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Resurrection of a Historical Turntable for ORHF

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Introduction

This technical paper provides a review of the journey and challenges of taking a class 1 railroad grade turntable from storage to what might be the best operating turntable in the country at this time, for a not-for profit railroad museum in Portland, OR. The paper will present a brief history of the turntable and the work performed which made it possible to install the turntable as a functional part of the museum and its rail operations. The paper will discuss a brief history of the turntable up to its current refurbishment and installation, design of the refurbishments to the turntable and operating system, and aspects of construction related to its installation and commissioning.

The Oregon Rail Heritage Foundation (ORHF) provides for the preservation, operation and public enjoyment of Portland's historic locomotives, railroad equipment, and artifacts, and educates the public about Oregon's rich and diverse railroad history[1]. ORHF is predominantly an organization of volunteers who perform the work of maintaining, operating, and providing public rides using the locomotives and rolling stock of the rail center. The turntable was an upgrade for the not-for-profit organization which maintains and operates a fleet of historic locomotive and rail cars in an adjacent service building. The addition of a functioning turntable was found to be beneficial for both the maintenance of the various locomotives and rolling stock as well as decreasing the effort it would take to get locomotives turned around via the alternate route of traversing rail lines up to North Portland and back. In addition, it also promised the visiting public another exhibit of Portland's rail history in action.

The project of rehabilitating, installing, and commissioning the turntable, its machinery, and new electrical systems occurred between September of 2019, through the COVID-19 pandemic, and up to the grand inauguration of the operational turntable on October 14th, 2023. HDR Engineering provided inspection and design services related to the turntable structural, mechanical, and electrical systems. Everett Engineering (EEI) was hired as a specialty contractor to work with the prime contractor to install and align the turntable as well as work to commission the operation of the turntable. Recognition is given to ABHT Structural Engineers, Geo Design / NV5, Hennebery Eddy Architects, Resolve Architecture & Planning, The Bookin Group, and KPFF Consulting Engineers for design of the turntable pit and surrounding civil/site work, which will not be discussed in the paper. Recognition is also given to the prime contractor A2 Fabrication, Albany & Eastern Railroad, Carlson Testing, Omega Morgan, PetroChem, Rick Franklin Corporation, Rhino Industrial, Photo Electric, and Taurus Power and Controls for their roles in the overall construction of the turntable facility at the Oregon Rail Heritage Center.

History

This year, 2024, we celebrate the 100-year anniversary of the former Southern Pacific, Brooklyn Yard turntable. A continuous style girder bridge built by American Bridge Co., constructed with Carnegie Steel

[1] Oregon Rail Heritage Center. (2021, August 9). Turntable project - Oregon Rail Heritage Foundation. Oregon Rail Heritage Foundation. https://orhf.org/turntable-project/

– 100 feet long, with a 375-ton capacity. The turntable has served multiple roles of turning mainline service steam locomotives, to an initial role in maintaining Oregon's reduced steam fleet, to its current role as museum piece and functioning exhibit for continuing to maintain ORHF's ever-increasing fleet.

Historical Perspective

One hundred years ago, 1924, the roaring twenties were in full swing; Calvin Coolidge was elected President; The US enacted its first law attempting to control immigration; The dynamic speaker was invented as was the spiral notebook; the Royal Greenwich Observatory began transmitting time signals; IBM was born; The first photo facsimile was transmitted across the Atlantic; And, the first diesel electric locomotive entered service in the Bronx, NYC.[2]

Figure 1: The original installation of the turntable at Brooklyn yard. Note the crew working on setting the center bearing.

The 100-foot American Bridge Co. turntable was purchased by the Southern Pacific railroad to replace a smaller turntable to accommodate the ever-increasing mass of the new engines. The turntable was out of service for one hour and forty-eight minutes while the bridges were swapped out.[3]

The turntable was in service 24/7/365 during the steam locomotive era. However, as diesels became more numerous and powerful, steam engines faded into history. The last regularly scheduled steam train left Brooklyn Yard in the fall of 1955. The utility of the turntable started to fade as did the routine care they normally received.

In the mid-fifties, three decommissioned mainline steam locomotives were donated to the city of Portland, Oregon, for a future transportation museum. The city eventually lost interest in building it. They sat rusting on a siding next to an amusement park.

In 1974 a nationwide search was underway by an East Coast group to find a steam locomotive worthy of pulling a train to celebrate America's bicentennial. Portland's SP4449 was chosen and restored. Portland became the proud owner of an operating world famous 4-8-4 Northern class locomotive. Eventually the SP&S 700 would be brought back to life, too. The engines still did not have a permanent home; however, they were now housed in what remained of the old Brooklyn roundhouse complex where the turntable continued in service.

Figure 2: The turntable in service at the UPRR Brooklyn yard circa 1980's.

