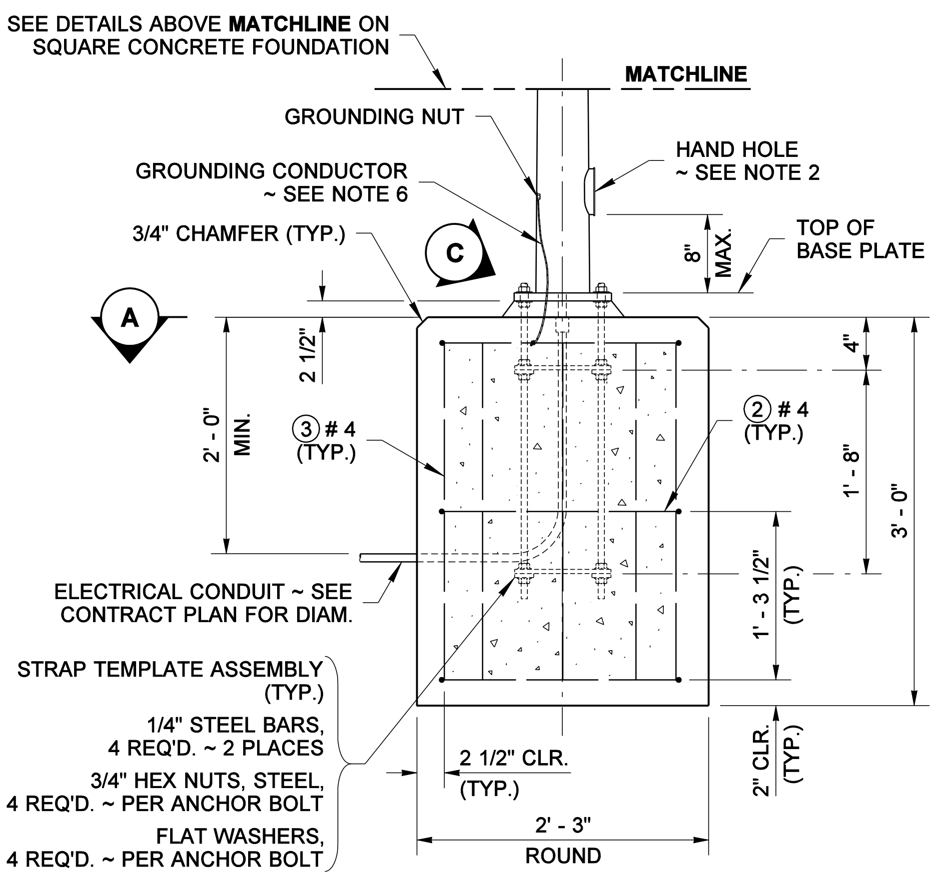
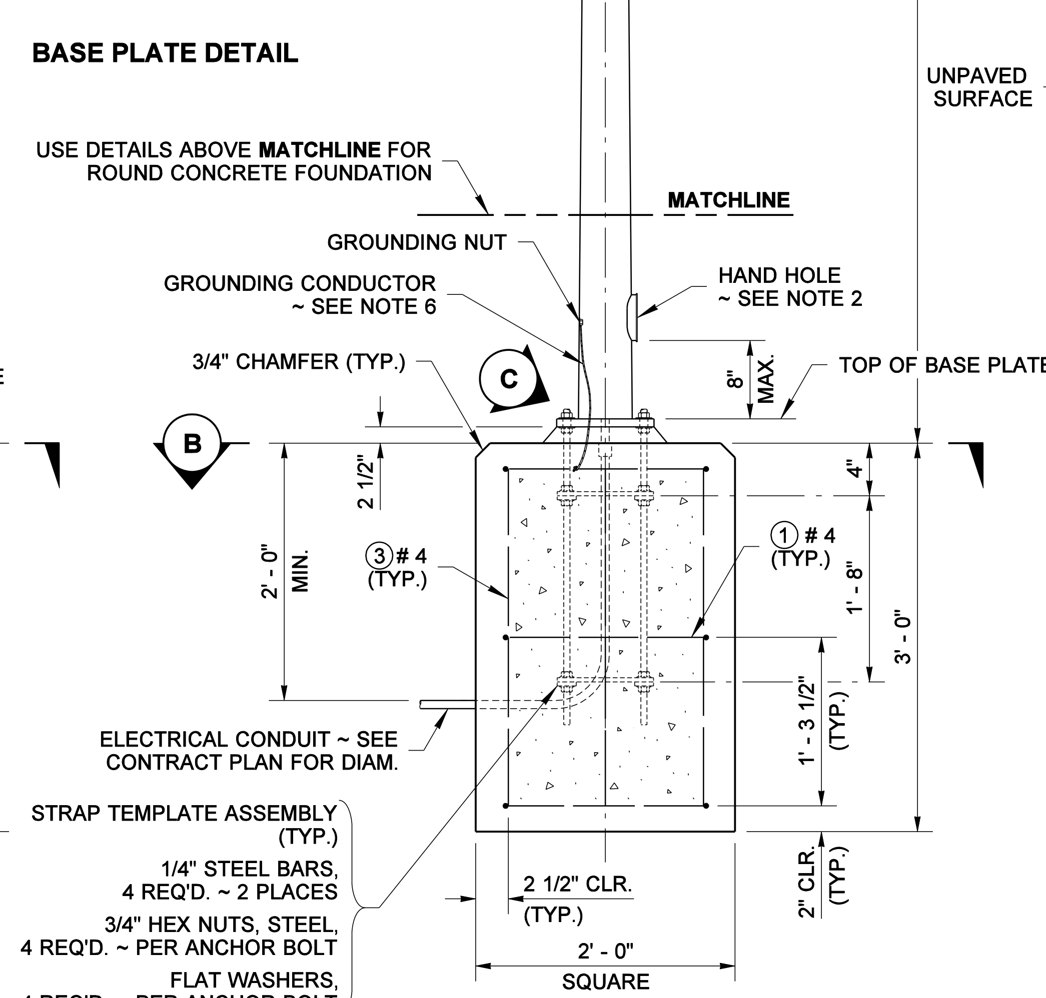




BASE PLATE DETAIL



ELEVATION
ROUND CONCRETE FOUNDATION DETAIL

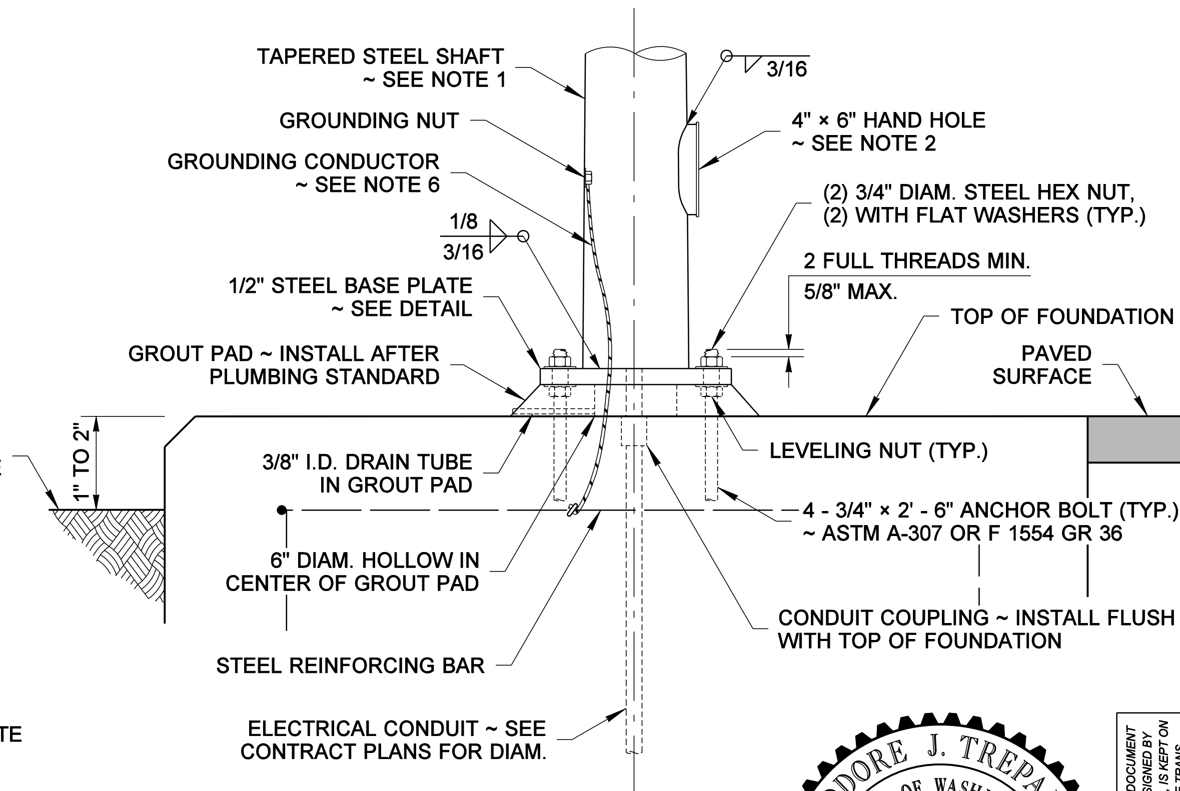


FIXED BASE

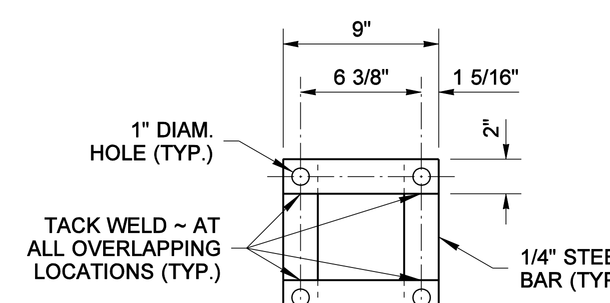
ELEVATION
SQUARE CONCRETE FOUNDATION DETAIL

NOTES

1. Steel shaft shall be tapered either round or dodecagon (12 sided), 11 gage, 4 1/2" O.D. at slip-fitter weld. Taper shall be 0.14 inches per foot.
2. Hand Holes shall include a removable, rain tight cover and gasket, fastened with two stainless steel screws (ASTM F 593).
3. Clamping Bolts shall be tightened to 50 ft-lbs max. torque. After state inspection, burr threads to prevent nut rotation. **DO NOT OVERTIGHTEN.**
4. The final height of the Anchor Bolts must be below the top of the Slip Plate Assembly to ensure proper function of the Slip Base.
5. All Poles shall be hot dip galvanized per AASHTO M111.
6. Grounding Conductor shall be non-insulated #4 AWG stranded copper, provide 3' - 0" min. slack. Clamp to steel reinforcing bar with connector suitable for use embedded in concrete.



DETAIL C



STRAP TEMPLATE DETAIL

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TYPE PS, TYPE 1, RM & FB SIGNAL STANDARD FOUNDATION DETAILS

STANDARD PLAN J-21.10-01

SHEET 1 OF 2 SHEETS

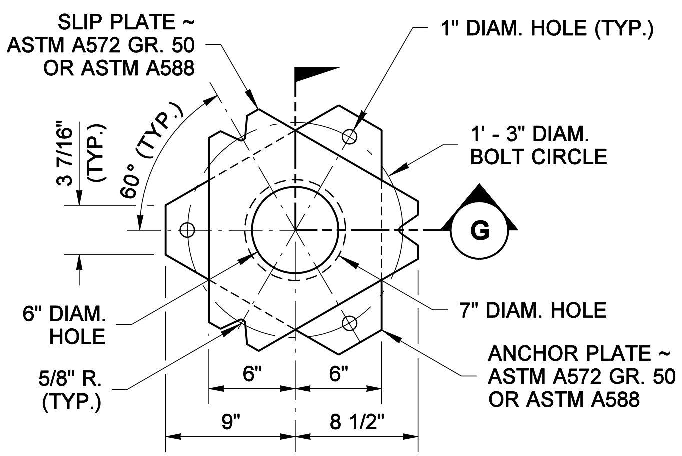
APPROVED FOR PUBLICATION

Pasco Bakotich III — 06-03-10

STATE DESIGN ENGINEER — DATE

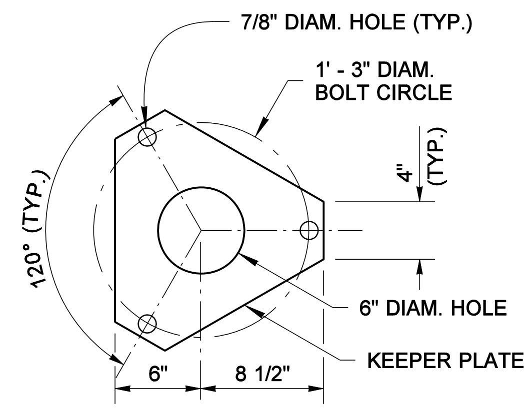
Washington State Department of Transportation

DRAWN BY: LISA CYFORD



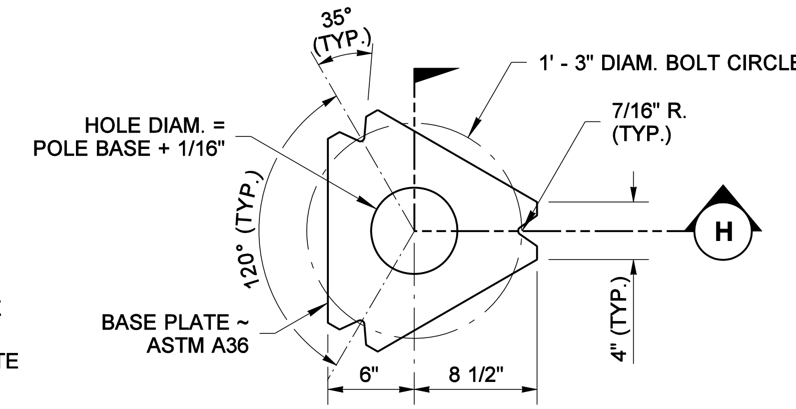
FOR DIMENSIONS NOT SHOWN
SEE BASE PLATE DETAIL

SLIP AND ANCHOR PLATES DETAIL



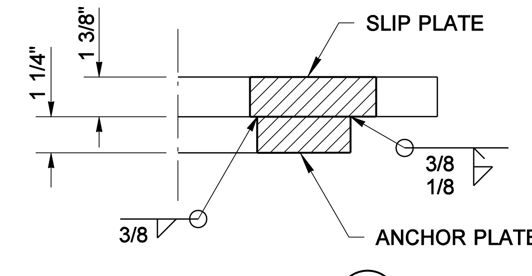
(28 GAGE SHEET METAL)
PLACE BETWEEN POLE BASE PLATE AND
SLIP PLATE ON TOP OF MIDDLE WASHERS
~ SEE **STANDARD PLAN J-28.42**

KEEPER PLATE DETAIL

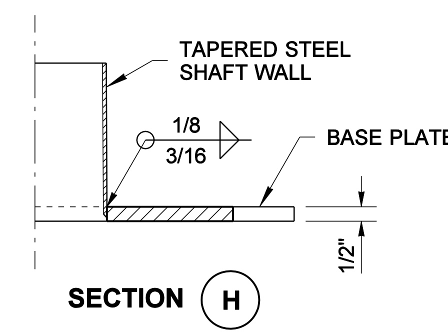


FOR DIMENSIONS NOT SHOWN
SEE SLIP AND ANCHOR PLATES DETAIL

BASE PLATE DETAIL



SECTION G



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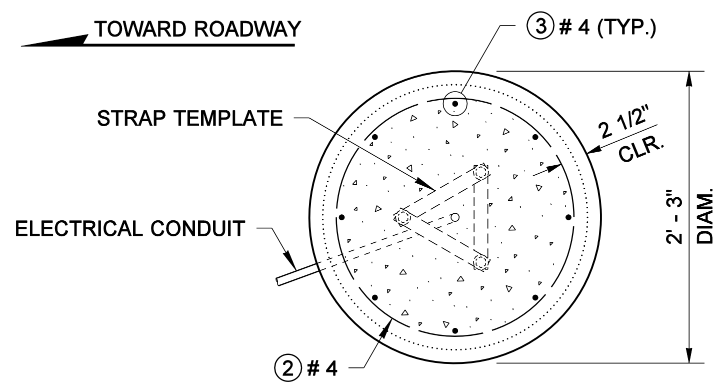

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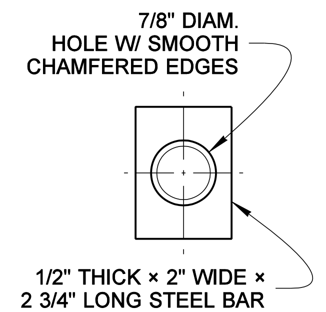
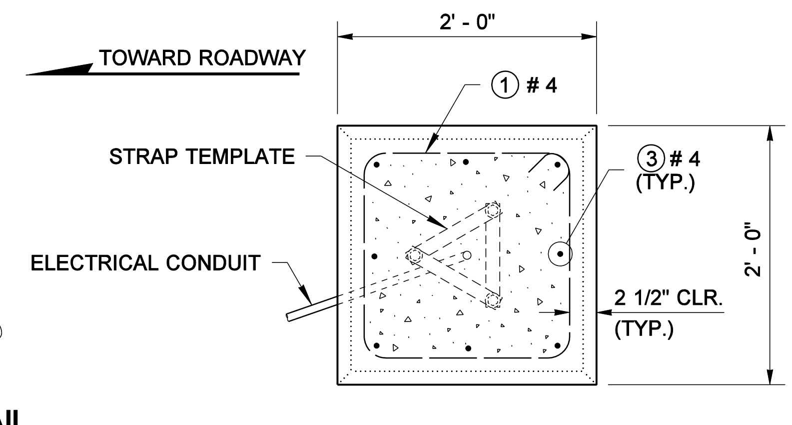


