Wyoming Division Historical Society HO MODEL RAILROAD CORNVILLE, ARIZONA (562) 458-9589

Welcome To The Wyoming Division Historical Society

Modeling the Union Pacific from Cheyenne, Wyoming to Ogden, Utah.

ABS Signals on the Wyoming Division
The design and installation of ABS plus some signals for situations particular to models
Revised January 2020
By Verryl Fosnight

I will first briefly describe the Wyoming Division layout. Following that is a brief description of its operating system consisting of a unique car forwarding system and operations by Rule 251D for double track running with simulated written track warrants. That is followed by a detailed description of how signals were designed and installed on it.

The Wyoming Division Layout

The Wyoming Division is a large HO layout that models the Union Pacific Wyoming Division from Cheyenne, Wyoming to Ogden, Utah. The layout was designed and built for operations. Figures 1, 2, and 3 show the track plan on three levels. These are the latest revised track plans (v13.4).

A very large double ended staging yard extends the layout both east of Cheyenne and west of Ogden. The staging is seen on the lower level of the bench between aisles 8 and 9 on the green lower level track plan. The approximate center of the “sceniced” part of the layout is the large helix (large oval seen on all three levels.

The era is 1957 with huge steam engines, 4-12-2’s, 4-6-6-4 Challengers, and 4-8-8-4 Big Boys, as well as all three of the UP gas turbine electrics, and the early diesels.

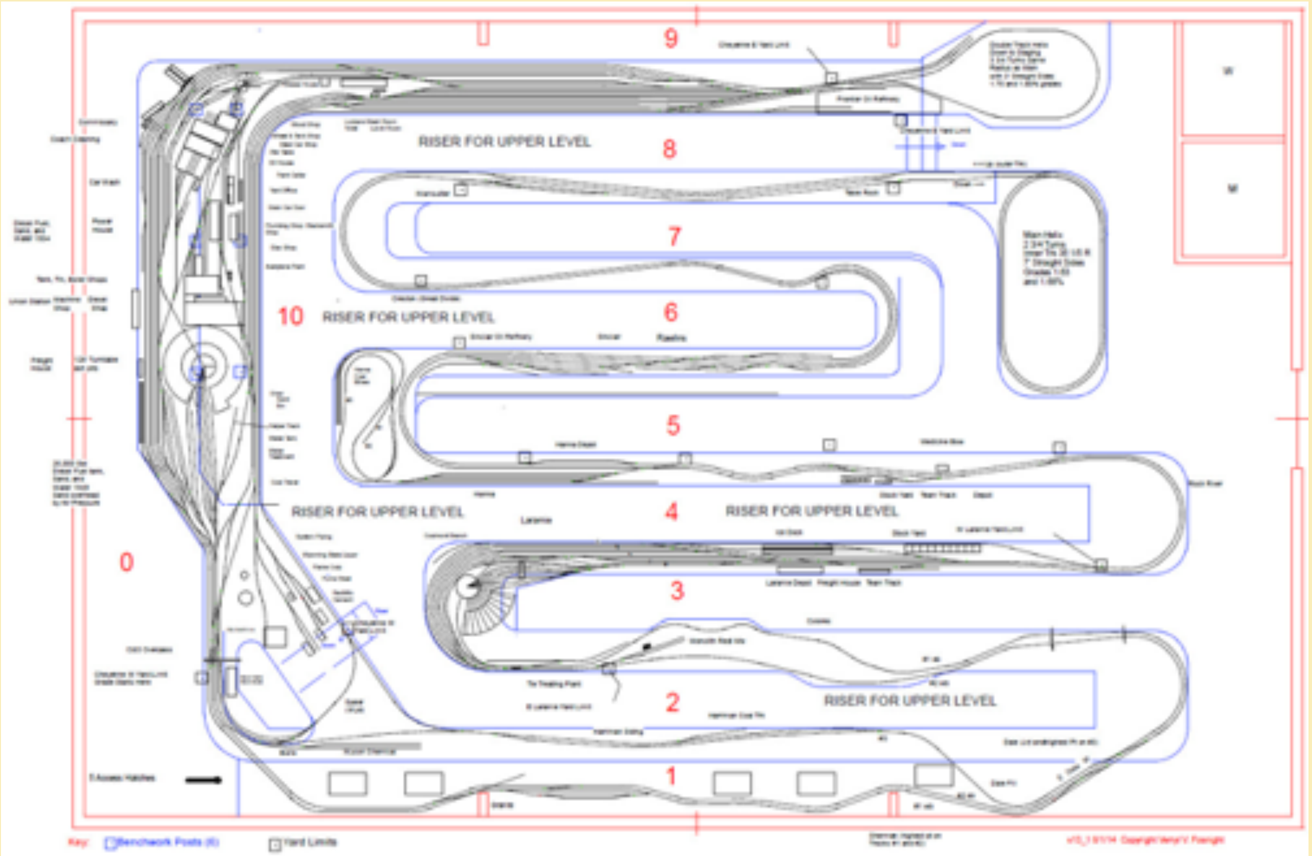


Figure 1. Wyoming Division Upper Level, version 13.4. The building is 50 x 75 feet.

The model has a double track main of 1,006 feet, and nearly 5,300 feet of HO track on two levels including the hidden track on a third level. On the black upper level a train running through Cheyenne eastward uses the smaller double track helix to spiral down to staging on the lower (green track) level; for east of Cheyenne we

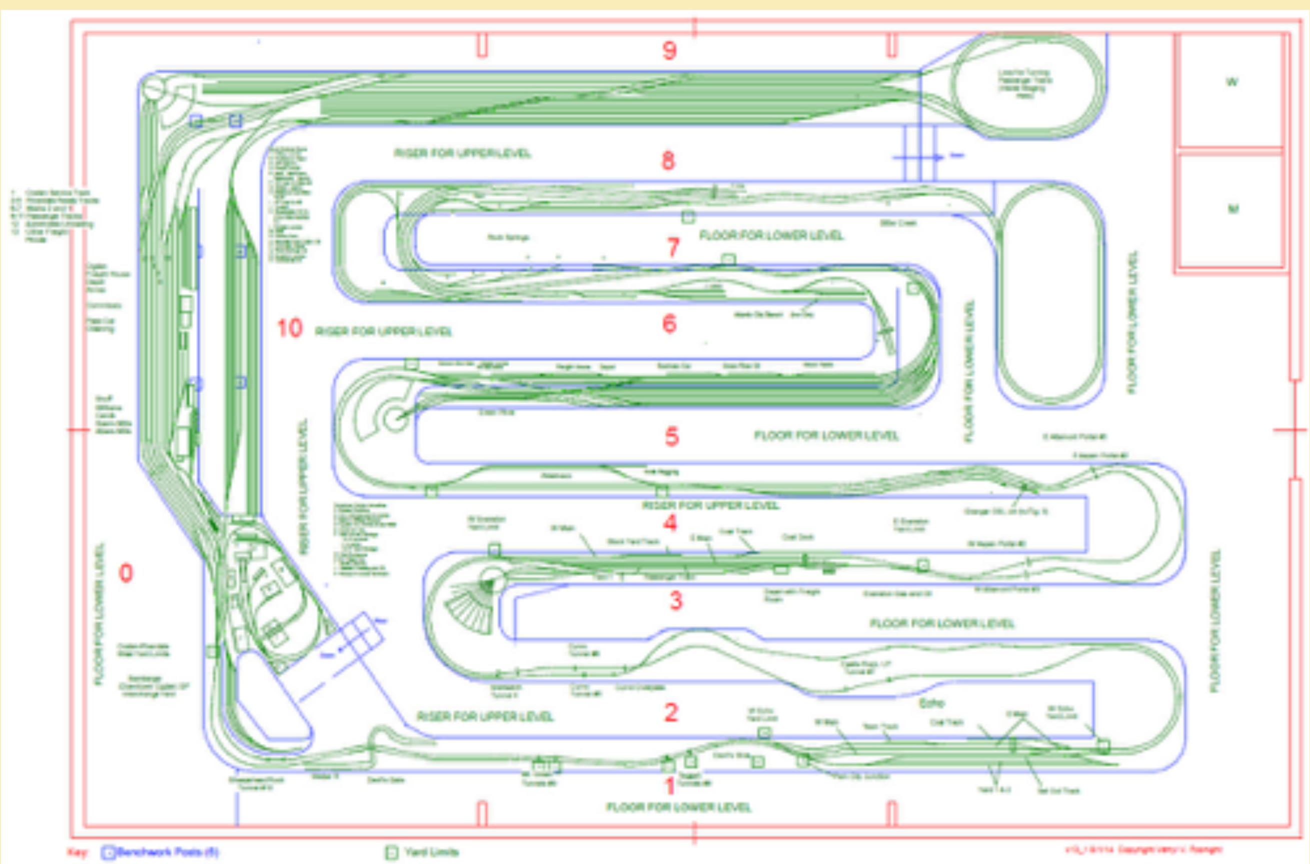


Figure 2. Wyoming Division Lower Level, version 13.4. The benches are free-standing mushroom design with aisles on all sides.

use the code name of North Platte, Nebraska which stands for Chicago; Marysville, Kansas; Kansas City; St. Louis; and beyond.

Ogden borders staging on the lower level; west of Ogden the same staging is entered from the other direction than from Cheyenne, with a code name for operational simplicity of Oakland or Los Angeles (west of Ogden). Simply stated, the point to point design of Cheyenne to Ogden is folded onto parallel benches with the main helix in the middle to connect the upper and lower levels. And staging is between these two “ends” of folded benches

The layout includes the Oregon Short Line (OSL) as hidden track on a third level below the 2nd level. The OSL starts at a junction on the lower level at Granger, near the right end of aisle 5 on Figure 2, that junction being indicated by an arrow on the orange plan. The whole OSL is shown in Figure 3 as the upper length of orange track which cuts across the corner of Aisle 4 and loops around the end cap of the bench as hidden track on the third level under level 2 and eventually terminates in another staging yard representing Portland, Oregon. With this secondary staging yard and the main staging (shown on the bench between aisles 8 and 9 on Figure 2), the layout is a coast to coast railroad.

