Swanton Pacific Railroad Track Manual

By
E. J. Carnegie

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This manual is dedicated to Elmer Stone for the many years that he worked, taught, and directed the track operations of the Swanton Pacific Railroad.
Elmer brought to the Swanton Pacific Railroad a wealth of experience, good humor, and for those who knew him, “Stoneology”.

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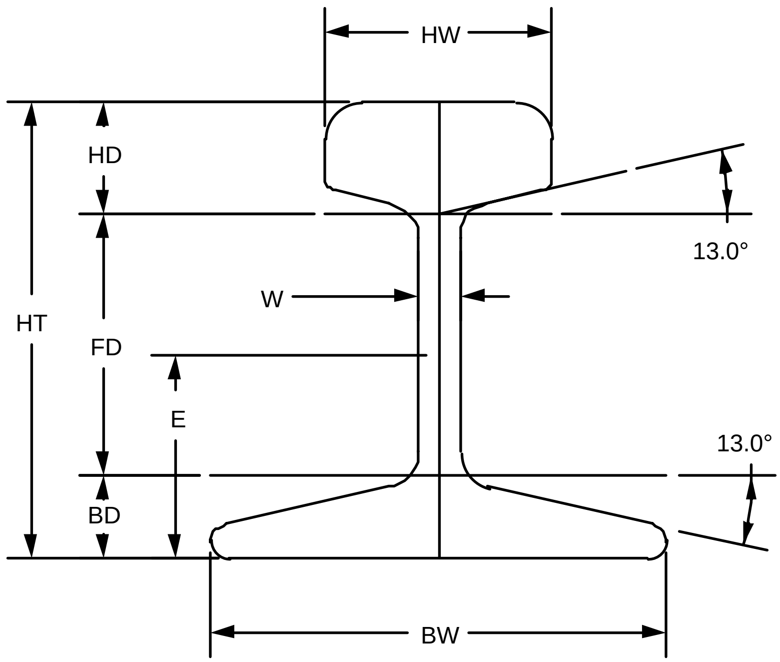
Chapter 1: Track Nomenclature

Lets start out by looking at a section of rail that we use on SPRR. Rail is listed by weight in pounds per yard. Most of the rail used on the SPRR is 16 lb. Rail, with some 12 lb. used in buildings, (for light use) and some 20 pound rail placed in storage. Rail is made up of three distinct parts, Head, Web and Base or flange. Standards for light rail in the sizes that are used by SPRR are established by the American Society of Civil Engineers, (A.S.C.E.). Definitions of dimensions are shown in Figure 1-1The size or weight of the can be found by measuring the height, H, or base, BW, which are equal in A.S.C.E. rail, and compare it with the standard dimensions as listed in TABLE 1-1.



HT -	Height	BW -	Width of Base	HW -	Width of Head
W -	Web	HD -	Depth of Head	BD -	Depth of Base
E -	Bolt Hole location				

Figure 1-1: Dimensions for tee rail

TABLE 1-1: Tee Rail Section Data

Normal Weight Per Yard	DIMENSIONS, INCHES							
	HT	BW	HW	W	HD	FD	BD	E
12 lb.	2	2	1	3/16	9/16	1 3/32	11/32	57/64
16 lb.	2 3/8	2 3/8	1 11/64	7/32	41/64	1 23/64	3/8	1 1/16
20 lb.	2 5/8	2 5/8	1 11/32	1/4	23/32	1 15/32	7/8	1 11/64

Rails are made in a hot rolling process cut to a normal length of 30 feet. SPRR has found that a great amount of variability exists in steel between one manufacture to another. Some rail will work harden and become brittle. Rail that will work harden, will bend once, but if forced to bend often will brake.

When laying straight track along a right-of-way the bed should be graded and compacted. If possible, the rail bed should be raised above the soil level or aligned to insure good drainage. The side bank should be clean of plant material and graded to minimize soil erosion. After the track bed is graded, underlayment should be placed on the soil to form a barrier between the soil and the ballast. The underlayment will allow water to drain through the material and stop the fines in the soil from moving up into the ballast. Ties can than be placed at the proper spacing along the right-of-way. Ties should be placed with the curve of the grain on the tie facing up, see Figure 1-2. You could think of the grain forming a dome to shed water. Tie spacing used for most tracks on SPRR is 18 inches. After the ties are aligned, the track can be put in place, and fishplates are bolted in place. The rail should be bolted with a gap of 1/8 inch between the rail ends. To minimize heat kinks, as the rail heats up and expands, grease should be placed between the rail and the fishplates. The fishplate bolts should be tight, but not over tightened.

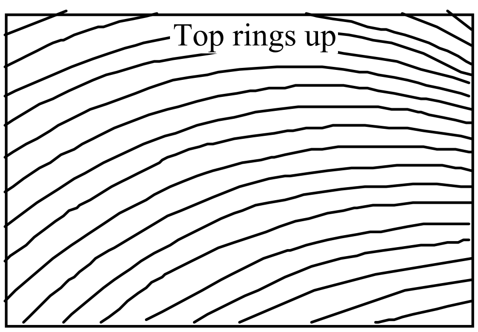


Figure 1-2: Position of rings on tie

After the track is in place and bolted together, the track is ready to be spiked in place. The spikes used by SPRR are 3/8 x 3". They are placed in a trapezoid pattern as shown in Figure 1-3. The ties are pre-drilled and then treated so that the treating goes through the holes and makes driving spikes easer. It is important to drive the spikes straight down through the predrilled holes because the treatment protects the tie from the penetration of the spike. Also a spike driven perpendicular to the rail will hold a greater side load.

After a sufficient amount of track has been laid, ballasting and alignment may begin. Every effort should be made to keep the track as straight as possible. Alignment is accomplished by a team effort of one person sighting down the rail and one or more workers using bars to move the rail as directed.

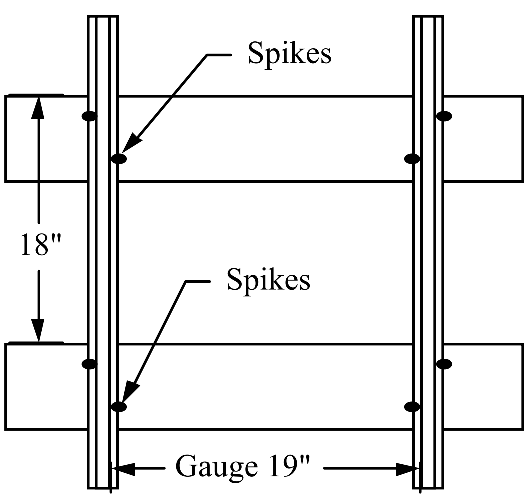


Figure 1-3: Spike spacing on tie

Once the track is aligned it is ready to be leveled and tamped. We have two methods to measure the amount of movement of the track to bring it into a uniform plane, either a sight board or transit. An old tried and proven method is to us a sight board, with a peep sight, and a rabbit block on a level. This method will be discussed first.

