L3 "FULL SPEED AHEAD" Project

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The GE 80 Ton designated L3 at the Atomic Test Site was delivered to the Nevada State Railroad Museum at Boulder City on March 14, 2006. It was brought up to operating condition, but used sparingly for switching operations. In a test/demonstration of its capability, it "rescued" a train headed by the #1000 bringing it up the Veteran's hill very slowly, but successfully. On another occasion, it was used for the last two runs of the day, again slowly. It then languished with only occasional use for switching which didn't require speed.

In 2016, we were in the situation of having our two primary locomotives (the #844 GP-30 and the #1000 NW-2) out of service, and our third locomotive (the #1855 Fairbanks Morse) operating but in need of repair. This left the L3 as potentially becoming our primary locomotive. I offered to investigate why the L3 operated so slowly when it should have been able to achieve about 40 mph. Due to the risk of damage, this project was deferred until the fall when the #844 came back into service.

Based on discussion over the years and confirmed by initial tests, the L3 did not go into transition. The task looked deceptively simple, determine how the Test Site disabled transition and re-enable it. And, supposedly, we have "as built" documentation. I found that there were no connection to the coils of the relays that should initiate transition. Trying simple things first, I tied strings to the armatures and manually "went into transition" - sort of - but progress. I tried a test with the wiring modified as if the string were pulled - light engine and the L3 ran scary fast, but with a load (full train) it reverted to slow operation., so the wiring was returned to its original configuration.

The biggest "anomaly" was that the actual wiring did not match the "as built" wiring diagram, nor any other L3 wiring diagram found (so far). Example 1: The schematic showed that transition is controlled by the T1 relay - there is no such relay in the cabinets. This meant that we could have the traction motors wired as series or wired as parallel, but no relay was available to latch the transition. Example 2: The schematic shows four high power contactors (P1, P2, S1 and S2) - there are only three (P1, P2, S1). Example 3: The V1 relay which should signal that the engine has reached sufficient speed to transition has no connections to its coil. The tedious process of disconnecting and tracing wires began, and it was further discovered that the #1 engine controls and the #2 engine controls were wired differently.

When sufficient information was noted to guess how the system should be wired to always be in parallel, the changes were made and tested. The changes were successful on engine #1 but not on engine #2. The problem was traced to a set of auxiliary contacts on the P21 contactor not making contact. Once it was determined that the interlock function was not needed if only parallel operations were used, the coil connection to the S1 (engine 1) and S21 (engine 2) were disconnected and taped, a jumper was added between the failed contacts on the P21, and a jumper was added to energize the P22 relay whenever the P21 relay is energized (retaining interlocks such as ground fault). The static test was successful with both engines loading .

In the first informal test, Chuck Brandt had the #1000 in tow and brought the WP caboose from the display area to the shop - no problems

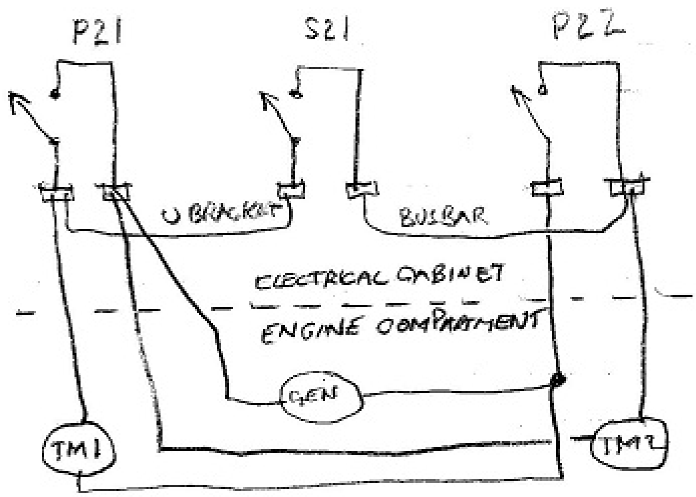
L3 Troubleshooting History

I reviewed documentation and schematics and photographed various details in the three electrical cabinets - especially several places in the upper cabinet where wires have been cut. I could not find any relay/contactor labelled T1 (Transition). In the schematic, it was noted that relay V1 is also part of the transition circuit - it should be in series with 600 ohms of resistors attached to the "hot" side of the generator, and activates when the generator voltage is "sufficient". The 600 ohm resistors were there, but did not have any connections, and there are no connections to the 75 ohm coil of the V1 relay. The contacts of the V1 relay appear to still have the connections necessary for transition, so I proposed a running test with me activating the V1 relay by pulling on a string attached to the armature. The thought being that if manually activating the V1 relay would cause transition, that a pushbutton switch could be added to the console to allow the engineer to select transition. There is a battery circuit that is activated when the throttle is in run1 or higher - this could be used to power the transition select switch. Also, talked to Bob Freeman - he confirmed that some of the run steps were not active - he didn't remember any details - a future project.