The other orange colored hidden track at the bottom of Figure 3 is a short representation of the Park City Branch. A local leaves Ogden and switches Echo then continues to Park City, Utah and leaves cars at that yard, and returns to Echo with a new train for a second round of switching before returning to Ogden.

The main yards are at Cheyenne and Laramie on the upper level and Ogden and Green River on the lower level. Minor yards are Hanna and Rawlins/Sinclair Oil on the upper level, and Evanston and Echo on the lower level. There is also the very short Coalmont Branch from Laramie (black plan, corner of the bench where aisles 4 and 10 meet). There is also the Reliance Branch to Reliance, Wyoming (coal mining) and Atlantic City (iron ore) from Rock Springs. The Reliance Branch is entirely at the very back of the Rock Springs bench below aisle 7 on the green plan. Rock Springs on the lower level should have a yard but we opted to use the bench space for 20 industries instead of a yard. Green River is nearby, so all freight traffic into and out Rock Springs goes through Green River. This makes Rock Springs a very large “switching puzzle” over 50 feet long with numerous facing point-trailing point turnouts to deal with by the Rock Springs Road Switching Crew who switch Rock Springs and shuttle freight back and forth to Green River.

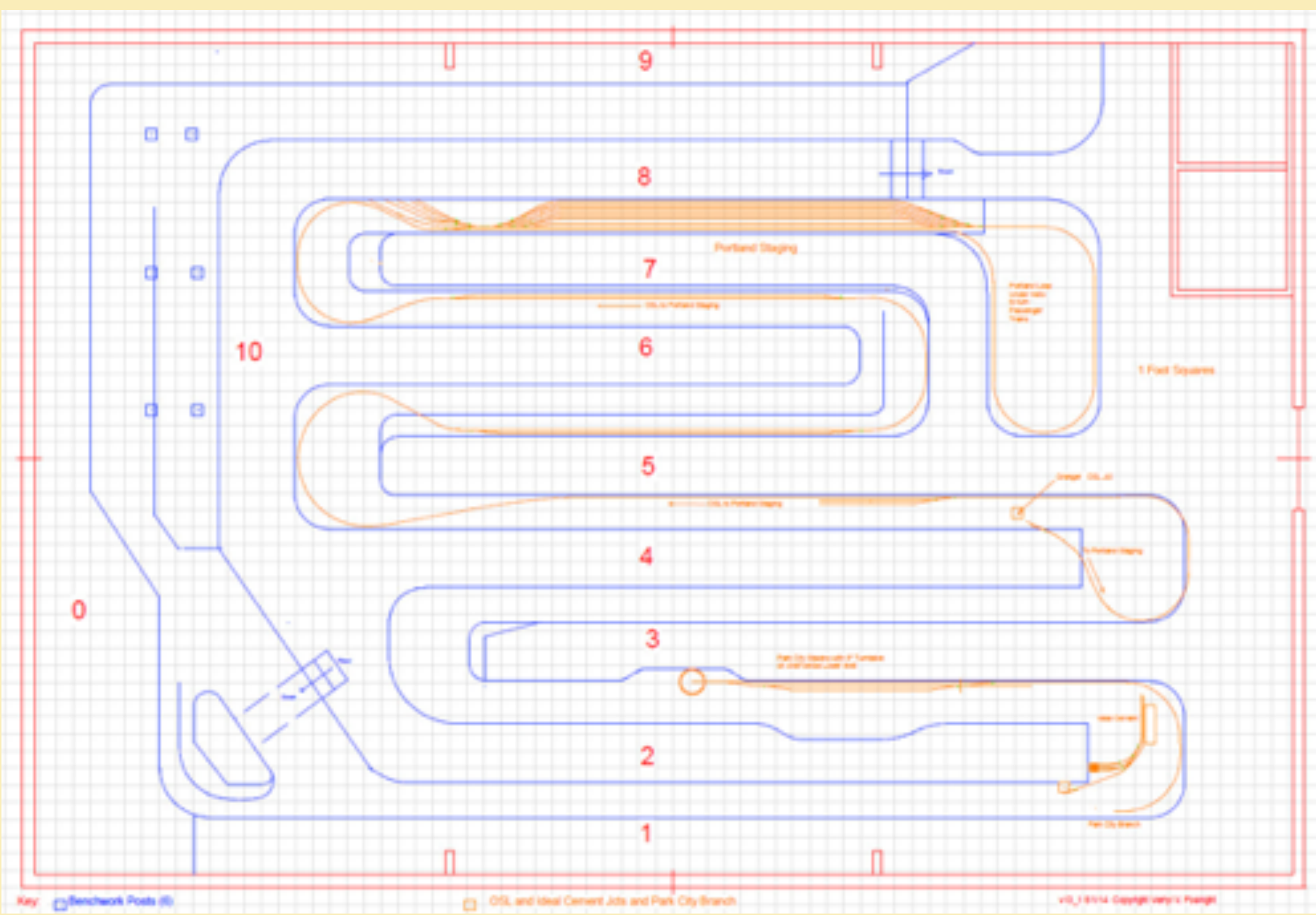


Figure 3. Wyoming Division Third Level, Hidden Track, version 13.4. The upper orange track over 4 benches is the OSL, and the lower is the Park City Branch in Utah. The Grid shows 1 foot squares and has been included here to show the size of all three levels.

Operations are governed by Rule 251D for double track running with written track warrants, but to streamline operations, the written track warrants are given as a list of destinations on a Train Order sheet for each train. The TO's are part of my four card car forwarding system.

Car Forwarding System and Track Warrants

The unique Four Card Car Forwarding system that I designed for the Wyoming Division includes a one sheet Train Order (TO) for each type of train. The system was described in the Fall 2015 issue of The Dispatcher, the magazine of the NMRA OpSIG. An updated copy of that paper is on my web site at http://wyomingdivision.org/ . That car forwarding system has single move car cards to which subsequent moves are listed line by line and new moves added on the next line either in batches or move by move. My system also has block cards for blocks of cars, locomotive cards, and the Train Order. A sample Train Order sheet is shown in Figure 4 below. The script indicates handwritten information added to the blank TO by whoever assembled the train, usually the staging YM.

I use TO's for trains of the following types: Passenger, Specials (through trains like PFE Specials), Forwarder (other through freight trains), Manifests (through trains with 5 or 6 head end cars to be switched), and Locals (also called Drags or Extras). This list is in order of descending superiority, and each type has a similar TO, tailored to the train type. Figure 4 shows a TO for a Manifest West train, that is, in e Cheyenne to Ogden direction. For a Manifest East, the order of the lines in the array would be reversed, Ogden to Cheyenne. Setup for an operating session is very simple using this system.

Locomotive Number:	4001	NP-Portland Manifest West	Date:		Clock In:	
Train Order (p 1 of 1)	Engineer:		Conducter:		Train No:	# in Session

Key:
- Coal/Fuel/Water/Sand — Available = Stop only if required to do so by Locomotive Card; not available, you should continue without stopping
- Pick Ups — ✔ = Check Fascia Boxes at location for cars you can pick up (going your way) and take them with you when you leave
- Set Outs — ✔ = Check your own Car Cards for cars to be left here, **but move off spot cars on to spots first.** Set out number written in.
- YM or None? — In yards with YM do work with him. With no YM do your own Car and Block Card work with switcher at that yard
- Get Helper — Yes = Do get helper from YM, Hostler, or Helper Engineer, receive instructions on how to run with him pushing, then leave--you do OS
- Release Helper — Yes = Stop per YM instructions to allow helper to leave your train
- Engine Change — Yes = Stop to change locomotive(s) per YM and/or hostler instructions
- Phones — In case of a problem or question, call Dispatcher. **ALWAYS** answer any phone to take orders for you or others.

SEE ABOVE EXPLANATIONS TO ENTRIES IN ARRAY BELOW

#	Stops	Road Crew Instructions for Each Location (Verbal listing of Array of 8 Columns to Right)	Direction	Engine No.	Coal/ Fuel	Water/ Sand	Pick Ups	Set Outs	Get Helper	Release Helper	Engine Change
Start	East Staging Yard	Get train and clipboard with all cards from staging									
1	Cheyenne A/D (Depot)	Hostler gets Loco and gives new Loco & Card to Road Crew	R				✔	✔	Yes		
2	Tower A	Tower A Operator (TM) will help to Leave Yard									
3	Harriman Siding	Take only when directed by DS and Tower A Operator TM	R		Available						
4	Dale Junction	Change to left hand track per yellow switch panel in aisle	R->L								
5	Laramie	Change R->L track inside E Limit as enter yard	L->R		Available		✔	✔		Yes	Yes
		Work at Ice Dock or Stock Yard as needed	R								
6	Medicine Bow	No YM/Do your own work and Stock Yard as needed	R		Available		✔	✔			
7	Hanna	No YM/Do your own work and Stock Yard as needed	R		Available		✔	✔			
8	Rawlins-Sinclair	No YM/Do your own work and Stock Yard as needed	R		Available		✔	✔			
9	Wamsutter	No YM/Do own work FH & Stock Yard/Take siding per DS	R				✔	✔			
10	Table Rock	Leave Siding as directed by DS	R								
11	Rock springs	Continue to Green River to make pick ups and set outs	R		Available		✔	✔			
12	Green River	Pick up and leave cars for RS, GR, Westvaco in GR	R				✔	✔			Yes
13	Westvaco	All Pickups and setouts done by Green River YM	R				✔	✔			
14	Granger	PORTLAND TRAINS TURN OFF ON OSL JUST PAST WESVACO	R		Available						
15	Evanston	No YM/Do your own work and Stock Yard as needed	R->L				✔	✔			
16	Curvo Overpass	Change L->R track	L		Available						
17	Echo	No YM/Do your own work per Cards	L->R				✔	✔			
18	Ogden E Yard Limit	Change R->L track at E Yard Limit	R				✔	✔			
		Deliver train to Ogden YM for him to take to staging	R								
19	West Staging Yard	OgdenA/D->Staging by Ogden YM & Staging YM					Clock Out:				

NP-Portland Manifest West

Staging Yardmaster: **When this train arrives at your yard, you may use any cars from it for any other train.**

Figure 4. Sample Train Order, each line of which is the written authorization to occupy the track up to the location listed on that line.

