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Union Pacific Railroad West Colton Yard Transfer Table Replacement

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Introduction

During a 2016 inspection of Union Pacific's West Colton Yard Transfer Table, located in Colton, CA, one hour east of Los Angeles, several significant findings were noted in the substructure, superstructure, mechanical system, and electrical system. The owner decided it was in their best interest to replace the transfer table and rehabilitate the substructure and approaches. This paper discusses the unique challenges of the design and construction for this transfer table replacement project.

Photograph 1– General view of the West Colton Yard Transfer Table

Transfer Table Description

Union Pacific Railroad (UPRR) owns and operates a rail yard in Colton, CA, which includes a locomotive repair facility. Part of the facility is a transfer table that connects six tracks on the west side to eight tracks on the east side (see Photograph 1). Locomotives come from the rail yard on the west side, are loaded onto the transfer table, the table then moves to the corresponding track on the east side, and the locomotives travel to their designated bay in the diesel shop for repair, maintenance, painting, etc.

The original transfer table, constructed and put into service in 2006, was a 100' long, 20.5' wide, 4-span, continuous steel bridge supported by five spread footing concrete foundations. The foundations were oriented north-south, each supporting a single 136-lb/yd AREMA rail. The transfer table was supported by drive trucks that ran along the five foundation rails. At each rail, two articulating drive trucks, one to the north and one to the south, supported each of the five transfer table floorbeams. The floorbeams were connected to girders, which extended the full 100' length of the table. AREMA rail, which the locomotives ran on, was fixed directly to the top of the girder flanges. On eight of the ten drive trucks there was a gearmotor mounted directly to one of the two drive wheel axles, which could be run in forward or reverse to drive the transfer table north or south down the 240' length of foundation rail in the pit (see Figure 1). The eight drive motors were all controlled by and connected in parallel to a single VFD (variable frequency drive) with no position feedback, or limit switches to indicate when the table was near the end of travel at the pit wall.

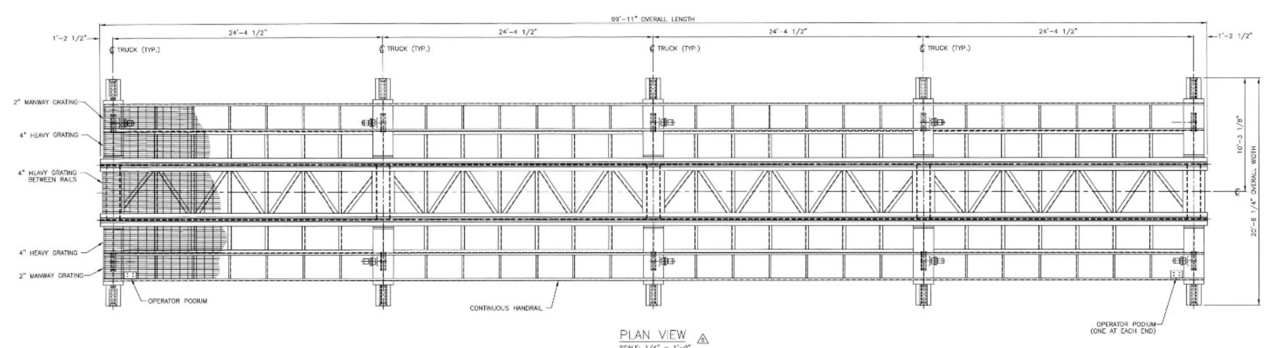
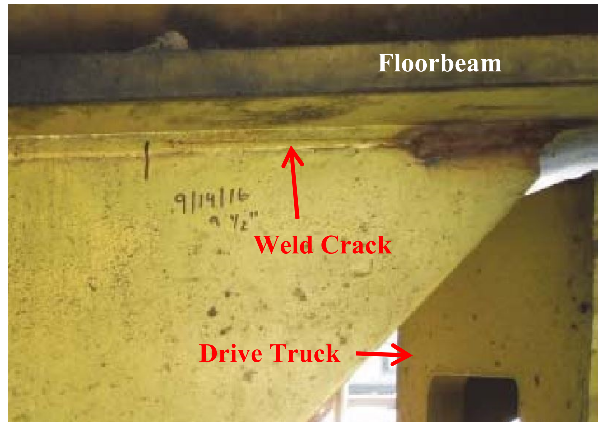