PLATE WASHER DETAIL



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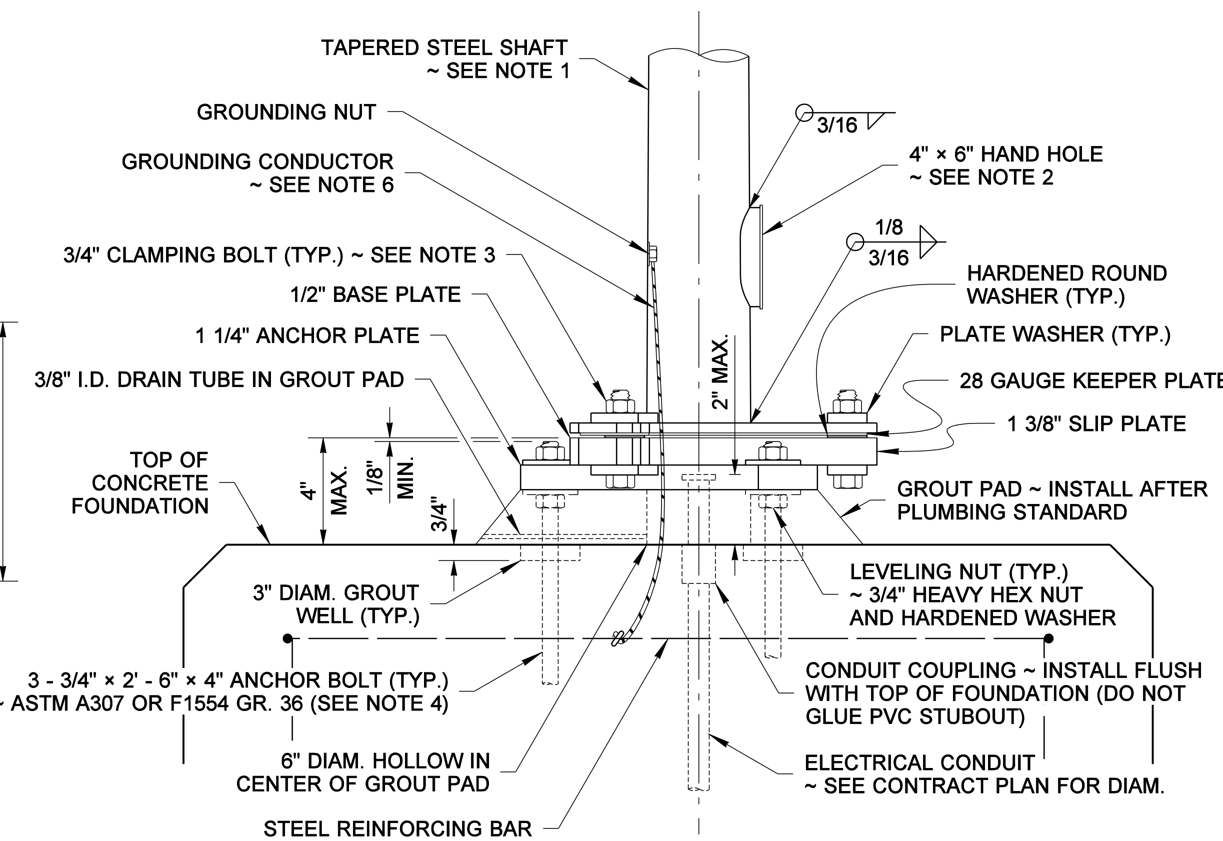
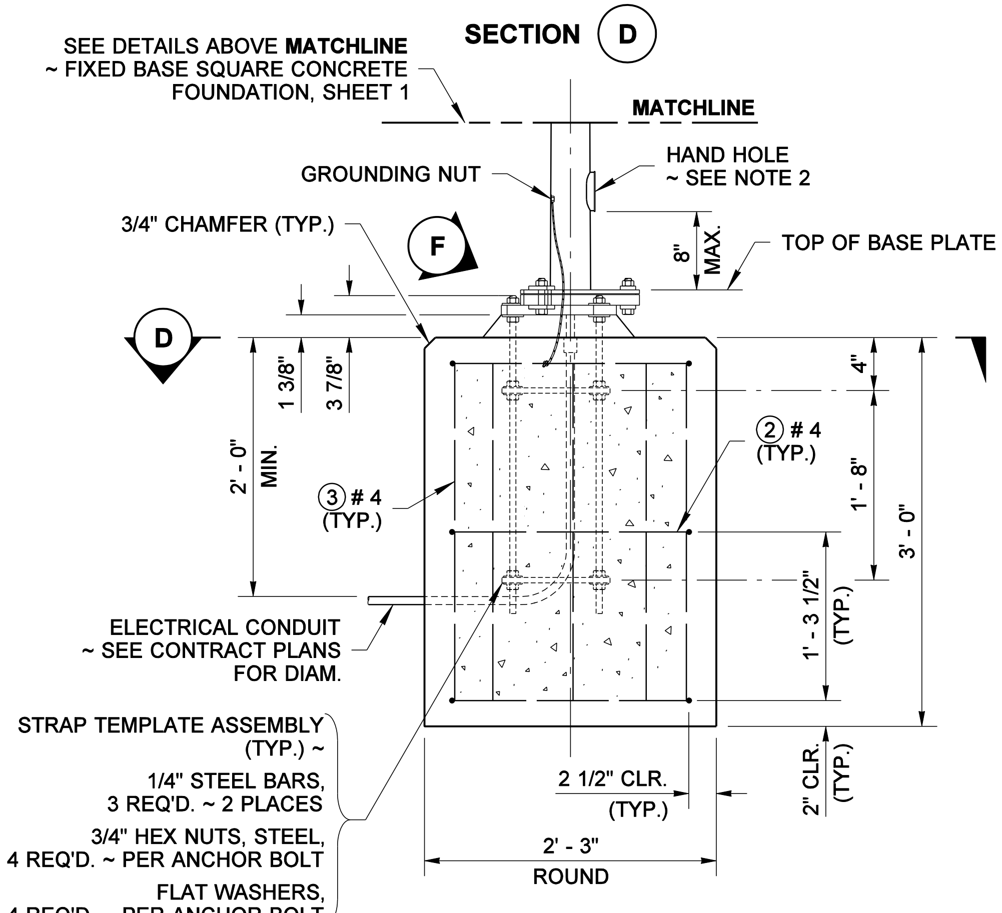
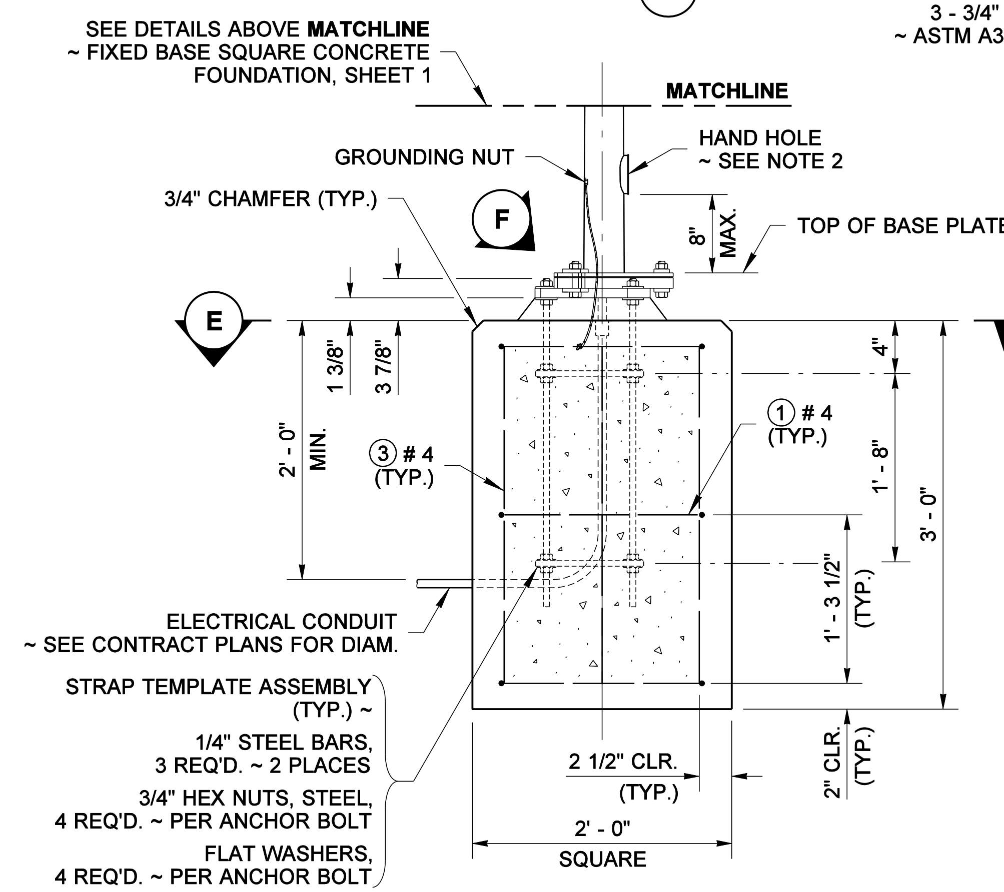


DETAIL F



ELEVATION

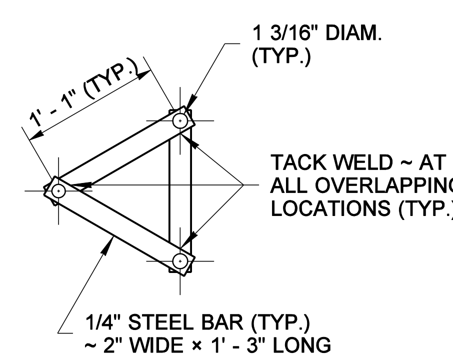
ROUND CONCRETE FOUNDATION DETAIL



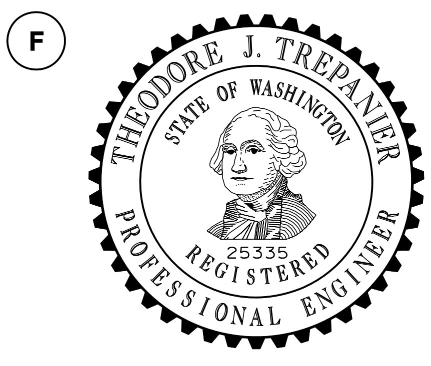
SLIP BASE

ELEVATION

SQUARE CONCRETE FOUNDATION DETAIL



STRAP TEMPLATE DETAIL



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TYPE PS, TYPE 1, RM & FB SIGNAL STANDARD FOUNDATION DETAILS

STANDARD PLAN J-21.10-01

SHEET 2 OF 2 SHEETS

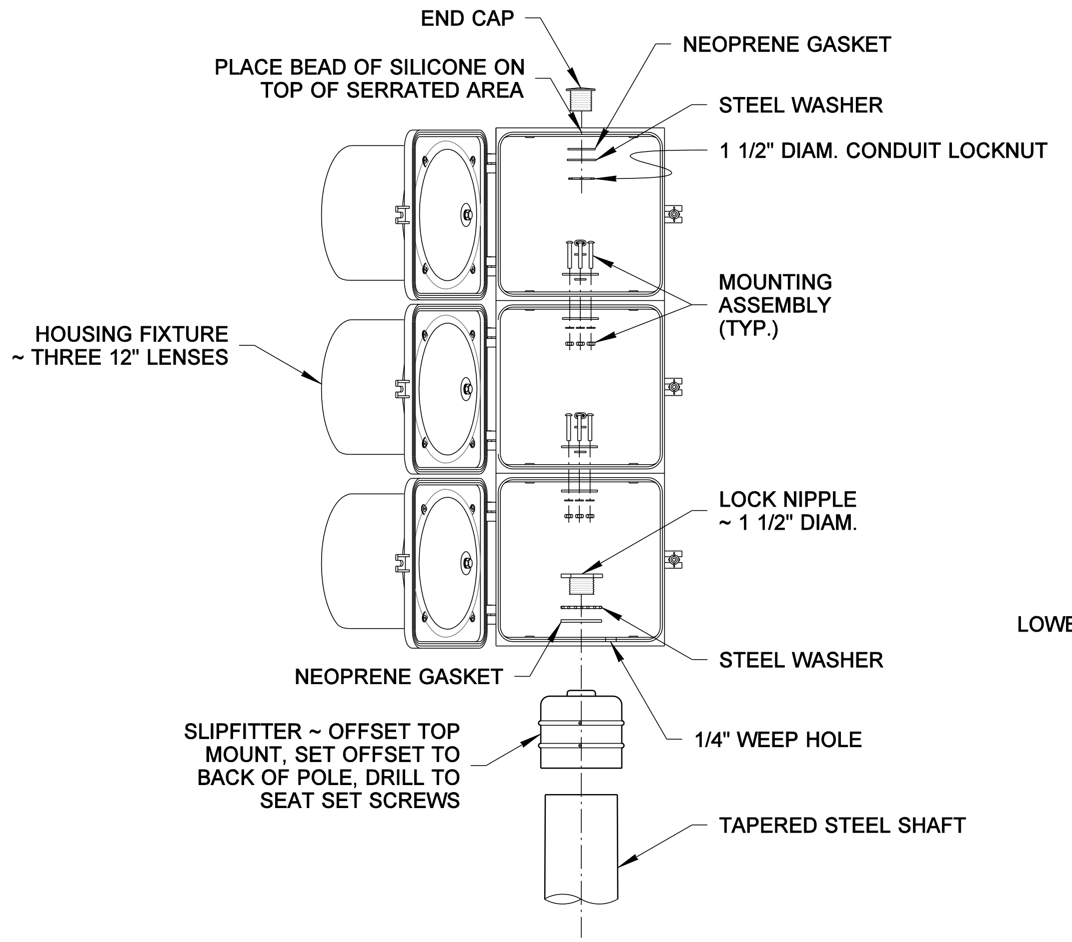
APPROVED FOR PUBLICATION

Pasco Bakotich III — STATE DESIGN ENGINEER

06-03-10 — DATE

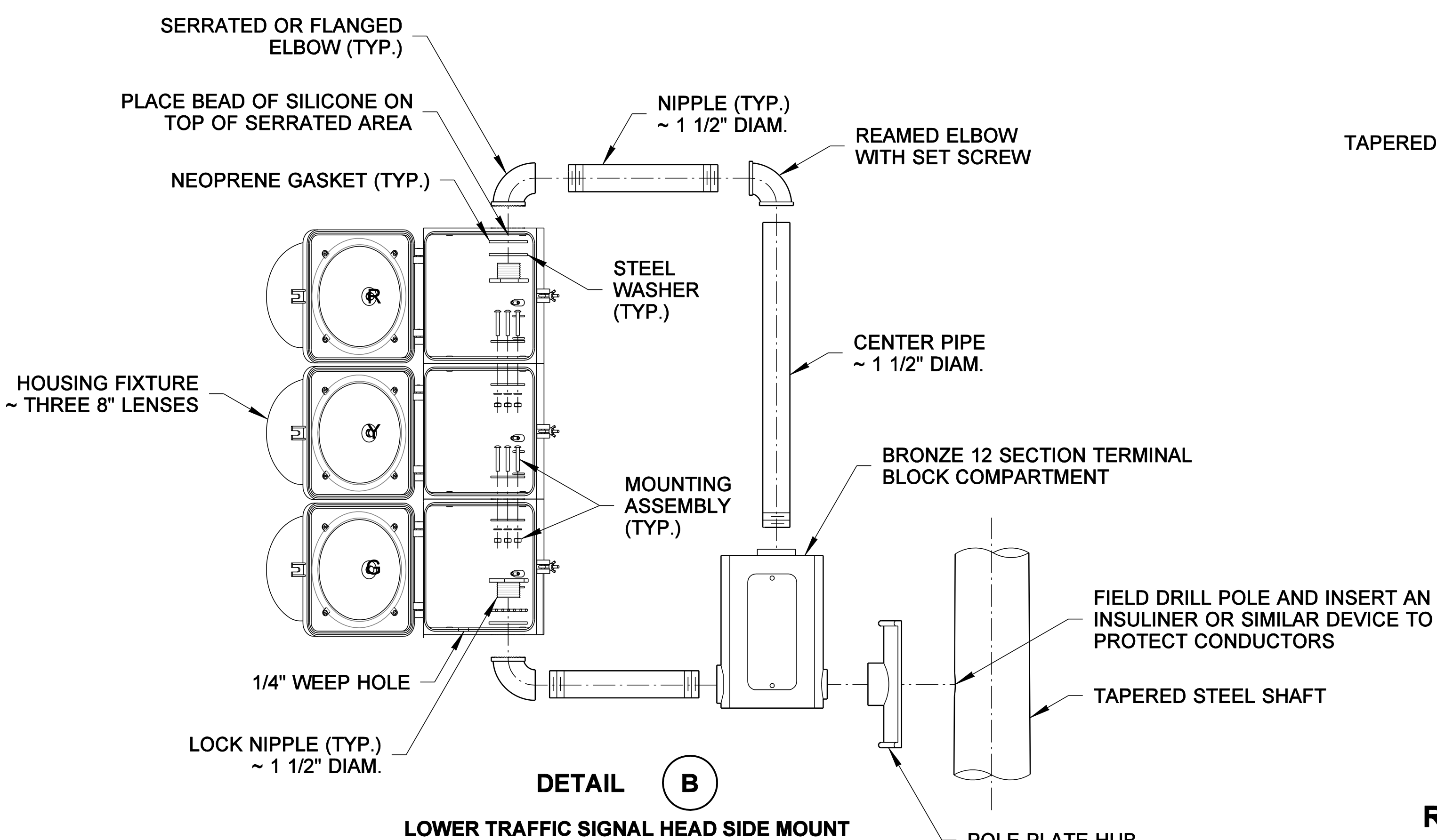
Washington State Department of Transportation

DRAWN BY: LISA CYFORD



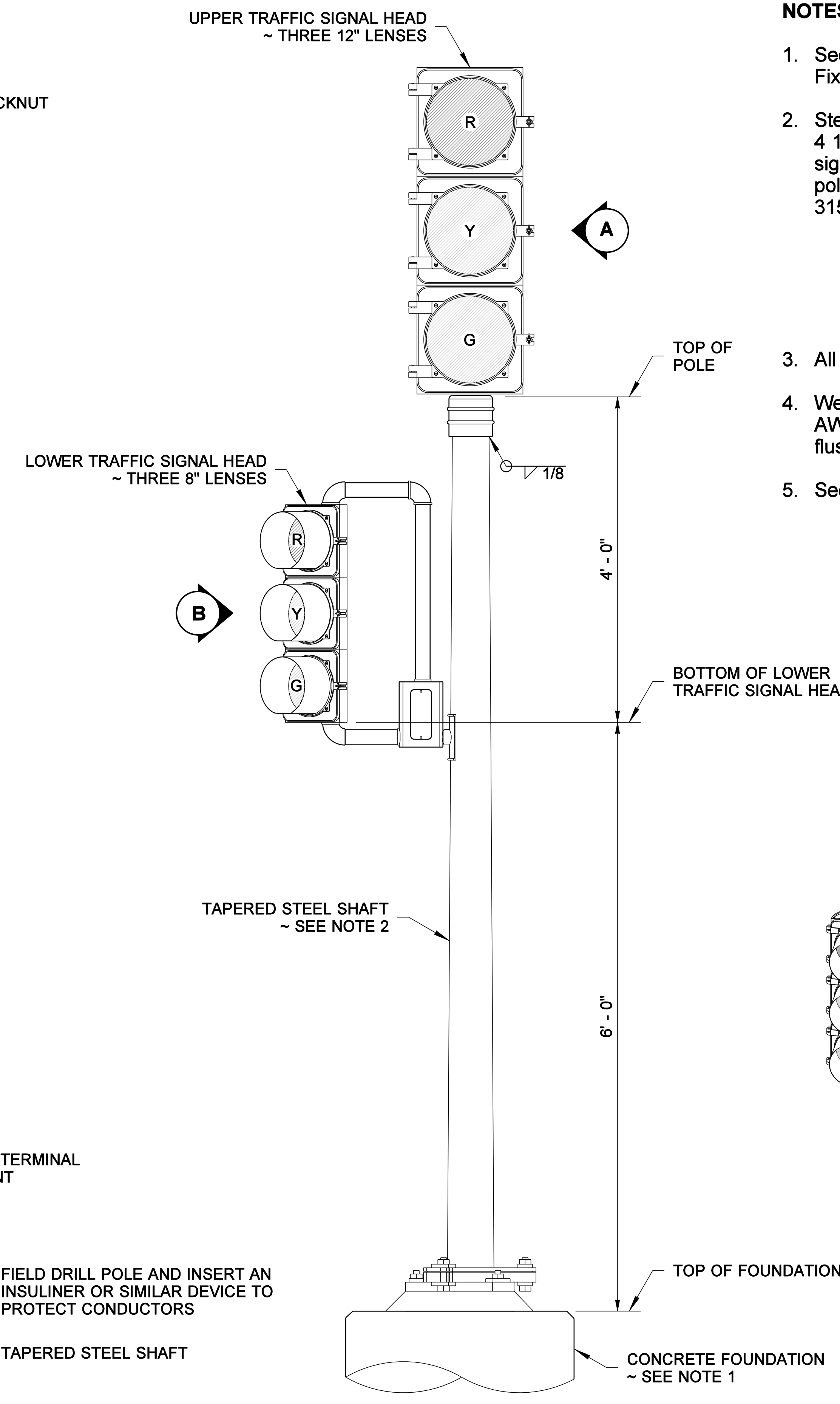
DETAIL A

UPPER TRAFFIC SIGNAL HEAD TOP MOUNT TYPE D



DETAIL B

LOWER TRAFFIC SIGNAL HEAD SIDE MOUNT TYPE K

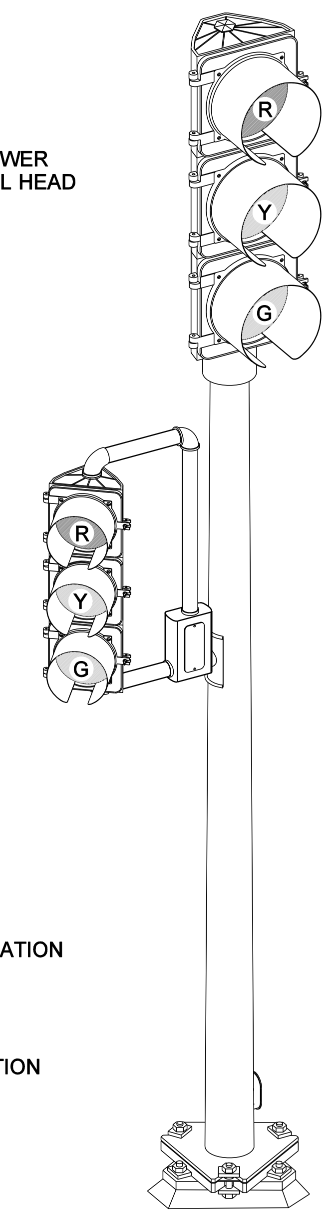


RAMP METER SIGNAL STANDARD

SLIP BASE SHOWN

NOTES

1. See **Standard Plan J-21.10** for Signal Standard Foundation details with a Fixed Base and Slip Base details.
2. Steel shaft shall be tapered either round or dodecagon (12 sided), 11 gage, 4 1/2" O.D. at slipfitter weld. Taper shall be 0.14 inches per foot. Pedestrian signal displays mounted on an octagonal (8 sided) traffic signal pole with a pole attachment angle other than 0°, 45°, 90°, 135°, 180°, 225°, 270°, or 315° shall utilize:
   - Type A mounting when two pedestrian heads are installed on the same signal pole.
   - Type B mounting when only one pedestrian signal head is mounted on a signal pole.
3. All poles shall be hot dip galvanized per AASHTO M111.
4. Welding of structures shall be in accordance with the latest edition of the AWS D1.1 Structural Welding Code - Steel. All butt welds shall be ground flush with base metal.
5. See **Standard Plan J-22.16** for Electrical details.