A road crew, usually an individual who is both engineer and conductor, receives a filled out TO with his train. Each line in the array is considered a Track Warrant from the location on one line to the location on the next line. As the train progresses, the crew or tower operator must report its location in real time at predetermined locations to the Dispatcher to "OS" (get marked On Sheet), by calling on a private phone system and saying, "This is train number xxxx North Platte to Portland Manifest West leaving location." The xxxx is the locomotive number, and if locos are changed the dispatcher must record that on his Train Sheet.

The Dispatcher then replies, "Thank you. You are cleared to [next OS location]."

The advantage of the single sheet TO's is that it presents an easy to present a list of instructions, not a wordy prose instruction sheet or booklet for each train. All information about that train is readily available in the standard format of the array.

My car forwarding system using single move car cards, block cards, locomotive cards and Train Orders was fully described in the Fall Quarter, 2015 Dispatcher's Office, and that paper, slightly revised is on my website at http://wyomingdivision.org/ .

Double Track Safety and Authority on the Wyoming Division

I wanted to have a traffic control system for granting track authority that was simple to master for amateur operators who operated only once a month or less, but prototypical enough to seem a lot like real railroading.

The Wyoming Division models almost the entire Wyoming Division of Union Pacific in 1957. Radios were not fully operational in 1957, but UP had a phone system from depot to depot, and Centralized Traffic Control (CTC) was only used on Sherman Hill and a few other areas like the single track OSL. ABS per Rule 251D was in use over the rest of the route, but I wanted a dispatcher to be involved to help passenger trains and other high priority trains pass slower freights, and to protect MOW crews, or others working on the main, and to cover other unusual situations. And in case I did not have enough operators for a session, I wanted to be able to run without the dispatcher.

Operations on the Wyoming Division are by Rule 251D with Direct Traffic Control with Track Warrants, and the TO's are an abbreviated simulation of pre-generated track warrants to eliminate the paperwork burden of individual slips of handwritten orders passed around.

The telephone OS procedure described near the end of the previous section comprises verbal confirmation of the Track Warrant. I do not require the crew to read it back to the dispatcher.

This safety and authority system is a simplified form of Direct Train Control (DTC). DTC is like Track Warrant Control (TWC), except the operational blocks are fixed and not variable, because the signal blocks are physically fixed. The Since the DTC control sections never have to change, the preprinted sheet works well.

Single Track Safety and Authority on the Wyoming Division

Most of the mains are double track, but Track #3 from Cheyenne to Dale Junction is single track bidirectional, and the Oregon Short Line (OSL) hidden track is also single track bidirectional. On these single tracks, trains operate by rule 271 as if the trains in each direction were on a timetable and under strict dispatcher control. We use a timetable only for passenger trains, following the UP practice of sending freight trains out as soon as they were ready, at least on the busy Wyoming Division, which was a traffic bottleneck because of Sherman Hill west bound and the Wasatch Mountains east bound. On the layout the Trainmaster sends out all freights, including those on the single bidirectional tracks, and the dispatcher should control all aspects of traffic using these single tracks.

This is not to say UP did not use a timetable, but operationally trains were called and sent out as needed. A train sent out conveniently near the timetable time would have been designated as that scheduled train. This allowed for operational flexibility to fulfill customer needs while having a timetable that the marketing department could point to for sales.

All required OS locations for both the double track and the single tracks are marked by hard to miss hot pink fascia signs.

Automatic Block Signals

In March 2017 an Automatic Block Signal (ABS) system was completed for the railroad. The Union Pacific had no CTC on the Wyoming Division except for Sherman Hill and the OSL. Although we usually operate with a dispatcher, I did not want the dispatcher to be necessary for operations by having a panel up on the mezzanine at the Dispatcher's desk. Dispatching is a great job, but Arizona is sparsely populated except for Phoenix 100 miles away, so we often need road crews more than a dispatcher for the double track layout. And even though a dispatcher is preferred for realism, with no dispatcher, operators can easily work out meets and passes between themselves, mainly because of the large size of the layout and its post and wall-free visibility.

<u>Signal Design Goals</u>

I wanted ABS with 3 aspect signals with separate red, yellow and green lenses in a vertical in-line single signal head, and I wanted the over-sized single snow hood as used by UP in blizzard prone Wyoming. I also wanted a few signal bridges to highlight yards.

At Dale Junction 3 blocks meet, and to complicate the junction further, I use it to follow UP practice and change the current of running from right to left for west bound trains (or left to right for east bounds).

Figure 5 shows the switch panel on the fascia in front of Dale which controls the Dale Tortoise machines. The map on the panel shows the junction, and arrows on the map define the routes to change the current of running. The switched route is shown by LEDs counter sunk into the panel surface. The bi-directional single track #3 (Harriman Cutoff) merges with both Tracks #1 (west bound)

Figure 5. Tortoise machine switch Panel set in fascia at Dale. The scenery is complete here.

and #2 (east bound). There are two routes west over Sherman Hill, #1 or #3. Number 3 runs only as far as Dale. From Dale on the west side of the Hill down into Laramie, there are the same two tracks, #1 and #2, but there is a change in the current of running at Dale, so, looking toward Laramie from Dale the left-hand track #2 is used down the Hill to Laramie, and #1, is used up the Hill from Laramie, so there is left hand running on both tracks between Dale and Laramie. This change of running was started by UP in 1905 when the entire railroad was doubled tracked, and #2 came into being. The new Track #2 from Laramie up to Dale was widely separated from the original 1860's track #1, and it was built with a gentler grade, so it became the east bound route up. Hence the change of running between Dale and Laramie.

For this complicated configuration I at first designed signals with multiple heads on the masts that would simulate realistic running through this territory. I used 2 aspect signals with as many as 4 heads on a mast, and the yellow or red LEDs were to be controlled by the outputs of the Tortoise switch machines that controlled the seven turnouts (three crossovers and the junction turnout). Thus, the signals in fact would reflect the operators' settings of the Dale turnouts; they would not control safety to tell operators when and where to go. They were in effect non-static scenery.

On the east side of Dale, the newer Track #2 ran right beside the older #1, so no improvement in grade was possible. Therefore, conventional right-hand running was the rule. But also on the east side from Dale toward Cheyenne there are two possible routes: down #2 (right hand running) or down #3, the Harriman Cutoff, which was single track bi-directional (up or down the Hill). Taking Track #2 through Cheyenne and beyond is used, as per UP, as the direct route to North Platte, Nebraska through Cheyenne. Beyond North Platte trains ran to either Marysville, Kansas and on to KC, St. Louis and beyond; or North Platte to Council Bluffs, Chicago, and beyond. All eastern destinations beyond Cheyenne in the above list are simulated by staging on the layout, and we call any of these destinations "NP" for North Platte.

The route east down Sherman Hill on Track #3 is used by UP and by the layout as a more direct route to Denver, and this route bypasses Cheyenne. So, #3 is not only a gentler grade up the hill west bound, but a cutoff to Denver for east bound trains. On the UP or the layout Denver is reached by taking the south leg of the Speer wye (visible in Figure 1 near the lower left corner). Beyond the southern point of the wye is considered layout hidden track that bypasses Cheyenne and its yard on the left and top benches in Figure 1, but it never communicates with Cheyenne until that "hidden" track reaches the far or east classification yard ladder where it junctions with the small helix lead, near the red aisle number "9" on the track plan. A train taking this Denver track route goes down the small helix, like all terminating east bound trains, but in this case, staging is thought of as Denver, Colorado.

<u>I relent and Add Computers</u>

I originally had a goal of no computers for the signal system, but Dennis Drury supervised the installation of his signal logic boards and the current detectors. He suggested that an Arduino computer would handle Dale, and it would do so without a CTC machine requiring an operator to man it. To have a nice op session requires about 25 operators; a full session requires 35 or more. In sparsely populated Arizona we usually only get about the 25, so I was loath to have an operator devoted to a CTC computer for Dale, and that did not seem like a very attractive job to assign to someone. And since UP did not have CTC except up Sherman Hill, I was willing to do without CTC and a computer. When Dennis suggested the use of Arduinos, which would not require an operator, I immediately agreed. My original Tortoise output scheme would simulate ABS, but it would not be rigidly ABS. But more important for Denis' design, Dale became an integral part of the blocks of ABS, not an odd section between one string of blocks and another.

I also designed the signals at each end of the siding on the bi-directional single #3 to be controlled by the outputs of Tortoise machines, even though this meant installing new Tortoise machines to replace the manual ground throws. Because the siding divided Track #3 into three signal blocks which were just slightly longer than a full 30 car train, Dennis easily convinced me to use each side of the siding as a short section of double track for Track #3 at the end of two longer blocks instead of three. This still requires an east bound and west bound trains to meet on the double track portion, as if one was shunted to a siding, but it allows the signals to be true ABS rather than simulations using Tortoise machine outputs. As at Dale, this way, the signals are true ABS for traffic control, as opposed to being "scenery" that reflects operator turnout settings, and a CTC machine and extra operator was not required.

I have nothing against computers. I could not live without the 7 desktops plus tablets I regularly use at home, at the layout and my office in two states. But I did not want to be bound to having a dispatcher for all sessions if turnout was light. Furthermore, these Arduinos would be merely microprocessors that needed no operator attention. They would operate just like the logic boards to set the signal lights. This means that they are unseen like the old relay systems used in 1957. Alternately, I can think of them as human switch tenders with an Italian heritage, none of whom want Columbus Day off.

Dennis kindly allowed me to share the code for the Arduino computer used at the Harriman Cutoff portion of track converted from a siding to a length of double track. It is at the end of this article.