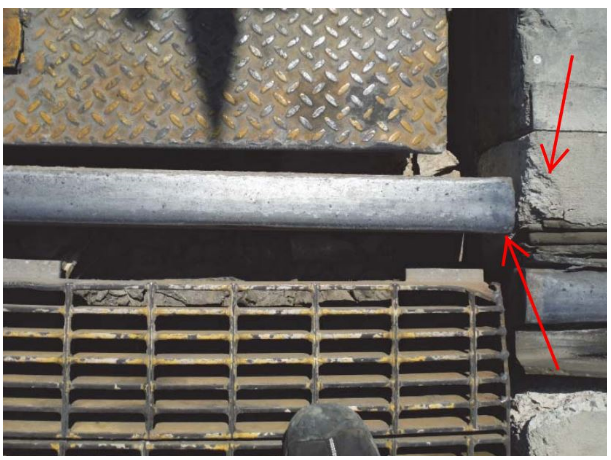
Figure 1 – Plan view of the original West Colton Yard Transfer Table

Original Table Deficiencies

An inspection of the West Colton Yard transfer table was performed in 2016 to evaluate the condition of the table and provide repair recommendations as necessary. The findings of that inspection report consisted of immediate, short-term, and long-term recommendations. Some of the inspection findings, including several cracks and cracked weld repairs, led to developing short-term recommendations which significantly limited the table's operating speed and impeded the typical operating procedure and daily workflow at the heavy-utilized repair facility. Due to the poor condition of the transfer table, UP published an RFP to replace the transfer table and rehabilitate the substructure and approaches. Some highlights of the reported structural, mechanical, and electrical deficiencies are discussed below.



Photograph 2 – Typical cracked weld in floorbeam gusset connection.



Photograph 3 – Damage from extreme table skew

In the superstructure, cracks at welds in the cantilevered section of the floorbeams were typical as were weld repairs at this same connection detail (see Photograph 2). In the substructure, the concrete footings were cracked, displaced, and spalled in various areas. The rails clipped to the footings were not properly secured, or shimmed, which led to the rails shifting under tractive forces, and changes in rail elevation along the length of the rail. The approach sides of the pit walls sustained impact damage from the table skewing and hitting the approaches.

Creaking and popping noises were noted at two of the drive trucks. These noises were caused by misalignment of the drive trucks, and therefore the wheels, to the foundation rails. Excess noise was not the only symptom associated with this misalignment issue. The wheel flanges would ride hard on the rail head leading to accelerated component wear. In addition, it contributed to the constant headache of the transfer table wanting to travel at an angle to the rails rather than parallel to the rails (skewing) within the pit. Other problems that added to the skew issue were loss of traction at certain drive trucks due to poor load distribution, small variations in motor

Photograph 4 – Original transfer table drive truck construction and distance from the controlling VFD, having a large number (8) of motors drive the transfer table, lack of feedback in the control system to keep motors synchronized, the inability to separately control the speed of each motor, and changes in elevation of the foundation rails.

Maintenance personnel reported that at times the transfer table would skew up to 1' from end to end and the table would get "jammed" in the pit (see Photograph 3). The accepted method for correcting skew was to run the table at full speed into the wall at the end of the pit to "swing" the table around until all five bumpers contact the wall. Over time, these high-impact stresses deformed the bumpers (see Photograph 4) and intensified the mechanical and structural issues.

New Transfer Table Design

Key Design Criteria

- Reuse existing pit, foundation rails, and electrical service.
- Load capacity for a 250-ton locomotive + ½ a locomotive when stationary, and a 22-ton car mover when in motion.
- The existing transfer table must stay in operation to support the repair facility until the new transfer table is installed and has been commissioned.
- Structural design will mitigate existing issues with cracked weld, fatigue, and vibration.
- Design improved drive and control system with automatic and manual skew correction.

Reconfiguration of Drive Machinery

The transfer table drive machinery was designed to complement the electrical system's skew control and to deliver sufficient power to the enhanced design of the transfer table superstructure. It was hard to ignore the similarities between the transfer table skew and the skew of a tower drive vertical lift bridge. With so many successful tower drive vertical lift bridges in operation, the transfer table drive machinery started to take shape in that same vein. Two identical drive systems were used in a master/follower arrangement (see Figure 2). Each drive system consists of two 25 HP motors, which are coupled to opposite sides of the input shaft of a 144:1 parallel shaft reducer, floating shafts are coupled to the output shafts of the reducer, which are coupled to the axle of a wheel block assembly (see Figure 3). One motor per drive system runs during transfer table operation, with the control system designed to automatically