[2] Historic Newspapers. (2024, August 13). Historic Newspapers - the world's largest newspaper archive. https://www.historic-newspapers.co.uk/

[3] Austin, E., & Dill, T. (1987). The Southern Pacific in Oregon.

In 2002, the Oregon Rail Heritage Foundation (ORHF) was formed. It was made up of neighborhood activists and the volunteers that worked on the engines. Its mission: Find a permanent home to preserve the three, Portland-owned, mainline class steam locomotives. Because two of the locomotives were in operating condition, it has always been a part of the plan to acquire the turntable as well. Mainline steam locomotives are designed for optimum performance to be run in the forward direction. Thus, it was common practice when trains ended their run, the engine was "turned" in preparation for its next assignment. Without a turntable, getting an engine turned can be a logistical nightmare as well as very expensive!

Around 2005 or so, ORHF learned that Union Pacific (UP), following the merger with the Southern Pacific (SP) RR, intended to transform Brooklyn Yard into an intermodal yard. All remaining structures would be leveled including the turntable.

The president of the Oregon Rail Heritage Foundation, Doyle McCormack, a retired engineer with the SP and UP, and the chief mechanical officer and engineer of the SP4449, approached a local UP manager about the possibility of taking the turntable to a new facility. UP agreed and was anxious to move on, but also extremely patient and understanding of the task of relocating the table.

The big move came in 2012 to a new facility two miles down the mainline near the Oregon Museum of Science and Industry. Rick Franklin Corporation carefully lifted the table out of the pit, with equipment normally used to clear derailments, and on to a flat car for the move to the new rail center. Everything that didn't crumble during the lift was loaded and transported off-site for storage.

Design

Design for the turntable performed a function of validating the existing turntable equipment and design for use in a new lighter duty service at the Center, filling in the data gaps from unknowns related to lack of previous design documents or the varying as-built condition of the table and its machinery, and providing guidance for the installation and commissioning of the turntable. Contrary to the design efforts of many heavy movable structure projects for Class 1 railroads under the guidelines of the American Railway Engineering and Maintenance-of-Way Association (AREMA), the project was more seen as a functioning museum piece where reuse of equipment was more driven by historical preservation, rather than a desire to minimize project costs. In some cases, though, current code compliance, or just the ability to reproduce components as original, mandated the replacement with modern equivalents. Further examples will be provided in the following design discussion. Overall, the fact that the turntable and its machinery would be used as a museum piece allowed the team to compromise on design aspects such as the operating speed of the table, which had a direct impact on motor sizing, and the power feeds required for operating the table. Reuse of certain components such as the track wheels or pit rails were able to be accepted in as-is condition, knowing that the number of cycles

Figure 3: Original corroded end truck. Note riveted construction and areas of complete section loss on top flange.

moving forward would be greatly reduced from the previous service.

Since the nature of the turntable project was one of on-going refurbishment, it was quite different than the typical staging of movable bridge projects. Instead of construction staging favoring a degree of work to facilitate quick changeout of structural components or operating systems with least impact to the traveling public, the nature of some engineering and design support was that of ever-evolving investigation as the turntable components were disassembled and reviewed.

The following are a few of the engineering support tasks that occurred, but will not be discussed in detail:

- Review of the end truck frames to determine if repair or replacement was a better option. It was deemed prudent to completely replace the frames due to deterioration, but consideration had to be made that the geometry be maintained while fabricating the new frame with modern structural steel sections.
- Review of the center bearing roller element condition after disassembly and cleaning of the center bearing. All components were found to be in good condition and the center bearing spun quite freely by hand once cleaned and lubricated.
- Review of the existing in-service track wheel conditions compared to suspected unworn spares. The existing wheels were put back into service, deeming the spare wheels as… spare. It was decided that the level of use would probably not put further wear on the in-service wheels and that a new spare was preferred to a worn spare.
- Review of the existing motors for reuse. Anecdotally, crews who had worked on the turntable in its past operation reported that the existing cast motor housings exhibited cracks. The difficulty of repairing the castings and expected remediation of asbestos containing material inside the motor drove for the use of new motors.
- Design calculations for a new motor pinion for use with a new gearmotor. The tapered bores of the existing pinions and finding two different face widths on the motor pinions drove the need to confirm the dimensions and proposed material for a new motor pinion.

Figure 4: Storage condition of the table on a flatbed rail car. Original ties and paint shown.

Table Structure Evaluation and Repairs

Some of the earliest engineering performed on the project was associated with validating the load rating of the turntable structure. The original plans identified the table as rated for 375 tons, but no calculations or documentation of the method for determining the rating was provided in the original documentation. In addition to the on-paper rating, the initial load rating process was to also consider any as-found conditions of the table steel and make recommendations for repair. The rating was focused on the main deck girders of the turntable, since replacement and refurbishment of the end beam steel, drive trucks, and diagonals were anticipated at the time of the rating.