<u>Design Characteristics of the ABS</u>

Here is a summary of the characteristics of the ABS Design on the Wyoming Division:

A. Each track of the double track is signaled independently from the track for the other direction in the conventional ABS manner.
B. The signals are generally ABS 3 aspect (Green, Yellow, and Red) signals.
    a. Green indicates the immediate 2 blocks ahead of the train are unoccupied. Full speed should be maintained for a green aspect.
    b. Yellow indicates the immediate block ahead of the train is unoccupied but the second block ahead is occupied. Reduced speed is required, that is, a speed that safely allows the train to slow and stop to avoid a collision or other mishap.
    c. Red indicates the immediate block ahead of the train is occupied, and the train should be slowed to a safe stop before the end of the block with the red signal, and certainly before collision with a train ahead.
    d. It should be noted that the instant a loco enters a block, that block's signal will change from green to red if both the next blocks are unoccupied before the train enters the block. This is because the locomotive of the train draws current from the block just entered, which current draw is detected as if the block were occupied, which it is by your own locomotive.
    e. It should also be noted that the instant a loco enters a block that is already signaled yellow, that signal will change to red because of the occupancy of the just entering train the instant it enters the block.
    f. These two instances of "self-occupancy" causing a red signal are to be disregarded; the train should proceed normally as if the signal was still green or yellow, respectively.
        1. Except for the above exception of self-occupancy, all red aspects on either direction of double track, other than those at yard limits (see "C" below), or those that are red due to self-occupancy (see B. d. and B. e. above) are permissive reds, which means that after stopping, the train may proceed forward at a very slow speed not to exceed that required to make a safe stop for any obstruction on the track immediately ahead that is visible (personnel, broken track, another train, etc.)
        2. All red aspects of single (bi-directional) track, including sidings, are absolute reds, which means a train must stop and must stay stopped until the signal changes to yellow or green (if there is a green), or until instructed to proceed through the red at a safe speed by the dispatcher.
C. The signals at yard limits controlling entry to all manned yards (our so called major yards) Cheyenne (east yard limit), Laramie and Green River (east and west limits) and Ogden (west yard limit), have only yellow or red aspects, and they are normally red, that is red until manually overridden to change the aspect to yellow over red.
    a. These reds are absolute reds and not permissive reds.
    b. The normally red signals confronting each train approaching these yard limits are normally red to all trains requiring a stop absolutely, whereupon the train crew must notify the Yardmaster (YM) of its presence and its desire to enter the yardmaster's yard.
    c. The YM will set the route into and through the yard for the train, and then give his clearance to enter his yard at reduced speed by pressing an electric switch on his fascia inside the yard which turns the signal from red to yellow-over-red (both red and yellow). This yellow/red gives a train permission to proceed into the yard at reduced speed along the route previously set by the YM. After about 30 seconds, the signal reverts automatically from yellow over red to red.
    d. This automatic reset to red is to relieve the YM from having to remember to reset it manually.
    e. There is no green aspect for these locations.
    f. The entering train, and all trains within the yard, must follow the directions of the YM, even superior trains on the mains. Technically, the mains "belong to" the dispatcher even in yards, but as a practical matter in model yards with limited yard trackage, the YM must have clearance control all tracks including mains in his yard.
    g. Note that the major yard entry signaling the "normally red" condition mandates that the last previous signal, which is ABS, be normally yellow, because for ABS, red implies the previous signal must be yellow for following trains. So, if the block bordering and outside a manned yard is either unoccupied by a train waiting to get in or not (unoccupied or with a train waiting to secure YM permission to enter), either condition requires a following train to slow on encountering the second block approaching a yard because of the necessary yellow signal.
D. The signals at yard limits controlling egress from all manned yards (Cheyenne west bound), Laramie and Green River (west and east bound) and Ogden (east bound) have the ABS standard 3 aspect, (Green, Yellow, and Red) colors, and they signal the standard ABS first and second block ahead occupancy. Those signals must be obeyed just as any other ABS signal with 3 colors with the following conditions.
    a. The train must receive the Dispatcher's verbal clearance to proceed out of the yard on to the next block, even though those signals may be green or yellow (depending on the occupancy of the next two blocks). This requirement enables the Dispatcher to keep track of where all trains are on his Train Sheet.
    b. If the egress signal is red, the block just outside the yard is occupied, so the road crew should not even call the dispatcher to ask for permission to leave. When the signal turns yellow, the call may be made.

(Yellow must come before green, because the occupying train has then moved onto the second block ahead.)

c. This verbal clearance from the dispatcher is required when leaving any yard, by the OS'ing requirement and verbal confirmation requirement in the section Car Forwarding System and Track Warrants and the Train Order example, i.e., Rule 251D with DTC.
d. After the verbal confirmation of the written Track Warrant implied by the TO, the train may proceed out of the yard per the ABS signals as set forth above.

Direct Traffic Control with Track Warrants Special Situations

Outside the Yard Limits of the 4 manned yards of Cheyenne, Laramie, Green River, and Ogden, the Rule 251D ABS Signal System is supplemented by Direct Traffic Control with Track Warrants, and this provides for dispatcher control of special situations on the layout. Some of these are:

a. emergency movements on the wrong track (the track meant for the other direction). For example, the dispatcher may authorize a train to use the wrong track to pass another train or wreck.
b. infrequent and occasional movements by trains working in minor yards, that is, yards other than the 4 major yards, that may have to briefly and temporarily use one or both mains to accomplish its work. This is much more common for any model yard that is smaller than real yards.
    a. For example, a yard train may need to use the main as a tail track to move a long string of cars from one yard track to another (this happens frequently at the east end of Rawlins/Sinclair, to pull cars from a main or the alternate main onto the two refinery tracks, or vice versa. Echo is another such place where a switching train must cross the mains from Echo yard to the freight house or to Ideal Cement. The same need to work crossing the main(s) often occurs in Rock Springs, Wamsutter, Medicine Bow, Hanna, or elsewhere, because that work exists on both sides.
    b. In such places (not limited to the above), the working local switch engineer should take care to "flag" the main(s) with the cute LED lighted "flagmen," or a tent-folded old card used as a flagman.
    c. Such occurrences may require the crew to call the dispatcher to request permission to do such work while occupying the main, if the main blockage is extended. The DS should be given an estimate of the time required to do the work.
    d. The dispatcher may grant the authorization for that period of time or not.
    e. If the authorization is not granted, the train must wait until the dispatcher calls back with an authorization, or until the condition set by the dispatcher is satisfied (e.g., a superior train passing).
    f. When the work is done, a second call to the dispatcher must be made to notify him of the work completion and clearing of the main and to get clearance to proceed forward.
    g. Although these rules are strictly required by the rule book, a road crew can remember all such rules by recognizing the Dispatcher's need to keep his Train Sheet current, so he can control the whole layout.
    h. The dispatcher alone can decide to allow the work for the requested period, or require the crew to wait, or even clear the main, for a specified event, usually the passing of another train on the main.
    i. Given the spaciousness of the layout and visibility of approaching trains, and that the mains are generally double tracked, a dispatcher is not needed for such moves; road crews can safely fend for themselves without a dispatcher, but a dispatcher greatly enhances realism. But if there is no Dispatcher, road crews should flag the mains where the visibility is limited.
c. The yard limits for each yard are clearly shown by a white Yard Limits signs for each yard such as that shown in Figure 11.

It may be that the Dispatcher authorizes movement beyond the requested destination. This could happen if the train calls dispatch before reaching the next normal OS location. For example, it had to stop to drop off a car before that regular OS destination on the Train Sheet that the dispatcher uses. To reduce the number of OS calls to a reasonable number, the TS lists only the OS locations, and these are spaced to make for meaningful dispatching. The Train Orders that the road crews use have more locations than does the dispatcher's Train Sheet. This excess is to list all the upcoming stops to inform the road crews of those upcoming stops. For example, the dispatcher may say to an eastbound crew leaving Hanna, "You are clear to Laramie," which is the next east OS location on the TS. Consider the west bound TO in Figure 4, and imagine an east bound one, which is the west bound one (Cheyenne to Ogden) arranged in reverse order (Ogden to Cheyenne). If this verbal authorization is given, the Road Crew may inform the Dispatcher, "I must stop on the main in Medicine Bow to leave a car and perhaps pick up a car there [before I get to Laramie]. I will need 5 minutes there to work on the main at Medicine Bow."

Then the Dispatcher shall correct himself to give clearance only as far as Medicine Bow, and note on his Train Sheet to indicate the extra stop and required time. He should also tell the Road Crew to report from Medicine Bow (OS from there) at the start of the five minutes. When the train has completed its Medicine Bow work and is ready to proceed, hopefully before the end of the five minutes, the crew should call DS again. This second call will be a call to request for and to receive clearance from Medicine Bow to the next regular OS stop at Laramie.

This special procedure is covered for safety with ABS alone. The train stopped at Medicine Bow would cause that block's signals to be red and that red would protect the train. However, high superiority trains, passenger trains, for example, would be unnecessarily delayed, causing them to stop when they could proceed at reduced speed. Such a delay would be puzzling to the passenger crew and to the passengers. If the above move were to potentially slow or stop the passenger train (cause a yellow the second block away from the stop) or a red (at the block), a dispatcher—if we had one that day—could hold the freight train at Medicine Bow for the passenger train to pass the working freight on the other (wrong) track by judicious use of the crossovers just east of Medicine Bow and before the Laramie Yard. Without a dispatcher, and the Track Warrant and DTC, operations would be less prototypical, which is why I always like to have a dispatcher. He can control the main and trains that may be approaching and trains that may be blocking it for special circumstances.

Note that while the Dispatcher controls the mains, the ABS provides the all-important protection against collisions.

Signal Design and Installation

The design and installation of the signals proceeded by steps.

<u>Location of Signals and of Block Boundaries (Gaps in Tracks)</u>

The first step in installing the signals was to plan the signal blocks. To know how many signals and type to buy, I made two schematic drawings of the layout with Allen's input, one for each level of the mushroom design. They are shown in Figures 6 and 7. Allen and I wanted to make use of the DCC blocks as much as possible, but some new track insulating gaps were required, and this required a rearrangement of power district circuit breaker protection. New gaps were cut for two reasons. The first reason was because some the power district gaps fell naturally within a yard because of our DCC instillation desire to minimize the number of boosters, in other words, to make the power mains our maximum 50-foot length. But the signal blocks must end at a yard limit, not within a yard. The second need for some new gaps was for better visibility of the signals. The signals ideally should be located right at the gaps, but sometimes the signals at the original gaps made them difficult or impossible for an operator so see from the aisle, or they were within a yard. If the distance between the signal location with good visibility and an existing gap was too great, a new gap was cut.

The lesson to be learned is to plan the DCC power district gaps so that they complement the blocks as required by ABS.

