Metro Rail DESIGN Issues – Special Trackwork (Turnouts & Diamonds)

Metro Light Rail System

Metro Heavy Rail System

DEVELOPMENT OF RAIL TRANSIT SYSTEMS

Basic Rail Transit Development History

- Many Rail Transit Property Engineering Groups and DESIGN BUILD CONSUTANTS do not fully understand the FTA and State Oversight Agency Requirements.
- Metro Rail Operations has noticed over the past years and numerous Design Build Contractors either copy other Transit Design Details or modify existing references as it best fits the project and not understand the State Oversite Agency Inspection Requirements as it relates to curve speeds and turnout designs issues.
- Most Construction Engineering Groups designing New Rail Transit Systems require some type of Design Criteria REFERENCES but do not generally have O&M Staff familiar with Special Trackwork Details.
- **These Published Rail Transit Reference Documents are generally created with specific agendas and by special interest groups and are copied.**

Today's O&M Reference Materials and Guidelines

- These Published Rail Transit Reference Documents are:
  - Transit Cooperative Research Program (TCRP),
  - National Fire Life Safety Requirements (NFPA),
  - American Public Transportation Association (APTA),
  - American Railroad Engineering and Maintenance of Way Association (AREMA)
    - Including NEW SECTIONS for Rail Transit Design Plans and Recommendations,
  - American Association of Railroads (AAR),

- In addition, the Engineering Companies use Manufacturing Special Trackwork Designers and Shop Drawings to provide the compliance with drawings and specifications to get the best possible cost to the new rail transit projects.

SPECIAL TRACKWORK ISSUES WITH RAIL TRANSIT SYSTEMS

Special Trackwork Design Issues

- The Rail Transit Design Agencies were
  - Still using Road Design Engineering for Curve Speed Calculation and was creating the Metro Rail Design Criteria (MRDC) for all New Design Build Contractors.
  - It provided Calculations for Speeds on Curves, Spiral Lengths, and Supper Elevation based on Highway Engineering and Rail Transit Published Reference Material and not the Generally Accepted by Federal Transportation Administration (FRA) Rail Safety Standards or the State Oversight Agency.
- The State Oversight Agency having problems with Obtaining Rail Track Inspectors have moved to the hiring of Retired FRA Track Inspectors familiar with the FRA RAILROAD STANDARDS and Railroad Authorized Curve Speed Calculations including Turnout Crossover Speeds.

Special Trackwork Design Issues (Cont'd)

- The Metro Rail Design Criteria (MRDC) controlled and updated by the Metro Construction Engineering has PROVIDED two different formulas for Rail Transit Operating SPEEDS:
  - One based on the TCRP Track Design Handbook for Light Rail Transit (LRT):
    - Curve Total Equilibrium (Et) = 3.839 * V^2 / R for LRT Designs.
    - Using the Standard Turnout Design acceptable Equilibrium Total (Et) of 3-inches of unbalance results in a 2% Greater Operating Speed for Turnout Crossover Speeds.
  - One based on the AREMA and FRA Standards for Heavy Rail Transit (HRT):
    - Curve Total Equilibrium (Et) = 4.011 * V^2 / R for HRT Designs.
    - Using the Standard Turnout Design acceptable Equilibrium Total (Et) of 3-inches of unbalance results in the Oversight Operating Speed for Turnout Crossover Speeds.
    - **This is the FRA Formular for Curves that most State Oversight Agencies are using as indicated in their General Orders that the Rail Transit Properties must adhere to.**

MRDC Special Trackwork Speed Design Issues (Cont'd)

- The Metro Rail Design Criteria (MRDC) controlled and PROVIDED a list of Rail Transit Operating SPEEDS for Light and Heavy Transit Designs using Standard AREMA Turnouts based on the CURVED AREMA Geometry with Curved Switch Points using 3-inches of Unbalance for Lateral Turnouts:

NOTE:

Since Special Trackwork does not have Superelevation on the Turnout Curves, the application of a higher speed formular is not applicable and must be set using (Et) = 4.011 * V^2 / R for HRT Designs for both LRT and HRT.

4.2.11.1 **Allowable Civil Speeds**

TABLE 4.2

MAXIMUM ALLOWABLE CIVIL SPEED THROUGH TURNOUT

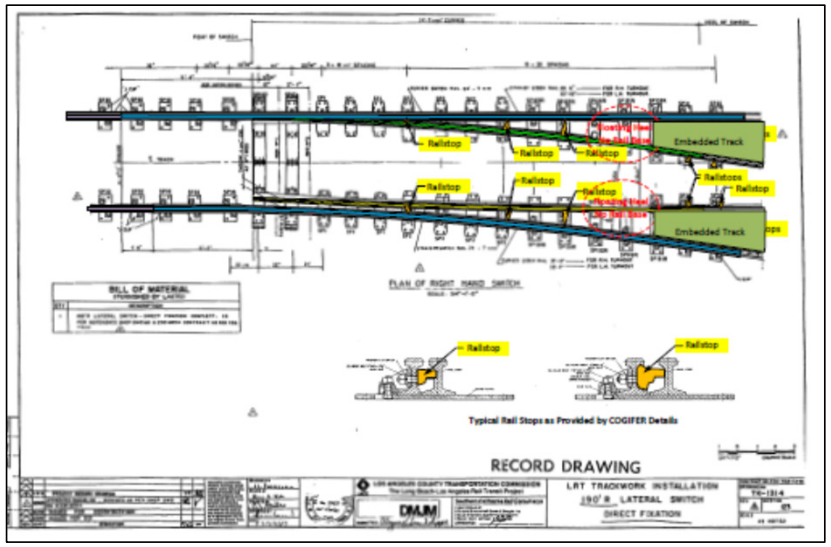
TURNOUT	CIVIL SPEED (MPH)
190-Foot Radius Lateral Turnout	12
No. 5 Equilateral Turnout	16
No. 8 Lateral Turnout	19
No. 8 Equilateral Turnout	27
No. 10 Lateral Turnout	25
No. 10 Equilateral Turnout	35
No. 12 Equilateral Turnout	43
No. 15 Lateral Turnout	35
No. 20 Lateral Turnout	50