Now to study string theory. Because the are no connections to the coil of relay V1 which enables transition at a set generator voltage, I tied a string to the V1 armature. Running only engine 1 (just in case I was actually conducting a smoke test) when we got to a steady speed in run1, I pulled the string to activate the V1 relay. No smoke! Contactors clicked, but no change in speed/acceleration was felt. There was a change noted on the load meter - it read 200 amps when V1 was in the "series" (inactivated) position, but changed to 100 amps when V1 was in the activated (string pulled) position. This was opposite expectations. Also, once transaction has been initiated, it should self-latch - that didn't happen - the contactors return to the "series" position when the string was released. The change in load indication seemed backward - I would expect a higher current draw when the motors are in parallel - so maybe the contactors were not actually wired for transition. Because of the unexplained results, testing at higher run levels was posponed.

There is a difference in power wiring between engine 1 and engine 2. Engine 1 has three cables on the front connection - engine 2 only has two. The only way to track the cables (if necessary) will be to disconnect them from the contactors. There is a difference in apparent load on the switching system. The open load on all three engine 1 contactors (P1, P2, S1) is 1.7 ohms. The open load on all three engine 2 contactors (P21, P22, S21) is only about 0.9 ohms. Given the inaccuracy of measurements of small resistances, it has the appearance of one having serial traction motors, the other having parallel traction motors - strange.

Also noted - needing repair - there is a return spring on contactor S21 that is hanging loose. I didn't determine whether it was intentionally disconnected, or there was a failure. The corresponding spring in contactor S1 is in place. The power contactor circuitry does not match the diagram. The diagram has Transition contactors (T1 and T2) - they doesn't physically exist. The diagram has two Serial contactors for each engine, only one each exists. The Serial contactor that exists is labelled S1 (and S21) - but has the function of the contactor labelled S2 in the diagram. A probable diagram for the load switching has been sketched, but requires the assumption of a connection between one of the traction motors and the generator at a location not in the electrical cabinet (for example, directly connected at the generator output).



So where does the extra cable go? Why is there a 2:1 difference in the apparent load between engine 1 and engine 2? What is the actual resistance of a traction motor? Can the hypothicated switching circuit be verified/corrected? If verified, there will be two options: 1) a push-on/push-off switch on the console; 2) rewire the V1 relay to be in "parallel" as the default rather than in "series".

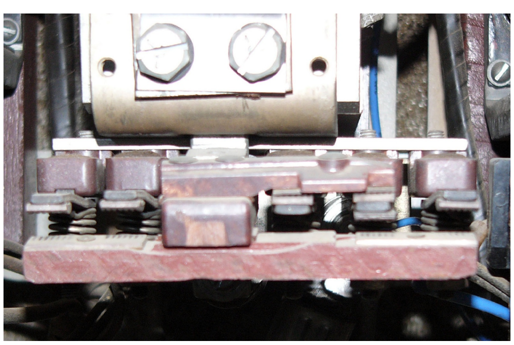
I reviewed what I've found and speculated with Bob Freedman. Tracked more of the wiring - some of which required disconnecting wires to be able to confirm the routing. While "watching the relays click", noted that the response to the reverser control was not quite as expected. They start with both FORWARD or REVERSE relays de-energized, but once a direction has been selected, moving the selector to the center position does nothing (relays remain as last set) - there is only forward and reverse, no neutral. Confirmed the operation of the side 2 relays as P21 engages when the throttle is run1 or above - activating the V21 relay manually (yeah, "string theory" again) deactivates S21 and activates P22. Relay V21 is a "break before make" so there is a very short time during activation when neither S21 nor P22 is activated. I'm still not clear as to how the sequence of the FWD, REV, GF1 and GF2 relays cause the field to change from forward to reverse. It does look feasible to swap the leads on the output of the V1 and V21 relays to have PARALLEL as the default condition rather than SERIAL. There would not be any transition - all operations would be at "high power" (parallel). If "low power" (serial) is needed for some reason, a DPST (100 V, 1 Amp) switch and a pair of 150 ohm 20 Watt resistors (and wiring) would need to be added to electrically activate and hold V1 and V21 in position.

Did baseline run speed and acceleration timing. Started at the 20.75 quarter mile marker and went to the 20.92 culvert marker - took 45 seconds. Starting at approximately 20.6 was up to full speed passing the 20.75 marker - took about 36 seconds to pass the 20.92 marker - a calculated 16 MPH (didn't feel that fast). Rewired the V1 and V21 relays such that the operating condition is always Parallel rather than Serial. Counting the terminals from left to right, the wires on the number 1 terminal were labelled 11 and 21 and those on the number 3 terminal were labelled 13 and 23. Wires labelled 11 and 21 were then swapped to the number 3 terminal, and those labelled 13 and 23 were put onto the number 1 terminal. Took Mike T down the track to do his track inspection, then coming back up the hill brought it up to full throttle after the trail crossing. Didn't get to "full speed" - we were still accelerating uphill when the rocking motion became excessive - guessing to be somewhere between 25 and 30 MPH - scary fast! Temperature rise was only a few degrees. Next week try some stuff with real loads.