<u>Ordering the Signals</u>

With the schematics drawn and the final gaps for signals drawn on them, I could count the needed signals and order them.

I bought my signals from Richard Piccuilla at customsignalsystems@yahoo.com because he was able to produce signals that were reasonably close to those in photos from the steam engine days of UP (1957 or prior), and he could supply them with the single large snow hood reaching over all three LED lights. The signals came with internal resistors to limit the LED current. He also made a few bridges to span the tracks and these featured a variety of signal heads. He sent me an approval signal before I made the final order. His signals are very good looking, and I would recommend him if he can produce signals that visually match your needs. I found no others that looked like UP signals with the big snow hoods.

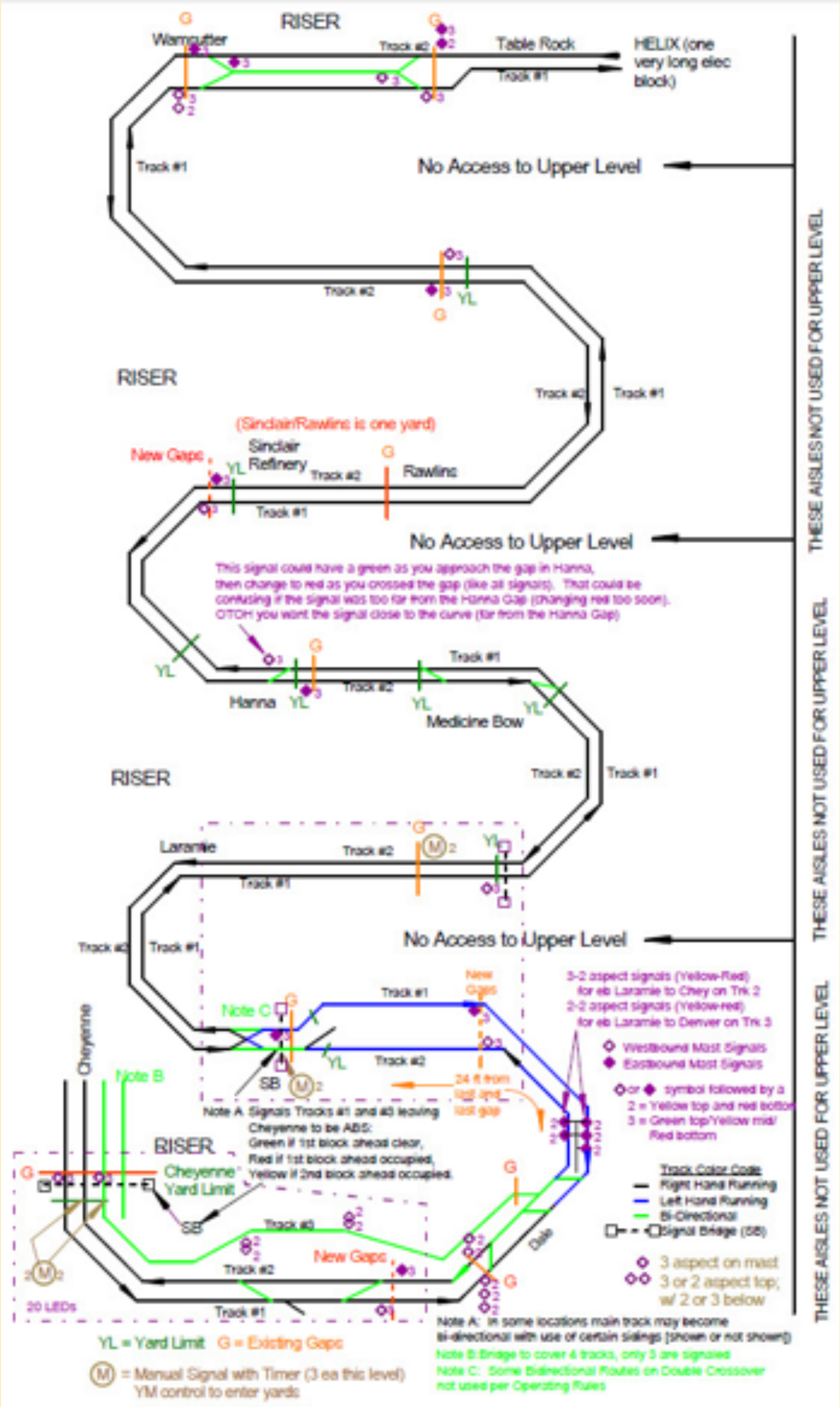


Figure 6. Schematic representation of signal blocks on upper level. The signal masts are shown by diamonds and bridges by a dashed line across the tracks with squares at the ends. See key at lower right. Left running tracks are blue; black are normal right running. Harriman Cutoff is lime green.

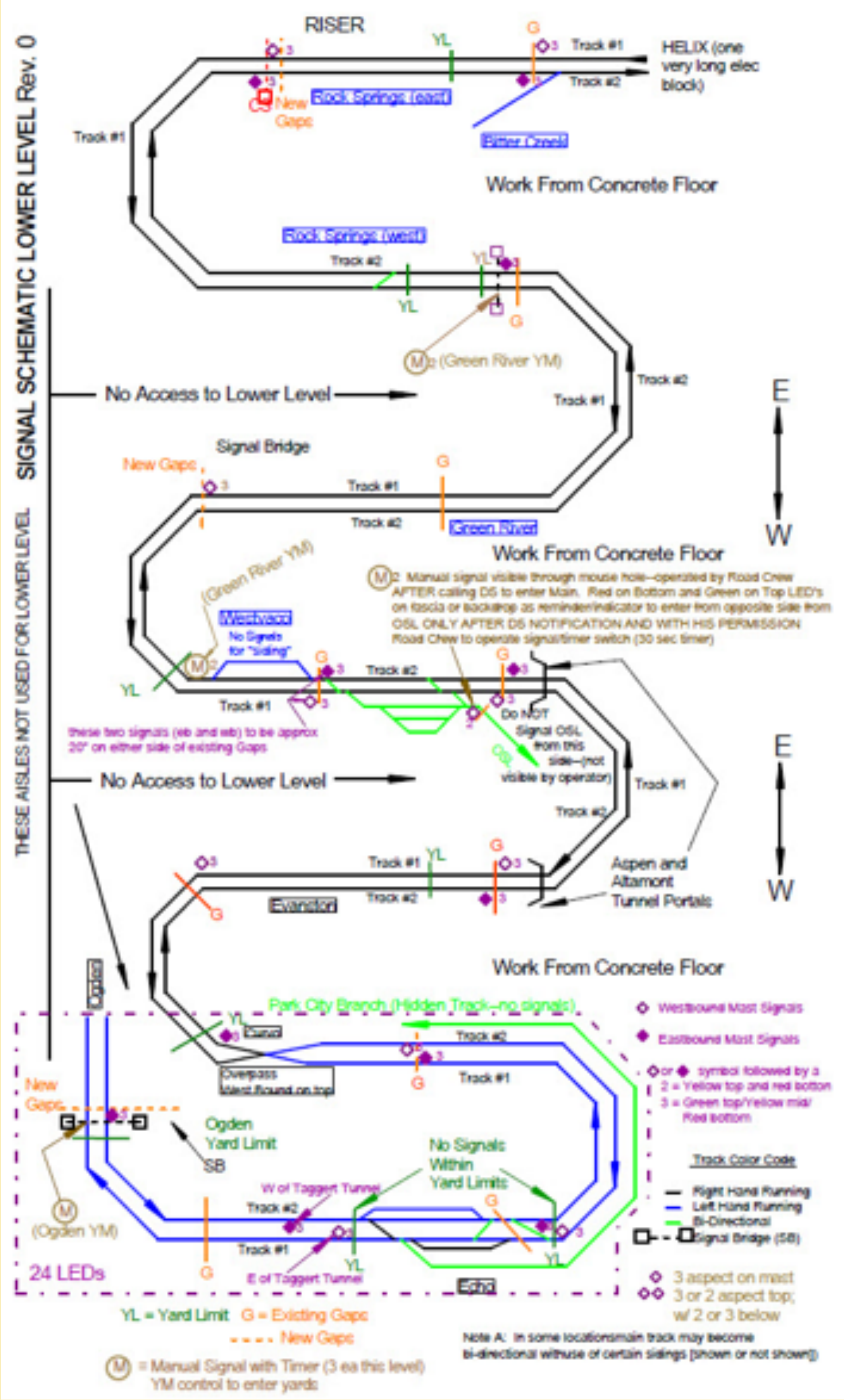


Figure 7. Schematic representation of signal blocks on lower level. The open diamonds are two aspect signals on masts or bridges; filled diamonds represent three lights. Original gaps are orange lines; dotted orange lines are new gaps. I drew these schematics on AutoSketch, AutoDesk's "AutoCad light."

Signal Masts or Signal Bridges

Most signals were mounted conventionally on masts near the gaps, but some were mounted on signal bridges, if a bridge would look better. For example, a long signal bridge was used near Tower A at the west yard limits of Cheyenne to span 4 tracks. Others were used at and over 2 tracks at Laramie and Green River to look more like the beginning of those yards. These bridges have signal heads facing both directions. Richard custom built the bridges to match my wide track spacing that varied from 2 ½ to 3 inches. Figures 8 and 9 show the bridge at Cheyenne spanning 4 tracks looking east and west, respectively.

Figure 8. The west side of the signal bridge spanning 4 tracks at the west yard entrance of Cheyenne. Since no trains are about to enter the yard, the two entering tracks signal show each show normally red. The other two tracks are used in the other direction so are signaled only on the other side of the bridge. Part if the DS desk is at the far right on the mezzanine. The other bench is a workbench.

Figure 9. The east side of the Cheyenne signal bridge spanning 4 tracks at the west yard entrance of Cheyenne. Since no trains are on the block starting just past the signal bridge or on the following block, the two signals over each of the 2 departing tracks show green ABS aspects. The second track from the left is the beginning of the Harriman Cutoff (Track #3). The last track to the left is a stub track for the Cheyenne Stock Yard. The rear double doors to far right.