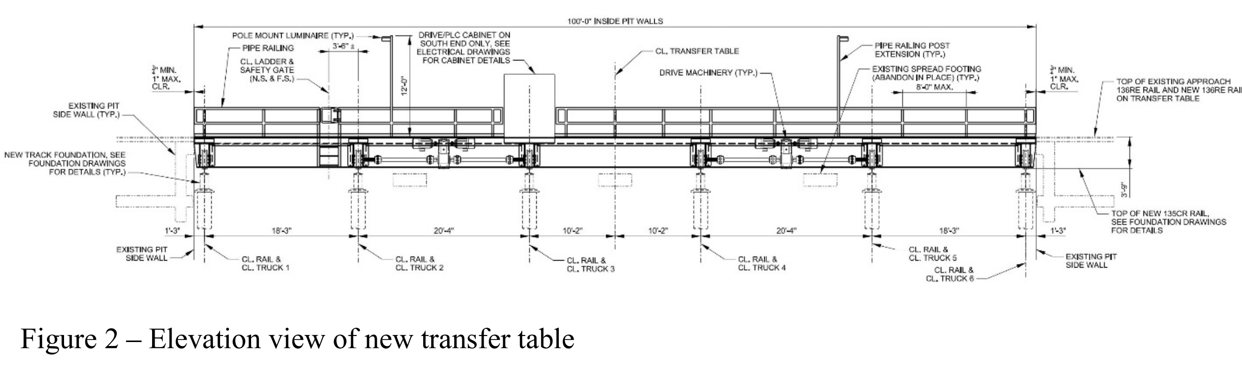


Figure 2 – Elevation view of new transfer table

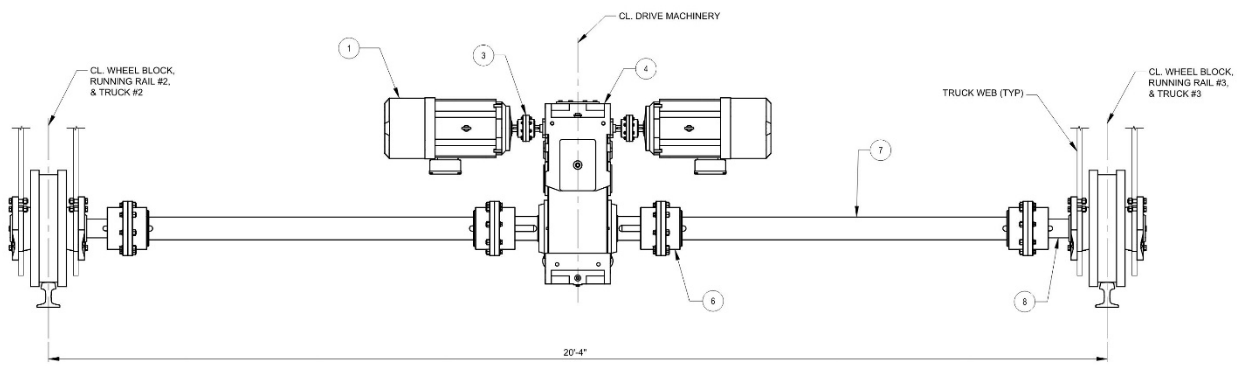


Figure 3 – Elevation view of new transfer table drive machinery

alternate the active motor for each drive system each time the transfer table is operated. Switches are also included in the control system to select a specific motor if necessary.

A single VFD is used for each pair of drive motors, with the capability to program, tune, and alternate the operation of two motors. An output contactor is present between each motor and its respective drive to prevent multiple motors from operating on a single drive.

This new drive machinery configuration has the advantage of reducing the number of active motors from eight to two while having four driving wheels. Since two wheels are driven from the same non-differential reducer, they will rotate at the same speed. These improvements greatly reduce the requirements for a complex control system with position feedback at multiple locations and individual speed control of eight motors. In addition, the new machinery design provides an additional motor for redundancy without losing any functionality.

Due to the importance of this transfer table to Union Pacific's operations at the West Colton Yard, off-the-shelf components were used wherever possible to keep downtime for maintenance and repairs to a minimum. Every mechanical drive component was designed with manufacturer cataloged items. Turned bolts, or shoulder bolts, were used at all interfaces to eliminate the need for field alignment during future repairs.