Transferring Light Rail Turnout Designs

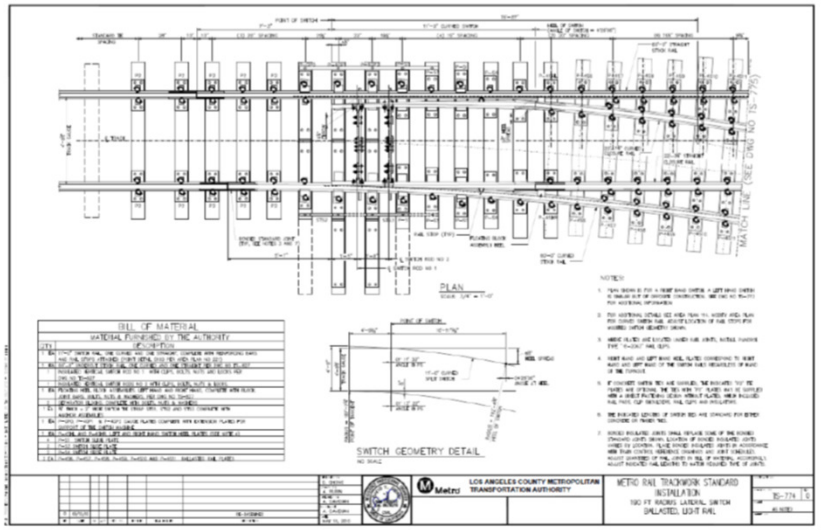
- Ballasted and Direct Fixation Territory:
  - Ballasted and Direct Fixation Track Designs
    - COGIFER vs METRO RAIL STANDARD DESIGN DRAWINGS
  - Transferring the COGIFER Light Rail Turnout Designs to Metro Designs required two Consulting Interpretations and the Manufacturer's process:
    - **Original COGIFER Design to Metro Initial Design Build Contractor (DMJM)**
    - **Metro Initial Design Build Contractor (DMJM) to Metro Rail Trackwork Standards**
    - **Metro Rail Trackwork Standards to latest Manufacturing Design Shop Drawings**
  - When Transferring Turnout Designs, the specific details for the turnouts get lost and create Operating &Maintenance Problems to the Rail Transit Property.

Transferring COGIFER Light Rail Turnout Designs (Cont'd)

- Street Running Territory:
  - 190' Radius Turnout – Embedded Track Designs to Metro Rail Standard Drawings



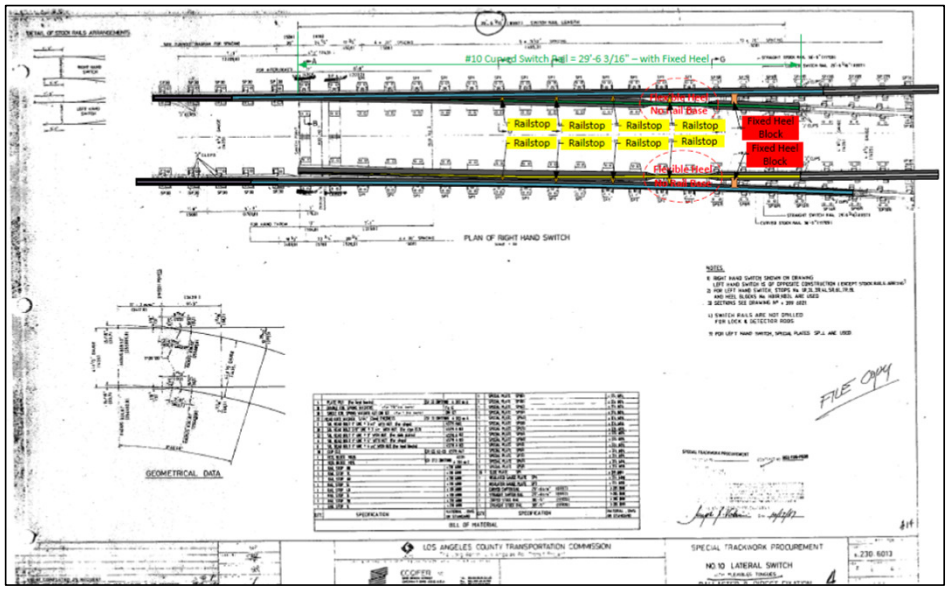
Note: **Floating Curved Switch Point (24'- 7 5/32), Rail Stops, With Zone of Flexibility, and Switch Rail Embedment**



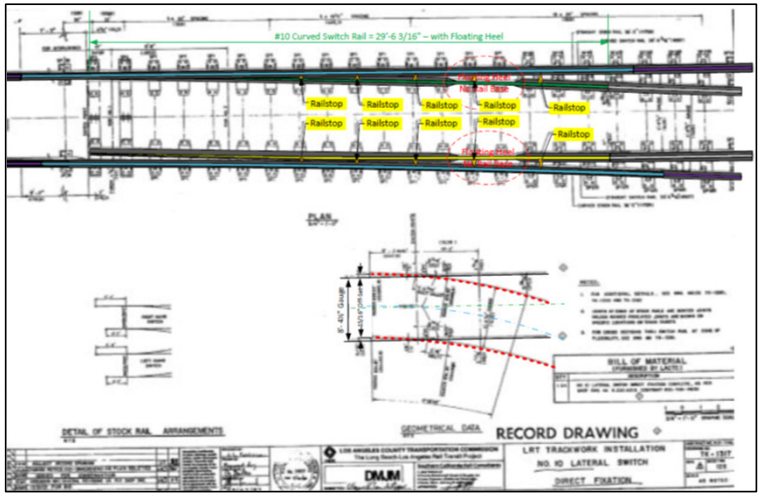
Note: **Floating Curved Switch Point (24'- 7 5/32), Rail Stops, NO Zone of Flexibility, and NO Switch Rail Embedment**