Load Rating

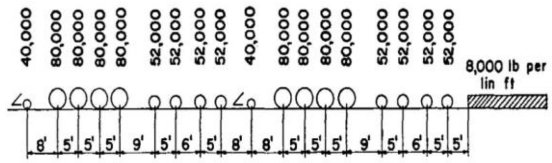

Figure 5: Cooper E80 axle loading.

A structural analysis model of the turntable was developed for the load rating. The load rating of the main deck girder of the turntable was performed using the designated 'normal' allowable moment and shear as specified in AREMA Chapter 15 with the Cooper E-80 locomotive loading. The reasoning being that if the turntable rating was able to pass the theoretical load, then all the locomotive inventory, including the rail center's venerable Southern Pacific "Daylight" 4449 locomotive and tender, would be able to be used on the turntable, albeit with a reduced tender load expected.

Analysis showed that the table had an acceptable rating, with center shear being the controlling effect and yielding a Cooper E-80 rating factor of 1.0. Any deterioration of the main girders was not significant enough to affect the rating, with one exception: the end bottom flanges. Inspection of the table steel followed the AREMA Bridge Inspection Handbook and the Federal Highway Administration National Bridge Inspection Standards and was performed in August of 2020. Although at this time it was recognized that significant work would need to be performed on the cross bracing throughout and bottom flanges of the main girders where they met the drive truck due to corrosion resulting in section loss. Most affected areas were horizontal surfaces where moisture was trapped either between steel plies, or between the timber ties and interfacing steel. Similar evaluation of the existing drive trucks also concluded with the necessity of full replacement. It was also decided that the turntable steel would benefit from blast cleaning of the existing paint, remediation of any hazardous coatings, and a recoating of all steel upon completion of repairs.


Figure 6: Deterioration of cross bracing gusset below ties.


Figure 7: Rebuilt top flanges of main girders at end of table superstructure. Note rivet head bolts used for historical aesthetic.

Cross Girder Repair

Through the course of the steel inspection, particular attention was given to the main cross girder and its condition. As early as 1933, there was documented upward deformation of the lower flange of the girder by as much as 5/8" and cracks propagating from some of the rivet holes in the vicinity of where it bore against the center bearing. Previous repairs had been developed and implemented to increase the thickness of the lower flange with additional steel and were assumed to be performed in-situ given the nature of the work. In addition to the pre-existing deformation, once the center bearing and shims were removed from the main cross girder during the storage period, areas of complete section loss were observed in the cover plate of the bottom flange exposing the bottom of the channels and plate of the center web. Again, the deterioration was located around the portion of the girder in contact with the center bearing. The concern with the deterioration was that in resetting the turntable on the center bearing, the deformed and corroded area would not be a solid mounting surface to position the turntable on the center bearing or its new foundation. But there was not concern about further stressing the lower flange, since the deformation was measured to be the same as the initial 1930's measurement and both past repairs and the new shim plate would add further localized section to the lower flange. In addition, the degree of pitting and wear would also leave a very minimal area of contact between the girder, any shims used, and the center bearing, causing high bearing stress and the tendency to trap water and propagate further deterioration through corrosion. In pursuing a solution for the deterioration, ORHF was intent on preserving the turntable's existing steel as much as possible and finding a cost-effective solution to provide a sound connection between the cross girder and center bearing.

Figure 8: Full section loss, pitting, and distortion on the bottom of the bottom flange where it was in contact with the center bearing.

In the case of the main cross girder repair several options were considered with the following determinations:

- Full replacement of steel – This was seen a cost prohibitive repair and would require further work to properly tie in and position a lower flange on the main cross girder in planar alignment with the table.
- Heat straightening of steel – Investigation of the approach was discussed with local contractors and the thickness of the lower flange and its past repairs, was deemed too significant to guarantee a proper corrective action without the same alignment concerns as complete replacement.
- Casting a mating shim plate – Through its work on the center locomotives, certain volunteer staff had experience with small lot casting, which seemed promising. But further investigation deemed that the casting would be hard to form up around the bottom of the flange and there were concerns that any material used would not have the bearing strength needed for the application.
- Scan and CNC of mating shim plate – This alternative was born out of a novel approach of having Light Detection and Ranging (LiDAR) scanning capabilities in the area for another project and was selected for further exploration. Moreover, this was ultimately the selected alternative.

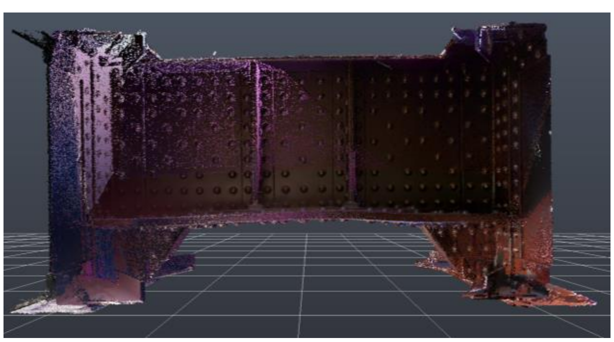

Figure 9: Photorealistic LiDAR scan showing up to 5/8" distortion at the main cross girder bottom flange.