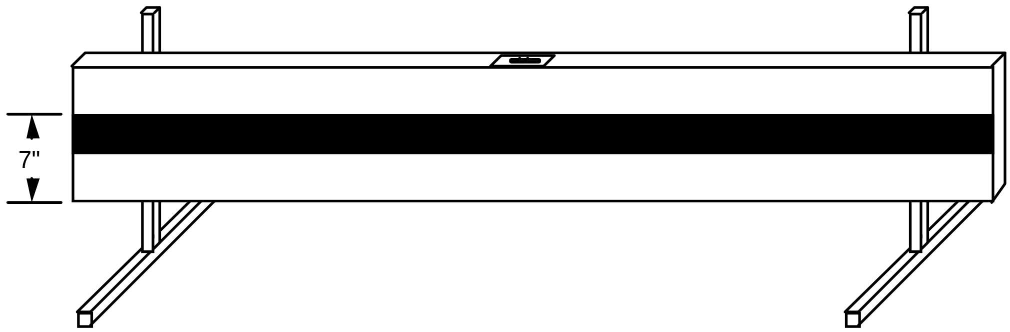


Figure 1-4: Sight board

A sight board, Figure 1-4, is made from a 2 x 10, eight or ten feet long. A three inch black band is painted over a base coat of white paint. The top of the black band is seven inches from the bottom of the board. A level is mounted in the top of the board to indicate when the board is level. Two adjustable legs are clamped to the back of the sight board and are used to level the board.

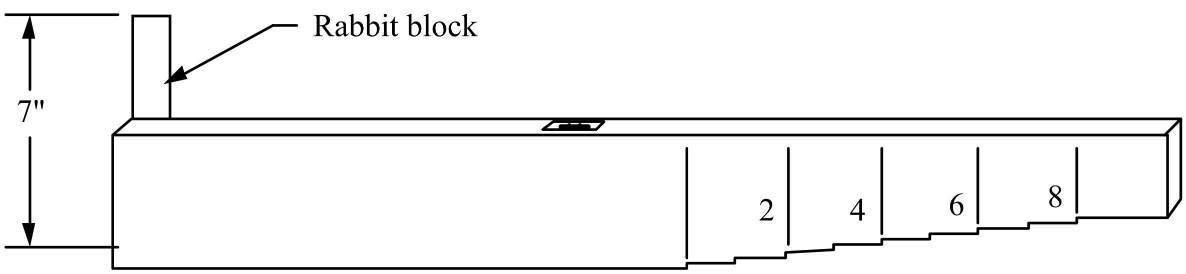


Figure 1-5: Track level

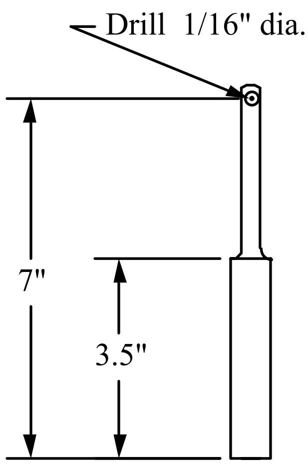


Figure 1-6: Peep sight

The track level is made from hard wood, 2 x 4, two feet long; this is so that it can take the abuse of being placed on the rail. At one end, the rabbit block is placed with its top seven inches from the bottom of the level. At the other end, a series of 1/8-inch steps are cut into the wood to allow for super elevation. The flat portion on the bottom of the level should be large enough to span the track.

The peep sight is turned from a 5/8 inch diameter aluminum stock 7 1/4 inches long. The top half is turned to 1/4-inch diameter. Next center punch for a 1/16-diameter counter sink seven inches from the bottom of the peep sight. Drill through and then counter sink the other side.

In order to use this equipment, start with a level tamped section of track at the elevation that is required. Place the sight board across the track and level the sight board with the adjustable legs. Next, sight down the rail to determine the high spot. Take the peep sight to the high spot and sight back toward the sight board with the bottom of the peep sight on top of one rail. Always use the same rail for sighting and leveling. Have another person move down the rail from the sight board toward the person using the peep sight. Place the level across the track with the rabbit block over the same rail that the peep sight is on. Then look through the peep sight, across the rabbit block on the level, to the sight board. Have a person, with a bar or jack, raise the track on the same side as the peep sight until the rabbit block is level with the top of the black band on the sight board. Tamp some ballast, under the tie, just below the rail, only to hold the tie in place. Next, using the track level, raise the other rail until the bubble on the track level is in the center. Tamp the tie in place, and than move eight or ten feet down the rail and repeat the same process again.

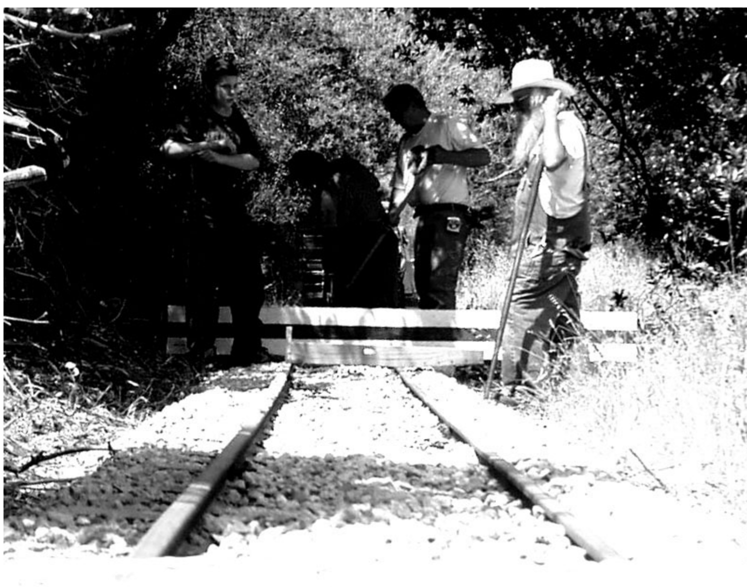


Figure 1-7: View from peep sight toward sight board

Figure 1-8: Sighting from peep sight over rabbit block to sight board

Keep this up until you are close to the peep sight operator. At this time the track between the sight board and the peep sight should be level. This section of track is now ready to be tamped. Every tie should be uniformly tamped under the rails where the tie receives the load. Care should be taken not to over tamp, because excess tamping can raise the rail and destroy the work in leveling the rail. This is not the easiest method but it does give you a good close look at what is going on with the track.

The other method used to establish a uniform plane for the track uses a transit and a rod. The transit is set up over the track, or next to the track, at a location where the track is at a proper elevation. With the scope leveled, place the rod next to the transit to establish the height of the instrument, HI, from the top of the rail. Have the rod person move down the track to establish a high location along the rail. Remember to use the same rail that was used to establish the HI.