ABS Signal System Logic and Current Detection

ABS automatically senses the presence of a train on a block x, and sets the signals for block x and block x + 1 accordingly. I chose current detection as my system of block occupancy detection. Many modelers feel that is the most consistent train detection method of many, but it does require that some or all cars on every train draw a current of a few microamps from the block rails. If current is flowing in that block of track, the current is detected, and that block is presumed occupied. Locomotives draw current from the tracks whenever the motor is running or if the lights or sound are on. Additionally, at least the last car of the train should draw current from the block to show part of the train is still in the block after the loco leaves. Some modelers maintain that all cars should draw current, but on my very large Wyoming Division with long blocks 1 ½ to 2 ½ trains long (29 to 50 feet), I felt this was unnecessary. Allen installed resistive wheel sets on all the cabooses we had, unless the caboose had lights that were always drawing current. Existing insulating wheel sets may be made resistive by painting electrical resistive paint between the left and right wheel(s) on a single or multiple non-conduction axles, or by adding resistors between the wheels or using a combination of the paint plus resistors.

With the necessary sets of train wheels drawing current from the block tracks (between rail A and rail B) when the train enters and remains in the block, some method of detecting that current is required. When current is sensed, usually by induction of a magnetic field by the current, the detecting device triggers a circuit to operate the signal, and this operating circuit is usually on some sort of control electrical circuit board that operates by digital logic. The current detectors we used were Control Point Occupancy Detectors made by Model Railroad Control Systems (model cpOD). They may be found at http://www.modelrailroadcontrolsystems.com/cpod-control-point-occupancy-detector/ .

The cpOD is a low cost, DCC only, current sensing block occupancy detector for model railroads. It works by sensing a current from Track A to Track B through the loco or resistive wheel sets. This can be seen in Figure 10 where the loco or resistive wheel set must be imagined as completing the circuit from DCC A to DCC B. The track current travels through a wire from one rail of the track and back to the other through with the insulated wire fed through the coil on the cpOD detector. That wire is the lead and winding of one half of a transformer. The other half of the transformer winding is built into the cpOD coil and drives the current detection device to provide an output to a digital logic signal device. I use the RamDen boards described below as the digital signal board.

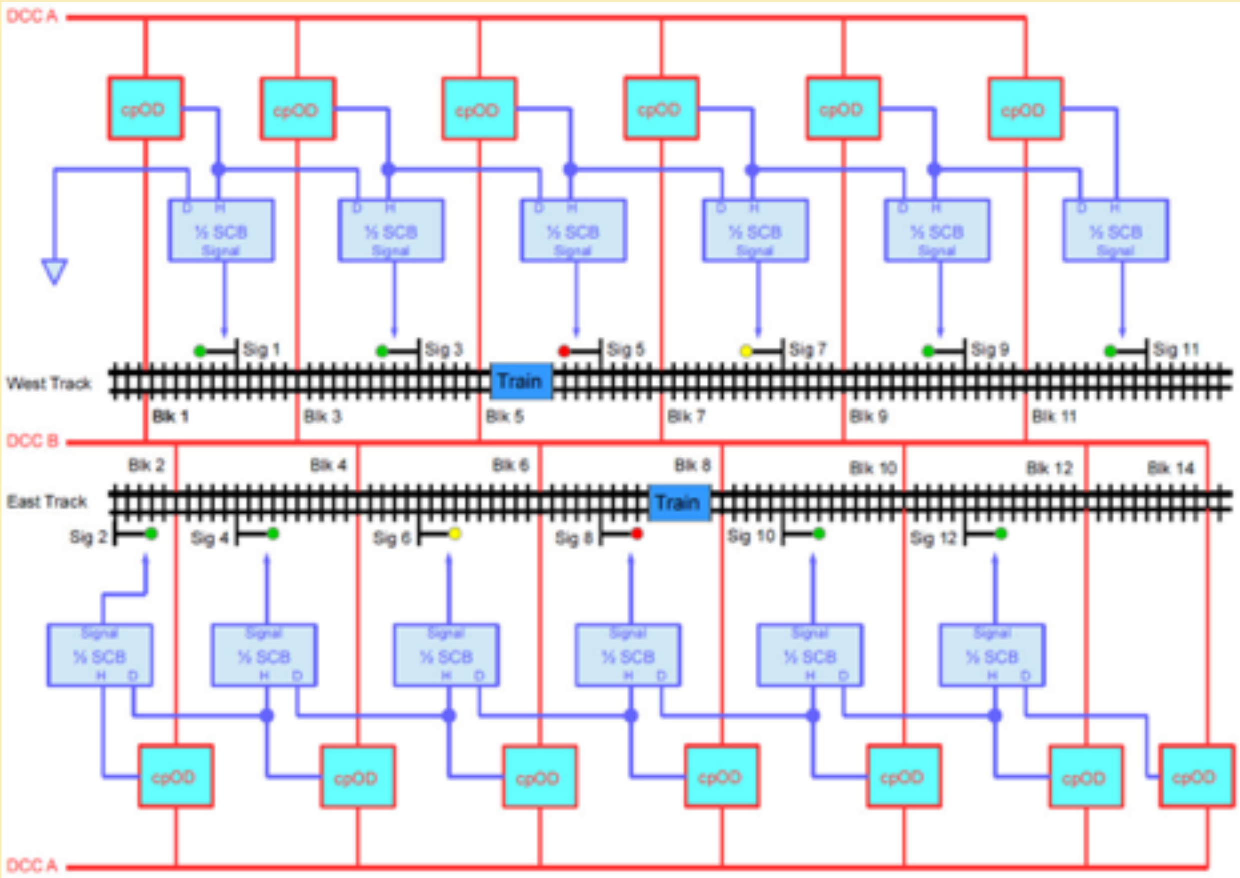


Figure 10. ABS System Block Diagram for Double Track using Dennis Drury's RamDen Enterprises SBC boards (drawing courtesy of Dennis Drury)

The cpOD is powered by a 5v DC power supply with power routed in a star pattern to all necessary locations. Each cpOD has separate wires from a single power supply, radiating like rays from a star. It thus does not use any DCC system power but the trivial (microamps) detection current for the magnetic induction in the coil. We used 12 ga copper wire to reduce losses in this cpOC power supply star network. The 5v power supply also supplies the current to the signal LED lights. We wired the supply into an outlet that was switched on and off with the DCC system power, so if the DCC power is switched on, the signal system is simultaneously turned on.

To have ABS we routed the "occupied" signal put out by the cpOD detectors into a small printed circuit board that Dennis Drury makes at his Ramden Enterprises. These Ramden boards control the adjacent signal based on the occupancy of the next two blocks. Each board is a double board serving two blocks. Each half board is labeled "1/2 SBC" in Figure 10. These boards feed the current to green, yellow, or red LED signal bulbs at the beginning of each of the next two blocks. The LED signals also have a current limiting resistor built into the common LED lead for each signal head, but the resistors are not shown.

For a double tracked main, Figure 10 shows how the occupancy detectors (cpOD) and the Ramden boards are connected to the two blocks (H for home block, and D for distant block), and to the cpOD's and to the 3 aspect signals of the home or immediate block. Note that each physical Ramden board has two halves, and each half is drawn as separate units in the drawing. Each half serves one of the parallel blocks on each track of the double track main. Therefore, four signal blocks, two blocks in line on each track, are driven by two Ramden Boards, each of which control the two track blocks on one track of the double track.

All the components for the lower track in Figure 10 are numbered with even numbers. When a train on the lower track in Figure 10 enters Blk 8, the current from the lower track rail toward the DCC B bus passes through the coil of that block's cpOD board, and a signal is induced in the coil. This induced signal is processed by the cpOD board connected to Block 8, and that cpOD Ramden board sends its output to the H (Home) input of the Ramden board of Blk 8, and half of the circuitry of that board turns that Blk 8 signal red.

The same cpOD signal is sent to the D or Distant input of the Ramden board of the previous block (for Block 6) that the train just left (that to the left), and half of that board's circuitry turns Sig 6 yellow, as shown. The train on Blk 8 causes the signals 4, 6, and 8 to be set to green, yellow, and red, as shown.

Assume that train travels left to right on the lower track, that is, right hand running. The lines with the arrowhead in the direction of the signals each represent 3 wires from the outputs of the board, for the green, yellow and the red outputs. The LED common is tied to the +5 volt bus. Before a train on the lower track in Figure 10 enters Block 10 (Blk 10) the signals Sig 10 and Sig 12 will show a green aspect if Blk 10 and Blk 12 are unoccupied, that is, if no current flows through the coils of the cpOD's connected to those blocks.

The same cpOD signal is simultaneously sent to the D (Distant) input of the Ramden Board of Block 6, and half of that board's circuitry turns Signal 6 yellow.

The two blocks ahead of the lower train, those blocks to the right of the train, are not occupied by a train (i.e., the cpOD's for Blk 10 and Blk 12 do not detect a current drawn between the rails of those blocks), so Blocks 10 and 12 display green signals.

As the train moves to the right along the track and moves into Block 10, the signals 6, 8, and 10 will change from yellow, red, and green as shown to green, yellow, and red, in the absence of another train on the lower track.

But if a second train (not shown) should follow the first train, the signal on the left-hand side of the block it is on will show a red, indicating its block is occupied. And until that second train's caboose with a resistive wheel set leaves a block, the current drawn by that wheel set will keep that trailing block's signal red. Furthermore, the block behind that caboose will show a yellow.

Should the two trains be on adjacent blocks, both those blocks will show red, with a yellow on the trailing block of the second (left hand) train. In other words, the red indication caused by a signal to a H (Home) input will override that sent to a D (Distant) input.

Since these double track signals are permissive reds, it is possible for two trains, or parts of two trains, to occupy a single block. If so, the trailing blocks behind the rear train will be yellow and Green, right to left (in the absence of any other trains).

Figure 11 shows a typical installation of cpOD's and RamDen boards on the Wyoming Division. This is a composite photo of about 12 feet of one open wire tray at the front of the Rawlins/Sinclair Refinery. (The wire trays were described in the "Building the Wyoming Division." article above. The open tray doors are marked with the eastbound and westbound two cpOD's, and the lower section shows a RamDen board. The two photos are centered about 8 feet from each other, so obviously the two components can be placed conveniently to minimize the amount of wire installed. Since the only network used is the new 5v star power network, the cpOD's and RamDen boards need only be near the two blocks they serve. We also made liberal use of the brass and nylon terminal blocks for the signal wires. I imported them from China to use in pairs for terminal bars for the DCC system installation.