PERSPECTIVE VIEW

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RAMP METER SIGNAL STANDARD DETAILS

STANDARD PLAN J-22.15-00

SHEET 1 OF 1 SHEET

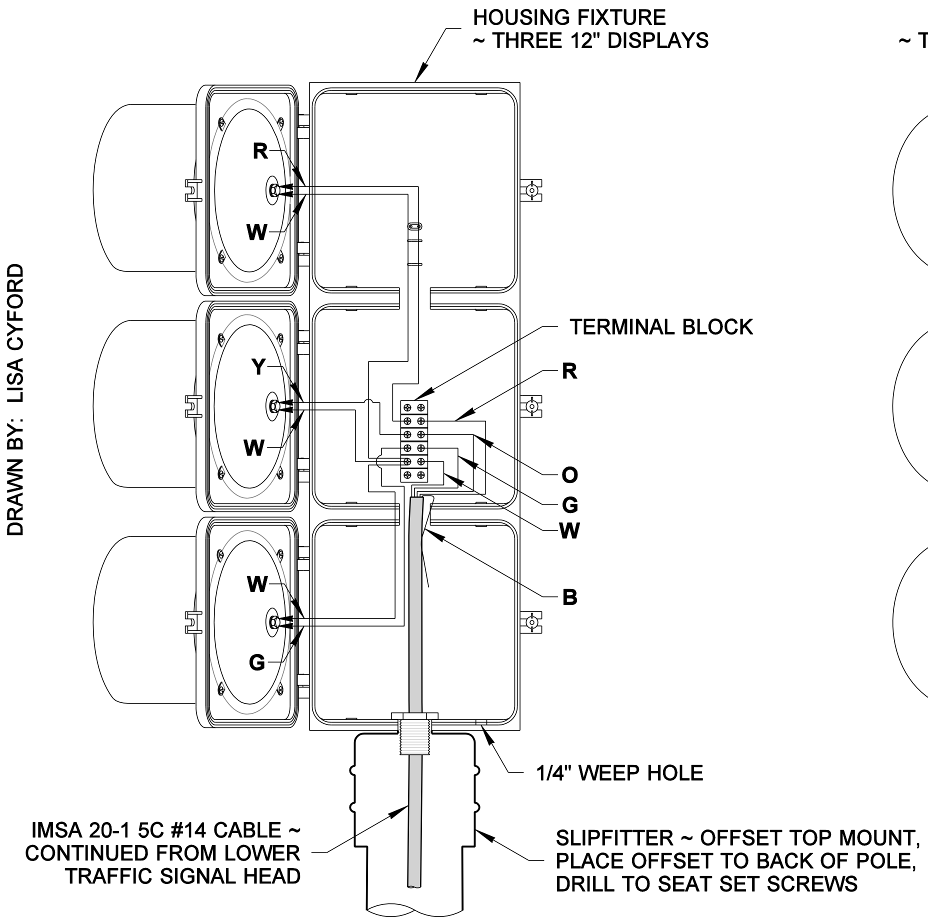
APPROVED FOR PUBLICATION

Pasco Bakotich III — *10-14-09*

STATE DESIGN ENGINEER — DATE

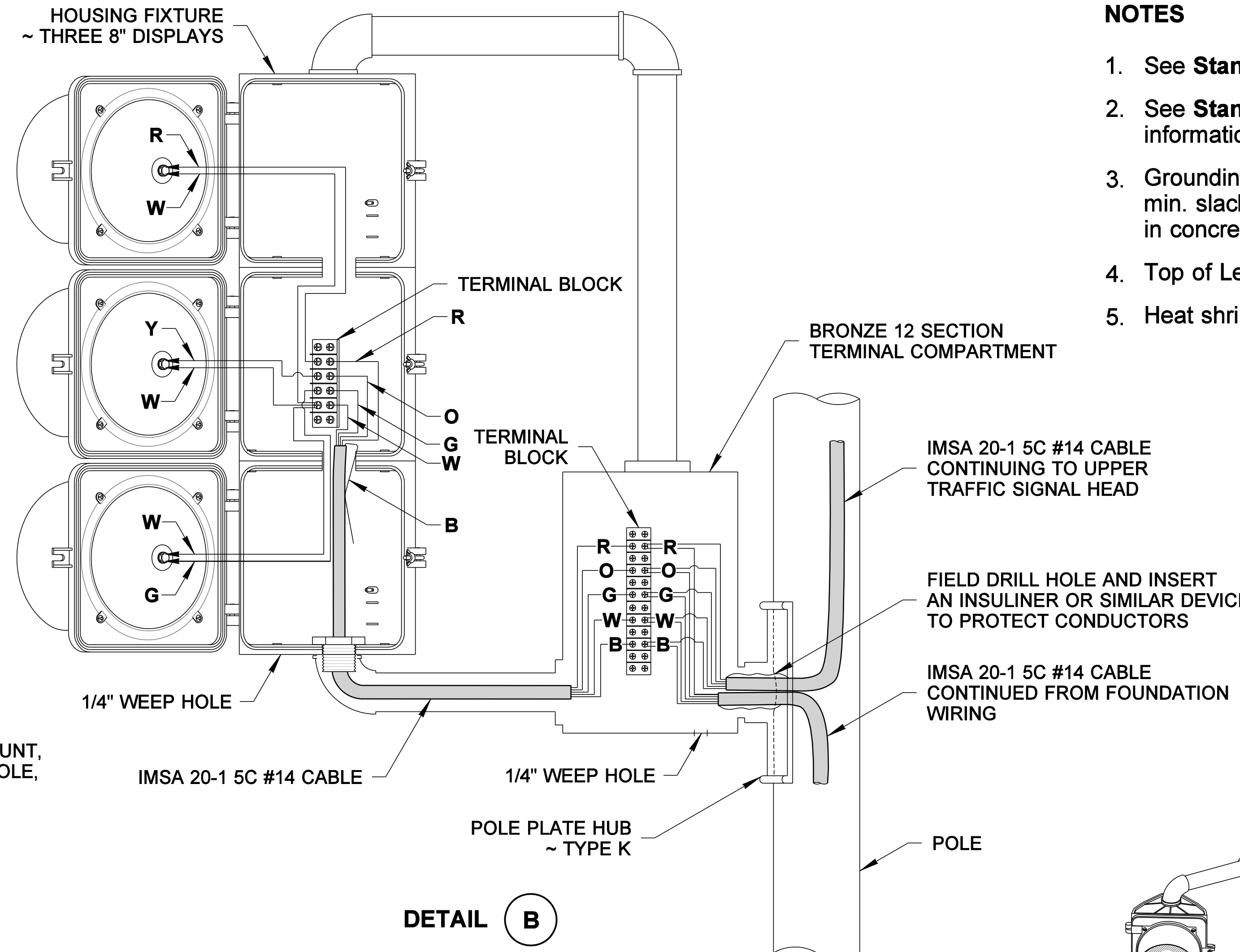
Washington State Department of Transportation

DRAWN BY: LISA CYFORD



DETAIL (A)

UPPER TRAFFIC SIGNAL HEAD WIRING



DETAIL (B)

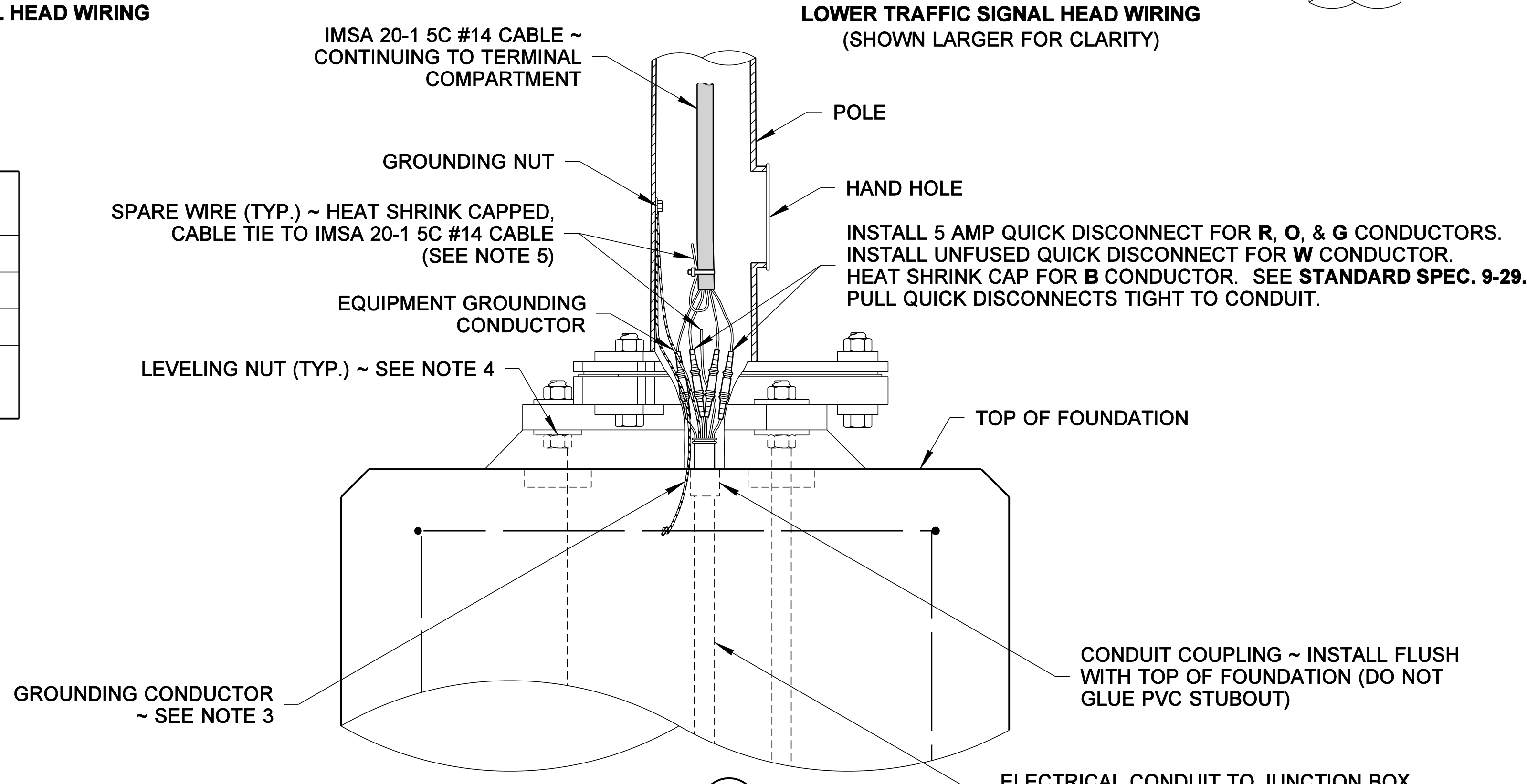
LOWER TRAFFIC SIGNAL HEAD WIRING

(SHOWN LARGER FOR CLARITY)

NOTES

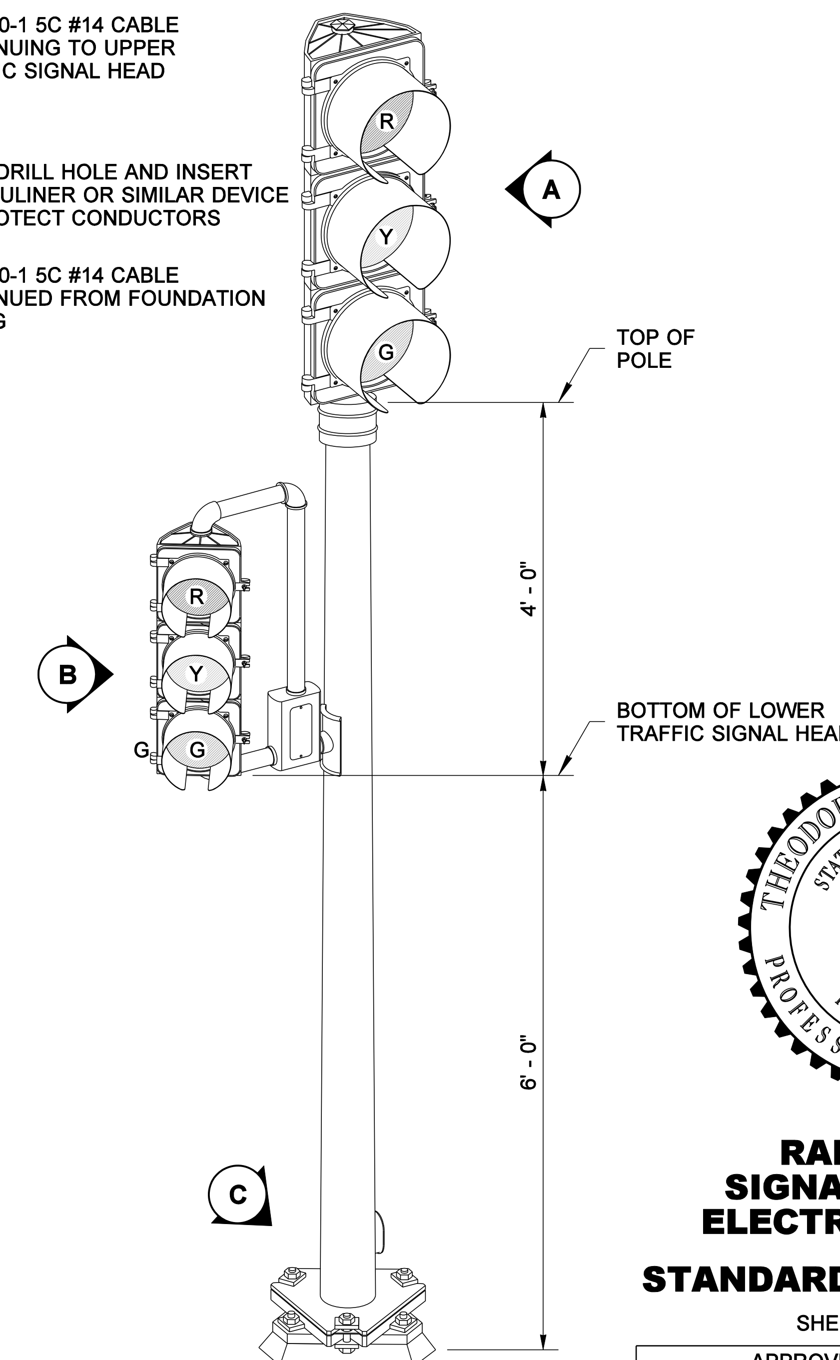
1. See **Standard Plan J-21.10** for Ramp Meter Signal Standard and Foundation Details
2. See **Standard Specifications 9-29.17** for additional Mounting Bracket and Fitting information not shown.
3. Grounding Conductor shall be non-insulated #4 AWG stranded copper, provide 3' - 0" min. slack. Clamp to steel reinforcing bar with connector suitable for use embedded in concrete.
4. Top of Leveling Nut height shall be 1" maximum above foundation.
5. Heat shrink cap all spare conductors not terminated on a terminal strip.

COLOR CODE	USE
R	RED DISPLAY
O	AMBER DISPLAY
G	GREEN DISPLAY
W	NEUTRAL CONDUCTOR
B	SPARE CONDUCTOR



DETAIL (C)

FOUNDATION WIRING



PERSPECTIVE VIEW

RAMP METER

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RAMP METER SIGNAL STANDARD ELECTRICAL DETAILS

STANDARD PLAN J-22.16-01

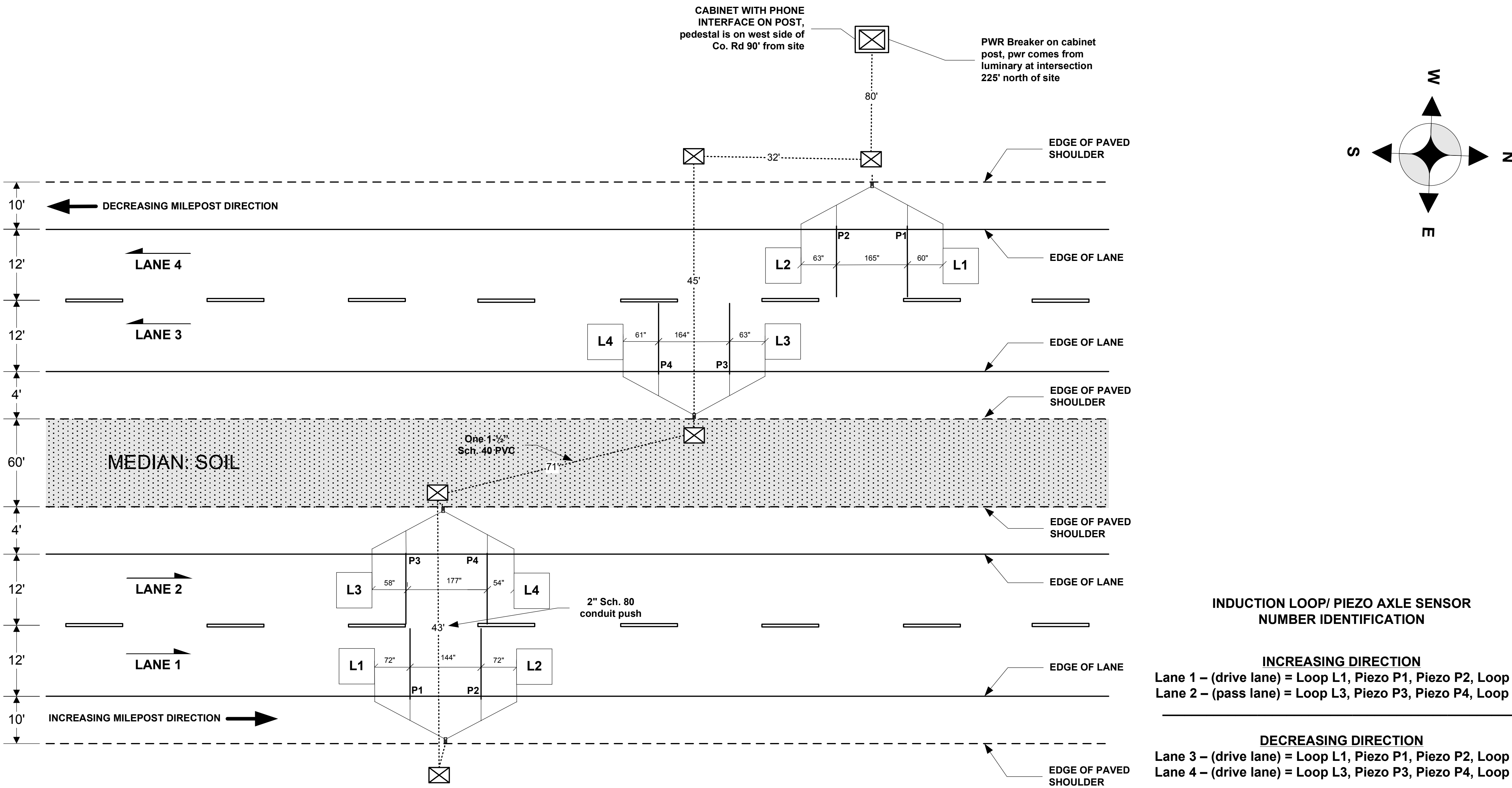
SHEET 1 OF 1 SHEET

APPROVED FOR PUBLICATION

Pasco Bakotich III — STATE DESIGN ENGINEER

06-03-10 — DATE

Washington State Department of Transportation



INDUCTION LOOP/ PIEZO AXLE SENSOR NUMBER IDENTIFICATION

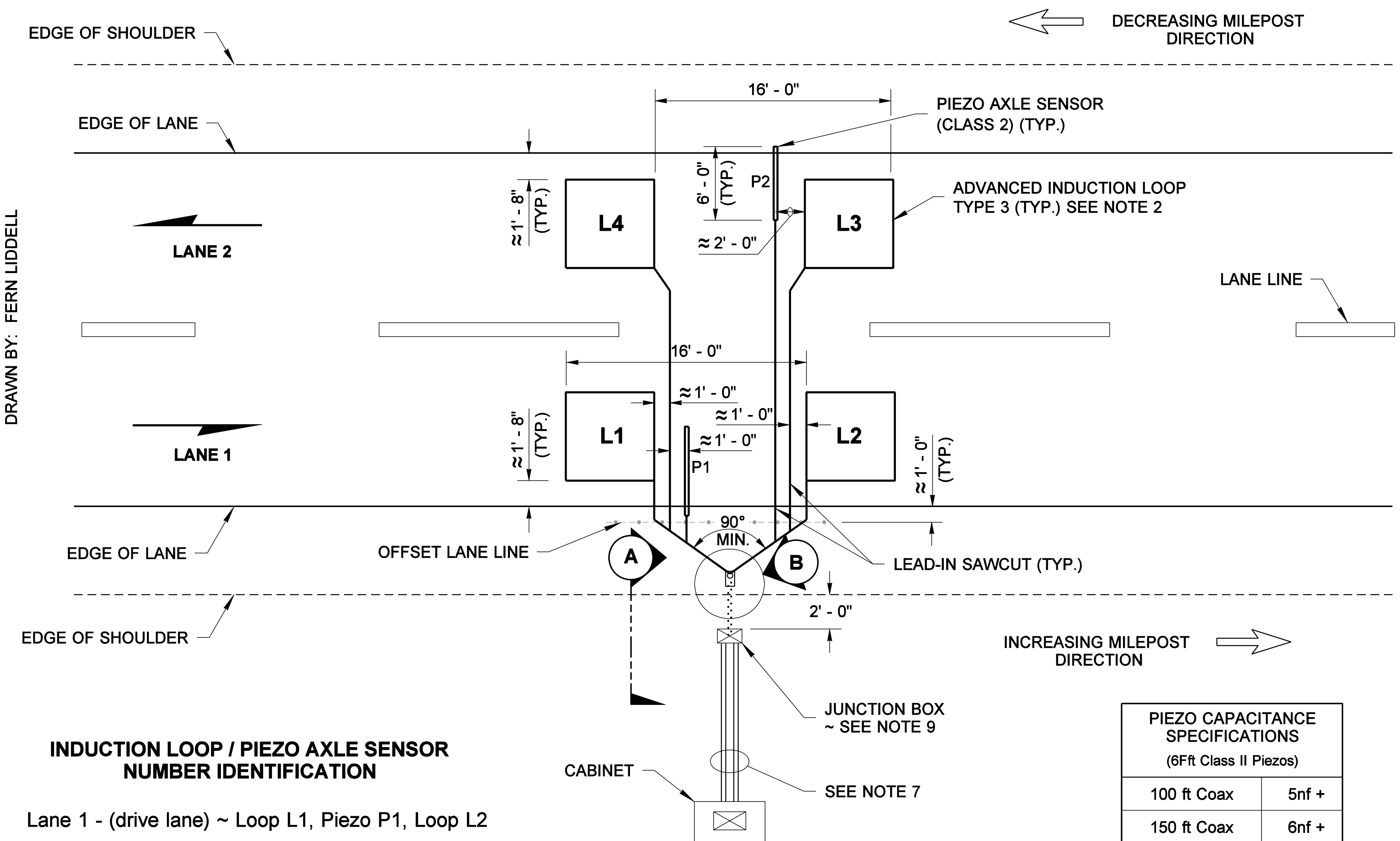
INCREASING DIRECTION
Lane 1 – (drive lane) = Loop L1, Piezo P1, Piezo P2, Loop L2
Lane 2 – (pass lane) = Loop L3, Piezo P3, Piezo P4, Loop L4

DECREASING DIRECTION
Lane 3 – (drive lane) = Loop L1, Piezo P1, Piezo P2, Loop L2
Lane 4 – (drive lane) = Loop L3, Piezo P3, Piezo P4, Loop L4

Layout drawn by:	Richard C. Rackleff	Pavement type:	ASPHALT	Counter type:	IRD 1068	Site number:	P28
Checked by:	Richard C. Rackleff	Power:	FULLTIME	Counter Serial #:	0506-1419	Site Location	SR 2 mp: 301.40
Date drawing completed:	2/24/2009	Original install date:	6/16/1992	Modem type:	ZDX	Site name:	CHATTAROY
Last drawing update:	2/24/2009	Last complete reinstall date:	10/31/2001	Modem serial #:	648023	Site Region:	EASTERN