Transferring COGIFER Light Rail Turnout Designs (Cont'd)

- #10 Turnout – Ballasted and Direct Fixation Track Designs:



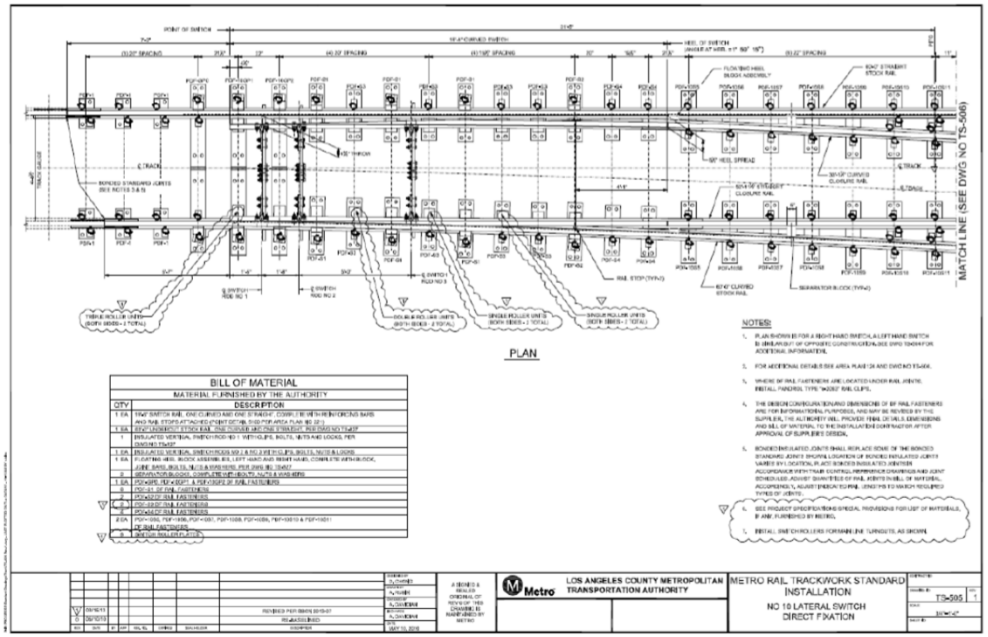
Note: **Floating Switch Point, Rail Stops, Fixed Heel Block, With Zone of Flexibility**



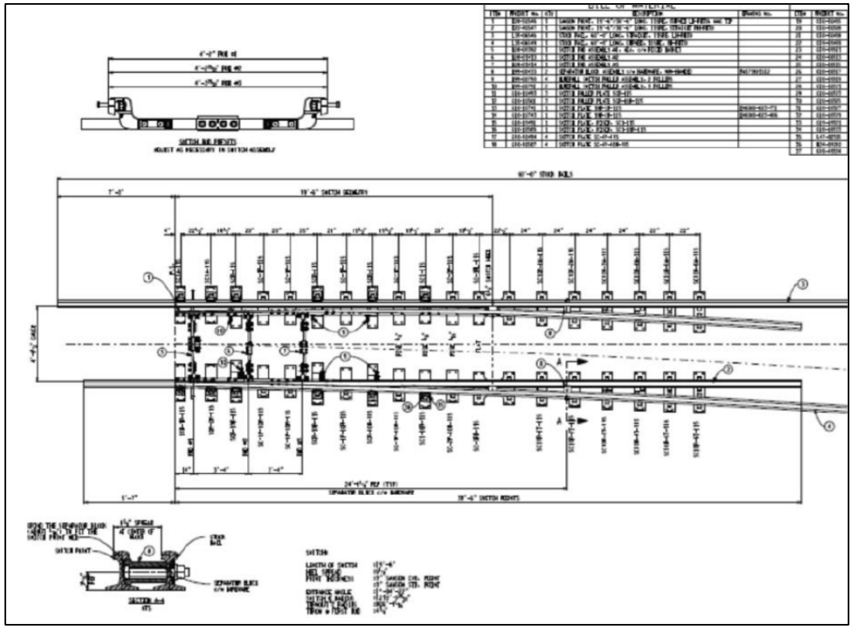
Note: **Floating Switch Point, Rail Stops, With Zone of Flexibility, But NO Fixed Heel Block**

Transferring Light Rail Turnout Designs (Cont'd)

- #10 Ballasted and Direct Fixation Metro Designs to Turnout Manufacturer:



Note: **#10 Turnout Floating Switch Point with AREMA Rod Placement**



Note: **#10 Turnout Floating Switch Point with Heel Blocks, and Custom Rod Placement for Better Control of Switch Points**

SPECIAL TRACKWORK OPERATING SPEED PROBLEMS FOR TURNOUTS

Transferring Operating Turnout Design SPEEDS (Cont'd)

- TURNOUT OPERATING SPEEDS for LA Metro Vehicles:
  - Heavy Rail Track Designs Originally Tested with Miami Dade Heavy Rail Vehicles
    - **METRO RAIL STANDARD DESIGN DRAWINGS designed for Standard Rail Transit Vehicle Truck Design using a Standard Wheel Diameter of 26-inches and a Truck axle Spacing of 6'-3"**.
    - Test proved that METRO CUSTOM Turnout Speeds through crossovers could be accommodated using the Florida Heavy Rail Systems operated on the Miami Dade Transit borrowed Test Vehicles at mainline #10 Turnout Speeds of 25 mph without problems.
    - However, the Metro Procurement through a High-Speed Vehicle that could operate at 75 mph Open Bid obtained LA Metro Vehicles with Wheel Diameters of 34½- inches and a Truck Axle Spacing of 7'- 7" which when tested on the Heavy Rail METRO CUSTOM Turnout Speeds detailed on Standard #8 Yard Turnouts and Showed Mainline #10 Turnout Crossover WHEEL CLIMB DERAILMENT at 12 mph not the AREMA TURNOUT DESIGN SPEEDS of 25 mph.