Place the rod on the high location and focus on the rod. Adjust the angle of the scope to the HI. If the high location needs to be raised, move the scope up the rod the amount that that location needs to be raised. This will normally be about 0.10 feet. A plane is now established between these two points. To test what will take place, have the rod person move back to the instrument,

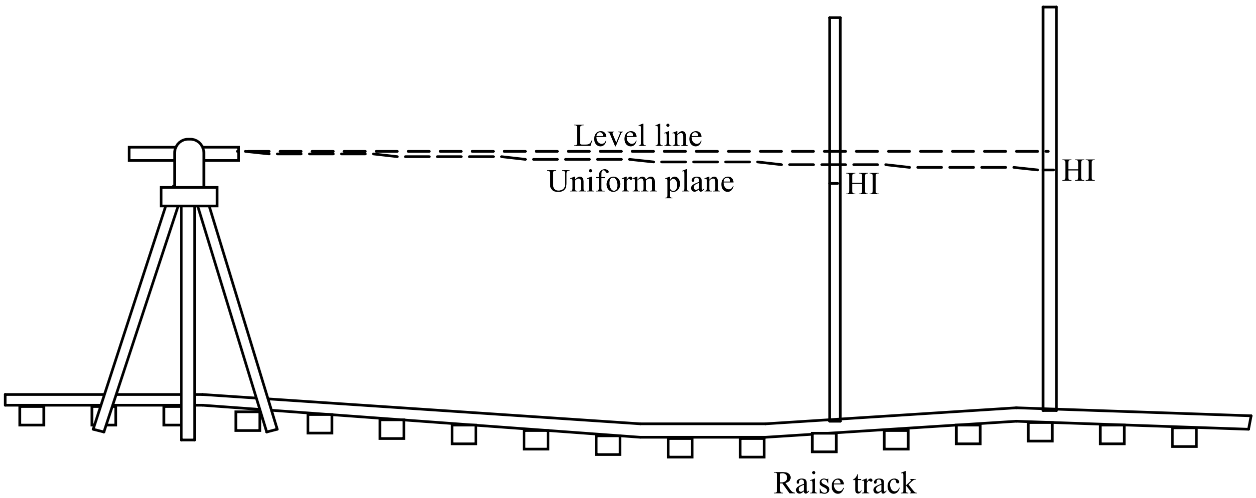


Figure 1-8: Diagram for leveling track with a transit

and place the rod on the rail about every ten feet. If any readings are smaller than the HI, that will indicate that that location is higher than the sight plane. This will then become a new high location. Adjust the angle of the scope again, and start from that location, moving back to the instrument. If a location is found where the reading of the rod is too large to fill with ballast, two choices can be made. One, raise the track bed by adding more base under the ties. The other alternative would be to establish a vertical curve to minimize the change. After the rod person has returned to the instrument and all is proper, you can start leveling. Start at about ten feet from the instrument, by placing track jacks on both sides of the rail. Place the rod on the rail and raise the rail, with the jack under the rod, until the reading on the rail reach HI. Place the track level across the track and level the other track. Move down the track another ten feet, and repeat the process as above. After all the track jacks are used proceed with tamping the track, see Figure 1-9.

Figure 1-9; Track leveled with track jacks

Chapter 2: Horizontal curves

When laying track along a curve the rails should be pre-bent by using a rail bender for the desired radius of the curve. If the track is forced around a curve, in time, it will have a tendency to try to straighten out or move. All curves should be as large as possible, as locomotives and cars use solid wheel sets.

Horizontal curves are divided into two distinct parts. The curve itself, and the transition into the curve. First we will discuss the curve.

All calculations are for the center of the two rails. As the distances from the center, to the rail are very small, compared to the radius, and will have no effect on the process. The easiest way to develop a curve is to swing an arc-of-radius, R, tangential to the rail from the point of where the curve is to start. This sounds easy, but in reality to draw an arc on the earth's surface of two hundred feet or so is not easy. You would be limited with this process to a large flat field with no obstructions, trees, hills, and for the best results, no wind. We will discuss two methods that can be used working only from a starting point on the right-of-way.

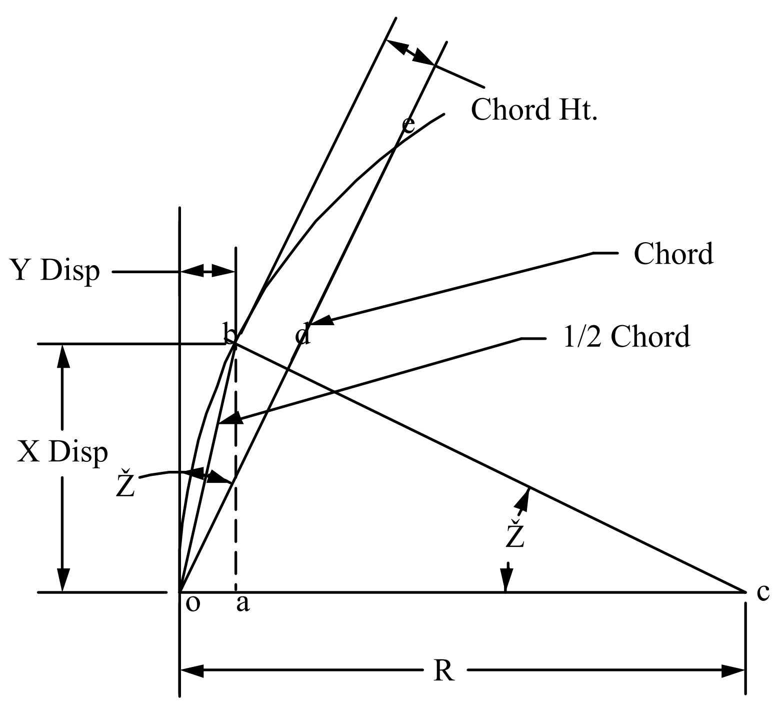


Figure 2-1 Geometry of horizontal curves

Offset method

First, we will look at a process where we will move in a straight line along the track, and at given distances, calculate how far we must move sideways to be on the curve. This process develops what can be called, a set of offsets. If you look at the right triangle a-b-c, in Figure 2-1, the radius R, is the line b-c, or c-o, and the side a-c can be found using the Pythagorean Theorem. The Y displacement is the radius, R, minus the line a-c. Y displacement can be found using:

Equation 2-1: $$\mathrm{YDisp} = R - \sqrt{R^2 - X^2}$$

The angle, ∂, can be calculated by using the arcsine of the X displacement, X, divided by the radius, R.

Equation 2-2: $$\partial = \mathrm{SIN}^{-1}(X/R)$$

The values generated with Equations 2-1 and 2-2 are only good for angles, ∂, less than 90^{o}. See TABLE 2-1.

TABLE 2-1: Offsets Y in inches for various radius, R, feet and X feet

	X Disp	10		20		30		40		50
Radius	∂	Y Disp	∂	Y Disp	∂	Y Disp	∂	Y Disp	∂	Y Disp
70	8.21	8.62	16.60	35.02	25.38	81.1	34.85	150.7	45.58	252.12
80	7.18	7.53	14.48	30.48	22.02	70.1	30.00	128.6	38.68	210.60
90	6.38	6.69	12.84	27.00	19.47	61.8	26.39	112.5	33.75	182.00
100	5.74	6.02	11.54	24.24	17.46	55.3	23.58	100.2	30.00	160.77
110	5.22	5.47	10.48	22.00	15.83	50.0	21.32	90.4	27.04	144.24
120	4.78	5.01	9.59	20.14	14.48	45.7	19.47	82.4	24.62	130.95
130	4.41	4.62	8.85	18.57	13.34	42.1	17.92	75.7	22.62	120.00
140	4.10	4.29	8.21	17.23	12.37	39.0	16.60	70.0	20.92	110.80
150	3.82	4.00	7.66	16.07	11.54	36.4	15.47	65.2	19.47	102.94
160	3.58	3.75	7.18	15.06	10.81	34.1	14.48	61.0	18.21	96.16
170	3.37	3.53	6.76	14.17	10.16	32.0	13.61	57.3	17.10	90.23
180	3.18	3.34	6.38	13.37	9.59	30.2	12.84	54.0	16.13	85.01
190	3.02	3.16	6.04	12.67	9.08	28.6	12.15	51.1	15.26	80.36
200	2.87	3.00	5.74	12.03	8.63	27.2	11.54	48.5	14.48	76.21
400	1.43	1.50	2.87	6.00	4.30	13.5	5.74	24.1	7.18	37.65