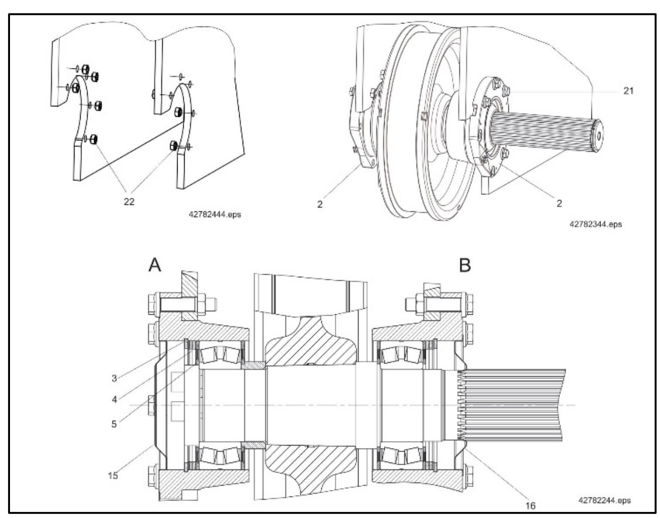


Figure 4 – Demag wheel block assembly corner bearing installation

One of the biggest challenges that arose during design was choosing a wheel block assembly that met the above requirements as well as the increased load capacity requirement. Machinery sizing was guided by both AREMA (American Railway Engineering Maintenance-of-Way Association) and CMAA (Crane Manufacturers Association of America). The latter was used heavily to size the wheels for the transfer table. Wheel loads increased throughout the design process as the table superstructure weight increased. The largest wheel block assembly on the market, Demag's DWS 630 with a permissible load of 132 kips, was chosen for the design. The design team and UP were pleased to learn that the wheel blocks came in a corner-bearing arrangement for quick replacement of the entire assembly (see Figure 4). To meet the wheel load requirements, the wheels had to be specified with the optional 42CrMo4+QT forged steel and the foundation rails had to be switched from AREMA rail to crane rail with a larger effective rail head width.

To help keep the table from skewing, which was one of UP's major concerns, each wheel needed to be accurately aligned to the foundation rails. To achieve this, the design called for spot facing and line boring the trucks, so the wheel axles maintained an acceptable parallel and angular offset.

Multiple factors also drove major design changes to the foundation rails and footings: the existing footings had shifted and spalled, the foundation rail needed to be replaced with crane rail, and the original transfer table had to stay operational until the new table was commissioned. These factors led the design team to decide not to reuse the five existing footings, but to add six new foundations. These foundations would consist of 20-inch diameter driven pipe piles at a refusal depth of approximately 60 feet with W21x132 beams mounted on top. The crane rail was to be mounted to the top of the beams utilizing

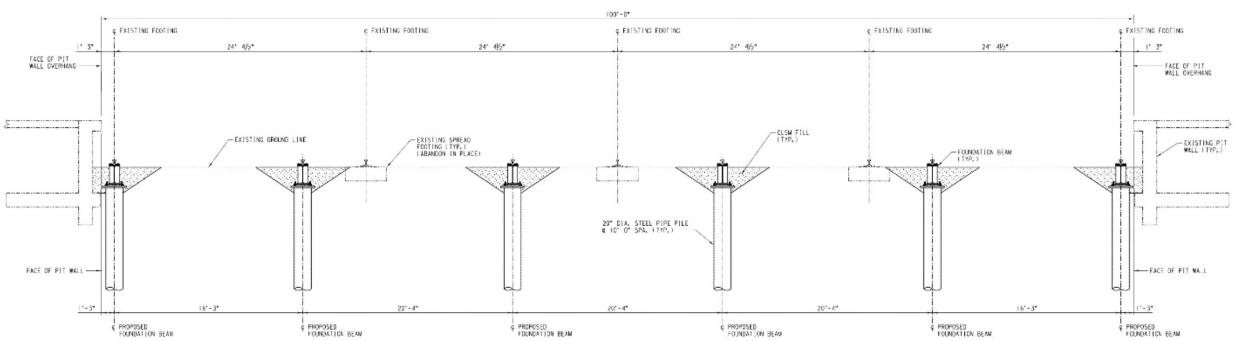


Figure 5 – Elevation view of new transfer table pit foundations

welded rail clips. The outermost foundations would be positioned in the same location as the existing ones, but the remaining four foundations were in new locations (see Figure 5). This allowed for easier staging of the project, especially construction staging when the original and new table were to be in the pit at the same time. This change also helped with wheel load rating and skew control. The addition of an extra foundation rail meant the transfer table would have six trucks and 12 wheels instead of five trucks and 10 wheels, decreasing the wheel load by 17 percent. Also, laying new crane rail gave the design team a chance to specify a straightness and elevation tolerance for the rail, which decreased the likelihood of skewing the transfer table.

Since UP could not tolerate the disruptions caused by making major adjustments to the transfer table once it was placed in the pit, the design required the contractor to fully assemble the transfer table in the shop and drive it up and down a 100' length of crane rail to simulate conditions in the field.

Electrical Service to New Transfer Table

The existing transfer table pit was equipped with a conductor bar system routed along the East wall to provide the main power connection to the existing transfer table. To maintain serviceability of the existing transfer table during commissioning of the new transfer table, the design included a new conductor bar system routed along the West wall of the pit (see Photograph 5). The main service line to the pit was tapped with a feeder to the new conductor bar system. This setup allowed for both transfer tables to be used interchangeably throughout the on-site testing periods of construction. Following the testing and closeout of construction, the original conductor bar system was removed along with the existing transfer table. The new conductor bar system, consisting of a rail and collector for each of the three phases and ground, remained to provide the main power connection to the new transfer table. A disconnect switch is also included in the rail yard to safely disconnect power to the conductor bar system while personnel are working within the pit.