Washington State Department of Transportation

DRAWN BY: FERN LIDDELL



INDUCTION LOOP / PIEZO AXLE SENSOR NUMBER IDENTIFICATION

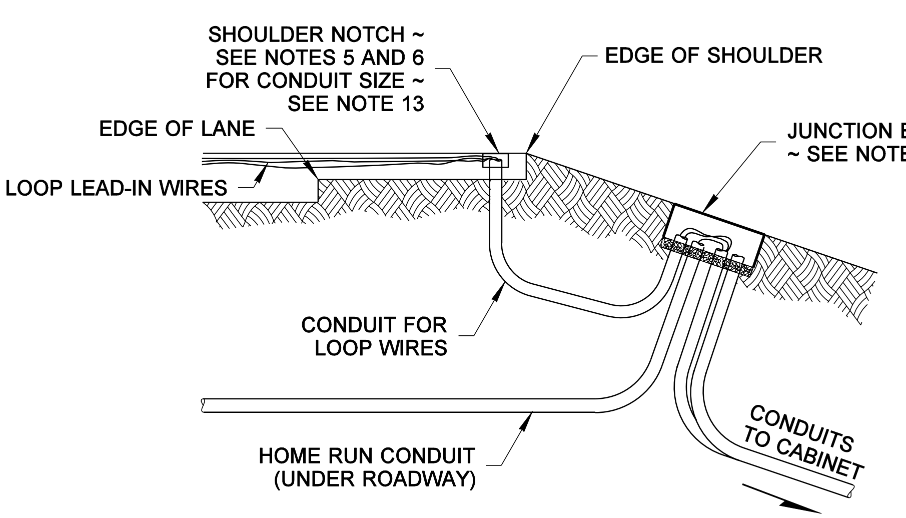
Lane 1 - (drive lane) ~ Loop L1, Piezo P1, Loop L2

Lane 2 - (pass lane) ~ Loop L3, Piezo P2, Loop L4

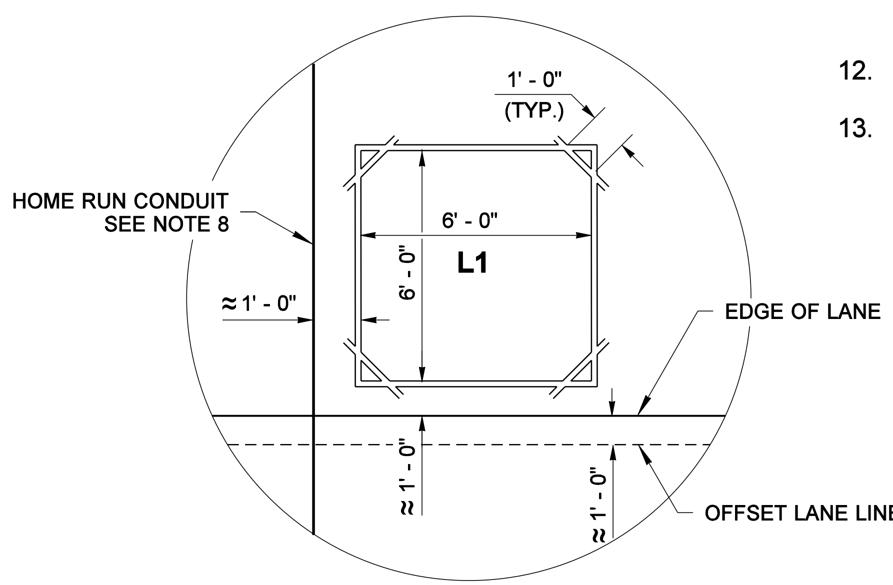
PIEZO CAPACITANCE SPECIFICATIONS (6Fft Class II Piezos)	
100 ft Coax	5nf +
150 ft Coax	6nf +
200 ft Coax	7nf +
250 ft Coax	8nf +

PLAN VIEW

TYPICAL 2 LANE PTR LAYOUT



SECTION A



LOOP SAW CUT DETAIL

NOTES

1. The contractor shall notify the Transportation Data Office (TDO) a minimum of five working days prior to the scheduled site installation. An inspector from the TDO shall be on site for all phases of installation. All sensors are to be tested by TDO electronics. If any sensors do not pass TDO specifications the contractor shall be responsible for replacement of faulty sensors at their own expense.

2. The loop inductance of two loops within the same lane shall be 20 micro henries of each other. All piezo ohms readings shall be O\L from shield to center conductor. See piezo specifications for piezo capacitance readings.

3. The loops and axle sensors shall be cut in the final lift of asphalt after lane splicing is completed. All PTR loops shall be space @ 16 in leading edge to leading edge.

4. For concrete pavement lanes with asphalt shoulders, install all of the piezo sensors and splices in the concrete lane. Also for concrete pavement lanes install the loops 4" to 6" away from the expansion joints.

5. The shoulder notch length along the roadway shall be 4" or the conduit length plus 2" or whichever is larger. The shoulder notch width perpendicular to the roadway shall be the conduit size plus 1/4".

6. After all sensor leads are installed, seal the end of the conduit with conduit sealant. See **Special Provisions** in the Contract for the material used to fill the notch in the shoulder, or use asphalt cold-patch.

7. Use schedule 40 PVC conduit from the Junction box to the Cabinet. Where there are 1 to 2 lanes, use 1 1/4" min. conduit for each direction. Where there are 3 lanes in each direction use 1 1/2" min. conduit for each direction of travel. Where there are 4 to 5 lanes in either direction of travel use one 2" min. conduit for each direction. Where there are 6 or more lanes in either direction use one 3" min. conduit for each direction.

8. Use schedule 80 PVC, HDPE, or steel conduit under the roadway. For conduit installation see **Standard Specification 8-20**.

9. Junction boxes installed in the paved shoulder or median shall be a heavy duty Junction box. If box is installed in unpaved shoulder use type 1 or 2. **See Standard Plan J-40.10** for size and type. See **Standard Specifications 9-29.2(1)B**. for further information.

10. All loop wire, loop leads, and piezo leads shall be labeled with colored electrical tape at all Junction boxes, Pull boxes and Cabinets, according to the color code identification chart, ~ sheet 2.

11. See **Standard Plan J-95.30** for Piezo Axle Sensor General Installation instructions.

12. For six lane layouts and above, see Contract.

13. For four lane layout wire applications and below, use 1" PVC conduit .
For layouts from five to ten lanes use 1 1/4" PVC conduit.
For layouts above ten lanes use 2" PVC conduit.

PRELIMINARY

PERMANENT TRAFFIC RECORDER INSTALLATIONS

STANDARD PLAN J-95.10-00

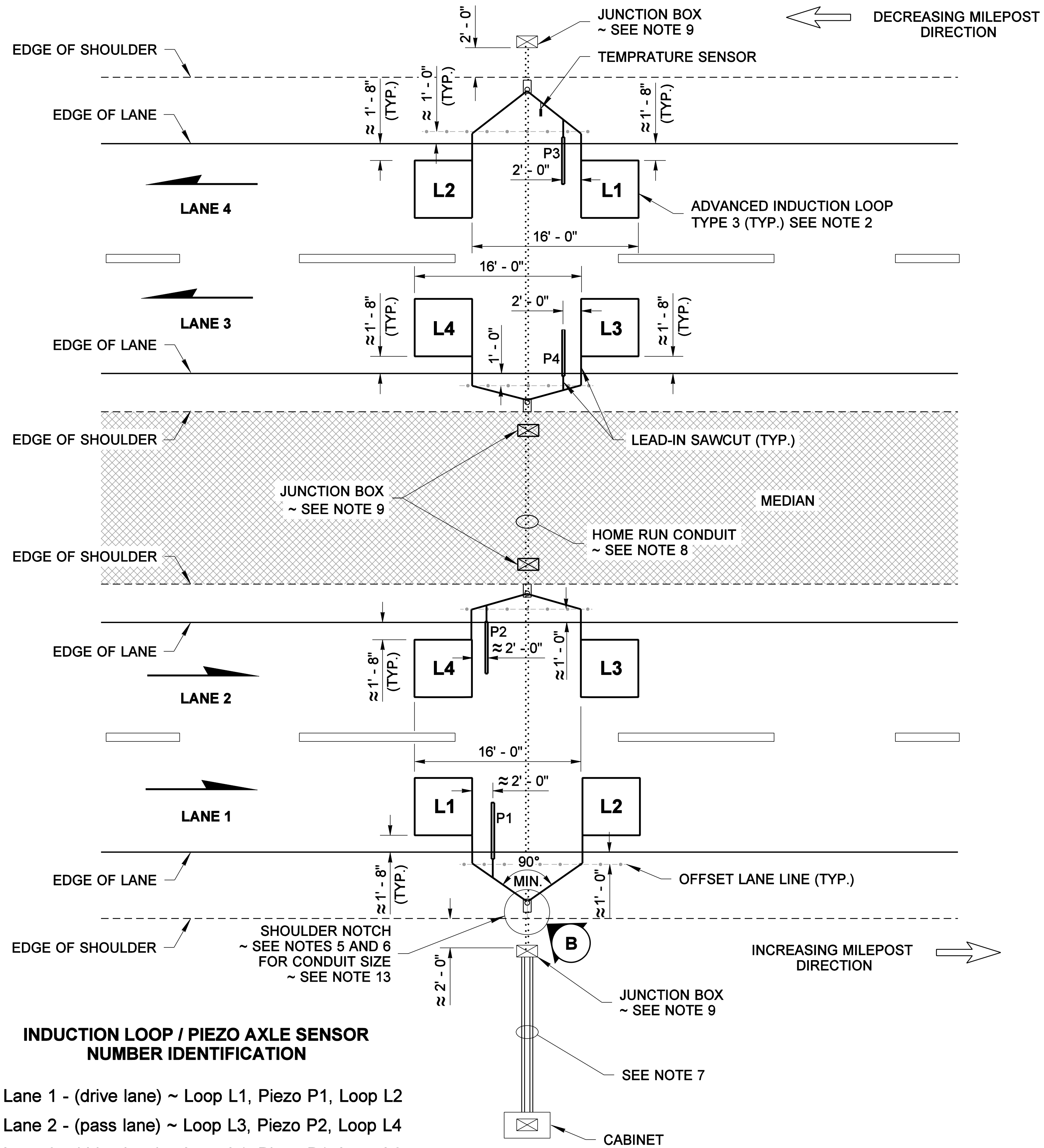
SHEET 1 OF 2 SHEETS

APPROVED FOR PUBLICATION

STATE DESIGN ENGINEER DATE

Washington State Department of Transportation

DRAWN BY: FERN LIDDELL



INDUCTION LOOP / PIEZO AXLE SENSOR NUMBER IDENTIFICATION

Lane 1 - (drive lane) ~ Loop L1, Piezo P1, Loop L2
Lane 2 - (pass lane) ~ Loop L3, Piezo P2, Loop L4
Lane 3 - (drive lane) ~ Loop L1, Piezo P1, Loop L2
Lane 4 - (pass lane) ~ Loop L3, Piezo P2, Loop L4

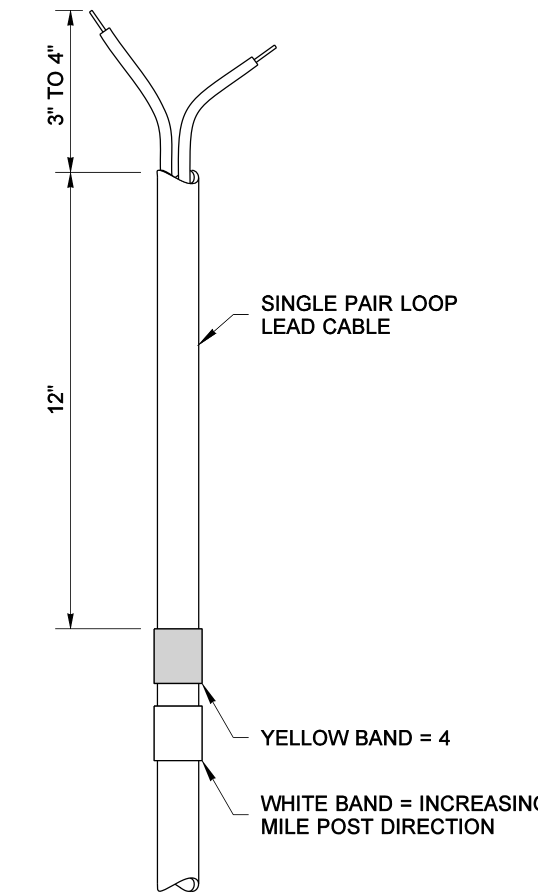
PLAN VIEW

TYPICAL 4 LANE PTR LAYOUT WITH MEDIAN

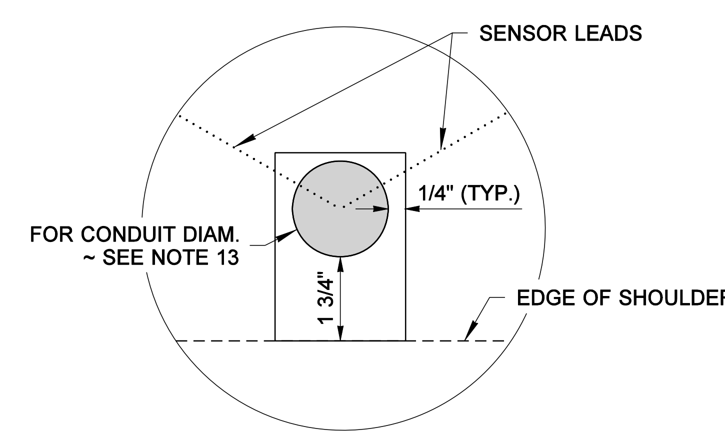
COLOR CODE IDENTIFICATION

COLOR	CIRCUIT NO.
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9
BROWN & BLACK	10
BROWN & BROWN	11
BROWN & RED	12
BROWN & ORANGE	13
BROWN & YELLOW	14
BROWN & GREEN	15
BROWN & BLUE	16
BROWN & VIOLET	17

WHITE IS ALSO USED FOR DESIGNATING INCREASING MILE POSTS



WIRE COLOR CODING (TYP.)



SHOULDER NOTCH DETAIL B

PRELIMINARY

PERMANENT TRAFFIC RECORDER INSTALLATIONS

STANDARD PLAN J-95.10-00

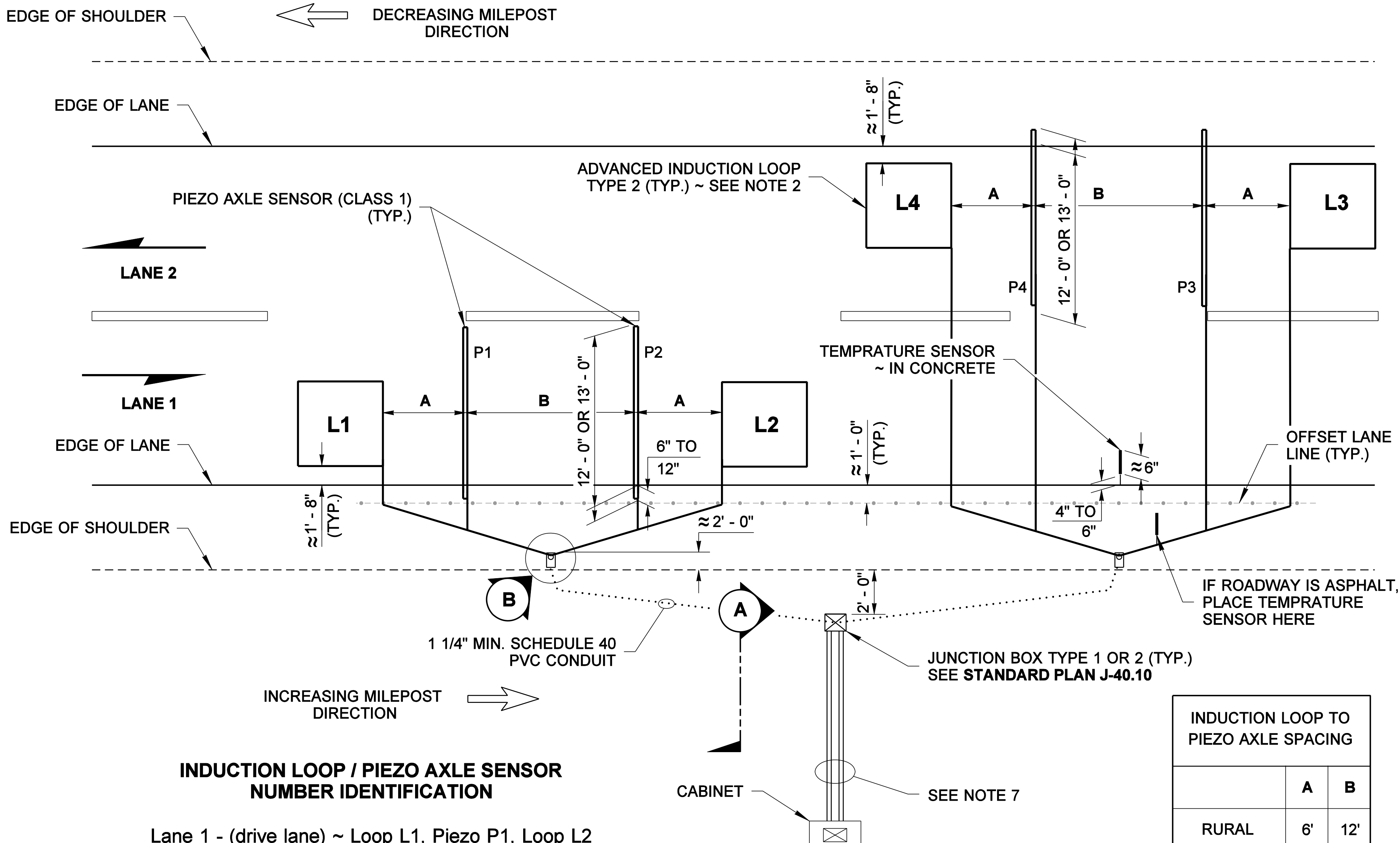
SHEET 2 OF 2 SHEETS

APPROVED FOR PUBLICATION

STATE DESIGN ENGINEER DATE

Washington State Department of Transportation

DRAWN BY: FERN LIDDELL



INDUCTION LOOP / PIEZO AXLE SENSOR NUMBER IDENTIFICATION

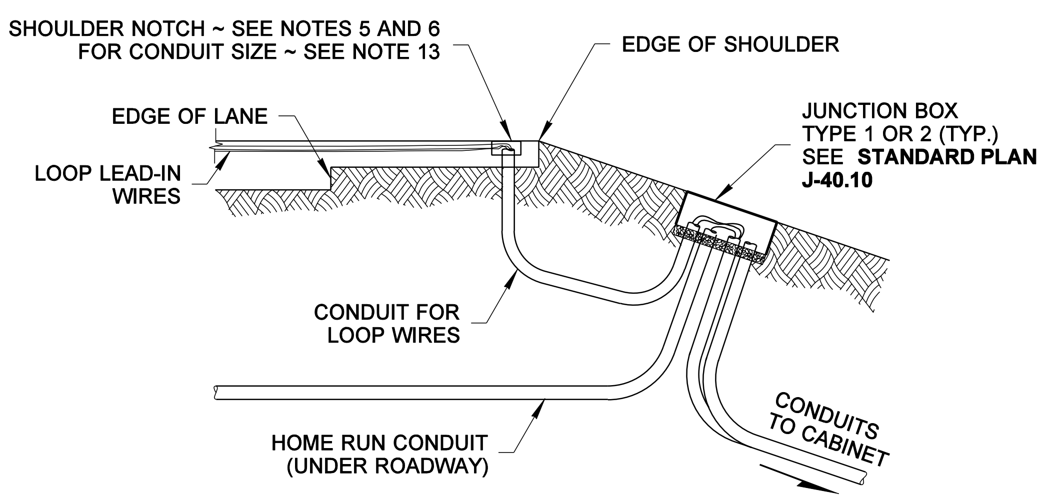
Lane 1 - (drive lane) ~ Loop L1, Piezo P1, Loop L2

Lane 2 - (pass lane) ~ Loop L3, Piezo P2, Loop L4

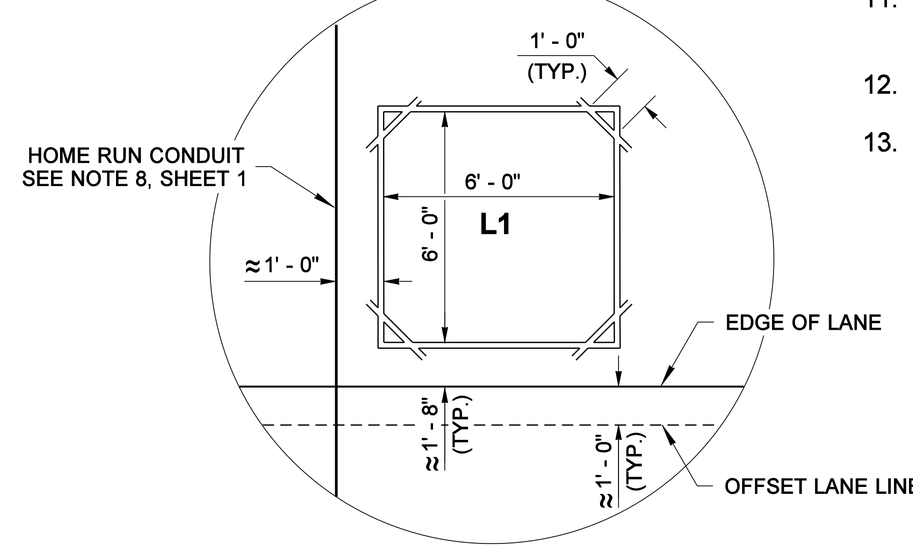
INDUCTION LOOP TO PIEZO AXLE SPACING	A	B
RURAL	6'	12'
URBAN	2'	10'

PLAN VIEW

TYPICAL 2 LANE FREEWAY



SECTION A



LOOP SAW-CUT DETAIL

NOTES

1. The contractor shall notify the Transportation Data Office (TDO) a minimum of five working days prior to the scheduled site installation. An inspector from the TDO shall be on site for all phases of installation. All sensors are to be tested by TDO electronics. If any sensors do not pass TDO specifications the contractor shall be responsible for replacement of faulty sensors at their own expense.
2. The loop inductance of two loops within the same lane shall be 20 micro henries of each other. All piezo ohms readings shall be O\L from shield to center conductor. See piezo specifications for piezo capacitance readings.
3. The loops and axle sensors shall be cut in the final lift of asphalt after lane splicing is completed. All PTR loops shall be spaced @ 16 in. leading edge to leading edge.
4. For concrete pavement lanes with asphalt shoulders, install all of the piezo sensors and splices in the concrete lane. Also for concrete pavement lanes install the loops 4" to 6" away from the expansion joints.
5. The shoulder notch length along the roadway shall be 4" or the conduit length plus 2" or whichever is larger. The shoulder notch width perpendicular to the roadway shall be the conduit size plus 1/4".
6. After all sensor leads are installed, seal the end of the conduit with conduit sealant. See **Special Provisions** in the Contract for the material used to fill the notch in the shoulder, or use asphalt cold-patch.
7. Use schedule 40 PVC conduit from the junction box to the cabinet. Where there are 1 to 2 lanes, use 1 1/4" min. conduit for each direction. Where there are 3 lanes in each direction use 1 1/2" min. conduit for each direction of travel. Where there are 4 to 5 lanes in either direction use one 2" conduit for each direction. Where there are 6 or more lanes in either direction use one 3" min. conduit for each direction.
8. Use schedule 80 PVC, HDPE, or steel conduit under the roadway. For conduit installation see **Standard Specification 8-20**.
9. Junction boxes installed in the paved shoulder or median shall be a heavy duty Junction box. If box is installed in unpaved shoulder use type 1 or 2. **See Standard Plan J-40.10** for size and type. For further information, see **Standard Specifications 9-29.2(1)B**.
10. All loop wire, loop leads, and piezo leads shall be labeled with colored electrical tape at all Junction boxes, Pull boxes and Cabinets, according to the color code identification chart ~ sheet 2.
11. See **Standard Plan J-95.30** for Piezo Axle Sensor General Installation instructions.
12. For six lanes and above layouts, see Contract.
13. For four lane layout wire applications and below, use 1" PVC conduit.
    For layouts from five to ten lanes, use 1 1/4" PVC conduit.
    For layouts above ten lanes, use 2" PVC conduit.