As an example to use this method, let’s lay out a curve of a 150 feet radius, see Figure 2-2. We will proceed by placing a string line along the track from where we want to start the curve out 40 to 50 feet. Move along the center of the track line 10 feet. Place a stake 4.0" inches from the string line. This stake will be the first center line of the curved track. Next, move out another 10 feet for the 20-foot location and place a stake 16 1/16". This will be the second location on the curve. Do the same for 30 feet, placing a stake at 36 3/8", and for 40 feet, place a stake at 66

1/4". You now have a curve laid out for 15.5° of arc. If you need longer curve, you can either add more points, as above, or start a new starting point and proceed as above.

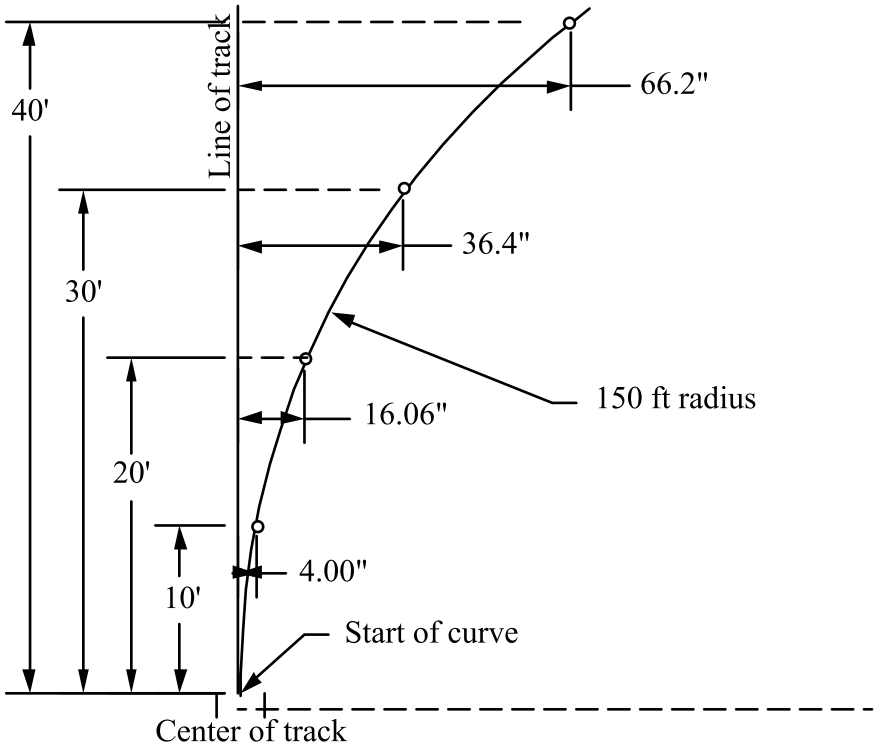


Figure 2-2: Example of offset method

Middle Ordinate Method

Second, we will develop a process called the Middle Ordinate method. A chord, o-d-e is a straight line between two points on a curve, see Figure 2-1. The Middle Ordinate, MO, b-d is the distance between the chord at the center, and the center of the curve, o-b-e. It is calculated by subtracting the distance c-d from the radius, R. Next let's calculate the side, c-d of the triangle, c-d-o

Equation 2-3: $\text{c-d} = \sqrt{R^2 - (\text{Chord}/2)^2}$

Next, subtract Equation 2-3, from the radius R.

Equation 2-4: $MO = R - \sqrt{R^2 - (\text{Chord}/2)^2}$

It is interesting to note that if a chord is picked that is twice the X Disp used in Equation 2-1, Equation 2-1 is equal to Equation 2-4, or the YDisp equals MO.

When using the Middle Ordinate method one can find more points along the curve by using half chords after the first MO is located. The half chord, b-o can be calculated by using the triangle, o-d-b

Equation 2-5: $1/2 \text{ Chord} = \sqrt{(\text{Chord}/2)^2 + \text{MidOrd}^2}$

Using Equations 2-4 and 2-5, Table 2-2 is developed.

TABLE 2-2: Middle Ordinates for 40-foot chord, 1/2 chord and 1/4 chord

Chord	40 ft.		1/2 Chord			1/4 Chord		
Radius	MO		ft.	in.	MO in.	ft.	in.	MO in.
70	35.02	in.	20	2.54	8.80	10	1.59	2.20
80	30.48	in.	20	1.93	7.65	10	1.21	1.91
90	27.00	in.	20	1.51	6.77	10	0.95	1.69
100	24.24	in.	20	1.22	6.08	10	0.76	1.52
110	22.00	in.	20	1.01	5.51	10	0.63	1.38
120	20.14	in.	20	0.84	5.04	10	0.53	1.26
130	18.57	in.	20	0.72	4.65	10	0.45	1.16
140	17.23	in.	20	0.62	4.31	10	0.39	1.08
150	16.07	in.	20	0.54	4.02	10	0.34	1.01
160	15.06	in.	20	0.47	3.77	10	0.30	0.94
170	14.17	in.	20	0.42	3.54	10	0.26	0.89
180	13.37	in.	20	0.37	3.35	10	0.23	0.84
190	12.67	in.	20	0.33	3.17	10	0.21	0.79
200	12.03	in.	20	0.30	3.01	10	0.19	0.75
400	6.00	in.	20	0.08	1.50	10	0.05	0.38

As an example, to use Middle Ordinate method, let's lay out a 150-foot radius curve. We will use a 40-foot chord. From TABLE 2-2 use Middle Ordinate, MO, is 16.07 inches for a 150' radius curve. The first point on the curve, a, is located by moving 20' along a straight line from o, and placing a stake 16 1/16" from the reference line just like laying out the curve as was done above. The stake at point a will be on the desired curve. Next place a temporary stake, t, 16 1/16 inches from point a, and 20 feet from point o, which is one-half of the chord. The temporary stake at, t, is used to sight to the end of the chord to locate point b. Place a stake 40 feet from the starting point o, in line with o-t. Now two stakes are on the 150' curve, a and b. To use the half chords, a line from o to a should be 20 feet 1/2". Find the mid point and place a stake 4 inches from the center of the half chord, point c. The same procedure can be used going from a to b. This procedure now produces an arc with four stakes to define the curve. To expand this process to produce a longer curve the temporary stake t is moved