Used the L3 to bring the 844 to the shop. No engine problems, but handling that weight without brakes on the 844 was difficult. Went to the yard and got the rest of the train - HEP, Dining, ADA, 602, 501, 603 and Caboose. During running brake test, I accidentally caused emergency, so had to wait for the entire train to recharge. Went down to almost the 20.75 marker. When starting uphill, only the #2 engine was loading (both had loaded when moving the 844). Continued into the shop at about 5 MPH. Stopped to let the engine cool down (it had gone from 150 up to about 180), then put the train into the yard. While passing the platform, the #1 engine began to load so we had a quick trip to the yard.

Changed the wiring back to the original configuration. Thinking about how to implement a manually initiated (e.g pushbutton switch) electrically controlled transition. Unfortunately, there are no unused relays available. So all thinking is now how to operate in parallel permanently. Now began the many days of disconnecting wires to determine whether a connect was direct or via another set of contacts (lots of function interlocks). As noted above, one of the contactors (S21) did not have its return spring attached. That was corrected, but testing contactor operation "by thumb" revealed a significant difference in the pressure required for full auxiliary contact engagement. A pressure gauge was fashioned and all six contactors were set to the same as P1 and S1 (the adjustment screw has jamb nuts on the spring end, and the screw heads interlock at quarter turns on the adjustment plate end).

I didn't succeed at finding the destination of all connections. I did find a taped-off wire (with ring terminal) near the V21 relay looking as if it may have been connected at one time, but I couldn't find the other end. With no activation power to the V1 and V2 relays, their COMMON (terminal 2) and NORMALLY CLOSED (terminal 3) terminals are used as a terminal block. As above, the wires in their original position on V1 have been labelled 11A (to P1 term 1), 11B (to P1 coil), 12A (70V power when in run), 12B (to "Traction Motor Cutout" panel), 13 (to S1 coil via P1 term 3). The revised connections are term1 has 13, Term 2 has 12A and 12B, term 3 has 11A and 11B. The wire from P1 terminal 3 to the coil of S1 was disconnected and taped to prevent any accidental activation of S1. The wires in their original position on V21 have been labelled 21 (to P21 coil), 22A (to S21 coil), 22B (to GF21 term 3), 23 (to ?). The revised connections are term1 has 22a, term 2 has 21 and 22B, terminal 3 has 23). When the engines were started, engine 1 responded to notch 1 in both forward and reverse and did load. Unfortunately engine 2 responded only by activating P21 (both forward and reverse) but not P22, so there was no loading. Engine 2 wiring was returned to its original (serial) configuration, and engine 1 was left in its new (parallel) configuration. This allows use of the L3 for switching.



Tracing the wiring from P22 coil lead to P21 auxiliary contacts terminal 5. When P21 is activated, the P21 coil is supposed to be connected to P21 aux terminal 4, which in turn is connected to in-run battery power (throttle to run 1 or higher). There is no apparent adjustment for contact separation. The lack of contact is caused by the horizontal bar containing the shorting plate not fully rising to contacts 4 and 5. The bar is rivetted to the actuator arm, and the assembly is worn such that the horizontal bar twists rather than fully rising. Since this wiring goes through safety interlocks (such as ground fault), I needed to have some confidence that jumpering P21 aux term 5 directly to in-run batter power would not cause a safety issue. Normally, when ground fault is activated, P21 is de-activated, which in turn would de-activate P22. With the proposed jumper, P22 would remain activated with a ground fault, but since P1 would be de-activated, there would be no power to the motors, so jumpering P21 directly to in-run power appears to be safe.

The above configuration (engine 1 parallel, engine 2 serial) had the following relay/contactor activations both in forward and reverse

Engine 1: P1, P2, GF1, GF2

Engine 2: S21, GF21, GF22

Since the active configuration of the GF contactors matched for serial and parallel, it was assumed (hoped) that adding the jumper from P21 terminal 4 to P21 terminal 5 and a jumper from P21 terminal5 to V21 terminal 3 (power when in run) should be safe. As with engine 1, the wire from P21 terminal 3 to the coil of S21 was disconnected and taped to prevent any accidental activation of S21. When the engines were started, they both activated to parallel and both loaded. Time for a road test.