Photograph 5 – New conductor bar system

An e-chain type system that would be located along the pit floor was also researched during design, but it was decided that a system such as this would be too susceptible to debris interfering the movement and damaging the system. The conductor bar system was chosen because it was determined this system would be more reliable and familiar to the Owner.

Operation and Control System

To operate the transfer table, an operator podium is located on each end of the transfer table (see Photograph 6). A joystick is provided to run the table in either direction. The joystick control is set up so the operator can control the speed of the table based on how far they move the joystick away from its center position. Depending on the position of the joystick, the table will run at zero speed, creep speed, half speed, or full speed. Each operator podium is also equipped with indicator lights for skew warning, skew fault, brakes set, brakes released, near track aligned, near end of travel, and end of travel. Aligning the desired tracks is strictly dependent on the operator, so there is no need for a track aligned indicator light. The control power ON pushbuttons at each operator podium are interlocked to allow operation from only one podium. There are other safety features incorporated into the control system such as initiating creep speed when the table reaches end of travel at either end of the pit.

Photograph 6 – Operator Podium

A skew control system was implemented into the design to continuously correct skew of the transfer table. The skew control system works much like that of a tower drive vertical lift bridge. A position encoder is mounted at each end tuck wheel assembly (see Photograph 7) to provide absolute position feedback from each end of the table as it moves along the foundation rail. The position encoders are spring loaded to hold their wheel on the foundation rail. Each end truck with an encoder also has a barrier in front of the encoder to prevent debris from damaging the encoder. The PLC control system utilizes the feedback from each encoder to calculate the difference in position from one end of the transfer table to the other and decrease the speed of the leading drive motor to correct the skew. An encoder is also mounted on each motor to provide closed loop speed feedback from each motor to its respective VFD.

Photograph 7 – Position encoder

It is common for the feedback from encoders to build up error in their position over time because of external factors such as slippage on the rail. Therefore, it was determined that a procedure was needed to reset the count on the encoders while the table is in a controlled and fixed position where we know that skew is absent. The bumper system at the end of the pit was designed to be used for the table to be straightened and held against while the encoders are reset. This approach is much like how encoders are typically reset (due to main counterweight rope slippage) on vertical lift bridges when the lift span is in the seated position.

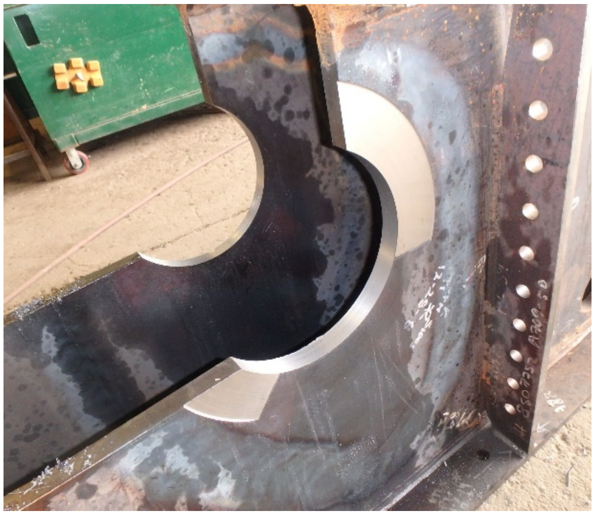
A manual skew correction procedure was also incorporated into the design as a backup to the automatic skew control system. A switch to select West drive or East drive only is provided to accomplish rotating the table back into alignment.

Photograph 8 – Limit switches

Maximum skew lever arm type limit switches were located at each end of the table. In a skew event, these limit switches were designed for the lever arm to contact the pit wall and trip prior to the table skewing enough to become jammed against the pit wall. Multiple proximity type limit switches were located at each end of the transfer table with target magnets strategically placed at various locations along the pit wall to indicate significant positions of the transfer table (see Photograph 8).