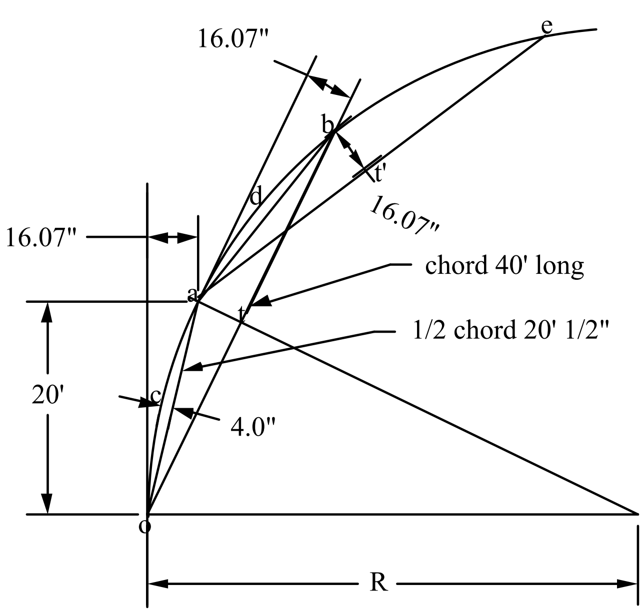


Figure 2-3: example of Middle Ordinate Method

to a point 16 1/16" from b to a point t', and 20 feet from point a. Just like before sight along, a-t' 40 feet and place a stake at e. A half cord could be used to find a point between b and e. The Middle Ordinate method allows a curve to be developed with measurements along the right-of-way only.

TABLE 2-3: Middle Ordinates for various chords

Chord	30 ft.		20 ft.		15 ft.		10 ft.	
Radius	MidOrd		MidOrd		MidOrd		MidOrd	
70	19.51	in.	8.62	in.	4.84	in.	2.15	in.
80	17.03	in.	7.53	in.	4.23	in.	1.88	in.
90	15.11	in.	6.69	in.	3.76	in.	1.67	in.
100	13.58	in.	6.02	in.	3.38	in.	1.50	in.
110	12.33	in.	5.47	in.	3.07	in.	1.36	in.
120	11.29	in.	5.01	in.	2.82	in.	1.25	in.
130	10.42	in.	4.62	in.	2.60	in.	1.15	in.
140	9.67	in.	4.29	in.	2.41	in.	1.07	in.
150	9.02	in.	4.00	in.	2.25	in.	1.00	in.
160	8.46	in.	3.75	in.	2.11	in.	0.94	in.
170	7.96	in.	3.53	in.	1.99	in.	0.88	in.
180	7.51	in.	3.34	in.	1.88	in.	0.83	in.
190	7.12	in.	3.16	in.	1.78	in.	0.79	in.
200	6.76	in.	3.00	in.	1.69	in.	0.75	in.
400	3.38	in.	1.50	in.	0.84	in.	0.38	in.

TABLE 2-3 is useful to determine the radius of an existing curve by laying out a chord along the curve for one of the chord lengths in TABLE 2-3. From the center of the chord measure the distance from the chord to the rail in inches. Look up the that distance in the body of the TABLE and move over to the radius. As an example a chord of 15 feet was measured along a section of curved rail and the MO was measured as 2 1/2 inches. This would indicate a radius of about 135 feet, as 2.5" would be between 2.60" and 2.41".

Curve Transition

A transition into a curve provides a smooth ride rather than a jerk when entering a curve. The preferred method is to develop a spiral with a continuing radius change until the desired radius is reached. The Talbot spiral is relative simple to use and the process is very similar to the offset curve method discussed above. The first step is to determine how long the spiral is to be. This will be the spiral length, L. The spiral length is where the desired curve becomes tangent to the spiral curve. As an example lets assume the spiral is to be 40 feet long. The next step is to develop four stations, starting at zero and ending at the spiral length. Each station number is the length in feet divided by 100’. The incremental distance along the spiral is I = Distance/100’. With L = 40’, four increments would be 40’/4 or 10’ each. I1 would be 10/100 or 0.1 and I2 would be 0.2 and so forth. The incremental offset is calculated from equation 2-6, where D is the degree of curve, L is the spiral length divided by 100’ and I is the incremental distance.

Equation 2-6: $Y = 0.291\ D/L\ (I)^3$

The relationship between the curve radius R and the degree of curve is shown in equation 2-7.

Equation 2-7: $R = 25/\sin(D/4)$

The curve will start at station 0+00 with a curve offset calculated by equation 2-8

Equation 2-8: $\text{Offset} = 0.291\ D/L^2$

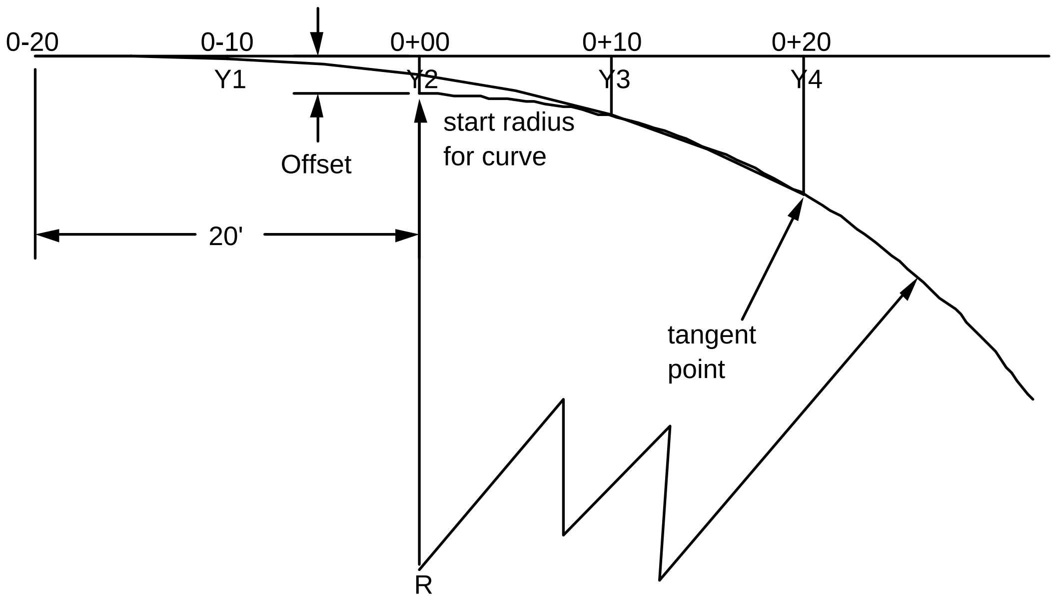


Figure 2-4: Talbot spiral method

Figure 2-4 shows the procedure of the Talbot spiral procedure, and TABLE 2-4 is

TABLE 2-4: Talbot spiral points for various radius for a L = 0.4

			l =	0.1	0.2	0.3	0.4
R	D	Offset		Y1	Y2	Y3	Y4
ft.	degree	in.		in.	in.	in.	in.
120	48.1	6.71		0.42	3.36	11.34	26.87
130	44.35	6.19		0.39	3.10	10.45	24.78
140	41.15	5.74		0.36	2.87	9.70	22.99
150	38.38	5.36		0.34	2.68	9.05	21.44
160	35.96	5.02		0.31	2.51	8.48	20.09
170	33.83	4.72		0.30	2.36	7.97	18.90
180	31.93	4.46		0.28	2.23	7.53	17.84
190	30.24	4.22		0.26	2.11	7.13	16.90
200	28.72	4.01		0.25	2.01	6.77	16.05

the incremental offsets and the curve Offset for a spiral length of 40 feet.