Special Trackwork Design Speed Problems (Cont'd)

- The Metro Heavy Rail Transit Vehicles were designed with:
  - A Wheel Diameter of 34½ inches and a Truck Axle Spacing of 7 feet – 7 inches
  - Was determined by initial Pre-Revenue Testing on the initial Metro RED LINE, that the Heavy Rail Vehicles derailed passing through the #8 Turnouts at 8 mph in the Yard
  - And showed Wheel Climb on the Metro Custom Mainline #10 Turnouts Crossover Moves through Video Validation at 12 mph not the design speeds of 25 mph as expected.
- This resulted in the Metro Rail Operator (SCRTD) to restrict all Heavy Rail Mainline Metro #10 Turnouts
  - To be set by Train Control to a Maximum Crossover Speed of Cab Code Speed of only 9 mph since the HRT Vehicles were designed with the Next Speed Code of 25 mph that was proven to provide Wheel Climb on the Custom LA Metro Crossover Turnout Designs.

Special Trackwork Design Speed Problems (Cont'd)

- Based on this Heavy Rail Transit Vehicle Turnout Speed Restriction, all future Metro RED Line #10 turnouts were adjusted to operate at only Cab Speed Codes of 9 mph and a New Metro Custom 645-foot Radius Turnout was developed with a Floating Switch Points of 21- feet and a Curve Frog to be traversed at 9 mph saving Tunnel Crossover Length.
- This resulted in the following Heavy Rail Turnout Speeds:

Lateral Turnout Number	Maximum Allowable Civil Speed (MPH)
645-foor Radius – Lateral	Switch Point of 21 feet = 9 mph
# 8 – Lateral Turnout	Switch Point of 16½ feet = 9 mph
#10 – Lateral Turnout	Switch Point of 19½ feet = 9 mph

Turnout Operating Speeds for Heavy Rail Expansion

- With the Design of the Metro Heavy Rail Underground Transit System expansion by the PURPLE LINE to the Los Angeles Hospital:
  - It became apparent that the Design Build Contractor had followed to Metro Rail Design Criteria (MRDC) Turnout Design for Single Track Headways and Crossover Placement based on a crossover speed of 25 mph not the current LA Metro restriction of 9 mph due to the HRT Vehicle Truck Design.
- This created Single Track Travel Times that were unacceptable to serve LA Metro and allow Scheduled Maintenance on the Underground Heavy Rail Transit Line Mainline.

Turnout Operating Speeds for Heavy Rail Expansion

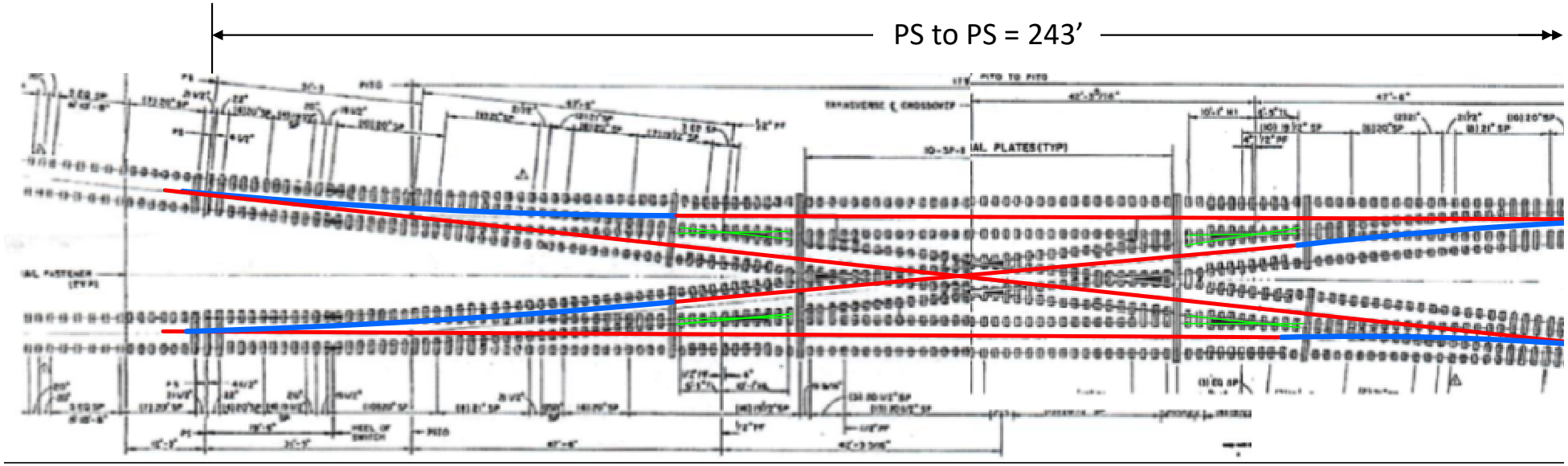
- The Metro Heavy Rail Underground Transit System Design Build Contractor knowing:
  - That the Current Alignment Design and Tunnel Metro Standard #10 Crossover Placement would not provide a valid service, requested that an outside REVIEW of the HEAVY RAIL Turnout Designs be conducted to see how the New Alignment and Crossover Designs could accommodate the LA Metro SINGLE HEADWAY OPERATING CRITERIA.
- Metro together with Advanced Rail Management (ARM) prepared a detailed **Subway Crossover Wheel / Rail Safety & Speed Performance including Red Line under car video and accelerometer testing** through the existing Turnout Designs in June of 2014 to validate Crossover Speeds on Metro Turnouts.