PRELIMINARY

WEIGH-IN-MOTION SITE INSTALLATION DETAILS
STANDARD PLAN J-95.20-00

SHEET 1 OF 2 SHEETS

APPROVED FOR PUBLICATION

STATE DESIGN ENGINEER DATE

Washington State Department of Transportation

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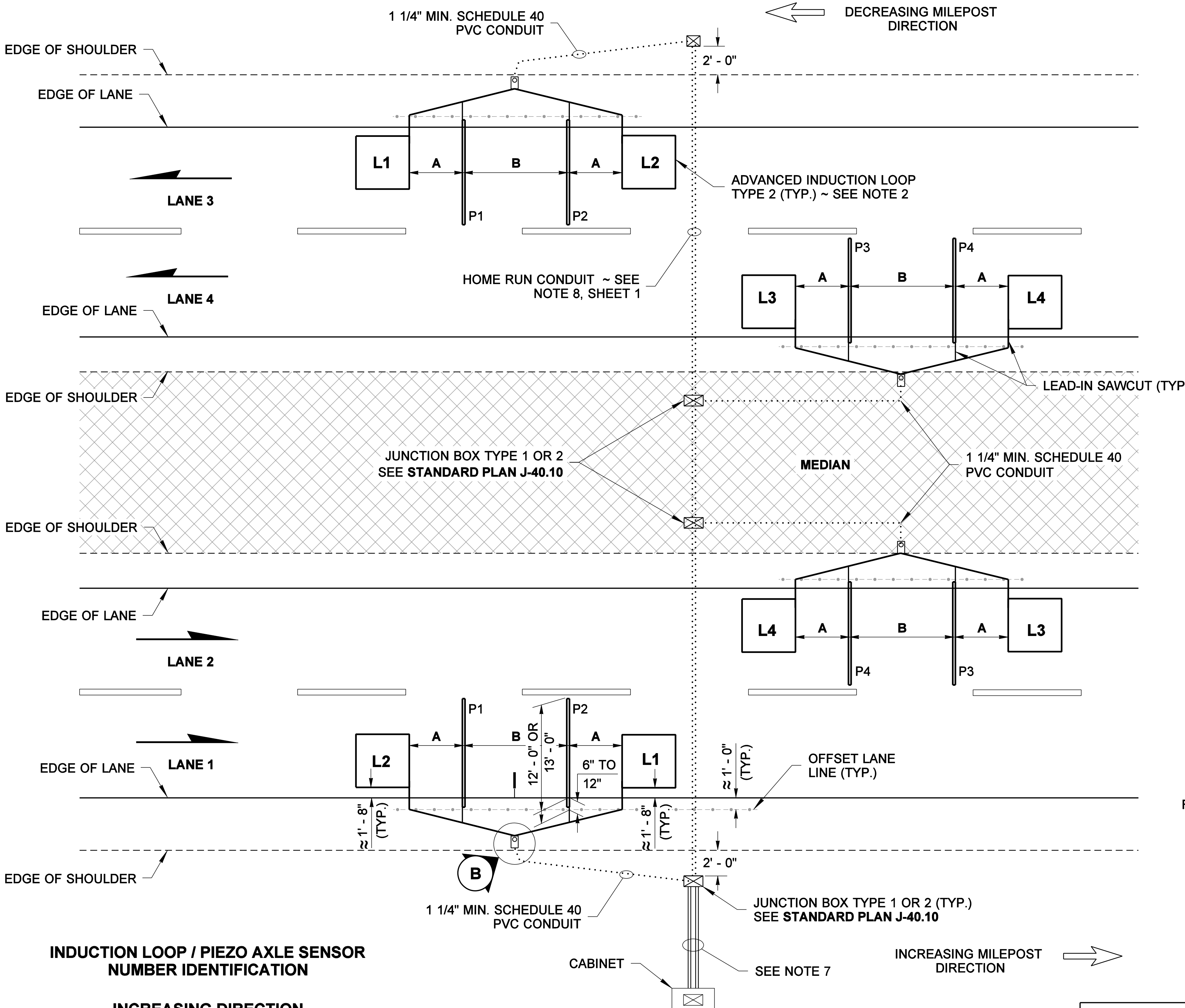


PLAN VIEW

TYPICAL FOUR LANE FREEWAY WITH MEDIAN

INDUCTION LOOP / PIEZO AXLE SENSOR NUMBER IDENTIFICATION

INCREASING DIRECTION

Lane 1 - (drive lane) ~ Loop L1, Piezo P1, Piezo P2, Loop L2

Lane 2 - (pass lane) ~ Loop L3, Piezo P3, Piezo P4, Loop L4

DECREASING DIRECTION

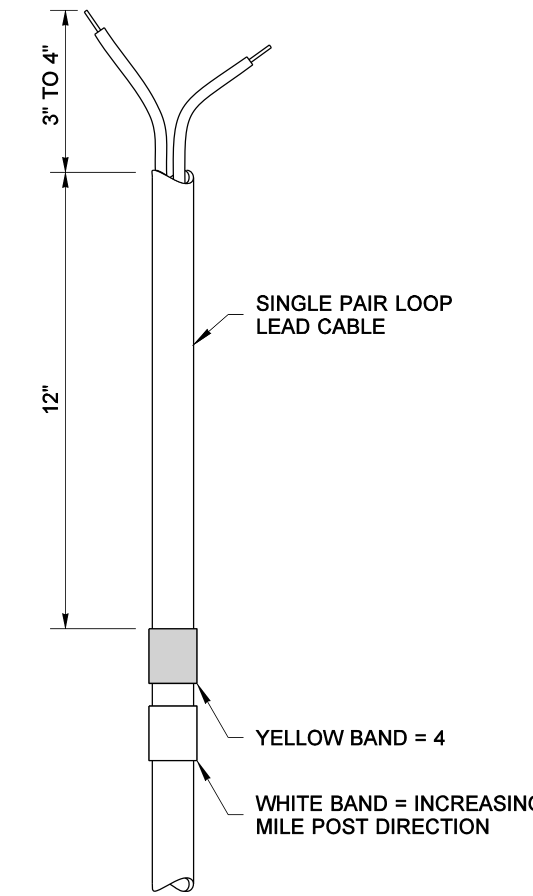
Lane 3 - (drive lane) ~ Loop L1, Piezo P1, Piezo P2, Loop L2

Lane 4 - (drive lane) ~ Loop L3, Piezo P3, Piezo P4, Loop L4

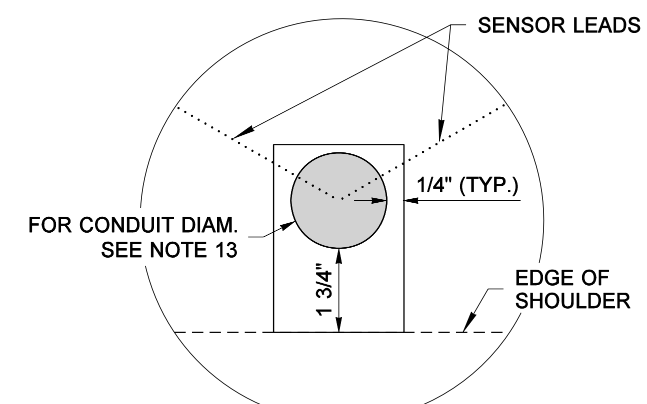
COLOR CODE IDENTIFICATION

COLOR	CIRCUIT NO.
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9
BROWN & BLACK	10
BROWN & BROWN	11
BROWN & RED	12
BROWN & ORANGE	13
BROWN & YELLOW	14
BROWN & GREEN	15
BROWN & BLUE	16
BROWN & VIOLET	17

WHITE IS ALSO USED FOR DESIGNATING INCREASING MILE POSTS



WIRE COLOR CODING (TYP.)



SHOULDER NOTCH

DETAIL B

INDUCTION LOOP TO PIEZO AXLE SPACING	A	B
RURAL	6'	12'
URBAN	2'	10'

PRELIMINARY

WEIGH-IN-MOTION SITE INSTALLATION FOR FOUR LANE HIGHWAY STANDARD PLAN J-95.20-00

SHEET 2 OF 2 SHEETS

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STATE DESIGN ENGINEER | DATE

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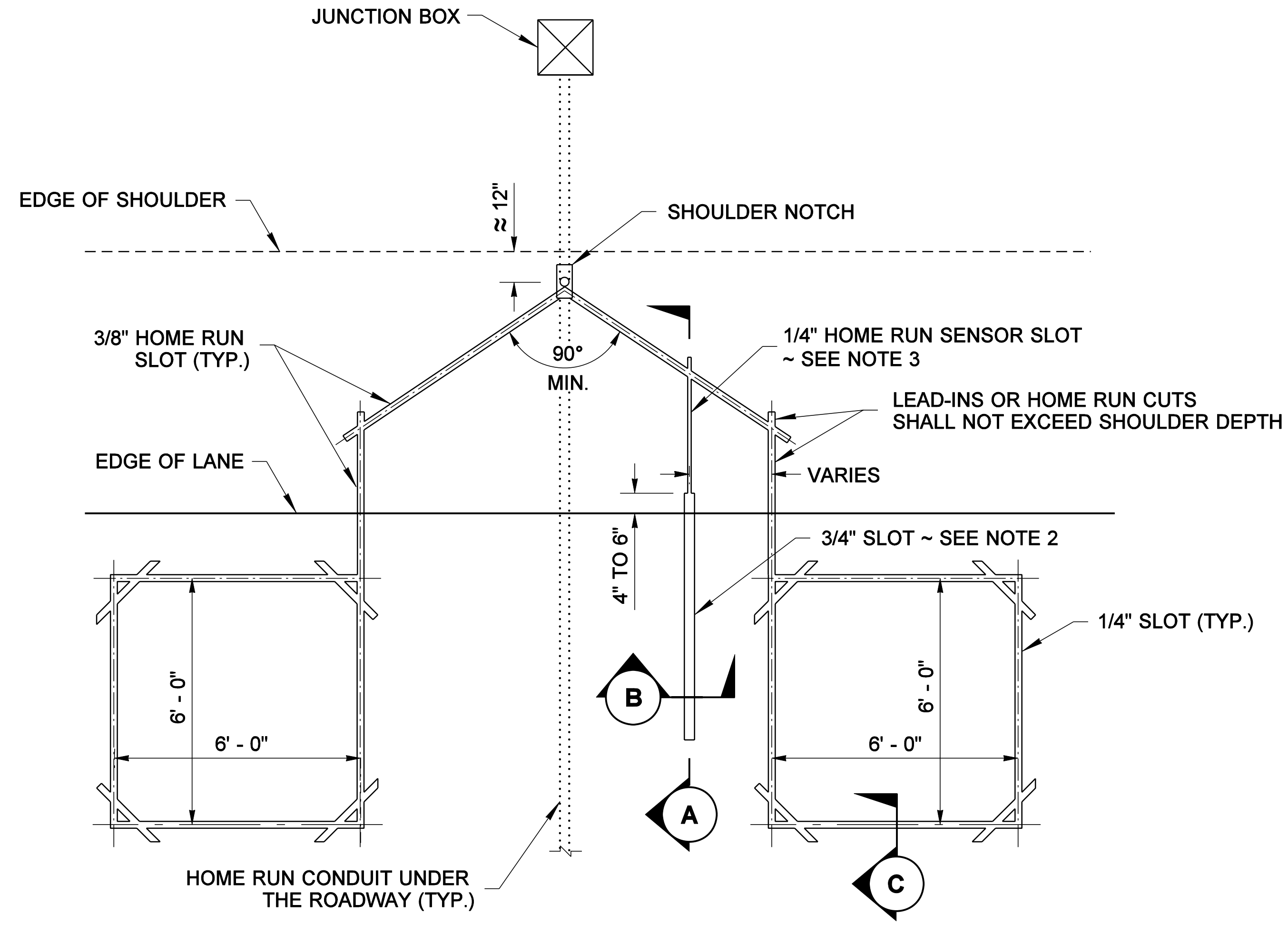
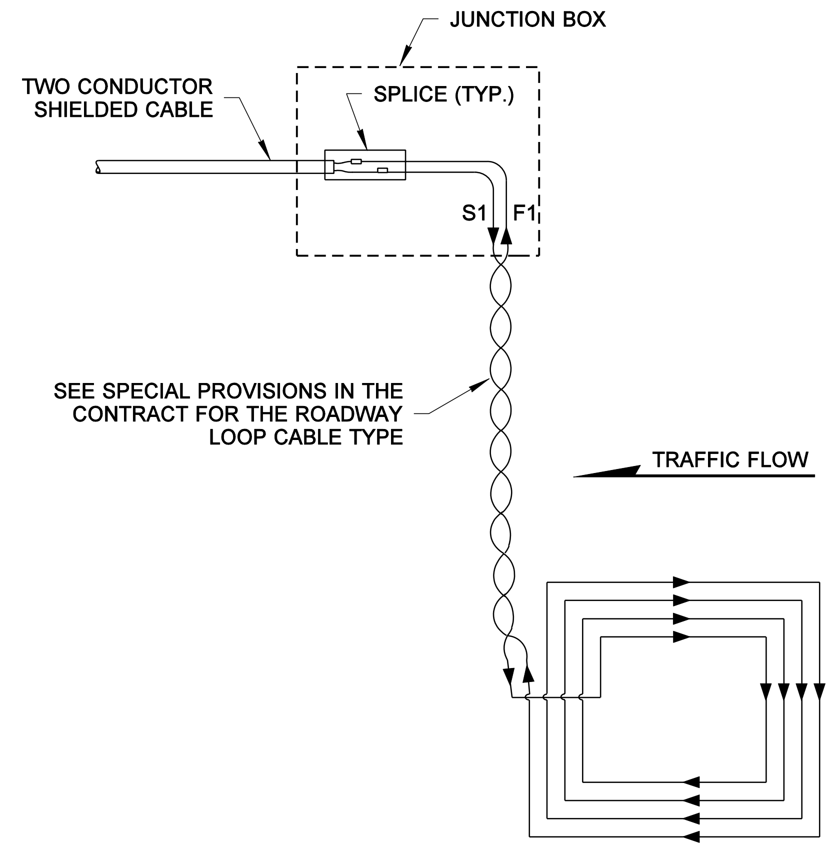


SAWCUT LAYOUT



TYPE 2 ADVANCE LOOP WIRING DIAGRAM

THESE ARE GENERAL INSTALLATION INSTRUCTIONS

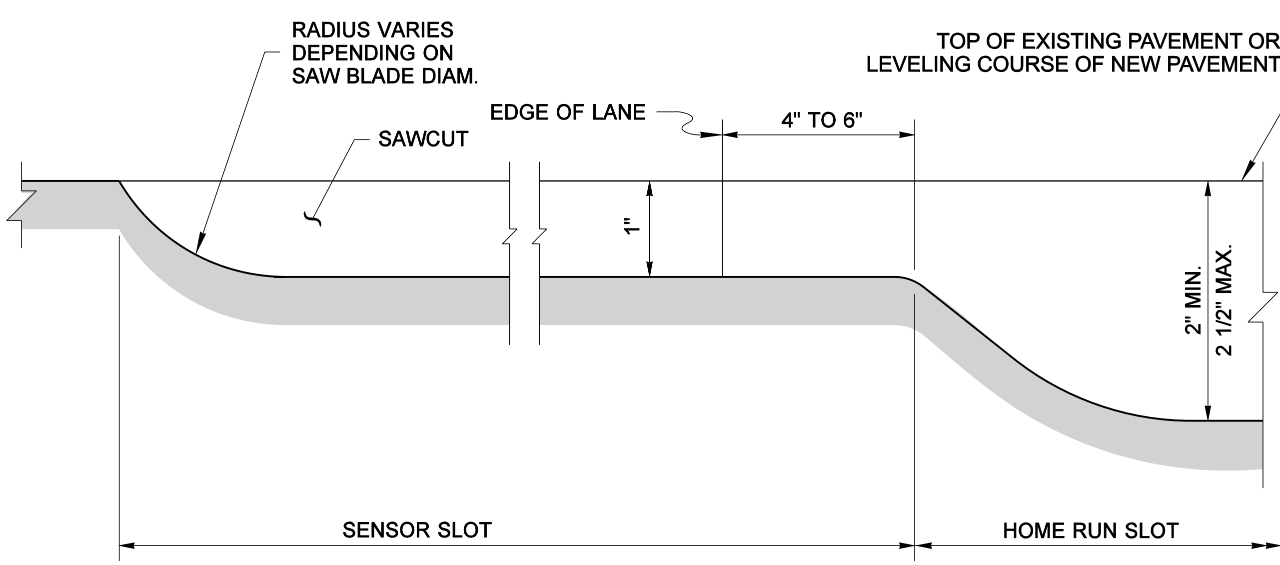
SEE SPECIFIC MANUFACTURER'S INSTALLATION INSTRUCTIONS IN THE SPECIAL PROVISIONS OF THE CONTRACT

1. Using pavement crayons, paint, tape measure and cord, carefully mark the layout of the sensor installation. Ensure sensors are placed exactly perpendicular to the flow of traffic and that all lines are straight. Verify that the passive cable length is enough to reach the cabinet. **DO NOT SPLICE CABLE**. Leave a 4' minimum cable length inside of the cabinet.

2. Using a wet-cutting pavement saw with a 3/4" diamond blade, wet-cut the slot for the sensor. The slot must be 3/4" wide, +/- 1/16" × 1" minimum deep. Cut the slot 8" longer than the sensor length, (including the lead attachment).

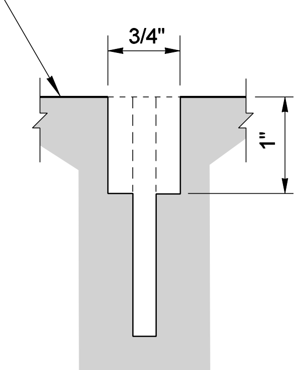
3. Cut home run slots for Piezo sensors. Center the home run slot on the sensor slot. Cut the home run slots 2" minimum to 2 1/2" maximum deep and 1/4" minimum wide. Cut the slots wider if installing conduit.

4. Using a power washer with water, remove and collect all the slurry and loose material from the slots. Sweep the slots with a stiff wire bristled brush. Dry all of the slots with a large capacity air compressor (150 CFM minimum). All of the slots and the pavement 1 ft. on either side must be completely dry.