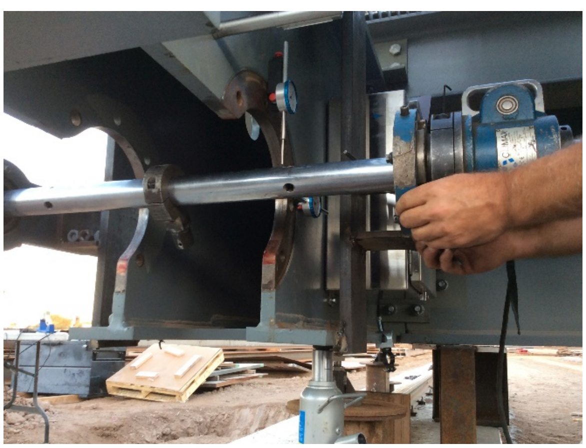
New Transfer Table Construction

Construction of the West Colton Yard transfer table began in 2018 at a shop in El Centro, CA, about three hours south of the rail yard. One of the first hurdles to overcome during construction was machining the trucks to mate with the wheel block assemblies. The truck weldments have a top and bottom flange as well as two web plates. After welding, the web plates had warped and were no longer parallel to one another. As the spot facing and boring operations were performed on the truck webs this issue became increasingly more obvious. In the most severe cases, the web spotface did not clean up the entire wheel hub mating interface on the truck web (see Photograph 9). Another issue with the spot facing and boring procedure was that these operations were initially performed on individual trucks in different machine setups for each side of the truck with no reference from one side to the other. Even if this method could have produced individual trucks with proper wheel bores, all six trucks would then need to be precision assembled in order to meet the wheel alignment tolerances. In the end, a three-part solution was developed. First, the transfer table was fully assembled at the shop and then the trucks were precision machined for the wheel block assemblies. A FARO laser tracker was used to generate a 3D point cloud of


Photograph 9 – Machining warped truck web for wheel block installation

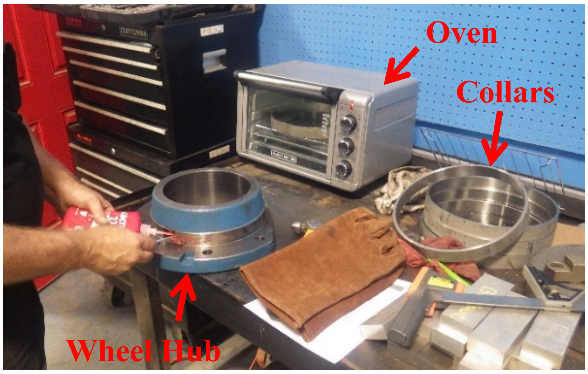

Photograph 10 – FARO laser tracker was used to map wheel block bores

all 12 wheel block bores in the six fully assembled truck beams (see Photograph 10). The point cloud data were analyzed, and the ideal bore locations were calculated to give the wheels the best possible alignment. Each truck bore was re-linebored, and spot faced if necessary, by offsetting the line bore equipment from the existing bore according to the calculated value from the laser tracker data (see Photograph 11). Second, the truck web spot facing was permitted to remove slightly more material than what is recommended by the wheel block manufacturer, but calculations confirmed this was an acceptable deviation. Third, some of the truck bores did not have enough material remaining to locate the new bore in an ideal location. These bores were machined to an oversized diameter, and the wheel block hubs were fitted with custom eccentric collars (perfectly matching the oversized diameter), which brought the wheel hub back to the ideal location (see Photograph 12). With these methods the wheels were installed to meet the tight parallel and angular alignment tolerances, which helped prevent loss of traction and skew.


Photograph 11 – Lineboring trucks on fully assembled table for wheel block hubs

Once the transfer table was fully assembly at the shop, and the machinery and electrical control equipment were installed, the table was test operated. The pit at the West Colton Yard was simulated at the shop by pouring temporary foundations and laying six 100' tracks of crane rail (see Photograph 13). Before operating the table, a machinery spin test was performed. The transfer table was jacked to raise the drive wheels off the tracks, and the machinery was run for 30 minutes in forward and reverse. Once the spin test was completed successfully, the transfer table was lowered back onto the tracks and test operations were performed. The transfer table was run more than a dozen times up and down the tracks at full speed. The table operated smoothly, and no significant defects were noted.

At the shop test in El Centro, CA, the control system was observed for proper operation. Generally, the control system and the automatic skew control functioned satisfactorily. When the manual skew correction procedure was tested, it was observed that the non-active drive truck was dragging along the



Photograph 12 – Installing eccentric collars on wheel block hubs after heating in oven


Photograph 13 – Fully assembled transfer table on temporary crane rail track at the shop in El Centro

tracks while the active drive was running. Therefore, it was determined that this function would not be capable of correcting the skew due to the overall rigidity of the table.