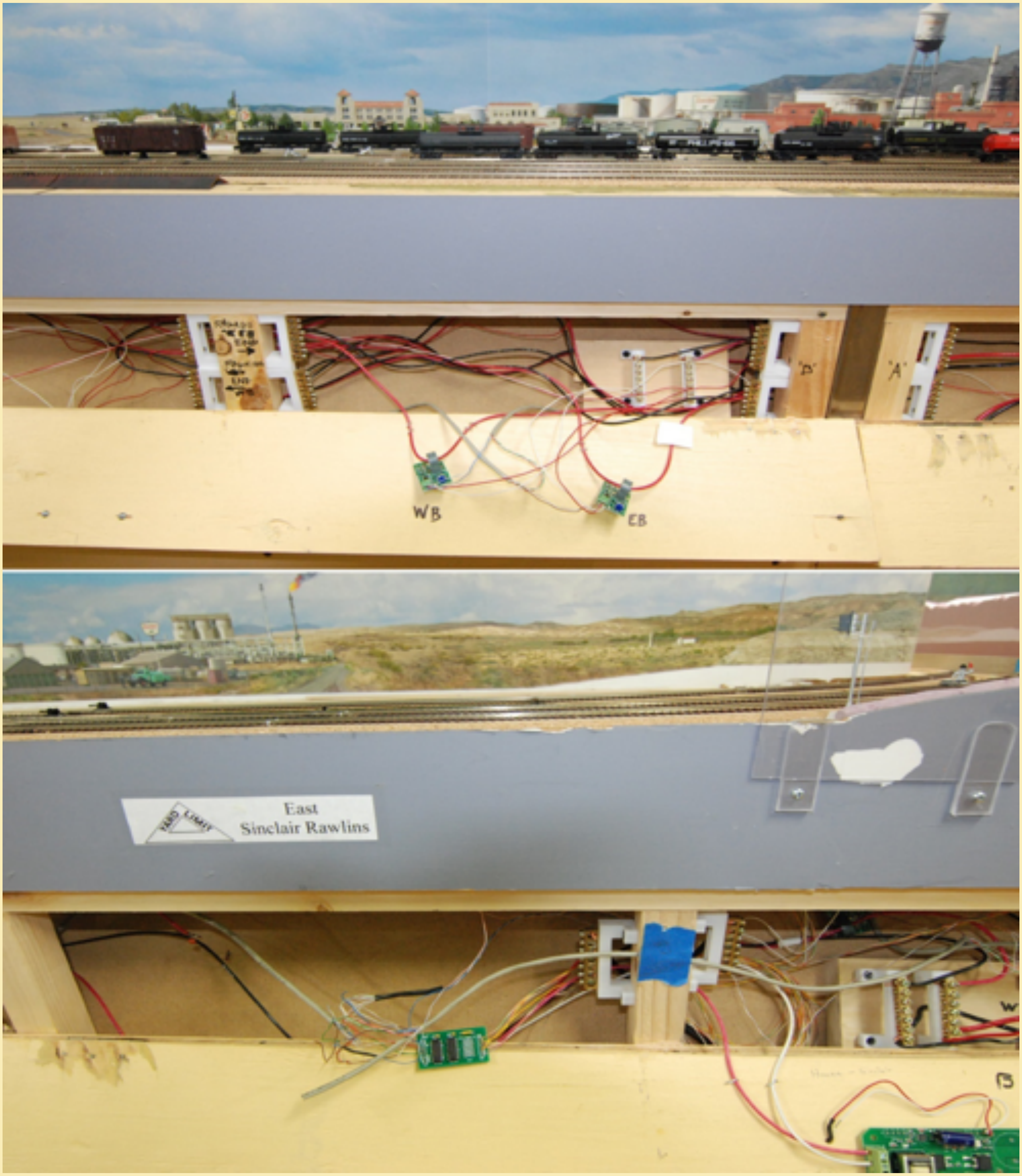
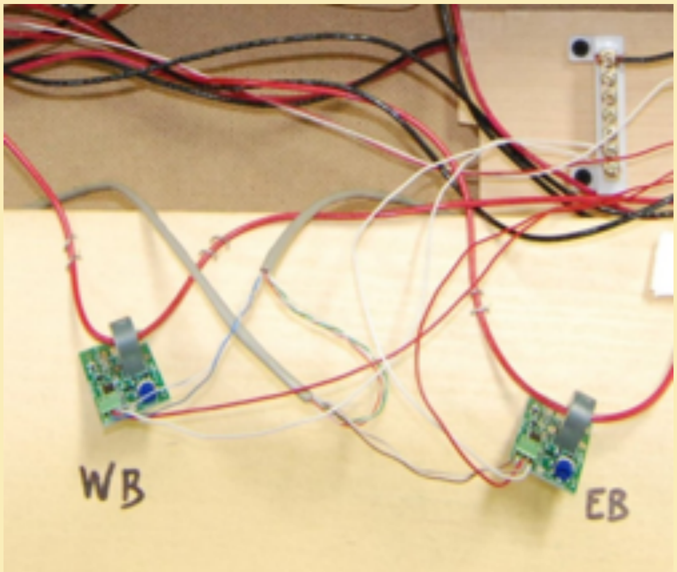


Figure 11. Two photos of boards installed at Sinclair Refinery in Rawlins, Wyo. for two blocks. The top photo has one double block RamDen board, and the lower has one cpOD. A photo backdrop of the refinery ca. 1957, complete with period trucks and individuals, represents the Sinclair Refinery. Note the removable polycarbonate shield on the fascia to protect the signal from operator elbows.



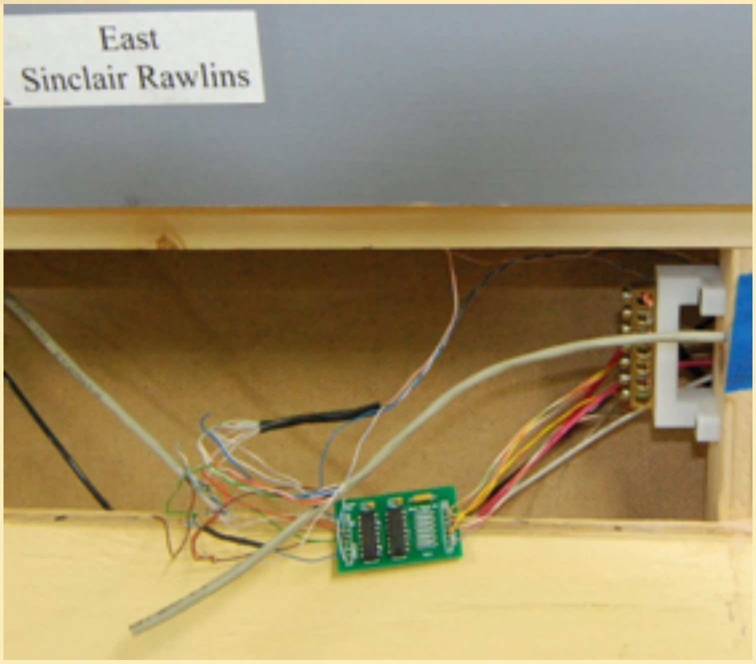


Figure 11a. Top: closeups of a small RamDen board.

Bottom: Two cpOD boards installed about 8 feet from the RamDen board they feed.

It is convenient to have these two components as individual boards, because they can each be installed near the necessary track components.

Yardmaster Controlled Access Signals

The entrance of one of the four major yards with permanent yardmasters on the Wyoming Division was the end of each string of cpOD – Ramden board-controlled ABS blocks. The yards are non-ABS signaled blocks with a two-aspect signal (yellow/red) at the entrance. They are normally red to make road crews stop at yard limits to get permission and instructions from the YM to enter his yard. That two-aspect signal is controlled by the YM who, when he has set the yard turnouts to set the train route into his yard, presses a button that turns the signal from normally red to yellow over red. A simple IC555 timing circuit returns the signals back to red-only in about 30 seconds, so the YM does not have to wait for the train entry to reset or to remember to reset the signal later. We affectionately call these signals “mother-may-I” signals, and they are not prototypical, but they certainly smooth yard limit communications.

Dennis Drury’s Arduino Computer Code for the Harriman Cutoff

Another special signal installation is to have two mast mounted signals, an upper and a lower three aspect heads, on both ends of the center siding at Wamsutter, and to have them on both mains. In Figure 12a below the local steam switcher has been trapped behind three box cars on the stub track on the far right of the double main with center siding at Wamsutter, Wyoming. This yard crew needs to free the switch engine and push those cars back onto the stub leaving them at the three industries on the stub. To do this the switcher pushes the cars out onto the right hand westbound main (after receiving clearance from the dispatcher to work on the main for 5 minutes), and backs onto the center siding pulling the cars with it. While he is doing this work on the westbound main, the signals are automatically set to red for both the main (upper red) and the siding (lower red).

Figure 12a. The local switcher pulls cars from the stub at the far right at Wamsutter and backs a train across the main onto the center siding. The polycarbonate shield to protect the delicate signals from operator elbows is seen edge on at the left edge of the bench. At this time in this move the two signal heads each show red to signify that both the main (upper signal head) and the center siding (lower signal head) are occupied.

Figure 12b. Here above the three cars have been moved to the stub, and the switchman has reset the turnout on the main for through operation. The local will use the center siding to temporarily store the cars while he runs around all three cars by backing down the center siding to the other end and returning forward on the eastbound main. The signal mast for the west bound track has reverted to green when the brakeman resets the main to the through position. The east bound track's signal on the other side of the double main has only the upper single head. At the other end of the siding about 20 feet away, the two masts have two heads for the east bound track and the center siding, and one head for the west bound main.

Figure 12c. Here the switch engine has returned light on the east bound main (with dispatcher clearance to work on the main) and has backed to the three cars to couple to their other end. The main signal (Upper head) is still green. The lower signal shows no aspect illuminated. The position of the wye switch does not determine the lower signal head aspect lighting. That is determined by the setting of the turnout to leave the right hand west bound main, and for that turnout with a through setting no aspect is needed to protect the center siding from this direction. The signal at the far end would show a red if that entry turnout were set to enter the center siding.