Metro Heavy Rail Turnout Design Speeds

- This combined testing of the Metro Red & Purple Line Heavy Rail Vehicles over the Existing Metro Heavy Rail Turnouts created a comparison of AREMA Standards to those Created by LA Metro Construction as related in the Metro Rail Standards – Trackwork Details being used by the Metro Design Build Contractors.

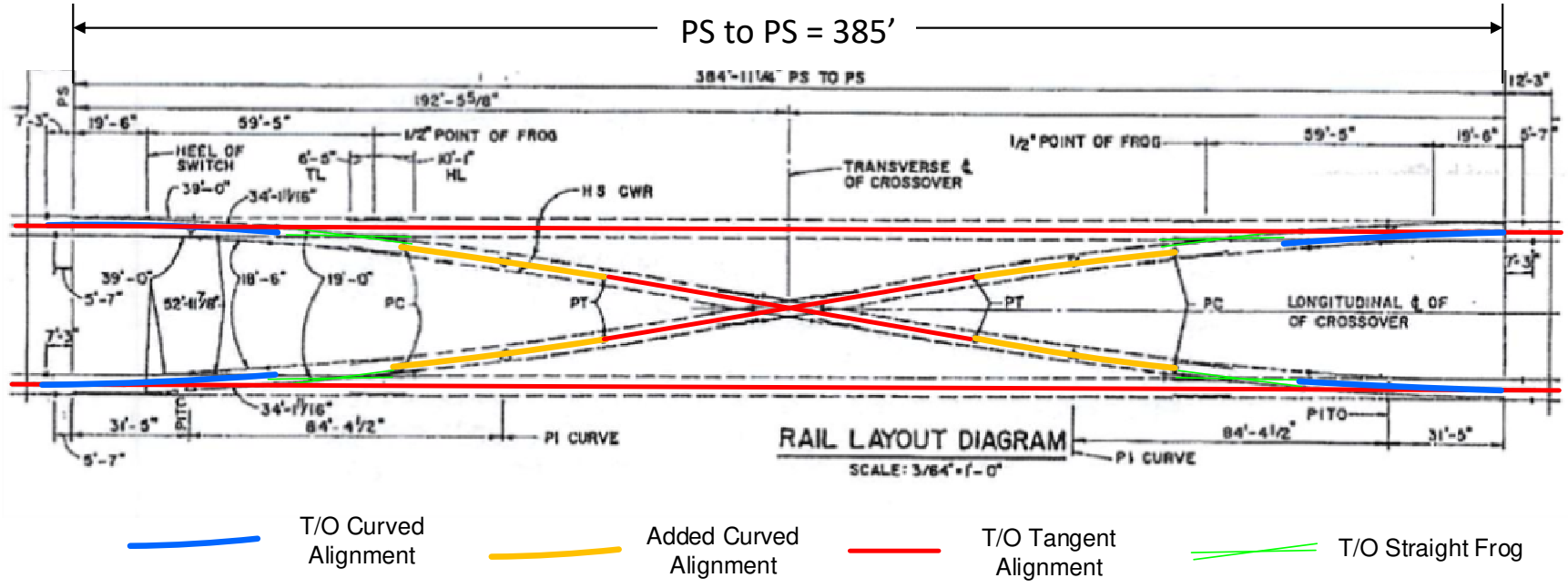
LA Metro Heavy Rail Turnout Design Speeds

- **Standard AREMA #10 Diamond Crossover With Curved Points – on 19’- 0” Track Centers and 19-6” Points**



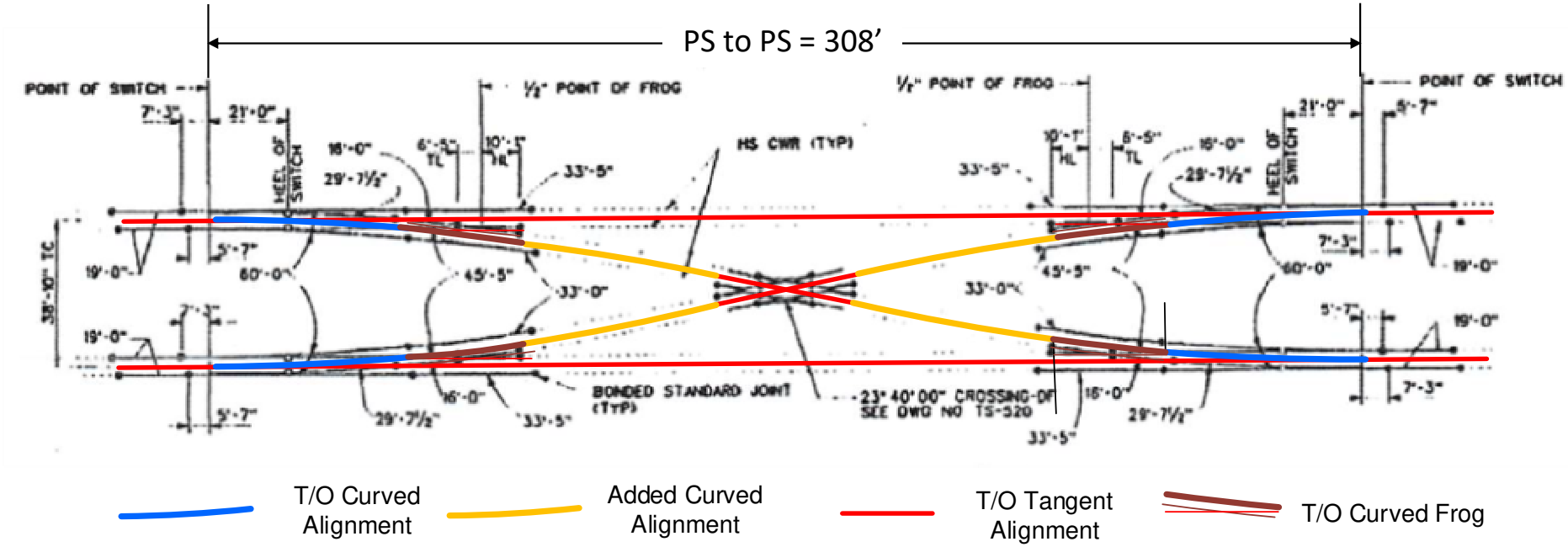
LA Metro Heavy Rail Turnout Design Speeds (Cont'd)