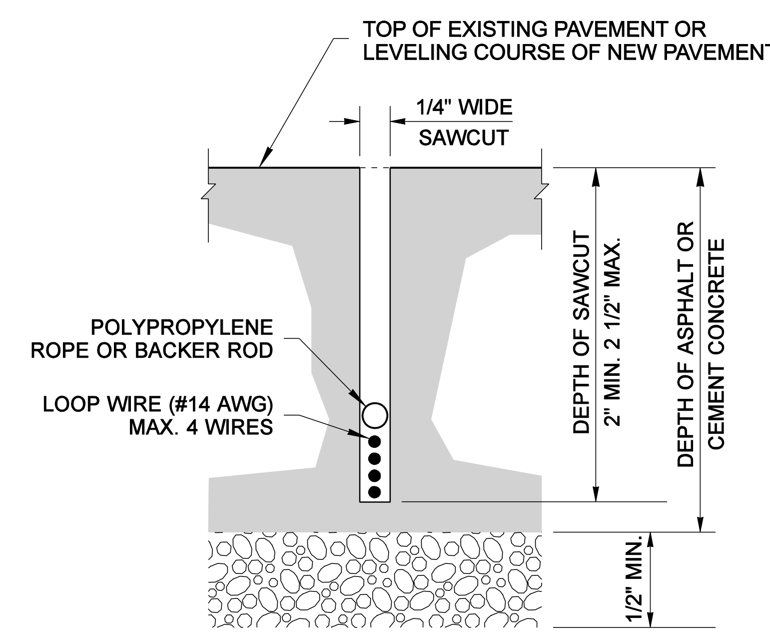


SECTION A

BEFORE SENSOR INSTALLATION



SECTION B



SECTION C

PRELIMINARY

PERMANENT TRAFFIC RECORDER AND WEIGH-IN-MOTION DETAILS
STANDARD PLAN J-95.30-00

SHEET 1 OF 2 SHEETS

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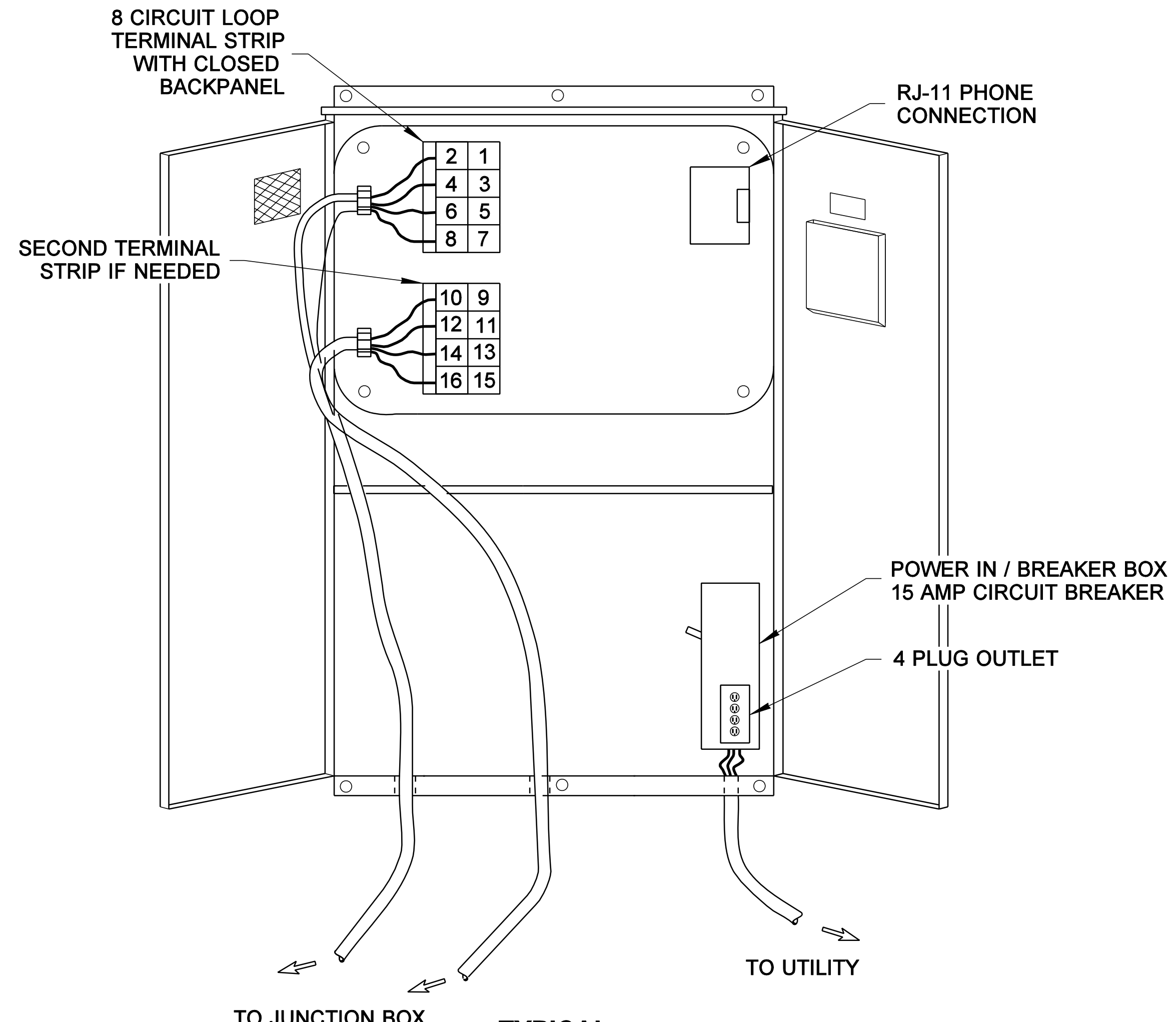
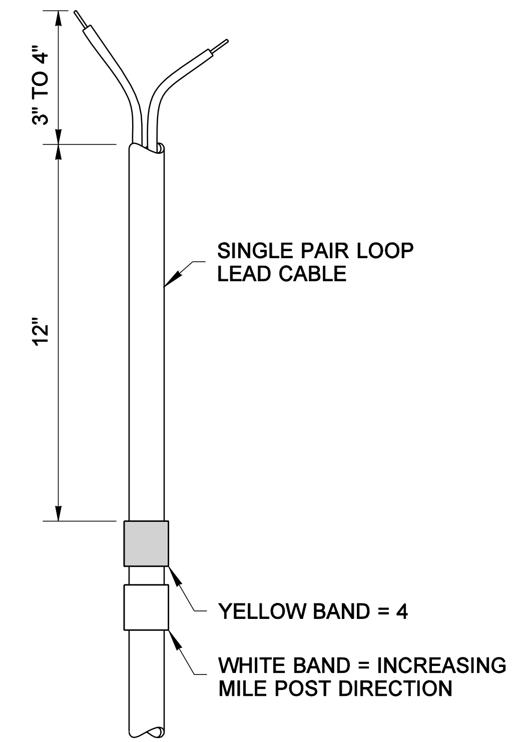


TYPICAL SERVICE CABINET

SEE NOTES 2 THRU 5

COLOR CODE IDENTIFICATION	
COLOR	**CIRCUIT NO.**
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9
BROWN & BLACK	10
BROWN & BROWN	11
BROWN & RED	12
BROWN & ORANGE	13
BROWN & YELLOW	14
BROWN & GREEN	15
BROWN & BLUE	16
BROWN & VIOLET	17

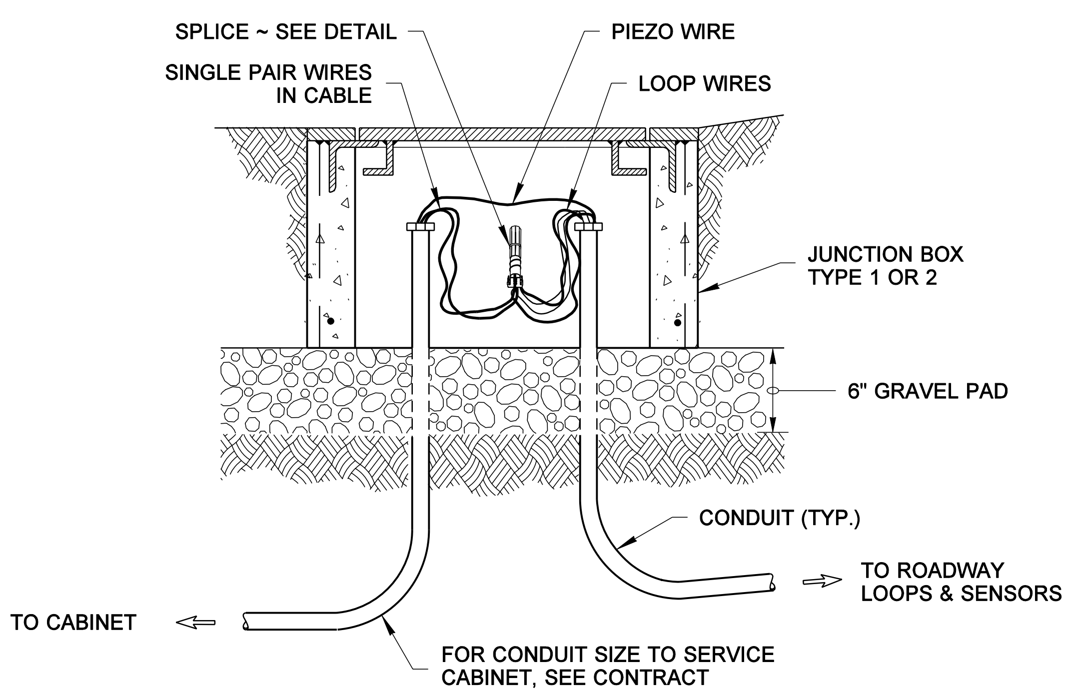
WHITE IS ALSO USED FOR DESIGNATING INCREASING MILE POSTS



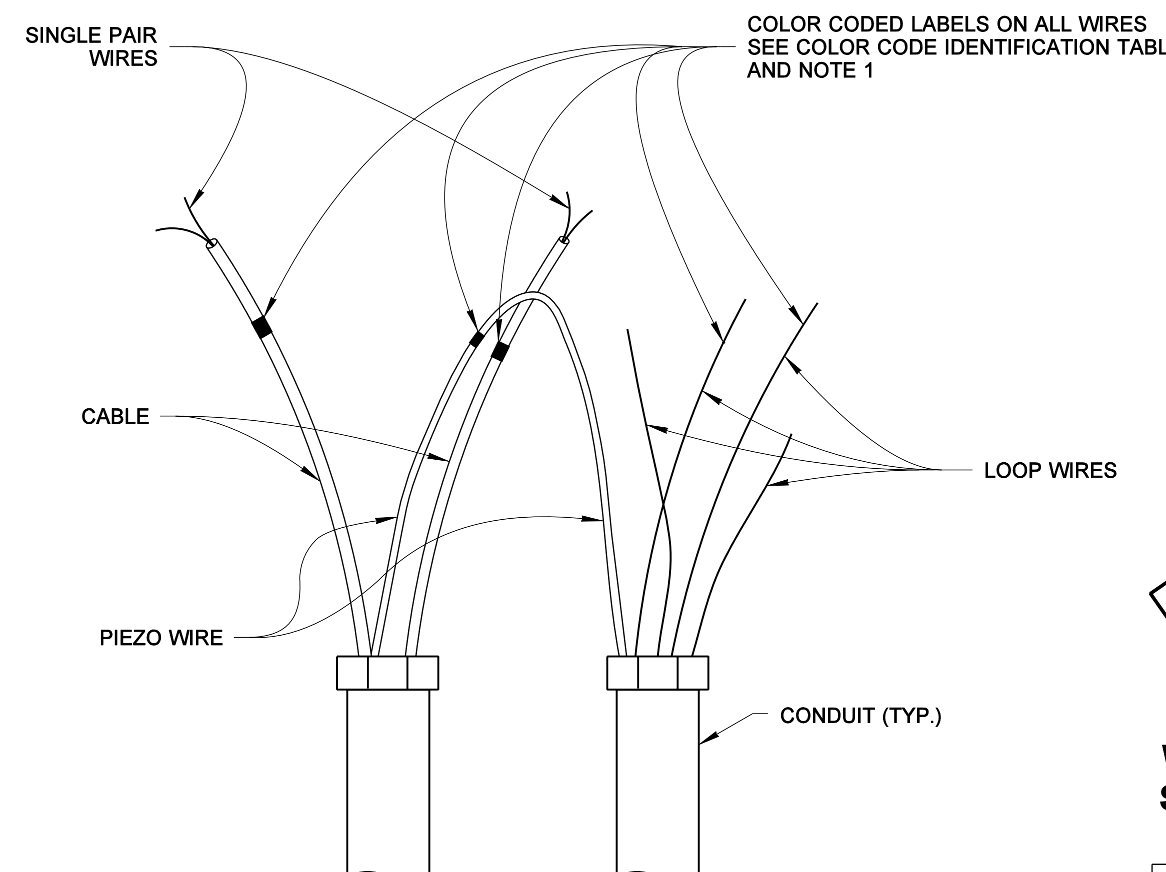
COLOR CODE WIRE DETAIL

NOTES

1. The Loop and Piezo leads in all Junction Boxes and Cabinets are to be color-coded. Use colored tape on each specific wire, see table. Wrap the tape on the wires approximately 6" beyond conduit in all Junction Boxes.
2. The maximum load in the cabinet is 5 Amps.
3. The cabinet may be pedestal or pad mount. See **Standard Plan J-6c** for details.
4. See **Special Provisions** in the contract for the Cabinet dimensions. See **Standard Specification 9-29** for other requirements.
5. For Grounding Details, See **Standard Plan J-9a**. See **Standard Specification 8-20** for other requirements.
6. For splice requirements, see **Standard Specification 9.29**.



JUNCTION BOX



JUNCTION BOX WIRING

(SHOWN PRIOR TO SPLICING)

PRELIMINARY

PERMANENT TRAFFIC RECORDER AND WEIGH-IN-MOTION DETAILS

STANDARD PLAN J-95.30-00

SHEET 2 OF 2 SHEETS

APPROVED FOR PUBLICATION

STATE DESIGN ENGINEER DATE

Washington State Department of Transportation

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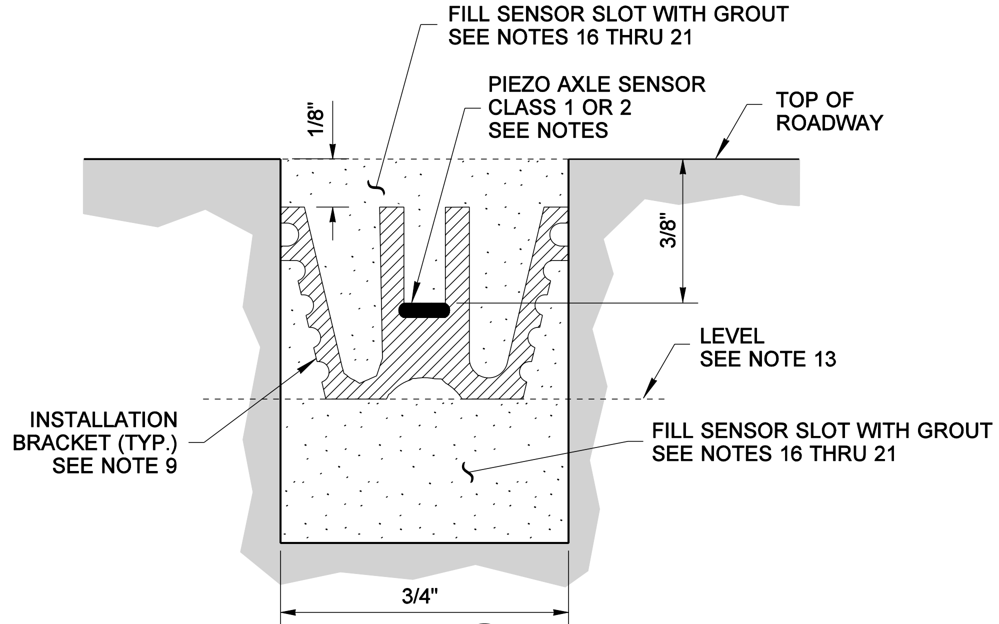
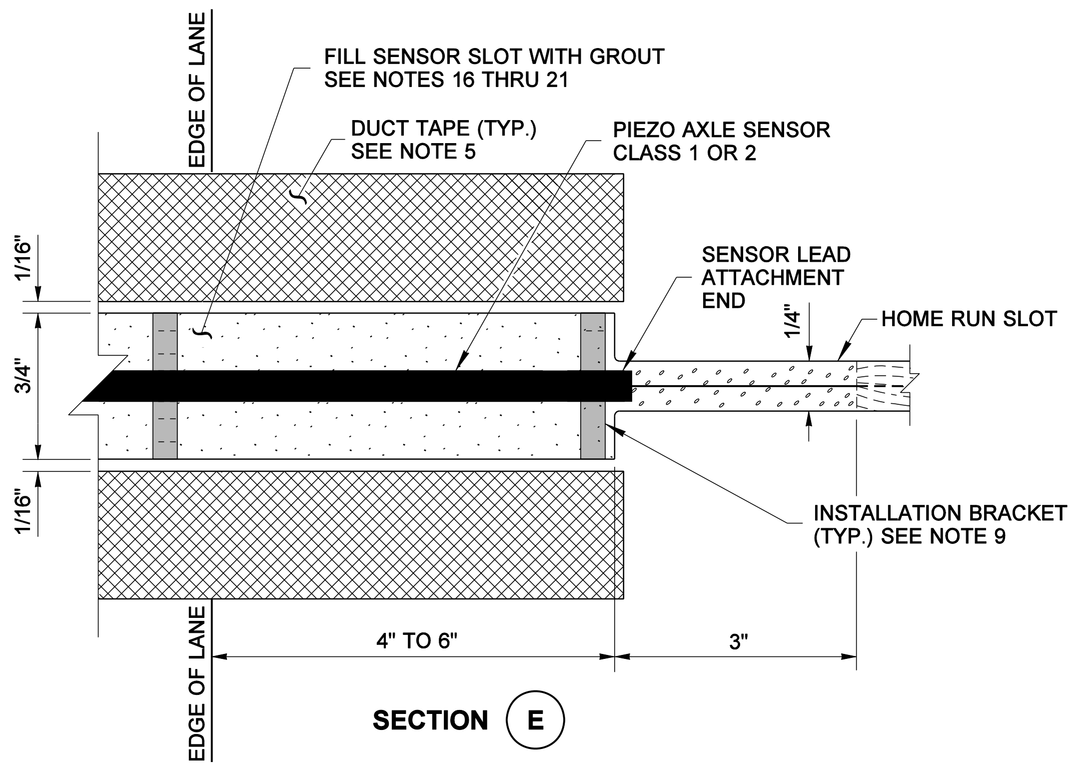
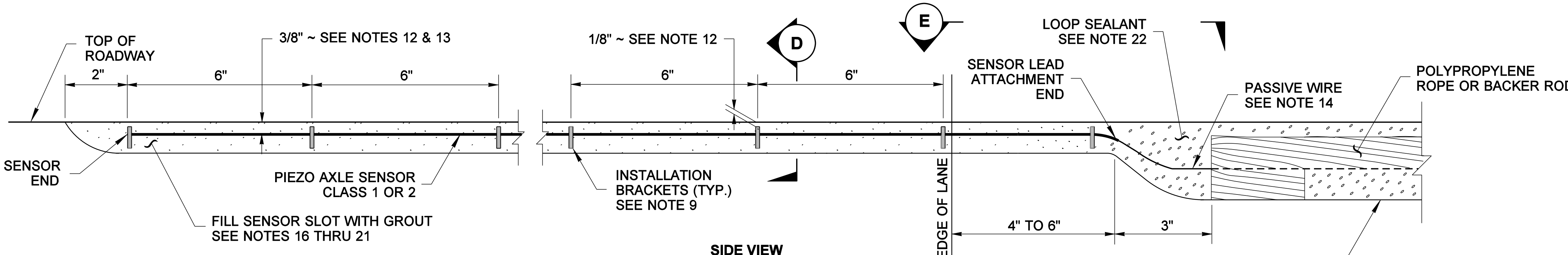


SECTION D



SECTION E



SIDE VIEW

BRACKET AND PIEZO LAYOUT

THESE ARE GENERAL INSTALLATION INSTRUCTIONS

SEE SPECIFIC MANUFACTURER'S INSTALLATION INSTRUCTIONS IN THE SPECIAL PROVISIONS OF THE CONTRACT

5. Place 2" duct tape along length of both sides of the sensor slot. Tape 1/16" away from the slot.
6. Visually inspect sensor to ensure it is straight without any twists or curls. Check passive cable for bare wire. Check lead attachment for cracks or gaps. Check the data sheet to ensure the correct sensor is being installed: Class 1 Piezo Axle sensor for Weigh-in-Motion, and Class 2 Piezo Axle sensor for Permanent Traffic Recorder.
7. Place the sensor on the tape next to the slot. Handle the sensor with clean latex (or equivalent) gloves.
8. Clean the sensor with the grit of a steel wool or emery pad. Wipe it down with isopropyl alcohol and a clean, lint free cloth.
9. Place the installation brackets on the sensor every 6" for the length of the sensor. Use the 3/4" brackets.
10. Place the sensor in the slot in the road. The end of the sensor should be at least 2" from the end of the slot, and should not touch the bottom of the slot. The lead attachment end should also not touch the bottom or the sides of the slot.
11. If any of the 3/4" brackets do not fit snugly against the sides of the slot or are loose, replace them with a 1" bracket.
12. Starting at the lead attachment end, position the sensor so that it is parallel to the surface of the road, approximately 3/8" below the surface of the road. At this depth, the installation brackets are 1/8" below the surface of the road.
13. Visually inspect the length of the sensor to ensure that it is at a uniform depth along its length and that it is level (not twisted, canted or bent).
14. Run the passive wire the length of the home run slot. Place the poly-propylene rope under and over the passive cable (inside the slot). This will keep the grout from running out into the deeper home run slot.
15. Place all of the induction loops to the site specifications.
16. See the Special Provisions in the contract for the grout type used for Weigh-in-Motion Peizo Sensors and Permanent Traffic recorder Peizo sensors.
17. Using a low speed mixing drill (450 rpm) and a mixing paddle, premix the grout for 2 minutes or until smooth. Add hardener to the grout and mix according to the manufacturer's instructions.
18. Pour the grout into the slot using a small bead. Make sure that the grout flows under the sensor slowly, eliminating air pockets. Start at the end and pour towards the lead attachment. Repeat until the slot is completely full of grout, at least in 2 passes, (approximately 1/2" thick each).
19. Using a putty knife or a trowel lightly spread the grout smooth along the length of the slot. The resin should be slightly higher (1/16") than the tape as it will shrink while curing.
20. Remove the tape as soon as the final grout pour is complete.
21. Once the grout for the Weigh in Motion Peizo Sensors is cured, (approximately 35 minutes, depending on grout type and ambient temperature), use a belt sander to sand the top of the grout flush with the surface.
22. Allow the loop sealant and the grout for both sensor installations to fully cure (45-60 minutes) before opening to traffic.