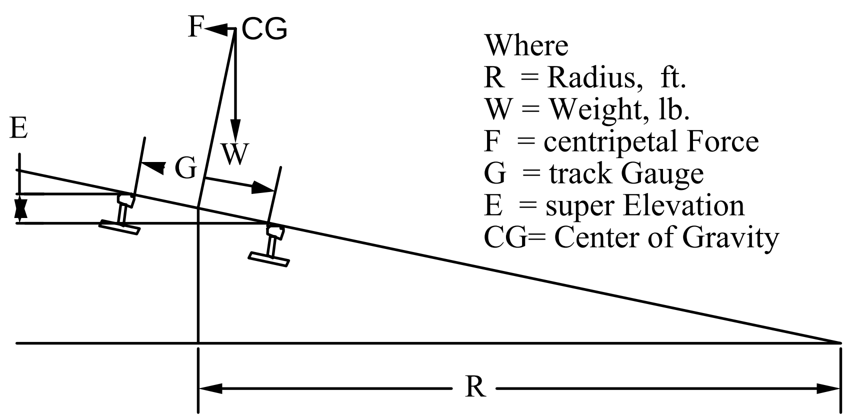
To use the Talbot spiral system start at the location where you want the curve to start, 0+00. Place a stake at a distance Y2 and at the same time place another stake at the Offset distance. Next, set two stakes at locations 0-20 and 0-10 at 0 and Y1. Than place the last two stakes 0+10 and 0+20. These stakes will define the spiral into the curve. The next step is to construct the desired curve. This process will use the same process as discussed above except the curve is started from location 0+00 at the Offset stake.

For low speed operations a simplify procedure is satisfactory. All that is required is to just double the radius for the first displacement by using TABLE 2-1. Place the first stake at X Disp 10 feet and Y Disp at double the radius and proceed from that point as discussed above. If the transition radius is greater than 200 feet it is not necessary to pre bend the transition.

Chapter 3: Super Elevation for the Swanton Pacific Railroad

Super elevation is where the outside track in a turn is elevated above the inside track. This elevation causes the train to lean into the turn. Super elevation is used in order to ease the train around a curve and to counter the centripetal force produced while a train is making a turn. The flanges on the railroad wheel will absorb the side forces produced in a turn, but there is a penalty to pay for this force. The greater the side forces on the flanges, the greater the rolling resistance produced during a turn. Not only is there is an increased pull to move the train, but the wheel flanges and the track are being worn.

In order to calculate the required amount of super elevation for a railroad the centripetal force F needs to be counteracted by the tilt of the car toward the turn. You can visualize this by thinking of a pendulum hanging in the center of a train. When the train is moving in a straight line the pendulum will hang straight down in relation to the car floor. As the train enters a turn, the pendulum will swing to the outside. If the train is tilted toward the center of the turn, the outward swing of the pendulum could be counteracted and it will point perpendicular to the floor again, see Figure 3-1. The weight and centripetal forces on a body can be assumed to act on the center of gravity of that body, or in our case a car. The centripetal force, F, can be calculated using



Where
R = Radius, ft.
W = Weight, lb.
F = centripetal Force
G = track Gauge
E = super Elevation
CG= Center of Gravity

Figure 3-1: Diagram of a railroad car in a turn

Equation 3-1

Equation 3-1: $F = \dfrac{Wv^2}{gR}$

Where: W = car weight in lbs.
v = velocity in ft./sec.
g = acceleration constant ft./sec^2
R = radius of curve in ft.

For equilibrium to exist, the force vectors F/W must equal the displacement vectors E/G, and solve the equality for, E, super elevation see Equation 3-2

Equation 3-2: $E = \dfrac{FG}{W}$

Combine equation 3-1 and 3-2

Equation 3-3: $E = \frac{v^2 G}{gR}$

Equation 3-3 would be easier to use if the velocity are expressed in mph V rather than ft./sec. Also, if all of the conversion factors and the value of g, 32.2 ft./sec. were expressed as a single constant.

Equation 3-4: $E = \frac{0.0668 V^2 G}{R}$

It is apparent from Equation 3-4 that the amount of super elevation is independent of the weight. Also, if the velocity is doubled, the amount of super elevation required for equilibrium would increase by 4, and the larger the radius, the less super elevation. This equation is very close to the equation that is recommended by the American Railroad Engineering Association for a comfortable ride.

Equation 3-5: $Ea = \frac{0.071 V^2 G}{R}$

There is only a 6% difference between Equation 3-4 and 3-5. The British recommended a similar equation that produces a much smaller amount of super elevation. The British super elevation for steam engines is;

Equation 3-6: $SE = \frac{0.025 V^2 G}{R}$

TABLE 3-1 shows the relation between the three super elevation Equations, 3-4, 3-5, and 3-6. For the comparison, a maximum speed of 10 mph was used.

TABLE 3-1: Super elevation, in, for 19" gauge and 10 mph

Radius ft.	E	Ea	SE
200	5/8	11/16	1/4
180	11/16	3/4	1/4
160	13/16	13/16	5/16
140	15/16	15/16	5/16
120	1 1/16	1 1/8	3/8
100	1 1/4	1 1/4	1/2
90	1 7/16	1 1/2	1/2

Equation 3-4 is very close to equation 3-5 and is between the other two. It is recommended that Equation 3-4 be used, and TABLE 3-2 be used as a guide to establish the amount of super elevation. The track crew should establish the recommended maximum speed for a section of track and use the procedure discussed in the Chapter 2, on curves, to establish the radius of the curve. Once the recommended maximum speed and the radius is found refer to TABLE 3-2 for the closes value and pick the required super elevation.

TABLE 3-2: Super elevation in inches for various speeds and radius.

Radius ft.	V = 5 mph	V = 7 mph	v = 10 mph
200	3/16	5/16	5/8
180	3/16	3/8	11/16
160	3/16	3/8	13/16
140	1/4	7/16	15/16
120	1/4	1/2	1 1/16
100	5/16	5/8	1 1/4
90	3/8	11/16	1 7/16

Chapter 4: Switches

Switch nomenclature is shown in Figure 4-1. The switch points are made from a section of rail that is machined to a point and to fit next to a stock rail. The switch point should be machined to be slightly lower than the stock rail to ease a wheel from the stock rail onto the switch point.