- **Metro Modified #10 Diamond Crossover With Curved Points – on 42'-10" Track Centers and 19'-6" Points**



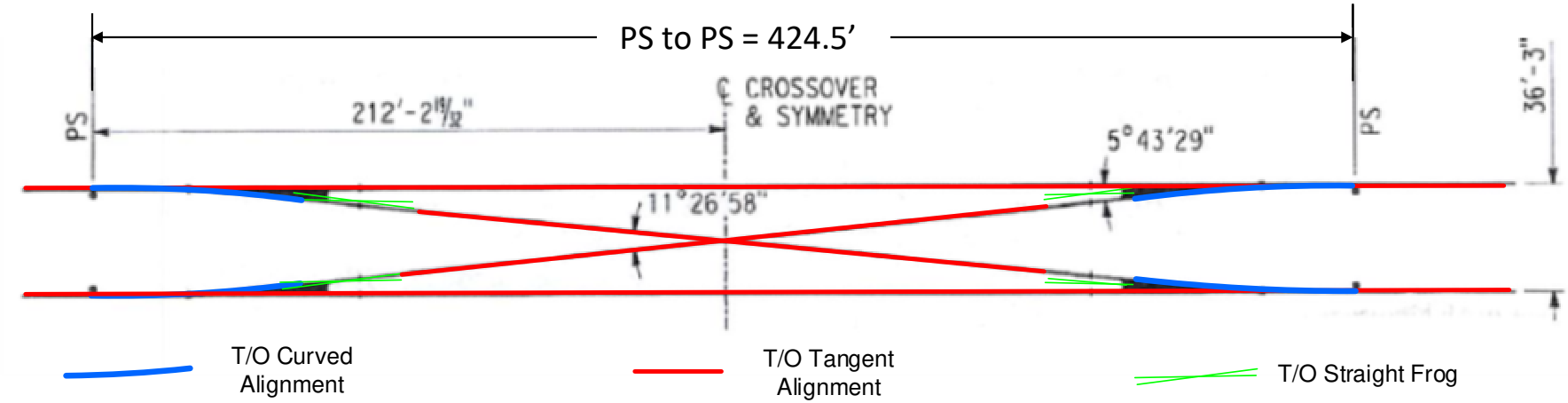
LA Metro Heavy Rail Turnout Design Speeds (Cont'd)

- **Metro Custom 645' Radius Diamond Crossover With Curved Points on 38'-10 Track Centers with 21'-0" Points**



LA Metro Heavy Rail Turnout Design Speeds (Cont'd)

- **Metro Future Terminal Standard AREMA #10 Diamond Crossover With Curved Points on 36'-3" Track Centers requires 424.42 feet PS to PS.**



- Based on the New Future #10 Diamond Crossovers, it was required to fit in the Constructed Crossover Box Structures already in the Alignment of approximately 354 feet.

LA Metro Heavy Rail Turnout Design Speeds

- **Study GOALS:**

The study was made to determine the following, based on derailment safety, lateral forces, and passenger comfort in the cars:

A. To determine if the speed of operation as limited by wheel lift could be increased on the three existing main line crossover geometries and if so, by how much.

B. To determine whether such increased speed of 15 mph or 20 mph produced an acceptable ride quality and passenger comfort including rail safety.

C. To recommend the crossover design(s) and investment cost consequences for the West Side Purple Line Extension (WSPLE) project since the Overall Crossover Box Length has been constructed.

D. To support the specification development for vehicle procurement to assure curve and crossover operation will meet performance expectations.

Phase 2 – Test Equipment Placement

On-Board Accelerometers for Rider Comfort

Under-Car Video for Monitoring Wheel Rail Interaction through Crossovers

LA Metro Heavy Rail Turnout Design Speeds (Cont'd)

Test RESULTS:

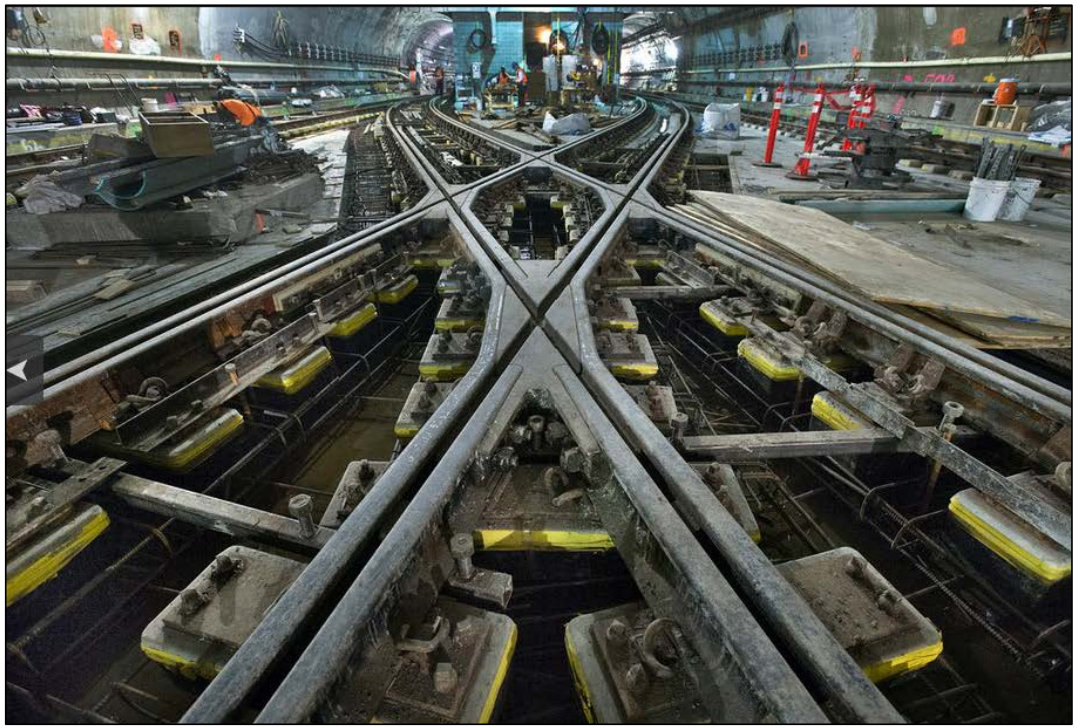
- Accelerometer time-based "strip chart" records were extracted for each key run and compiled in the report.
  - The times of the start of each run were correlated to the visual records to understand the points along the alignment where significant jerks were detected. (in progress)
- **The study documents that the existing crossovers (except East Union Station) cannot be reliably operated at 25 MPH, even with the modifications to wheel profile, lubrication, and suspension.**
- The study found that the modifications to the wheel and rail profiles and the modifications to the suspension system were performing very well over the whole length of the Metro RED Line.
  - There was no flange contact on most curves and the cars tracked without hunting or other irregularities at all speeds on tangent track. There were almost no audio indications of rail corrugations or defects.

Conclusions & Possible New Metro Crossover Speeds

Location	Turnout Type	Track Centers	Tangent Length Between Curves	Crossover Speeds		Modifications
				current	proposed	
Existing Rail Transit Metro RED Line & Metro PURPLE Line Crossovers:						
	Standard AREMA #8	15'-0"	45'	10 mph	15 mph	No Change
Union East	Standard AREMA #10	19'-6"	98'	10 mph	25 mph ?	Change Approach Trk
Union West	MRL Modified #10	42'-10"	98'	10 mph	25 mph	Guard Frog to Frog
Intermediate	Custom 645' Radius	38'-10"	45'	10 mph	15 mph	Replaceable Pt Tips
Pocket	#10 & Eq. #8 AREMA	19'-6"	128'	10 mph	25 mph	No Change
Proposed Westside Expansion – Purple Line Extension (PLE)						
Intermediate	PLE Modified #10	36'-3"	60'	10 mph	15/20 mph	Guard Frog to Frog
Terminal	Standard AREMA #10	36'-3"	343'		25 mph	

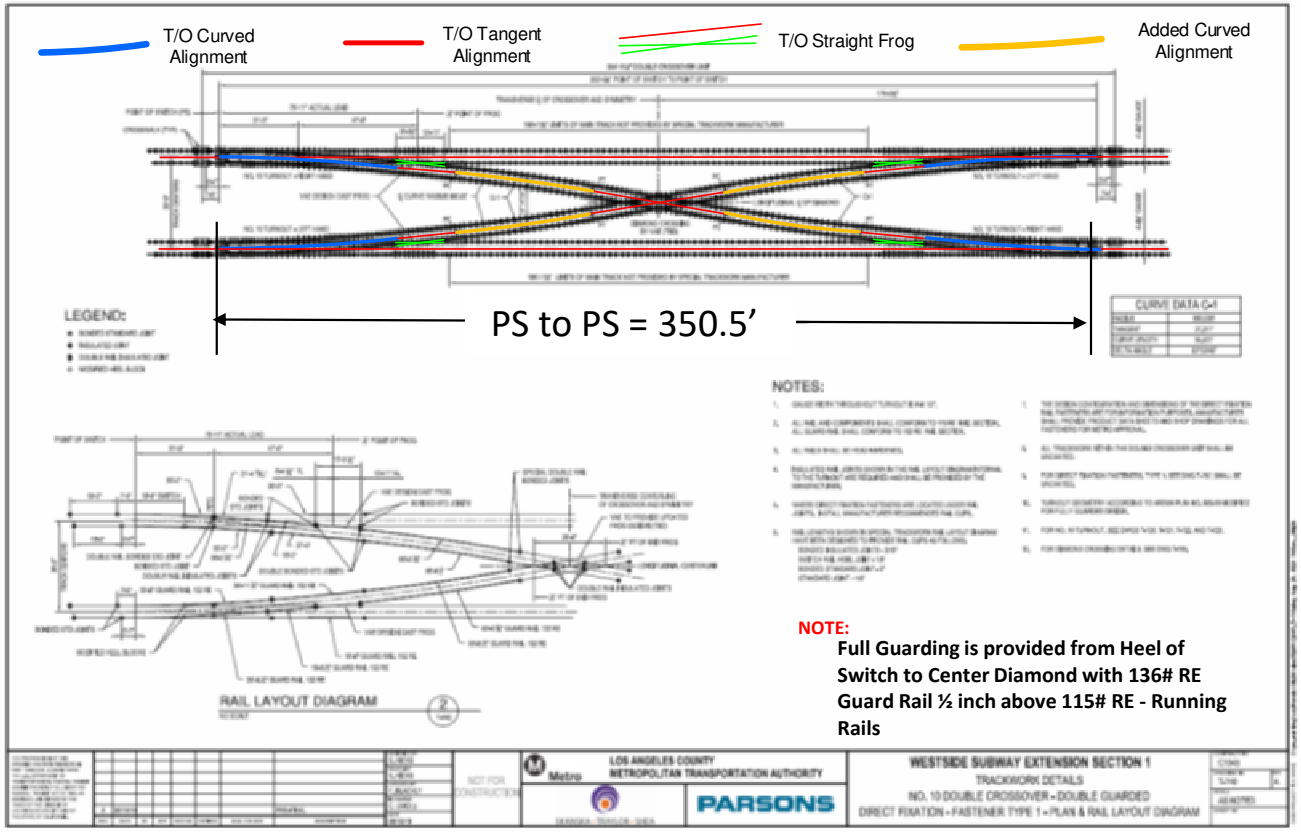
Future Metro New Standard #10 Fully Guarded Diamond Crossover

- To Design a Metro Diamond Crossover using AREMA Turnout Standards, it was determined that the New Turnout Alignment must be designed with FULL #10 CROSSOVER GUARDING and then only to operate at a maximum crossover speed of 20 mph could be obtained.