The intent of the selected alternative was to scan the underside of the main cross girder and then fabricate a shim plate whose top surface matched the contour and profile of the underside of the girder while providing a bottom surface that was flat and planar to the underside of the turntable. The approach would be broken up into 3 main stages of work: scanning the existing steel, creating the custom shim plate, and fit-up and alignment with the existing steel. The work had to be completed prior to the landing of the turntable structure on the center bearing and foundation. During the work, access was facilitated by having the turntable structure sitting elevated on rail car trucks after the steel repairs, allowing clear access to the underside of the main cross girder for work.

The scanning phase of the work consisted of scanning both the underside of the main cross girder and surrounding steel with LiDAR to an accuracy of 0.005", which is in-turn nominally reduced by the scan-stitching process. A physical spot-check operation on the deteriorated surface using a straight edge and depth gauge was also performed to validate the LiDAR scan. The straightness and planar surface of the table main longitudinal girders were also checked using a 48" level.

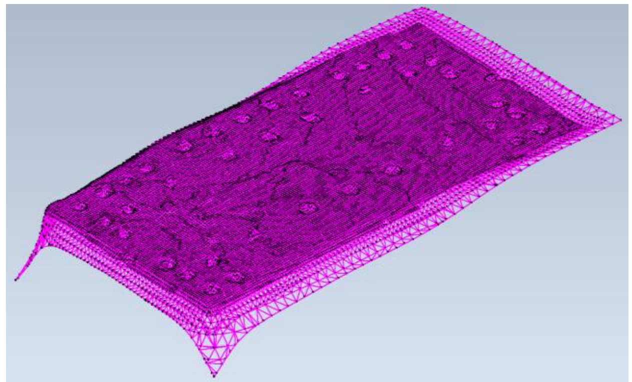

Figure 10: 3D 'Cloth Drape' of the LiDAR point cloud to create a solid contoured surface for the top of the shim plate.

Design of the custom shim plate was performed in AutoCAD Inventor after importing the point cloud of the (LiDAR) scanned area. A 'cloth drape' digital surface interpolation was performed over the point cloud to create a solid surface representing the contours of the scanned underside of the cross girder. In addition to establishing the surface, some manipulation of the resulting 3D model was performed to reduce the resulting high points of the scanned surface. The reduction of just the high spots up to ½" in some locations was to account for inaccuracy of the scan as well as potentially decrease the fit-up time it would take to physically reduce any high spots of the cut shim plate with the existing cross girder. The reductions were not uniform but applied judiciously in accordance with observed variations across the area in the difference between the scan data and the manual 'spot-check' measurements.

Once adequate adjustments to the model were made for fit-up, the final contour was established for the plate and a review of the capabilities of the CNC mill head used by EEI, and a reasonable load-up time for the cutting program was pursued. The design model was provided in two different levels of detail to check the cutter routing program for a 1/4" mill cutter. In the end, it was found that the higher detail model could be used without significant program load-up time and the model was provided with blank mounting hole locations to account for field fit-up and proper hole location when mounting.

During installation, it was expected that the custom cut shim plate would fit up with the underside of the main cross girder lower flange and also be aligned planar to the underside of the main longitudinal girders of the turntable, so as not to result in excessive longitudinal or lateral out-of-level alignment of the turntable once placed on the center bearing. The planar alignment criteria were no more than 0.3 degrees in the longitudinal direction and 0.5 degrees in the lateral direction. In addition to these fit-up requirements, load transfer capacity is also fundamental, and the American Institute for Steel Construction (AISC)'s allowable bearing stress was referenced for this limit. It was determined through calculation that to not exceed the allowable bearing stress by a comfortable margin, the contact ratio of the bearing plate with the underside of the girder must be at least 50%. The interface between the plates was filled with steel epoxy putty to seal and fill voids.

Motor Replacement

As noted earlier, in the evaluation of the existing turntable machinery, it was determined that the motors would need to be replaced. From an engineering perspective, it was also recognized that there was an opportunity to slow down operation of the turntable for a more controlled ride. Similar to other class 1 RR's, the impression of past operators was that the table had a potential for speeds higher than the comfort level of the operators.

Figure 11: One of two original 25 HP, 600 RPM, 3 PH motors with tapered output shaft.

Prior to the involvement of the engineering and contractor team, the rail center had solicited suppliers for a motor and drive package to replace the original drum controller and wound rotor motors. The quote provided for motors that were almost double the size of the existing motors in Horsepower (HP). As a result of the package cost, and concerns on the sizing, the rail center also procured a gearmotor and drive package from a local electrical supplier in anticipation of the table refurbishment. The procured gearmotor and drive package was the same HP rating as the existing motor (25HP), but with a higher motor speed (1800RPM). The additional gearing provided an output speed equal to the existing motor (600 RPM). The engineering task was to review both sets of motors and drives for their applicability for operating the refurbished turntable.