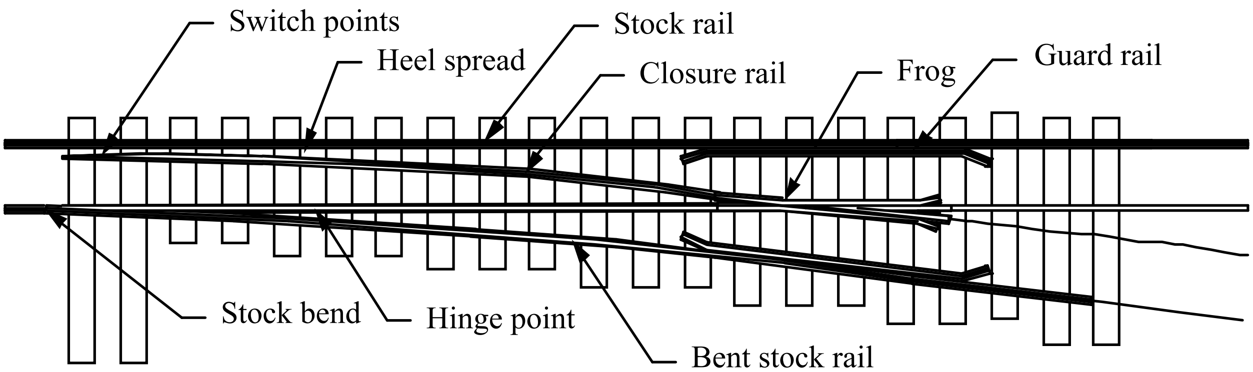


Figure 4-1: Nomenclature for a switch

The closure rail is fastened to the frog and is hinged to the switch point. The frog is a weldment or casting that allows the wheel to cross a rail. Frogs are defined by numbers that express the ratio of the frog angle. The frog number is:

Equation 4-1: $$N = \frac{Heel\ length}{Heel\ spread}$$

Where the variables used in Equation 4-1 are displayed in Figure 4-2. An empirical relation works to eliminate the guesswork selecting a frog for a specific curve.

Equation 4-2 $$N = \sqrt{\frac{6R}{G}}$$

Where, N, is the frog number, R, is the radius of the curve, in feet, and G, is the track gauge in inches. For example, our gauge is 19 inches and let’s use a radius of 150 feet.

$$N = \sqrt{\frac{6 * 150}{19}} = 6.9$$

The minimum frog number should be a 7. Most of the frogs used on SPRR are number 8.

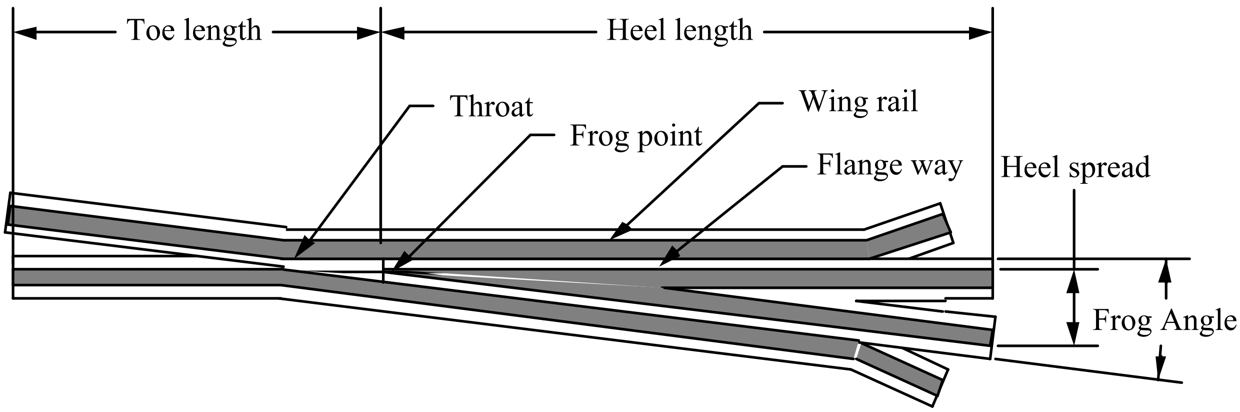


Figure 4-2: Nomenclature for a frog

Once the frog number is determined a frog can be constructed. Start out with the heel point section. Cut two sections of rail for the heel length and add a small amount for bending. Bend the end of both rails so the web will line up with edge of the railhead. At the other end, drill two 9/16 holes for the splice plates. Grind off the excess railhead in the direction of the bend to form a straight line along the railhead. Machine off to a point, the other side one half the frog angle. Weld the two halves together to form the point. Next, cut two sections of rail to construct the wing rails. Bend one end about 25^{o}. Make a bend about 8 to 10 inches from the other end one-half the frog angle. Drill two 9/16 holes for the splice plates. Remove part of the rail base to allow the wing rail to set against the point and have a flange way space of about 5/8 inch. Weld the wing rail to the frog point, making sure that the heads of the toe and the heel form a straight line. Construct the other wing rail as a mirror image of the first and weld in place as above. Make sure that the throat and flange way have the proper clearance, and the rail heads form a straight line.

An Excel program is available to calculate all the variables necessary to construct a switch, based on formulas from American Standards Association, A.S.A. turnout standards.

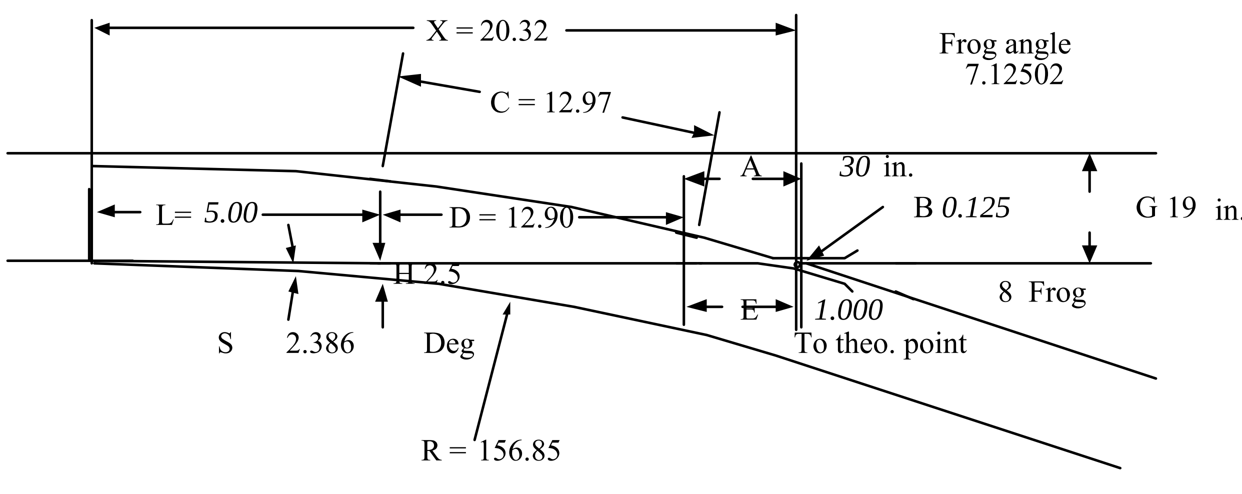


Figure 4-3: Computer output for switch design

TABLE 4-1: Computer input and output parameters

Input Parameters		
A =	30	in
B =	0.125	in
G =	19	in
H =	2.5	in
L =	5	ft.
N =	8	Frog #
P =	0	in
Cast Frog =	0	in

Output Parameters					
Switch Angle	S =	2.39	degrees		
Switch Radius	R =	1882.2	inches or		
		156	feet	10.2	in
Theoretical	X =	243.8	inches or		
Lead		20	feet	3.827	in