Another observation noted during the shop test was the “bump” capability of the table. For the purposes of this paper, the “bump” is defined as the shortest distance of transfer table travel that the operator can achieve by “bumping” the joystick. This “bump” technique is used frequently when making the final alignment between transfer table and rail yard tracks. A shorter “bump” allows for more precise track alignment when bringing the table to a stop at a specific track location. It was noted during the shop test that the existing transfer table was able to achieve a “bump” distance of ¼”, but the new transfer table was only able to achieve a “bump” distance of ½”. To shorten the “bump” distance capability of the new transfer table, the creep speed mode was altered to be slower than 10% for a few seconds, then increase up to the desired 10% after a few seconds of run. The drive deceleration ramp was also decreased for cases when the joystick is moved from the center position into the creep speed position and back to the center position (this function was deactivated for all cases when the joystick moves past the creep speed position).

Once the shop testing was complete, the transfer table needed to be transported from El Centro, CA three hours north to Colton, CA. The original plan was to move the 99 foot long, 17.5 foot wide, 8.5 foot tall, 225,000-pound table in two pieces. However, the Contractor developed a procedure, and secured permitting, to move the table in a single piece without disassembly. The endeavor required specialized lifting equipment and independently operated trailers with remote steering, but the time and effort saved in the pit at West Colton was well worth it (see Photograph 14).

With the transfer table at its destination in the pit at West Colton, all of the final testing and tweaks still needed to be performed while keeping the original table fully operational. When the new transfer table was tested in the pit, it rubbed hard on the sides of the pit walls. The table could not be fully tested or commissioned without some adjustments. As a result, the approaches were cut back a small amount to match the original design drawings and to make room for the new table (see Photograph 15).


Photograph 14 – Fully assembled transfer table being set into position in the pit at West Colton

Photograph 15 – A small amount of the west pit wall is being trimmed off

Further testing showed that the transfer table operated as intended but had a tendency to "float" east and west in the pit. Tractive forces from oncoming and offgoing locomotives pushed the table from side to side. The flanges on the wheel block assemblies limited the table float, but also experienced increased stress and wear from the large lateral forces. In addition, with the transfer table pushed to one side or the other, a gap opened up between the approach rails and the table rails. Some gap is inherent to the design of the transfer table, but minimizing the gap is helpful for reducing deformation to the rail head from repeated impact with locomotive wheels. UP suggested that the table design include provisions for adding guide rollers to resist this movement, if necessary. Four guide rollers were designed and installed in a rectangular pattern near the center of the table (see Figure 6 & Photograph 16). Without a good way to quantify the forces, the guide rollers were conservatively designed to overcome the friction force between the transfer table wheels and the crane rail. In other words, the guide rollers can push the table transversely if it starts running at an angle to the crane rails. For easy adjustability, the guide rollers are on a slanted bracket equipped with jacking screws and slotted connections. If the rail head to guide roller gap needs to be adjusted the bearing bolts are loosened and the jacking screws are moved to the desired location. The guide rollers also act as a simple mechanical way of correcting skew. Therefore, it was recommended that the maximum skew limit switches be repurposed as reference/feedback switches to reset and ensure the accuracy of the position encoders without the need to run the transfer table to the end of the pit. Trip plates were also recommended to be strategically placed in an aligned "zero skew" arrangement so that every time the transfer table passed these trip plates, the position encoders would be reset to an accurate "zero skew" condition. The other limit switches at the end of the table were susceptible to damage due to the lack of clearance near the pit walls and were removed. These switches provided feedback related to the originally designed position encoder reset procedure and other non-crucial indication such as near track aligned. Therefore, their removal did not affect the operation of the transfer table control system. The automatic skew control system continued to work well when observed throughout final testing. However, it is unknown if the automatic skew control system was left in service following the installation of the guide rollers. Final testing was completed with the guide roller in place. Operation was very smooth and quiet. The guide rollers engaged periodically to keep the table running true. All tests were successful, and the owner accepted the completion of the project.

Conclusion

Through careful planning, thoughtful design, constant communication, and the ability to adapt to changing circumstances, this transfer table replacement project was a success for all parties involved. Applying lessons learned from past heavy movable projects to this project helped deliver a substantial upgrade over the existing table to the client. This project was not without its own unique challenges though. Perhaps the biggest takeaway is that a robust mechanical solution, even if more costly upfront, might be preferable to an electrical skew control solution, as was the case with the guide roller design.