At the start of the evaluation, the following design criteria were considered:

- Working the table in adverse conditions such as AREMA wind and ice loads will not be considered. Only a 'blue sky' day operation was considered. If the turntable had a problem with loads or operations, the approach would be to shut down and diagnose the problem with no real loss of revenue considerations. If adverse ice and wind were present, the turntable would not be operated.
- The original operating speed was unknown from the design documents and no calculations were provided for the original operating loads. A gut check assumption was that the table could operate with less HP and still have acceptable operating speed. As previously noted, staff who had worked with the table in the previous installation felt the highest operating speed was unnecessary.
- The turntable would be put into service with proper alignment and all running machinery in good condition so losses for machinery resistances should be close to the book value.

In review of the two motor and drive options, an independent calculation of the required power for the turntable to operate at a speed of a little over a half rotation per minute was performed taking into account the load of the 4449 Locomotive with its tender empty on the table. The table's self-weight, locomotive, resulting friction load, and efficiency of the operating machinery were considered. Comparison of the calculation to the two motor and drive alternatives indicated that the almost double sized package was in excess of needs and that the performance characteristics of the increased-speed motor and additional gearbox in-hand would not overtax the drive or circuit protection to be provided. A full analysis of the machinery loading was not performed, since the assumption was made that the drive would ramp up and be effectively working at less than the starting HP of the original motors. Evaluation of the almost double-sized motor calculation showed that assumptions about the resistive friction load in the center bearing and rolling friction at the truck wheels were overestimated, resulting in the higher HP estimate.

Figure 12: New gearmotor geometry on end drive truck. Also note the existing brake wheel in the drivetrain to the left of the photo.

In the end, the only downside for the faster speed gearmotor and drive provided was that the combination of motor and gearbox had a completely different geometry in both size and height from footing to center of shaft. In addition, the tapered bored motor pinions from the original motors would not fit on the straight bore shaft of either motor package. As noted previously, calculations were performed to provide a 'like' pinion design with current materials and the straight bore.

To address the geometry concerns of the new gearmotor, a support and motor arrangement design concept was provided with an extension of the motor support inboard of the existing drive truck machinery. The new pinion would mesh with the existing gearing on the drive truck. The design was further refined in the construction phase and is discussed further below.

Other Functional Systems

Through the course of the turntable refurbishment, assessment of existing and potential functional systems were considered. In the case of existing systems, the challenge was to either replace or repair. For all existing systems the evaluation came down to a review of the component condition and whether it was fit to continue service (with repairs) or whether there was some current safety or code concern that would predicate full replacement. The following are several examples of functional systems that were reviewed, inspected, and memo reports issued on the disposition recommended.

The original slip ring assembly was found intact for the turntable and had been removed along with the harp when put into storage. Its design differed from a modern slip ring assembly in that instead of a contact plate and brush for each phase the assembly had two circular contact plates pressed against each other for each phase. The entire assembly was sandwiched together, along with springs, inside a housing and the conductors were fed up through the center of the assembly via a pipe in the pedestal base. The existing slip ring was considered for replacement due to the non-standard arrangement and the fact that modern conductors would not fit in the base pipe while being compliant with the National Electrical Code (NEC). Otherwise, the contact surfaces were found to be in good condition

Figure 13: Slip Ring Assembly with cover removed. Note the series of contact plates rather that brushes and plates.

and the assembly could be kept for a display piece in later use.

The original brake used to stop the turntable consisted of a lever in the control house and a series of cranks and linkages connected to a band-and-brake-wheel at the drive truck adjacent to the operator's house. The original band brake had wood brake pads. The original brake functioned to both decelerate the turntable, in conjunction with the drum controller, and also act as a parking brake. The original brake was excluded from the design due to new motor drives being able to control the deceleration of the table. The existing brake wheel remains in the operating machinery drivetrain (See previous gearmotor geometry photo). The recreation of the linkages and providing space for the mechanism in the operator's house would require modification of the house beyond the desires of the project. Much of the lever, cranks, and linkages were also lost to the storage of the turntable or were in such a condition as to not be reused. A greater challenge would have been recreating the proper operating characteristics of the wooden brake pads, for which an industry is no longer available.

The solution to the exclusion of the original brake was a combination of the motor drives decelerating the turntable and deploying a span lock when aligned to a particular track to hold the table in position during parking. A span lock was never part of the original design of the turntable machinery systems, but ORHF deemed it desirable to have a lock to be able to secure the table in place when aligned with a particular track for extended periods of time, especially considering there would be no brake in the system. An engineering review of several different styles of turntable locks was provided for proof of concept. It was also noted that the inclusion of a lock was more in line with the current AREMA design standard. Lock system details are in development at this writing, but the concept is expected to be similar to a lock plate spanning between the approach track and table track, actuated by a manual lever arm. It is expected that the future controls for the table will incorporate a safety limit switch to disable the turning machinery when the lock is driven.