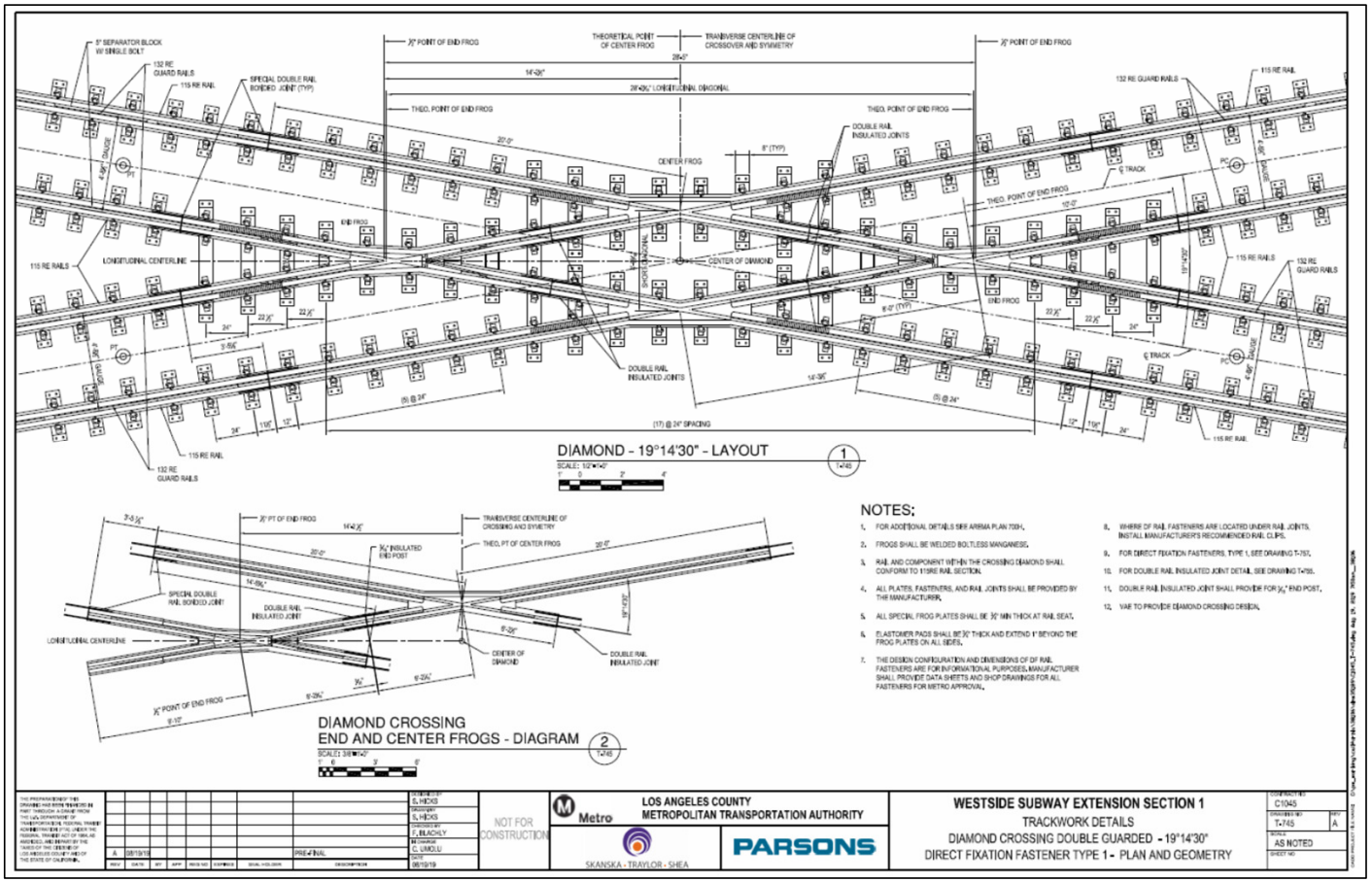


New Metro “#10 Fully Guarded” Diamond Crossover

351’– **73.5’ shorter than a Standard AREMA #10 Turnout**



New Metro “#10 Fully Guarded” Diamond Crossover



New Metro #10 Fully Guarded Diamond Crossovers

- The New Metro #10 Fully Guarded Diamond Crossover extends the Interlocking Points and Signals into the Bored Tunnel and the Station Box but provides a Design with Full Guarding so that the Metro Heavy Rail Vehicles (with 34 ½ inch diameter wheels and a 7-foot 7-inch Truck Axle Spacing) can perform the Crossover Moves at 20 mph.
- With this New Metro Fully Guarded Diamond Crossover Turnout Design using Standard AREMA Curve Point Turnouts with add curves and tangents between center diamond can be shortened so that the overall Diamond Crossover Track Alignment can operate at 20 mph and fit in the West Side Purple Line Extension Alignments Limited Space.
- This New Metro Turnout Design can effectively provide the Single-Track Headways required be the Metro Rail Design Criteria (MRDC).