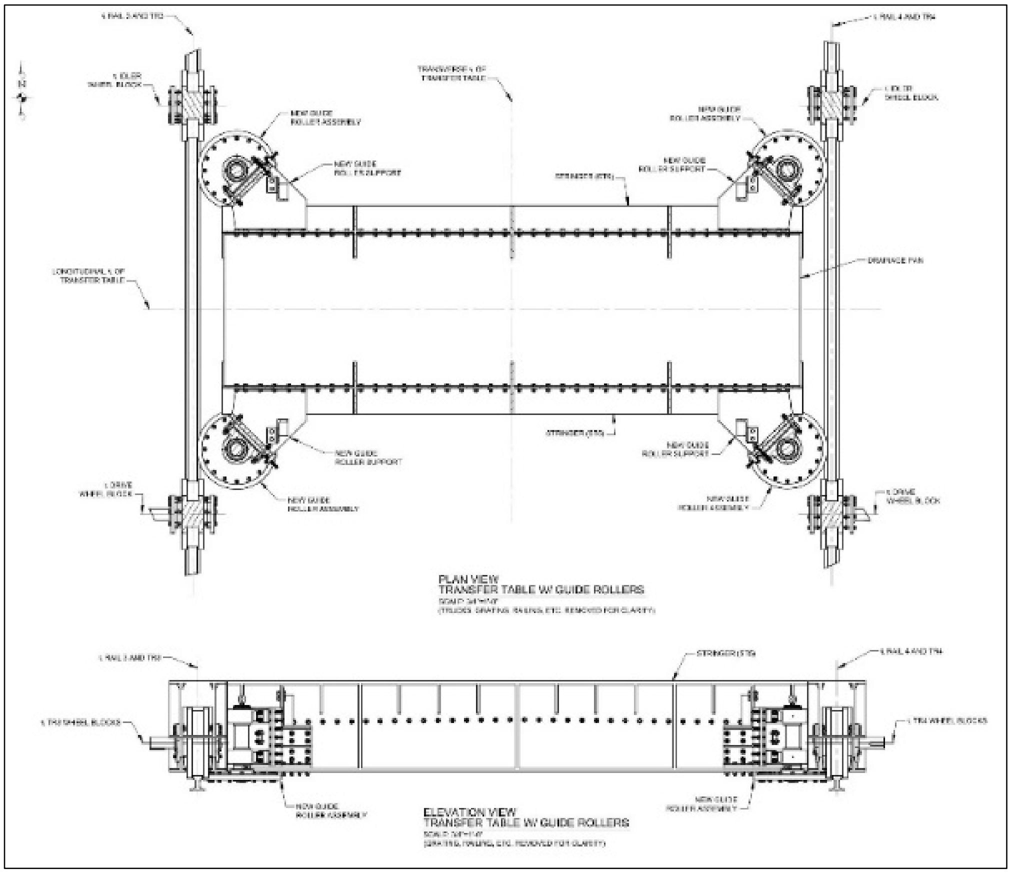
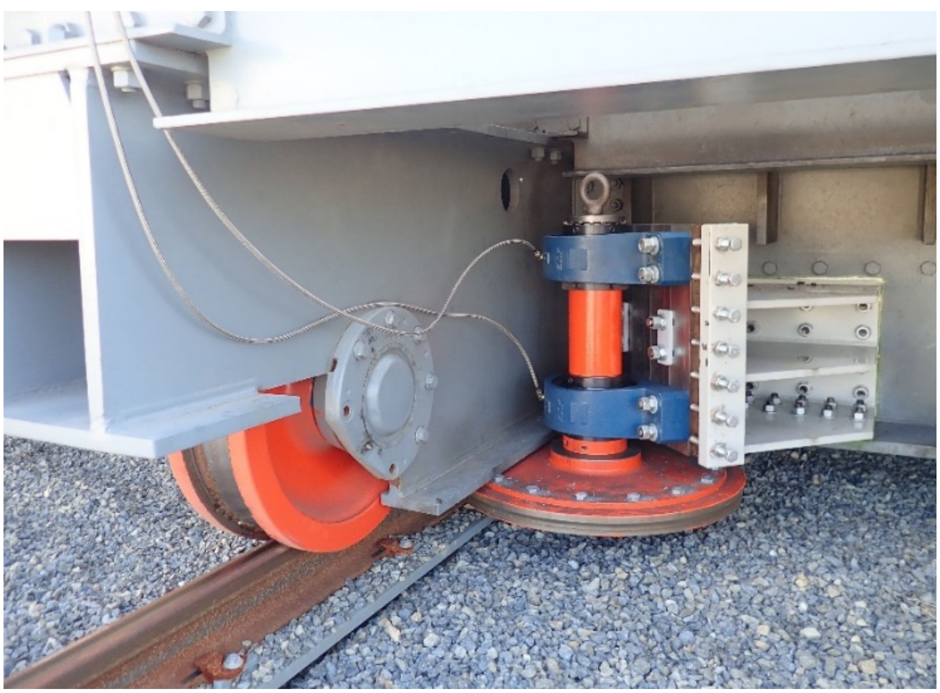


Figure 6 – Design of the new guide roller assemblies



Photograph 16 – Typical guide roller assembly installed on the transfer table