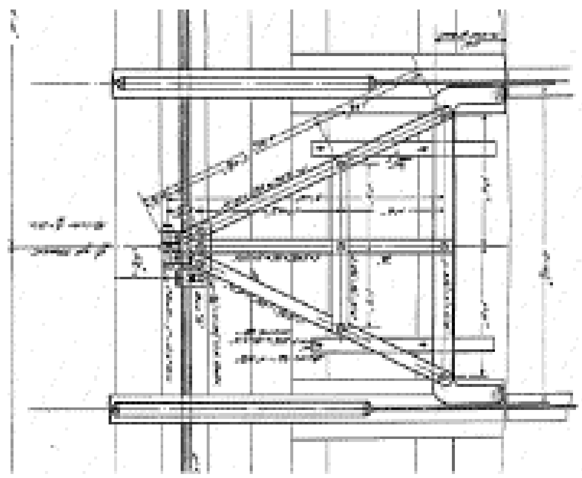

Figure 14: Example of the type of span lock bar desired on the turntable.

Construction

Center Bearing Adapter Plate - Shop Fabrication

After the LiDAR scan was performed, the 3D model was developed by HDR and the step file was produced, the file was sent to EEI for fabrication. Using scanning technology assisted with the field verification process, identifying existing rivets and holes in the structure that were used to eliminate the need of drilling additional holes in the main cross girder. It also captured the contours of the deformed center girder flanges. The scan revealed six existing rivet locations where the plate would be secured to the bottom flange to maintain plate position during installation.

The surface of the adapter plate that would contact the center bearing saddle was milled flat, flipped, and stitched in a 3 axis CNC mill on the top surface to match the bottom flange of the center cross girder. This would provide a surface that would maximize plate contact between the saddle and the main cross girder. Countersunk holes were drilled thru the shim plate at these locations to enable re-use of the hole locations and reduce extra holes being drilled in the field. The holes for the turned bolts that would secure the saddle to the main cross girder were drilled undersize to allow field drilling & reaming for turned bolts. Turned A325 bolts were fabricated as well.

Figure 15. Adapter plate - Post Machining

The existing saddle hole pattern was measured and confirmed. Two drill fixtures were designed and fabricated to lift the top saddle into place under the center cross girder and provide a means of accurately locating the new oversized holes for the four saddle bolts. Each drill fixture had a pair of lifting eyes and drill bushings.

New Powertrain

The new powertrain used a pair of 25HP motors with 3.5-1 gear reducers to use for running the turntable. The new motors and gearboxes were supplied by ORHF prior to designing the powertrain, so analysis and design centered around these components, and were a result of the various motor options reviewed in the design phase. The team generated conceptual design ideas for re-using as much of the original powertrain as possible while integrating the new motors and gear reducers with the old machinery.

The primary challenge was that the new arrangement could not be mounted in the same fashion as the original motor setup due to space and loading conditions. The old motors had pinions mounted directly to the motor output shaft, with bearings capable of handling the direct side loading from the open gear set. The new design needed to be compact and allow enough adjustment in the field to align with the existing drive gearing. It was determined that the new gearbox was incapable of handling the radial load from the pinion gear, so a shaft adapter combined with an outboard bearing was used. The shaft adapter diameter was larger than the acceptable bore size on the refurbished pinions, so a jack shaft was machined to fit the pinions and was driven by chain sprockets off the shaft adapter on the gear reducer. The original pinion bores were damaged, so the bore and keys were welded up and re-machined to shrink fit to the jack shaft.

Figure 16. New powertrain integrated with original open gearing and new fabricated drive truck frame.

The new powertrain was assembled to a fabricated steel base with machined mount points for bearings, gear reducer, and motor. The mount was designed for setting in place on the existing trucks as an assembled unit, aligning the pinion with the bull gear, and welding the base in place.

For maximum field adjustment, the jack shaft bearing mount points on the base were shim-able to allow for easy field adjustment.

The original drive and idler truck frames were in extremely poor condition, and ORHF commissioned fabrication of new trucks, as noted earlier in the paper. ORHF personnel refurbished the original bearings, idler/drive wheels at their facility and shop aligned and drilled the drive/idler wheels and bearings based on the original drawings. This included aligning the idler and drive wheels on each truck tangent to the theoretical radius of the radius track. This was completed prior to installation. ORHF personnel also fabricated new bearing studs and castle nuts for all the bearings. Aside from the fabrication of the replacement truck frames, all of this work was completed in-house at the ORHF. The refurbished components were shown as exhibits in the Center prior to installation.