Figure 12d. After coupling back on the three cars and pushing them further onto the center siding far for the pilot wheels to clear the siding turnout, the short train pulls ahead toward the camera onto the right hand (westbound) main, and the upper and lower reds come on. Then the switcher reverses to back the three cars back onto the stub track to be spotted at the three industries. After this small train has cleared the right hand westbound main, the switcher crew should call the Dispatcher to notify him that the work on the main has been completed and that the main is once again clear.

The bases of the signal masts are cemented to Hydro-Stone castings to simulate concrete, but the bases are not fixed to the benches. This provides safety against breakage if they are bumped. The four wires out of the signal bases extend loosely into the benches with a big loop hanging under the bench, so the signals may be pulled out a few inches and laid down if it is necessary to work in that area.

Special Signals at the Start of OSL

At Granger, Wyoming, 31 miles west of Green River (but you knew that), the hidden track OSL leaves the west bound track for Portland, Oregon. This junction and its signals are shown in Figure 13. From left to right is the normal 3 aspect signal on a mast with the big snow hood for the east bound main (this signal faces left away from the camera). Next is the west bound main signal (facing right and is green). Finally, is the left facing signal

Figure 13. OSL Junction and its signals, including “mother-may-I” panel signal and switch. If a real miniature operator were on a locomotive coming toward the camera, this Fascia mounted two aspect signal would be mounted facing the square mouse hole for him to see it, but I have only people sized operators whose best vantage point is where the camera is. Hence the signal is mounted here where a real modeler-operator can see it.

that a train from the OSL joining the main track should obey as it travels left to right out of the square mouse hole. Some of the hidden track through the opening in the backdrop at Granger. That hidden track wraps around the end of the bench and curves 180 degrees and drops in elevation where it can be seen below the two yellow fascia signs. From there it continues three full bench lengths and two more full 180 turns under the lower level until, 184 feet away it enters the Portland staging yard (see the orange track plan).

The left yellow fascia sign has a yellow over red two-aspect signal set into the fascia. The best operator practice for a train entering the main out of the mouse hole is to walk around the end of the bench from the far right to the left to follow his train toward this junction as it approaches these tracks from the far side of the backdrop toward the back of the mouse hole where it will enter the main. As his train approaches the mouse hole from the far side, the operator should hurry back around the end of the bench to this side to stop his train just before it comes out of the hidden track through the mouse hole to make sure he does not collide with a train on the main. He should stand facing the OSL portal mouse hole where he can see this fascia mounted signal. We keep the third signal on a mast to the right pointed toward the aisle and not the mouse hole so the operator can see it from this aisle, and that signal is an ABS signal with the east bound main (the OSL leaving train's route) as the signal's next block. The panel signal however is a special case. It is normally red (the photo makes it look orange). This red causes the operator to stop his train and call the dispatcher for clearance to occupy the main from the OSL. After he receives clearance, the road operator presses the momentary switch button below the signal lights. This acts just like the YM buttons in the 4 major yards; the momentary switch turns the normally red to a yellow over red aspect (both LED's illuminated), and the train can proceed just as into a yard, slowly but prepared to stop. In about 30 seconds the panel lights turn back to the normally red aspect.

The next photo, Figure 14, shows the whole situation at Granger better, because the tracks can be seen (on my layout compression forces the Aspen and Altamont tunnels to be right next to Granger). The green aspect is showing for the west bound into Altamont. The back of the east bound signal is on the Aspen Tunnel track near the bench edge. The hole in the fascia is more clearly seen here, and a side view of the first signal out of the OSL is on its white "concrete" base. We keep it turned toward the aisle for operators to see, not toward the tracks through the hole for locos to "see." The two tracks to the right of the mains are a Granger yard track (which we use to simulate stored coal loads from Kemmerer, Wyoming which is on the OSL. The other track close to the main is the preferred route onto and off the OSL. This is an alternate main that branches off the west main (the second track from the bench edge) 20 feet behind the camera. This alternate track is the preferred route onto the OSL, because it can be used as a siding from the main to the OSL to hold on while another train leaves the OSL. The turnout from the right hand main to the OSL and into the hole is a "last chance" emergency route to get to the OSL from the main in case and operator misses the preferred turnout to the preferred track. This turnout also brings an eastbound train off the OSL onto the west bound track until it can take a crossover to the near track the near main track which is the east bound main.

As mentioned above, the preferred route onto the OSL is via a turnout 20 feet behind the camera. Finally, as can be seen, we are in the beginning stages of scenery construction when this photo was

Figure 14. Granger junction and signals on the Wyoming Division with tunnels brought too close by modeling compression. (Note: this photo is an in-camera focus stacked image taken with the Lumix G9—see the Power Point "Model Railroad Photography" on this website tab.

taken. These mountains and plains have been covered with Wyoming dirt that Allen collected from one of a dozen locations throughout Wyoming.

Summary

The installation of a robust ABS system on the huge Wyoming Division HO layout was simpler and the cost less than I had dared hope. The advantages of the RamDen boards are low cost, ease of installation, small size, and simple operating logic from the user's point of view. They avoid having to have a computer and any computer programming for the purely ABS signals. Commercial signal controllers usually require programming, because they are made to be versatile to manage ABS and other signal configurations. Of course, we resorted to multiple Arduino computers which required programming for our special places, but the total cost of the RamDen boards plus Arduinos was less than the required number of other signal controller black boxes, even if we had used those with multiple modules. Each Arduino cost about $28 on Amazon. It would have been difficult to buy multiple module black boxes for the exact number of blocks I had, so the cost would have been even higher because of the wasted capacity of unused controller modules.

Another advantage was that it was unnecessary to make a separate signal network, which I did not need since I did not wish to have a CTC panel with operator or otherwise computerize the layout. The RamDen boards used 22-gauge wire that I bought at a surplus store in 5 colors—5,000 feet per color, so that it was cheap even though this was far more wire than needed. We used economical Cat 5 wire for the star configuration from the single 5 volt-5 amp DC power supply to each board, and I did have to buy a 5 volt 5 amp DC power supply (about $25), but no additional power was used directly from the DCC system other than the very small power through the new resistive wheel sets. Thus, no extra load was put on the 15-5A boosters of the Wyoming Division. Finally, the use of the individual cpCD boards, rather than a combination unit with several detectors on one chassis that includes signal light logic greatly simplified wiring. As with the RAmDen double block boards, all the wiring, except the 5v - 5A star wired power bus was done conveniently right at each bus. Multiple module units would require wiring out from it to each block; an 8 or 16 module unit would require a lot of long wire runs. And as Figure 11 shows, the current detectors were not necessarily very near the boards, for they did not have to be. Instead we could wire the current detectors close to the DCC circuit breakers, and the logic boards close to the individual signals.

There are 41 masts installed, usually with a single 3 light signal head plus a single large snow hood over all three, but many masts had multiple heads, such as those at Dale, both ends of the Harriman "siding" (converted to double track), and the Harriman Siding at Wamsutter (a center siding between the mains and common to both mains). Of the 41 masts approximately 13 have multiple signal heads of either 2 or 3 lights each. They usually are for blocks plus a siding (see Figure 12 b above). There are 4 bridges used with signals on both sides: Cheyenne west yard limits spanning 4 tracks, Laramie both yard limits, and the Green River east yard limits, the last 3 spanning the double track mains. These bridges set off those yards as the major yards they are on the Wyoming Division Layout. Working with Richard Piccuilla at customsignalsystems@yahoo.com required a lot of duplicate emails, because he was very careful to make sure I and he did not make mistakes in ordering, but, now that it is done, I guess that is a good thing.

The Crew

Figure 15 shows left to right Dennis Drury, Lenny Wyatt, and Allen Montgomery who together did the bulk of the installation of the signals on the Wyoming Division.

Figure 15 shows left to right Dennis Drury, Lenny Wyatt, and Allen Montgomery who together did the bulk of the signal installation.

Dennis provided the electrical engineering expertise to make my dream of signals on the Wyoming Division a reality. He attended my November 2015 Wyoming Division Invitational Operations Meet after I met him at the PSR Regional meet hosted by the Arizona Division of the NMRA. During that Invitational Meet, I mentioned I was ready to jump head first into signaling, but that I did not understand the way the various hardware was connected, and I hoped I would find some vendor to guide me. Dennis volunteered to design the ABS around his boards. This availability of technical help is another reason to join the NMRA. He ordered almost everything we would need and provided me a parts list for the rest. I designed the system and ordered the signals from the schematic track plans of Figures 6 and 7. He had his orders delivered to me, and all I had to do was pay for them—he did all the electronics engineering. Then he came to Sedona near the layout and stayed in his RV a month while he supervised and worked at installing the wiring and hardware. He also programmed the Arduino computers, and again all I had to do was buy them from Amazon.

Lenny Wyatt is in the middle. Lenny is a general contractor who built my house and built the two buildings of the Wyoming Division (50 x 75-foot layout building and the combination 56 x 30 foot shop and crew lounge building). He works nearly full time on the layout, except for the occasional contracting job locally. He is our resident electrician and locomotive repairman. He keeps the NCE DCC system operating, models, and mentors and trouble shoots every operating session. He scratch-built the 11 stall passenger house model of the Cheyenne roundhouse on layout, and now has completed the 16 stall freight house model to complete the roundhouse structure.

Allen Montgomery is our team leader. He is a passionate expert on all phases of model railroad modeling, DCC locomotive programming, car repair and calibration, repairs locomotives, and air brushes and weathers our cars and structures that he scratch-builds, and he is a dedicated operator. He and Lenny help me host every op session we have. Allen is also very strong on UP history and research on our era for the UP. It was on one of his research trips that he gathered the buckets of Wyoming dirt and gathered photos and information on trips to the University of Wyoming Library.

And me? As Superintendent of the Wyoming Division, I provide the overall concept and design, and the Four Card Car Forwarding System that I developed, and I am the CFO. It is no secret that my favorite part of model railroading is operations. I tell folks I am not so much a model railroader, as a person who likes to give parties.

Appendix: Arduino code for two signal blocks, in which part of each is one half double track.

Arduino Code