PRELIMINARY

PIEZO INSTALLATION DETAILS
STANDARD PLAN J-95.40-01

SHEET 1 OF 1 SHEET

APPROVED FOR PUBLICATION

STATE DESIGN ENGINEER DATE

Washington State Department of Transportation

README

CALIBRATION SPREADSHEET

Newman Lake, SR290 MP17 East Bouna 4-May-04
Loop-Piezo-Piezo-Loop S.O. 6240

	Steer	Drive			Trailer			GVW						
		1st axle	2nd axle	Total	1st axle	2nd axle	Total		Axle 1-2	Axle 2-3	Axle 3-4	Axle 4-5	Length	Speed
Actual	12.46			33.18			35.54	81.18	14.3	4.6	36	5	71.65	52
Pass	*1st Axle*	*2nd Axle*	*3rd Axle*	*Total*	*4th Axle*	*5th Axle*	*Total*	*GVW*	Axle 1-2	Axle 2-3	Axle 3-4	Axle 4-5	Length	Speed
108	23.80	30.55	30.60	61.15	9.95	47.70	57.65	142.60	14.5	4.5	35.9	4.9	70.0	53.0
233	24.95	31.10	32.55	63.65	9.85	48.75	58.60	147.20	14.5	4.5	35.9	4.9	70.0	53.0
338	24.65	31.05	30.95	62.00	9.85	49.65	59.50	146.15	14.5	4.6	35.9	4.9	70.0	53.0
411	13.70	17.80	16.95	34.75	5.40	28.00	33.40	81.85	14.5	4.6	35.9	4.9	71.0	52.0
500	12.85	17.45	17.80	35.25	5.70	27.60	33.30	81.40	14.5	4.5	35.9	4.9	70.0	53.0
584	14.75	18.35	18.20	36.55	5.70	27.95	33.65	84.95	14.5	4.6	35.8	4.9	71.0	53.0
692	13.85	18.65	16.80	35.45	5.95	28.30	34.25	83.55	14.6	4.5	35.9	4.9	70.0	53.0
771	14.05	18.40	18.60	37.00	5.95	28.85	34.80	85.85	14.5	4.6	36.0	4.9	70.0	52.0
835	13.40	18.70	17.75	36.45	5.65	28.65	34.30	84.15	14.5	4.6	35.9	4.9	71.0	52.0
906	14.10	20.25	17.65	37.90	6.05	29.95	36.00	88.00	14.5	4.6	35.8	4.9	70.0	52.0

	Steer	*Drive*	*Trailer*	*GVW*	*Axle 1-2*	*Axle 2-3*	*Axle 3-4*	*Axle 4-5*	*Length*	*Speed*
Pass #	*% err*	*% err*	*% err*	*% err*	*err ft*	*err ft*	*err ft*	*err ft*	*ft*	*err MPH*
108	91.01%	84.30%	62.21%	75.66%	0.2	-0.1	-0.1	-0.1	-1.7	1.0
233	100%	91.83%	64.88%	81.33%	0.2	-0.1	-0.1	-0.1	-1.7	1.0
338	97.83%	86.86%	67.42%	80.03%	0.2	0.0	-0.1	-0.1	-1.7	1.0
411	9.95%	4.73%	-6.02%	0.83%	0.2	0.0	-0.1	-0.1	-0.7	0.0
500	3.13%	6.24%	-6.30%	0.27%	0.2	-0.1	-0.1	-0.1	-1.7	1.0
584	18.38%	10.16%	-5.32%	4.64%	0.2	0.0	-0.2	-0.1	-0.7	1.0
692	11.16%	6.84%	-3.63%	2.92%	0.3	-0.1	-0.1	-0.1	-1.7	1.0
771	12.76%	11.51%	-2.08%	5.75%	0.2	0.0	0.0	-0.1	-1.7	0.0
835	7.54%	9.86%	-3.49%	3.66%	0.2	0.0	-0.1	-0.1	-0.7	0.0
906	13.16%	14.23%	1.29%	8.40%	0.2	0.0	-0.2	-0.1	-1.7	0.0
average	10.87%	9.08%	-3.65%	3.78%	0.2	0.0	-0.1	-0.1	-1.4	0.6
std dev	4.78%	3.32%	2.66%	2.82%	0.0	0.1	0.1	0.0	0.5	0.5

Units of Measure: Kips & Fe

IRD FORM No.: 5A

AXLE	PASS #:	1	PASS #:	2	PASS #:	3	PASS #:	4	PASS #:	5
	Veh. ID#:	108	Veh. ID#:	233	Veh. ID#:	338	Veh. ID#:	411	Veh. ID#:	500
	Length :	70	Length :	70	Length :	70	Length :	71	Length :	70
	Speed :	53	Speed :	53	Speed :	53	Speed :	52	Speed :	53
	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2
1	25.20	22.40	25.30	24.60	23.60	25.70	13.70	13.70	13.00	12.70
2	29.10	32.00	31.30	30.90	30.90	31.20	16.80	18.80	17.70	17.20
3	28.90	32.30	33.60	31.50	31.90	30.00	17.40	16.50	17.60	18.00
4	10.80	9.10	10.50	9.20	10.50	9.20	5.80	5.00	6.10	5.30
5	47.40	48.00	49.20	48.30	49.30	50.00	27.60	28.40	27.20	28.00
GVW	141.40	143.80	149.90	144.50	146.20	146.10	81.30	82.40	81.60	81.20

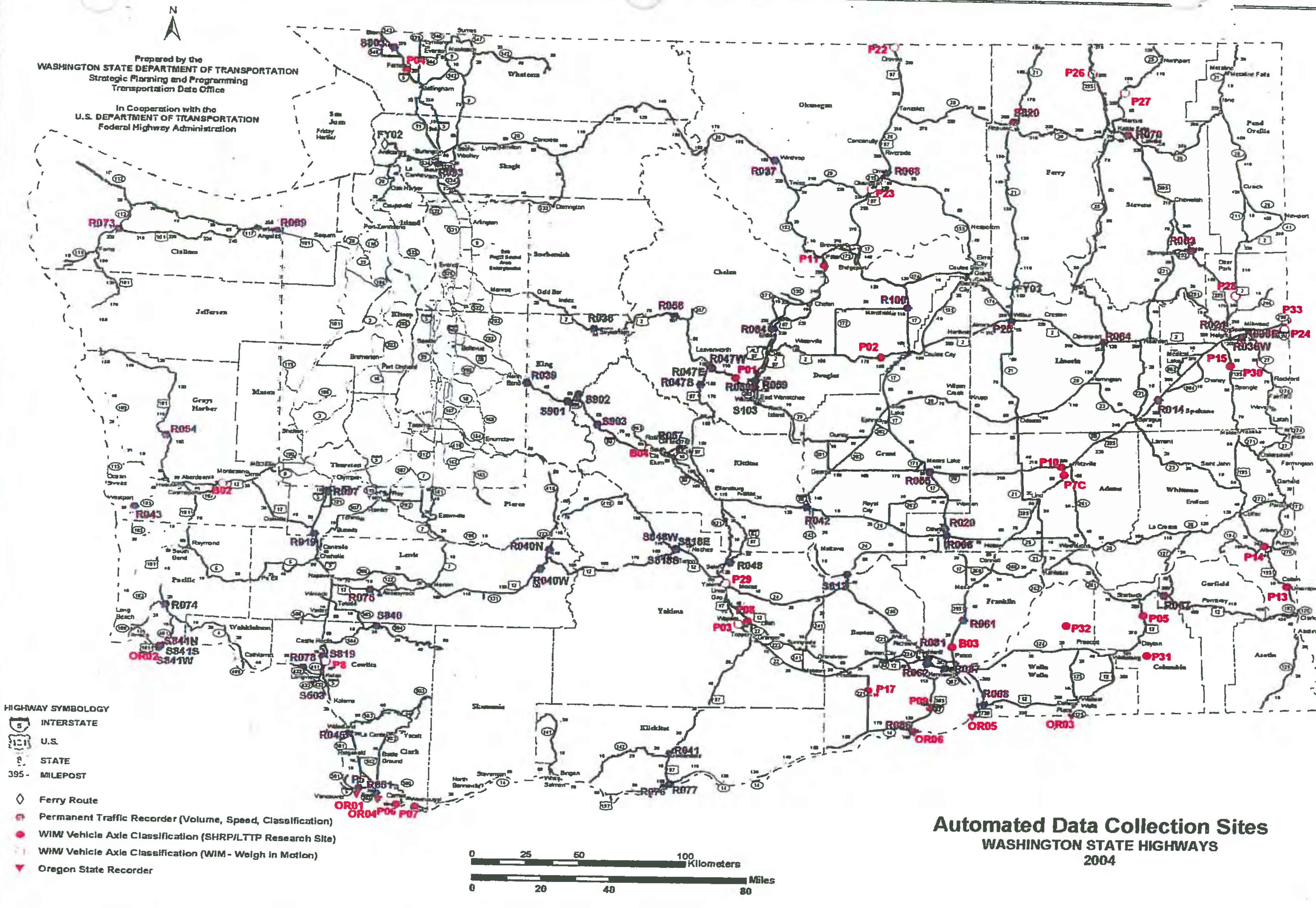
Axle Spacings		Axle Spacings		Axle Spacings		Axle Spacings		Axle Spacings	
1-2	14.50	1-2	14.5	1-2	14.5	1-2	14.5	1-2	14.5
2-3	4.50	2-3	4.5	2-3	4.6	2-3	4.6	2-3	4.5
3-4	35.90	3-4	35.9	3-4	35.9	3-4	35.9	3-4	35.9
4-5	4.90	4-5	4.9	4-5	4.9	4-5	4.9	4-5	4.9
	5		5.0		5.0		5.0		5.0

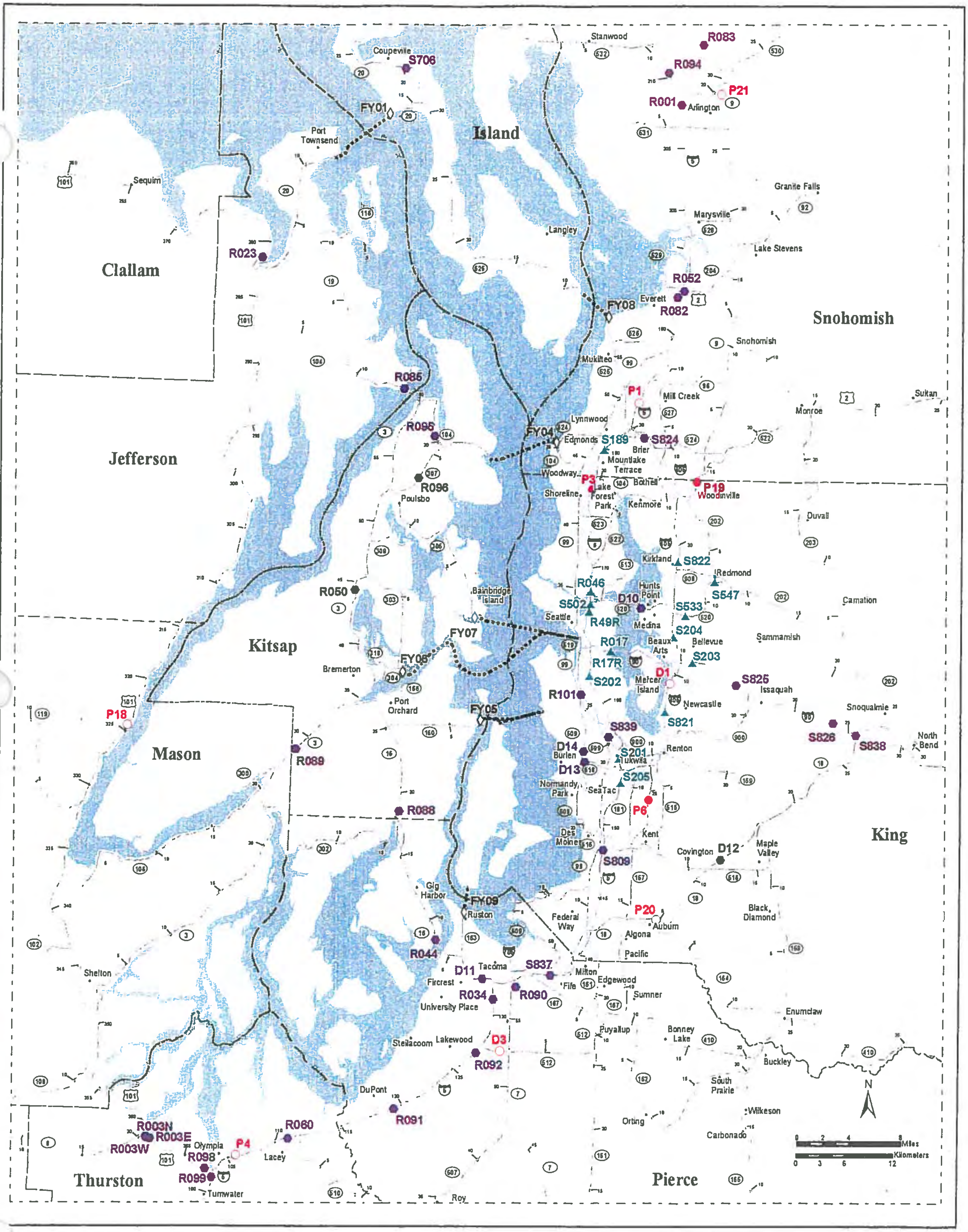
Wait for 5 passes to get New Calibra

CF1	0.657	Enter present cali
CF2	0.677	Enter present cali
Avg GVW 1	145.83	Average
Avg GVW 2	144.80	Average
New CF1	0.366	
New CF2	0.38	

AXLE	PASS #:	6	PASS #:	7	PASS #:	8	PASS #:	9	PASS #:	10
	Veh. ID#:	584	Veh. ID#:	692	Veh. ID#:	771	Veh. ID#:	835	Veh. ID#:	906
	Length :	71	Length :	70	Length :	70	Length :	71	Length :	70
	Speed :	53	Speed :	53	Speed :	52	Speed :	52	Speed :	52
	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2
1	15.70	13.80	13.70	14.00	14.70	13.40	14.30	12.50	14.60	13.60
2	18.50	18.20	18.40	18.90	18.40	18.40	18.40	19.00	20.00	20.50
3	18.30	18.10	16.00	17.60	18.30	18.90	17.80	17.70	18.30	17.00
4	6.10	5.30	6.10	5.80	6.50	5.40	5.90	5.40	6.50	5.60
5	28.10	27.80	28.40	28.20	28.70	29.00	28.00	29.30	29.90	30.00
GVW	86.70	83.20	82.60	84.50	86.60	85.10	84.40	83.90	89.30	86.70

Axle Spacings		Axle Spacings		Axle Spacings		Axle Spacings		Axle Spacings	
1-2	14.5	1-2	14.6	1-2	14.5	1-2	14.5	1-2	14.5
2-3	4.6	2-3	4.5	2-3	4.6	2-3	4.6	2-3	4.6
3-4	35.8	3-4	35.9	3-4	36.0	3-4	35.9	3-4	35.8
4-5	4.9	4-5	4.9	4-5	4.9	4-5	4.9	4-5	4.9
	5.0		5.0		5.0		5.0		5.0


Prepared by the
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
Strategic Planning and Programming
Transportation Data Office
In Cooperation with the
U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
N
HIGHWAY SYMBOLOGY
INTERSTATE
U.S.
STATE
395 - MILEPOST
Ferry Route
Permanent Traffic Recorder (Volume, Speed, Classification)
WIM Vehicle Axle Classification (SHRP/LTTP Research Site)
WIM Vehicle Axle Classification (WIM - Weigh in Motion)
Oregon State Recorder
0 25 60 100 Kilometers
0 20 40 80 Miles
Automated Data Collection Sites
WASHINGTON STATE HIGHWAYS
2004



2004 Puget Sound Enlargement

Automated Data Collection Sites

- ◊ Ferry Route
- ▲ Northwest Region Volume Recorder
- ● Permanent Traffic Recorder (Volume, Speed, Classification)
- ● WIM/ Vehicle Axle Classification (SHRP/LTPP Research Site)
- ○ WIM/ Vehicle Axle Classification (WIM - Weigh in Motion)

Communications

Outcome 3: The Five Methods of Data Transfer

1. Twisted Pair
2. Fiber Optics
3. Digital Cellular
4. Cellular IP
5. Radio IP

Two Types of Communication: Twisted Pairs and Fiber Optics

Both use a modem: meaning to modulate/demodulate.
A modem can be used to send digital data over a phone or fiber optic line. The sending modem modulates the data into a signal that is compatible with the phone or f/o line and the receiving modem demodulates the signal back into digital data. 170 controllers send their information in packets. A packet consists of a message that contains between 1 and 1500 eight-bit bytes.

Ex: 170 Controller----Modem----P.O.T.S. or F/O Line-------Central Computer

Twisted Pairs

It is normally made of 22 or 24 AWG wire and is always described in pairs.
The two wires in each pair must be twisted together to preserve signal quality.
*The twisting of the wire prevents "crosstalk" from other pairs in the same wire bundle. Each pair consists of a tip (+) wire and a ring (-) wire.

Two Types of Color Coding: Solid-Color and Band Striped

Solid Color Coding means using only one color of wire for identification.

Ex: Pair one is: Green/Red (tip/ring), Pair two is: Black/Yellow (tip/ring)

Band Striped Coding means using the base color of the insulation along with a smaller band of color repeated along the length of that base insulation.

Ex: Pair one is: White (base)with a Blue band (tip)/ Blue(base) with a White band (ring)

Mainline ITS 25 TWP Cable Assignments

	Pair Number	Function	
White/Blue	1	CMD	170 Ramp / Data / Gate Controller #1
White/Orange	2	RTN	170 Ramp / Data / Gate Controller #1
White/Green	3	CMD	170 Ramp / Data / Gate Controller #2
White/Brown	4	RTN	170 Ramp / Data / Gate Controller #2
White/Grey	5	CMD	COHU Camera Control
Red/Blue	6	RTN	COHU Camera Control
Red/Orange	7	CMD	NTCIP VMS
Red/Green	8	RTN	NTCIP VMS
Red/Brown	9	CMD	Legacy VMS Control #1
Red/Grey	10	RTN	Legacy VMS Control #1
Black/Blue	11	CMD	Legacy VMS Control #2
Black/Orange	12	RTN	Legacy VMS Control #2
Black/Green	13	CMD/RTN	HARS Sign Control #1
Black/Brown	14	CMD/RTN	HARS Sign Control #2
Black/Grey	15	CMD/RTN	HART Tranmitter Control #1
Yellow/Blue	16	CMD/RTN	HART Tranmitter Control #2
Yellow/Orange	17	CMD/RTN	Weather Station #1
Yellow/Green	18	CMD/RTN	Weather Station #2
Yellow/Brown	19	CMD	170 Ramp / Data / Gate Controller #3
Yellow/Grey	20	RTN	170 Ramp / Data / Gate Controller #3
Violet/Blue	21	MISC/SPARE	
Violet/Orange	22	MISC/SPARE	
Violet/Green	23	MISC/SPARE	
Violet/Brown	24	MISC/SPARE	
Violet/Grey	25	MISC/SPARE	

Pair	Wire	Color
1	1	White
	2	Blue
2	3	White
	4	Orange
3	5	White
	6	Green
4	7	White
	8	Brown
5	9	White
	10	Slate (Grey)
6	11	Red

Communications

	12	Blue
7	13	Red
	14	Orange
8	15	Red
	16	Green
9	17	Red
	18	Brown
10	19	Red
	20	Slate (Grey)
11	21	Black
	22	Blue
12	23	Black
	24	Orange
13	25	Black
	26	Green
14	27	Black
	28	Brown
15	29	Black
	30	Slate (Grey)
16	31	Yellow
	32	Blue
17	33	Yellow
	34	Orange
18	35	Yellow
	36	Green
19	37	Yellow
	38	Brown
20	39	Yellow
	40	Slate (Grey)
21	41	Violet
	42	Blue
22	43	Violet
	44	Orange
23	45	Violet
	46	Green
24	47	Violet
	48	Brown
25	49	Violet
	50	Slate (Grey)

Communications

Twisted Pair Troubleshooting

Clip one alligator clip to ground and the other to one conductor (blue of the first pair). Listen with the butt set "off hook" key in both positions. Then move the clip to the other conductor (white). Listen again. They should both sound equal if the circuit is good. You are measuring capacitance and are simply looking for a balanced pair of wires. Water or corrosion is the most common cause of noise on a circuit in the northwest. WSDOT TWP is more susceptible to water induced noise because we don't use common battery (-48 vdc) on the line all the time. Battery tends to dry out the pair over time and evaporate the water. Noise on the line confuses the VAX into thinking it's carrier tone with data. The result is usually a locked up modem or in your case, a "marginal" message. Ring out pairs using a telco style tone generator, measure them as described before and then tag and date them as good pairs. Remember that the rule of thumb is "tip top, ring right" In the telco world, the ring conductor has the battery and has the color while the tip conductor has no battery and no color. In a color scheme of blue, orange, green, brown, slate, they are all ring conductors matched up with white tip pairs. It's important that the proper tip and ring go together because they are wound around each other much like the wires in a loop tail out. Be on the lookout for "split pairs", ones where the ring conductors are landed correctly but the tip conductors are switched. They will always sound imbalanced.

Each controller shall have an ACIA C20 wrap-around with the following pin connections:

C20 Function Pin		C20 Function Pin	
(J) RTS	to	(M)	CTS
(J) RTS	to	(H)	DCD
(K) DATA-IN	to	(L)	DATA-OUT

Communications

Fiber Optics

An optical fiber is a long thin strand of glass called a di-electric (about the diameter of a human hair). They are arranged in bundles called optical cables and transmit light signals over long distances.

*A single fiber is made of: the Core, the Cladding and the Jacket.

Modern F/O cables can carry a signal up to 60 miles. For longer distances we use HUBS. The HUB contains equipment that picks up and re-transmits the signal down the next F/O segment (at full strength) until it reaches its destination.