Center Bearing Adapter Plate & Saddle Installation

The adapter plate and saddle installations were performed while the turntable was still supported by temporary trucks on a siding adjacent to the turntable pit. With telehandler support, the adapter plate was positioned underneath the center cross girder, supported by the lifting/drill jigs. The contoured surface of the adapter plate was covered in a thin layer of anti-seize, to act as a blue-fitting agent to determine rough percentage of contact with the bottom flange of the center girder. The plate was then lifted into contact with the bottom of the bottom flange, the undersize bolts and countersunk bolts tightened snugly. The bolts were un-fastened and the plate lowered down to view the contact area. Several iterations of hand grinding were necessary to maximize contact between the surfaces and meet the goal of over 50% contact roughly even across the plate surface. Once the contact was achieved and the surface cleaned, the mating surface was covered in titanium putty to help seal the perimeter and around the bolt holes to prevent water ingress between the plates. The plate was raised into position and the six countersunk bolts were torqued to spec.

The saddle was lifted into position with the drill jigs and the holes aligned using pins and undersize bolts. Once the drill jigs were aligned, the holes were drilled using a mag drill setup and undersized drills. The holes were then reamed with ascending sizes of shell reamers to achieve the finished fit and diameter. The holes were drilled, reamed, and bolts installed one at a time to ensure the saddle remained in place throughout the process. The turned bolts were tightened snugly, but not torqued to final spec to allow removal for shimming as necessary once the turntable was set in the pit.

The adapter plate provided a means of re-using the existing structural members without removal of deformed components. In bridges and turntables, deformed members in similar condition would likely require replacement to mate with other components. In this case, the deformed flanges were not compromising the structure significantly, and the adapter plate allowed the load from the saddle to be more evenly distributed across the bottom surface of the main cross girder.

Figure 17. Adapter plate installed with temporary bolts. Note flange deformation and adapter plate contour.

ORHF personnel refurbished the entire original center bearing in house, using it as a hands-on exhibit to engage visitors of all ages prior to installation.

Turntable Bridge & Truck Installation in Pit

The center bearing was swung into the pit via crane, centered in position, and aligned with the center of the bearing base with a survey mark installed in the concrete. It was secured in place with epoxy anchors and grouted in place.

The drive and idler trucks were staged on opposite ends of the pit. The interior wheels on each of the trucks were match marked and removed. The idler and drive trucks were rigged and set into the pit, roughly centering the truck wheels on the radius track and spacing the outer truck wheels with enough clearance between them to allow the table to be lowered in position without hitting the wheels.

Figure 18. Turntable set on slide gear and maneuvered into place by hydraulic rams.

Cribbing for slide gear was placed in the pit. The turntable bridge was towed onto a siding alongside the Center for removal from trucks. A self-propelled transporter was used to maneuver between the trucks that supported the table on both ends. The transporter jacked up the table and moved it off the tracks and centered the table tangent to the pit, with the ends of the turntable aligned to fit between the concrete pit walls on both ends. Slide gear was setup in sections underneath the turntable and transporter, aligning with the cribbing in the pit. Sleds were positioned under the turntable on the slide gear. Hydraulic rams were used to push the table uniformly along the slide gear into the pit until it was centered over the trucks. The turntable was lifted off the slide gear with hydraulic jacks and the slide gear was removed from underneath. The cribbing was removed in stages, slowly lowering the bridge into position between the idler and drive trucks. Special attention was given to ensure the center bearing saddle was aligning well with the base. Due to the tight clearance in the new concrete pit, the end floor beam flanges were trimmed to enable the turntable to drop the rest of the way down onto the center bearing and truck assemblies with minimal clearance.

Truck Alignment and Installation

Figure 19. Aligned idler wheel set after turned stud installation.

With the turntable fully supported on center bearing and with dunnage on both ends, work began on truck alignment. No wood ties were on the ends of the bridge at this time. Hydraulic 100-ton jacks were used under all 4 corners of turntable to level the ends with the center of table using a laser transit. The corner heights were secured by cribbing in place and shimming on all 4 corners. The top of the turntable was checked for level at multiple locations along the length. The pit track height and radius were also measured, and the track was noted to be approx. ¾” out-of-round.

Drive trucks and idler trucks were cribbed and shimmed roughly in position. The bottom flanges of the bridge girders were marked and notched in place where the flange would interfere with the wheels. The trucks were centered and leveled under the girders with crane support. Idler wheels were flown in from above and installed on both ends of the table. The trucks were aligned under the girders with the wheels equidistant from the girder on both sides. All idler bearing studs were tightened, and bearings secured in place. The original wheel assemblies allowed nearly 3/8” movement of the wheel axially between the bearings, and the trucks and wheels were aligned tangent to the existing radius track, evenly spaced between the bearings. The truck and wheel assemblies were jacked horizontally as necessary to align wheels tangent to track.