Dependent Variables		
E =	29	in
F =	7.13	degrees

Temporary Variables	
L cos S =	59.948
G - H - EsinF =	12.9030
Tan 1/2(F + S) =	0.0832

Closure Rails					
Curved	C =	155.7	inches or		
Rail		12.0	feet	11.7	in
Straight	D =	154.8	inches or		
Rail		12.0	feet	10.8	in
Middle Ordinate	M =	1.61	inches		

The Excel program will solve the various equations necessary to construct a switch. The input parameters will determine the values of the output parameters and closure rails. "A" is the length of the frog toe, in inches, which is the distance from the point of the frog to the toe. The toe length has an inverse affect on the switch radius because this section of the switch is made of straight rail sections. It is a good idea to keep this length as small as possible. The longer the toe length, the smaller the switch radius. "B" is the thickness of the frog point in inches, which is the diameter of the point. "G" is the track gauge, that is 19 inches for SPRR. "H" is the space between heel of the switch point and stock rail. "L" is the switch point length in feet. A good length is from 4 to 6 feet. The parameters H and L form a triangle for which the tangent is the switch angle "S". The value of "S" should be small, 2 to 3 degrees as this angle is the abrupt angle that the train will have to negotiate as it moves through a switch. "N" is the frog number as discussed above. "P" is the thickness of the switch point. It is recommended to use zero for point thickness.

The program calculates all the outputs. "S" is the switch angle and is the amount of bend that must be permanently bent into the stock rail to form the stock bend. This bend should be placed in front of the switch point, as it will shelter the switch point on that side. "R" is the switch radius that must be placed into the stock rail and the curved closure rail. The curve should start at the heel of the switch point, for a distance of a chord, the length of "C" the length of the curved rail. The Middle Ordinate is provided by the program to ease the process of producing the curved section. The length of the two closure rails are provided, but it is suggested that the switch be laid out and the closure rails be cut to length to fit the layout. The theoretical lead "X" is the length of the switch, from the point of the frog, to the point of the switch.

When constructing a switch, layout the lead and turnout leg of the track, so the curve becomes tangent to the lead. Use Equation 4-2 to determine the frog size. Construct the frog and place it where the two tracks meet. Place the parts in place to observe how they fit together. When satisfied with the placement of the frog, lay out the switch ties, and place switch tie plates on them; see Figure 4-4 as shown in Figure 4-5. Next, place the frog and lay the straight rail behind the frog in place. Lay the straight stock rail, align frog to rail and gauge. Spike the rail and frog in place near the frog rail. Check the length of the straight closure rail, gauge, and spike in place. Bolt the switch point to the straight closure rail. Next, bend and roll the curve in the turnout stock rail. Make sure that the heel space is correct between the straight closure rail and the stock rail. Align and spike in the stock rail, making sure that the switch tie plates are in place. Gauge and align the curved closure rail and spike in place. Bolt in place the other switch rail, keeping the bolts loose enough so the points will move freely. Finish spiking any ties and connect switch rod. Check the operation of the switch, and add guard rails.

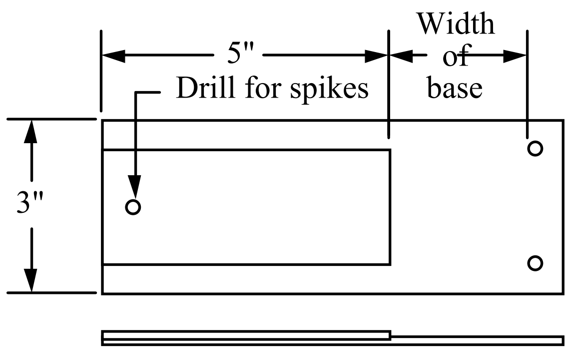


Figure 4-4: Switch tie plates

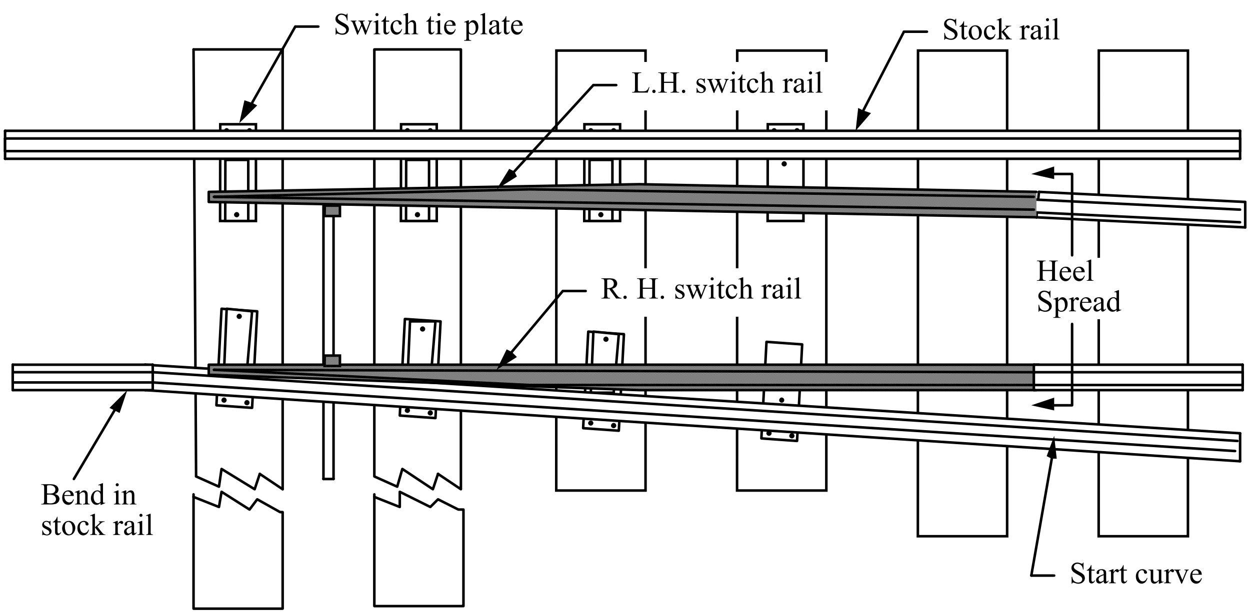


Figure 4-5: Placing switch rails and plates

The Excel program "turnout pt" was used to develop Table 4-2 of variables for different switch numbers, N. For this the table following input parameters were maintained constant.

A, the distance from the from the frog point to the frog toe = 30 inches.

B, the thickness of frog point = 0.125 inch.

G, track gage = 19 inches

H. heal spread of switch = 2.5 inches.

TABLE 4-2: Switch dimensions for various frog numbers N

N	Switch Radius	Frog Angle	Switch Lead	Closure Curved	MO	Closure Straight
6	76.48'	9.5	16.79'	9.45'	1.75"	9.35'
7	112.35'	8.13	18.61'	11.26'	1.69"	11.18'
8	156.85'	7.13	20.32'	12.97'	1.61"	12.90'
9	211.32'	6.3	21.93'	14.58'	1.51"	14.52'
10	277.50'	5.71	23.44'	16.10'	1.40"	16.04'