Fiber Optic Video

Citations

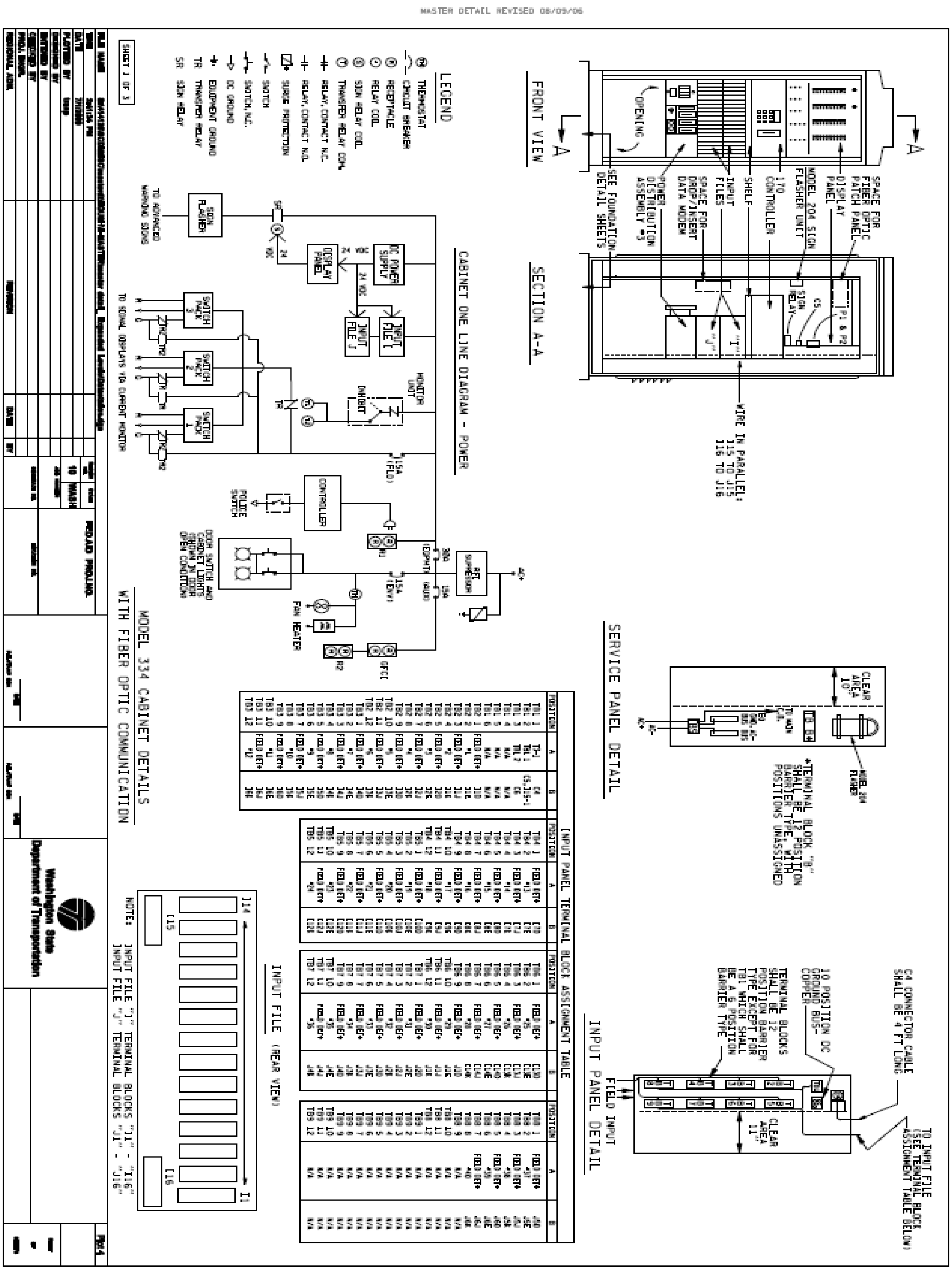
HowStuffWorks, Inc., How Stuff Works it's good to know, "How Fiber Optics Work". Copyright 1998-2007

HowStuffWorks, Inc., How Stuff Works it's good to know, "How Modems Work". Copyright 1998-2007

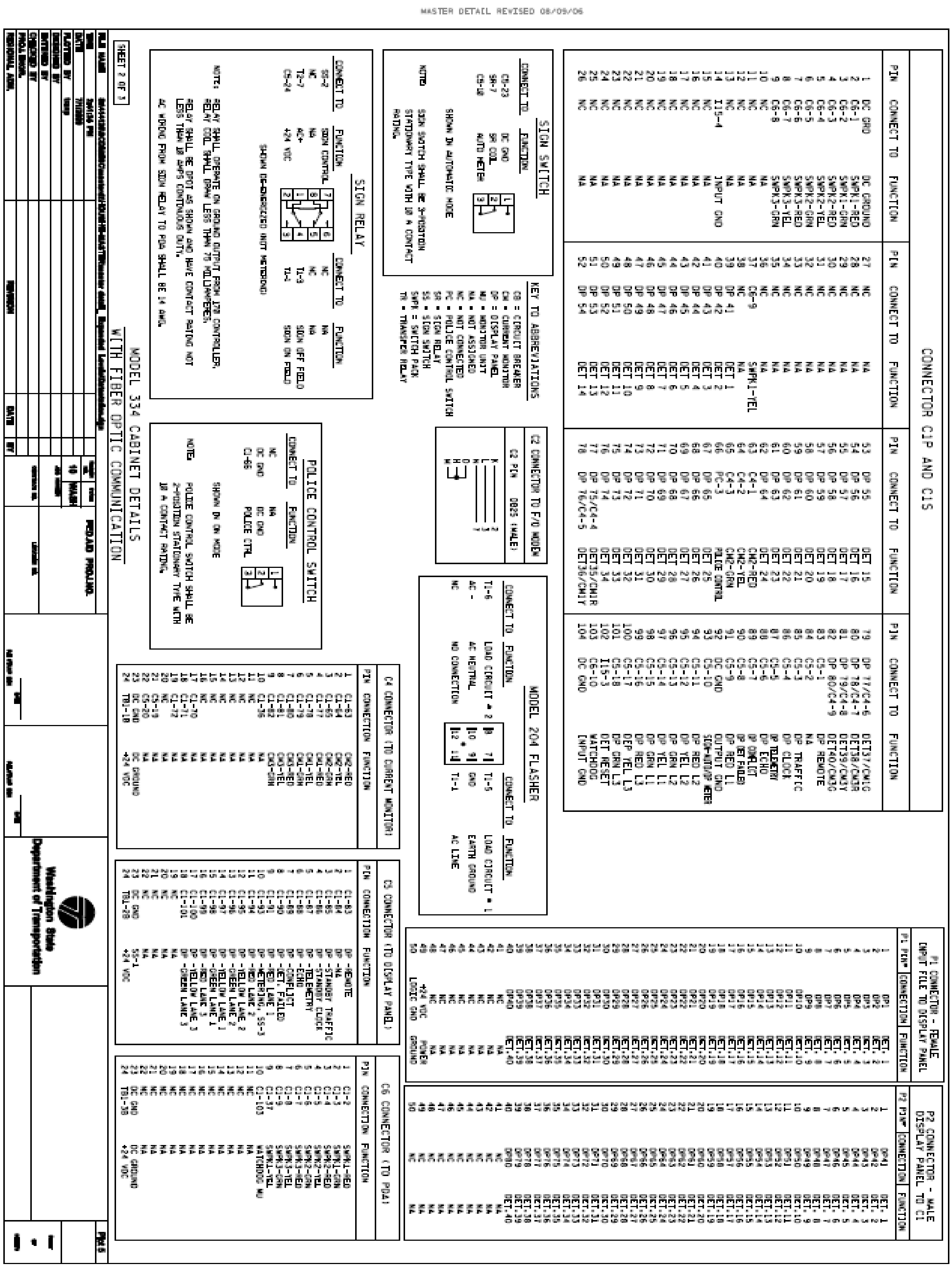
Leviton Telcom, Residential And Light Commercial Applications, "Book 2". Copyright 1998 Leviton Manufacturing Co. Inc

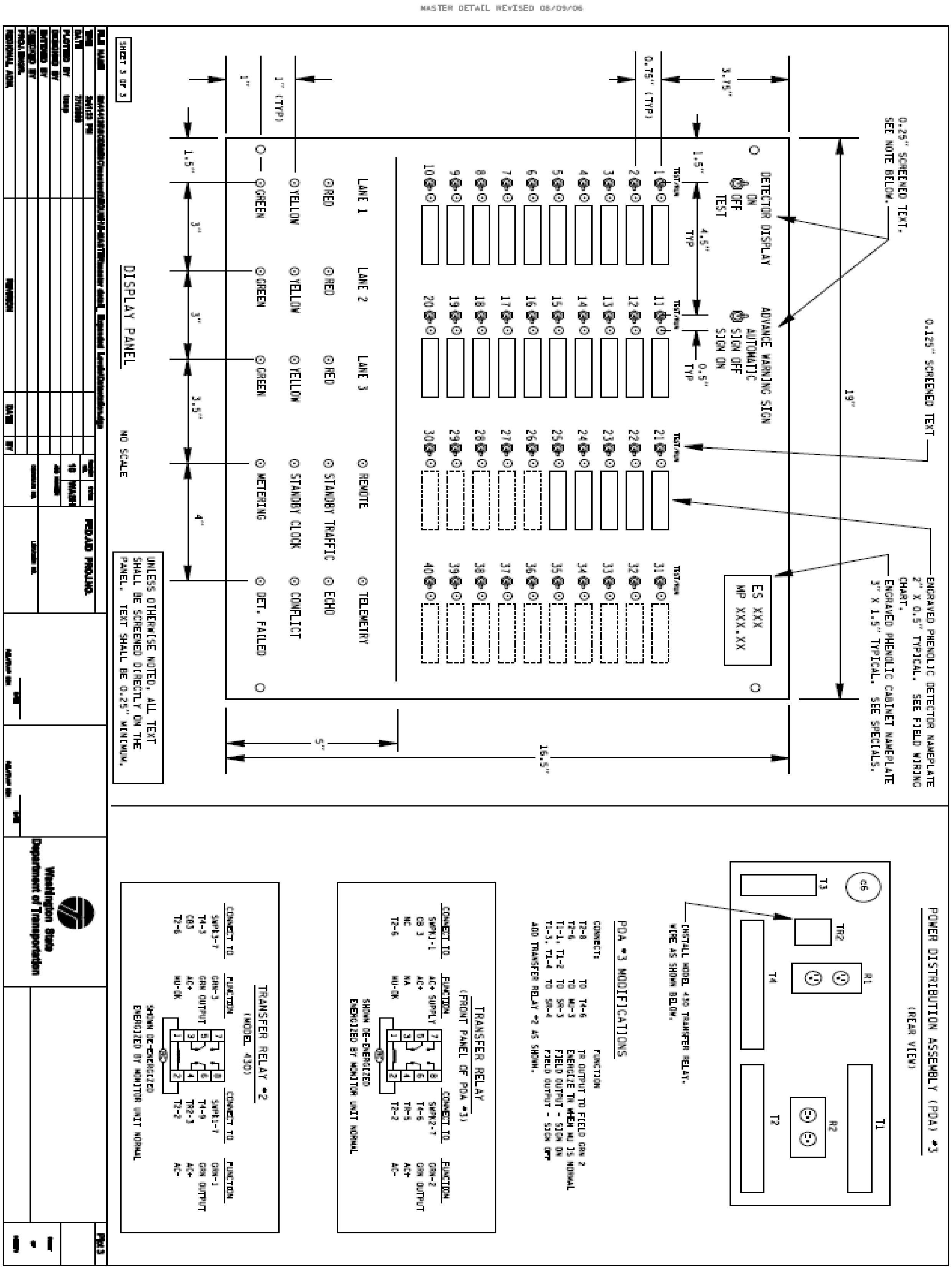
Morse, M., W.S.D.O.T. Ramp Meter / Data Collection version 4.47, "User's Manual" Created: 1996 Updated: 10 June 2009

NWR ITS Design Drawings: http://www.wsdot.wa.gov/NR/rdonlyres/E48B9C1A-9292-4DE6-A29F-EFAF77E51ACB/0/datastation.pdf


MASTER DETAIL REVISED 08/09/06
FRONT VIEW
SECTION A-A
CABINET ONE LINE DIAGRAM - POWER
LEGEND
SERVICE PANEL DETAIL
INPUT PANEL DETAIL
INPUT PANEL TERMINAL BLOCK ASSIGNMENT TABLE
INPUT FILE (REAR VIEW)
MODEL 334 CABINET DETAILS
WITH FIBER OPTIC COMMUNICATION
Washington State Department of Transportation

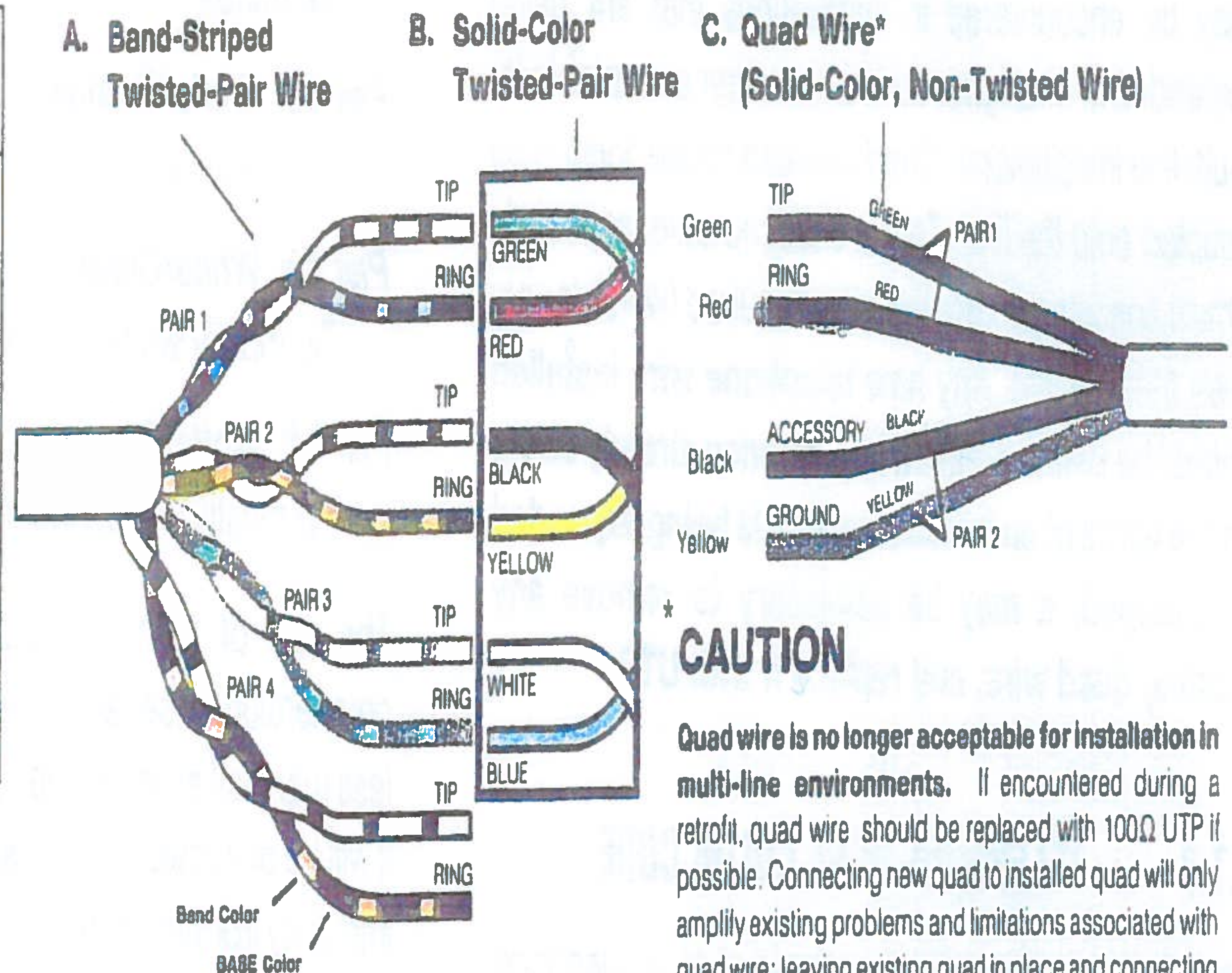
Communications




MASTER DETAIL REVISED 08/09/06
DISPLAY PANEL
NO SCALE
DETECTOR DISPLAY
ADVANCE WARNING SIGN
LANE 1
LANE 2
LANE 3
UNLESS OTHERWISE NOTED, ALL TEXT SHALL BE SCREENED DIRECTLY ON THE PANEL. TEXT SHALL BE 0.25" MINIMUM.
POWER DISTRIBUTION ASSEMBLY (PDA) #3
(REAR VIEW)
PDA #3 MODIFICATIONS
TRANSFER RELAY
(FRONT PANEL OF PDA #3)
TRANSFER RELAY #2
(MODEL 430)
Washington State Department of Transportation

Standard 4-Pair UTP Color Codes		
PAIR 1	T	White/Blue
	R	Blue/White
PAIR 2	T	White/Orange
	R	Orange/White
PAIR 3	T	White/Green
	R	Green/White
PAIR 4	T	White/Brown
	R	Brown/White

NOTE: For 6-wire jacks use pair 1, 2 & 3 color codes. For 4-wire jacks, use pair 1 & 2 color codes.



* **CAUTION**

Quad wire is no longer acceptable for installation in multi-line environments. If encountered during a retrofit, quad wire should be replaced with 100Ω UTP if possible. Connecting new quad to installed quad will only amplify existing problems and limitations associated with quad wire; leaving existing quad in place and connecting 100Ω UTP to it may also be ineffective, as the quad wire may negate the desired effect of the UTP.

For additional or commercial installation color codes see Table 3-1, page 3-7.

Digital cell communications

Digital cell converts binary code of 0s and 1s from electrical pulses. Because digital signals are made up only of binary streams, less information is needed to transmit a message. Digitized information can be transported through a noisy channel without degradation. Even if corruption occurs, as long as the one zero patterns are recognizable, the original information can be perfectly replicated at the receiving end. Some advantages of digital cell:

- Faster download speeds-19200 bps.
- Cell and modem in one package available from manufactures.
- More reliable data transfer over analog.
- Lower cost for per month charges over normal twisted pair copper.

Some disadvantages of digital cell:

- Limited locations
- Voice transmission take majority of bandwidth availability
- Small bandwidth

CELLULAR IP COMMUNICATION

Cellular IP (Internet Protocol) is currently used by the TDO office to collect data from traffic counters and weigh-in-motion devices that are within the cellular coverage network. This method is preferred to landline data collection because of ease of installation, and a substantial cost savings.

Cellular IP works by converting RS232 outputs of traffic counters to a packet and transmitting it wirelessly to a cell tower. This packet is then switched to a custom APN (Access Point Name) A custom APN gives TDO the ability to have individual or secure rights to a particular address. This is accomplished by using a static IP address instead of a dynamic IP address on the host computer. The data collected by the traffic counter in the field is then downloaded or viewed over the internet by a computer that has access rights to the IP modem. Charges are based upon per bytes of data sent. This system has a large bandwidth and can transmit real time video if needed.

Some disadvantages of the cell IP system:

- Voice takes precedence over data on cell tower use
- Availability depends on cell coverage area
- New system. Can be somewhat complicated to set up.

Radio IP communication

This is a new wireless radio system similar to the state based radios used in state vehicles. A site location is picked based upon coverage area and demand. Similar to the state voice communication radio system, locations are placed at higher elevations to broadcast down to lower elevations.

WSDOT owns the base broadcast station and all receiving radios. Broadcast on 700 MHz band. Currently there is coverage in areas of Olympic Region, NW Region and parts of NC Region. Coverage is expected to expand as time and monies allow. There are currently two types of radios in use, fast and faster. (Or slow and slower depending on your point of view!) The slower version radio will send and receive at about 1200 Bps. The faster radios will double that speed. Radios have an assigned static IP address and can be contacted via the internet from an approved user. So far this system has been very reliable. The advantage of this system for data station use is cost. For every radio system that can replace a copper land line we save 30 to 50 dollars per month. Over a couple of years the system can pay for itself.

- State installed radio system
- 700Mhz broadcast band
- Designed and built by IPMobileNet

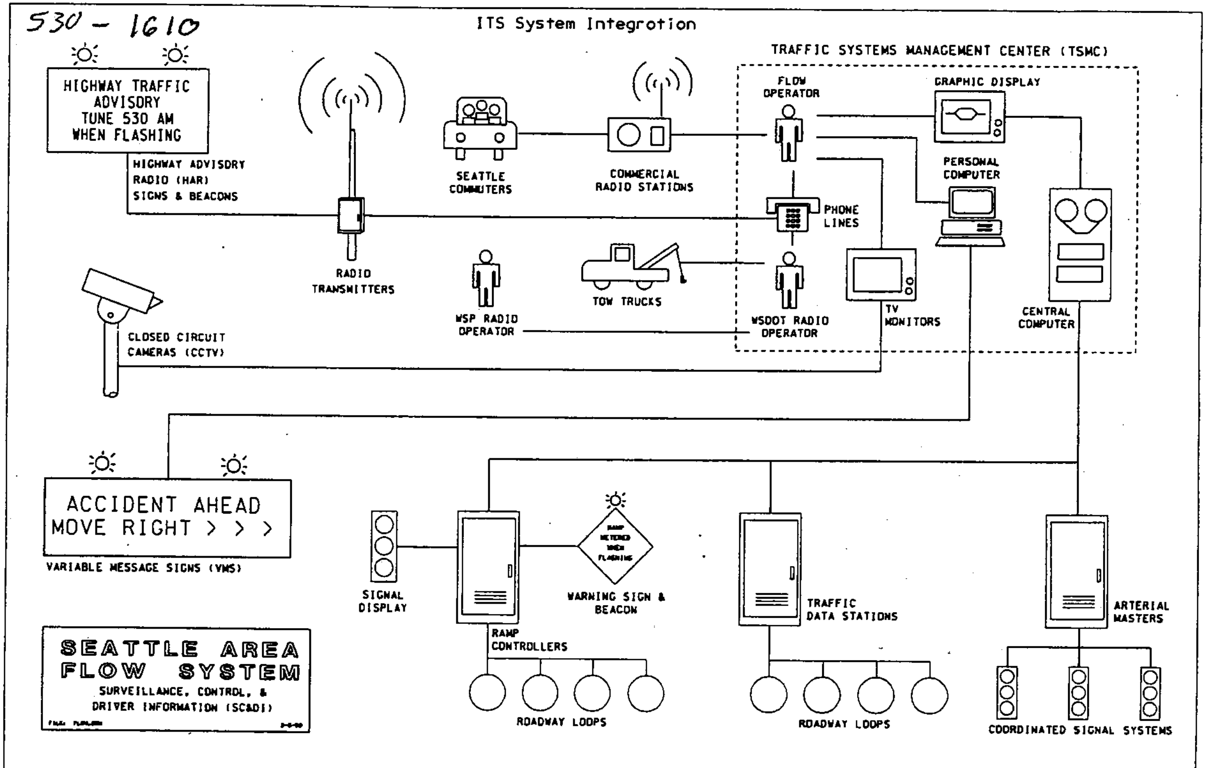


Figure 2.

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TIME 12:51:55 PM
DATE 10/17/2004
DESIGNED BY
ENTERED BY
CHECKED BY
PROJ. ENGR.
REGIONAL ADM.
REVISION DATE BY
10 WASH FED.AID PROJ.NO.
Washington State Department of Transportation
PLOT28