The drive and idler trucks were leveled, and the shim pack thickness between the bottom of the girder flange and the truck was measured under each corner. The shim thickness plus a 1/8” thick shim was installed on each corner to ensure enough load was taken by the drive trucks to provide adequate traction to rotate the table.

The truck mounting stud locations were determined based on the framework of the trucks and were drilled and reamed for minimal clearance using mag drills. ORHF personnel fabricated the truck frame studs in house. The studs were slip fit with minimal clearance to ensure trucks did not tend to shift under load. With the trucks secured, the center bearing saddle bolts were loosened and the saddle was allowed to drop approx. 1/16” onto the lower bearing, the saddle was shimmed in place to take up the gap, and the turned bolts torqued to spec.

Temporary alignment struts were welded in place to maintain alignment while the permanent struts were fabricated. Field fitting of the alignment struts was consistent with the approach that was suggested in the original turntable plans.

New Drive Powertrain Installation:

With the idler and drive trucks secured and aligned to the radius track, the new drive assemblies were installed. Each individual assembly had been shop fabricated, machined, assembled, and aligned as a unit, so the only alignment to complete in the field was correctly meshing the pinion with the bull gear on each end of the turntable. The assemblies were rigged and lowered into position onto the refurbished drive trucks. The ends of the turntable were jacked up using 100- ton jacks, to allow minimal clearance between the radius track and the drive wheels to enable the drive wheel to spin by hand to test the gear mesh. Come-alongs, jacking screws, and clamps were used to align the gears, along with shims between the base and truck frame. Once visually aligned, the pinion was blue-fit and the bull gear rotated to determine the wear pattern. Since the gears were refurbished and still had some uneven wear, the pattern across the face was not completely uniform, but the best possible contact was achieved toward the center of the bull gear face. With initial alignment complete, dial indicators were positioned on the base to detect movement of the base during welding. The base was welded out, alternating positions around the base to minimize heat distortion. After welding, the jack shafts required minor shimming to accommodate some minor heat

Figure 20. Welding the new machinery bases to the drive truck frames after gear alignment.

distortion that affected the gear mesh. The chain drive between the gearbox and jack shaft was installed, including the chain tensioner. The same procedure was completed on the opposite end of the turntable.

New Electrical Collector/Slip Ring Installation:

Following the drive assembly installation, the team installed a new slip ring, complete with a new guy wire support mounted to the collector tree at the center of the turntable. The slip ring assembly with guy wire support was a modern replacement for the existing slip ring assembly, as a result of the evaluation of the existing not being able to be reused earlier in the design work.

Commissioning and Testing:

Initial drive testing was performed after the new powertrain was installed. With the turntable in an unloaded state, the motors were temporarily wired up to the Variable Frequency Drive (VFD) and started with a very low frequency of 6 Hz. The bridge moved very smoothly under power. When testing under load with a locomotive favoring one end of the turntable, some popping noises were evident during operation. The team theorizes that since the original radius track that was installed in the pit was up to ¾" out of round, this might cause the idler and drive wheels to shift hard up against the bearings on one side, using up all the clearance between the bearings and forcing the loaded wheels to "pop" as it adjusts to the non-circular rail. For the intended frequency of use for the turntable, this does not appear to be an operational issue currently.

Conclusion

Although the turntable project was a departure from the norm in terms of how the project progressed in the refurbishment of the turntable, many of the aspects of the project mirrored what is practiced day to day in the heavy movable structures industry. The project progressed more like the restoration of a classic car rather than the short-operational-outage, staged-construction project that is pervasive throughout the industry. Despite that approach, it still allowed for innovation in technology such as 3D scanning and milling to solve deterioration problems which are as old as the table structure itself. Construction practices such as the alignment of open gears, dealing with the fit-up with structural and mechanical tolerances, and dialing in the operation of the table are the same as would have been encountered with the original installation. In any case, there was ample opportunity for the project team to garner illuminating experience in the course of progressing through a successful project. The following are a few lessons learned from the project:

- Sometimes functional requirements override the need to restore all details of the table back to original equipment. Modern design practices, like NEC requirements, have evolved since the original installation of the table.
- A mix of used and new components mean that the continued operation of the table will require some additional rehabilitation work. For example, the existing pit rails do not maintain a true radius in some locations so replacement in the future is expected.
- The ability of the ORHF to self-perform work such as cleaning and refurbishment of the existing drive machinery and center bearing, as well as fabricating replacement for original parts was extremely helpful in always having a shop on site.

- The elimination of some original features on the table such as the brake and drum controller for the motor meant that modern drives and a new table lock would be employed to address safe operation.
- The operation of the turntable will need to be simplified for volunteer use but will still need to maintain the functionality of a fully designed freight railroad turntable. Further controls upgrades are expected to include an industrial control panel, operating status indicator lights, limit switches and fault indication.
- The job is not over when the turntable is finally installed and operational. ORHF will be looking to formalize a maintenance and operation manual for the system as well as be compliant with FRA inspection schedule for the structure.