The first road test was Sunday 4/16/17. While the scheduled train was out on its run, the L3 was used to bring the WP caboose (? about 30 tons) to the shop. Because the #1000 (130 tons) was in front of the L3 (on the Pavilion display track), the #1000 was carried as "ballast" during the move. Chuck Brant had no problems bringing this load (approximately equal to a consist of a HEP car, two small open air cars, a coach and a caboose) uphill from west of the white bridge to the shop.

Other Stuff (not speed related)

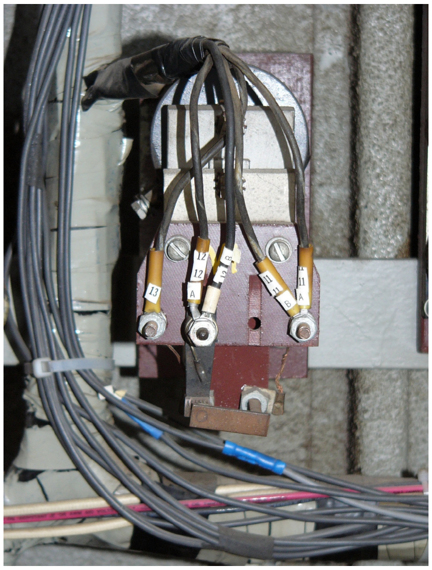
The whistle needs to be replaced.

Consider re-mounting the 480V generator and adding the wiring needed to power a train.

It would be nice if:

- the radio was programmed to our current frequencies
- the speed indicator actually worked
- the battery charger terminals were accessible (?reverser compartment) without having to leave the cab window open
- the plumbing that was used for the water shore-power electric heater could be rerouted to allow water fill from the ground - the fill and overflow pipes from the ground exist

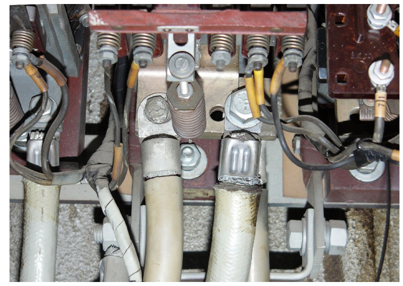
Appendix 1: Rewiring Summary



Engine 1:

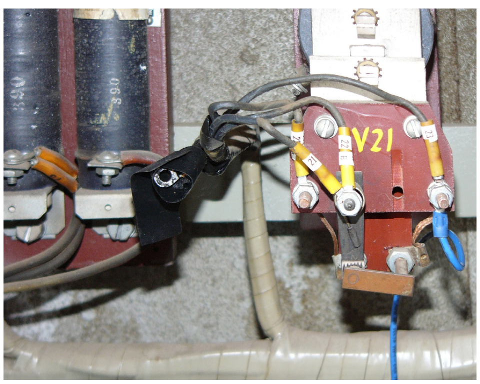
Revised V1 as follows

- Coil remains disconnected
- Terminal 1 (normally open) has wire 13 (to S1 coil via P1 term 3)
- Terminal 2 (common) has wires 12A (70V power when in run) and 12B (to "Traction Motor Cutout" panel)
- Terminal 3 (normally closed) has wires 11A (to P1 term 1) and 11B (to P1 coil)



Revise P1 auxiliary contacts

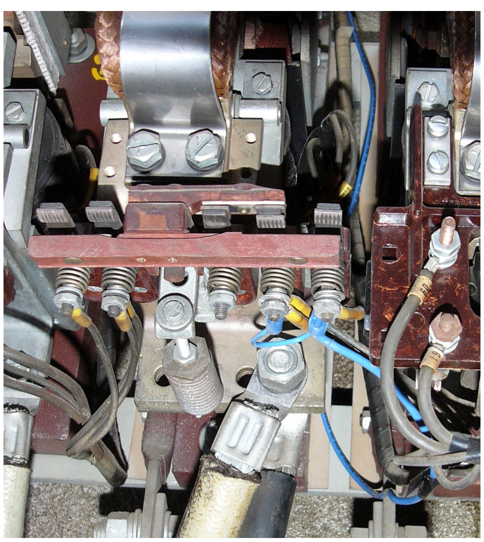
- Disconnect wire from terminal 3 (on bottom, goes to S1 coil) and tape



Engine 2:

Revised V21 as follows

- Coil remains disconnected
- Terminal 1 (normally open) has wire 22a (to S21 coil)
- Terminal 2 (common) has wires 21 (to P21 coil) and 22B (to GF21 term 3)
- Terminal 3 (normally closed) has wire 23 (to ?) and blue jumper (to P21 term 5)
- NOTE: Unconnected ring terminal (to ?) Left of V21



Revise P21 auxiliary contacts

- Disconnect wire from terminal 3 (on bottom, goes to S21 coil) and tape
- Connect (blue jumper) terminal 4 to terminal 5
- Connect (blue jumper) terminal 5 to V21 terminal 3