Issued: June 2, 2022 Railroad Investigation Report: RIR-22/09

Union Pacific Railroad Derailment with Bridge Strike and Fire

Tempe, Arizona
July 29, 2020

1. Factual Information

1.1 Accident Description

On July 29, 2020, about 6:06 a.m. local time, a northbound Union Pacific Railroad (UP) freight train, MTUPX-29, derailed 12 railcars at the south end of the railroad bridge over Tempe Town Lake on UP's Phoenix Subdivision in Tempe, Arizona.[1] At the time of the derailment, train MTUPX-29 was a mixed freight train consisting of 3 locomotives and 97 railcars. One of the derailed railcars struck the bridge structure, and part of the bridge collapsed, dropping railcars and bridge structure onto Rio Salado Parkway below and temporarily shutting down the road. Five of the derailed railcars were DOT-111 tank cars carrying various hazardous materials.[2] Two of these tank cars, both carrying UN1915 cyclohexanone, a flammable hazardous material, fell from the bridge during the derailment; the rest remained in-line with the track.[3] One of the fallen DOT-111 tank cars

[1] (a) Visit ntsb.gov to find additional information in the public docket for this NTSB investigation (case number RRD20LR005). Use the CAROL Query to search safety recommendations and investigations. (b) All times in this report are local time unless otherwise noted. Because Arizona is one of two states that did not go on daylight saving time during the summer of the derailment, local time in Tempe aligns with Pacific Daylight Time. (c) The UP Timetable for the Phoenix Subdivision lists train movement as either eastward or westward, but for clarity, this report will use geographic direction for train movement and track references. Thus, as the train was traversing the Tempe Town Lake Bridge, this report describes it as traveling north.

[2] The rest of the 12 derailed railcars were mixed freight.

[3] Cyclohexanone is classified as a Class 3 flammable liquid, packing group III. The safety data sheet listed cyclohexanone by its trademark name Nadone® and described the material as a clear, colorless liquid with a "mint-like acetone-like" odor.

released about 2,200 gallons of cyclohexanone, creating a pool of hazardous material below the damaged bridge. The cyclohexanone did not ignite, and no other tank cars were breached. Derailed lumber cars, which remained on the bridge, caught fire during the derailment. Some lumber fell onto and near the road, where it burned for several hours. (See figure 1.) There were no fatalities; one firefighter was treated for smoke inhalation at the scene. UP estimated the damage costs to be about $485,000 for railroad equipment, $435,000 for track and structures, and $10 million for the bridge. On the morning of the derailment, the sky was clear, and the temperature was 90°F with north-by-northwest winds at 5–8 mph.

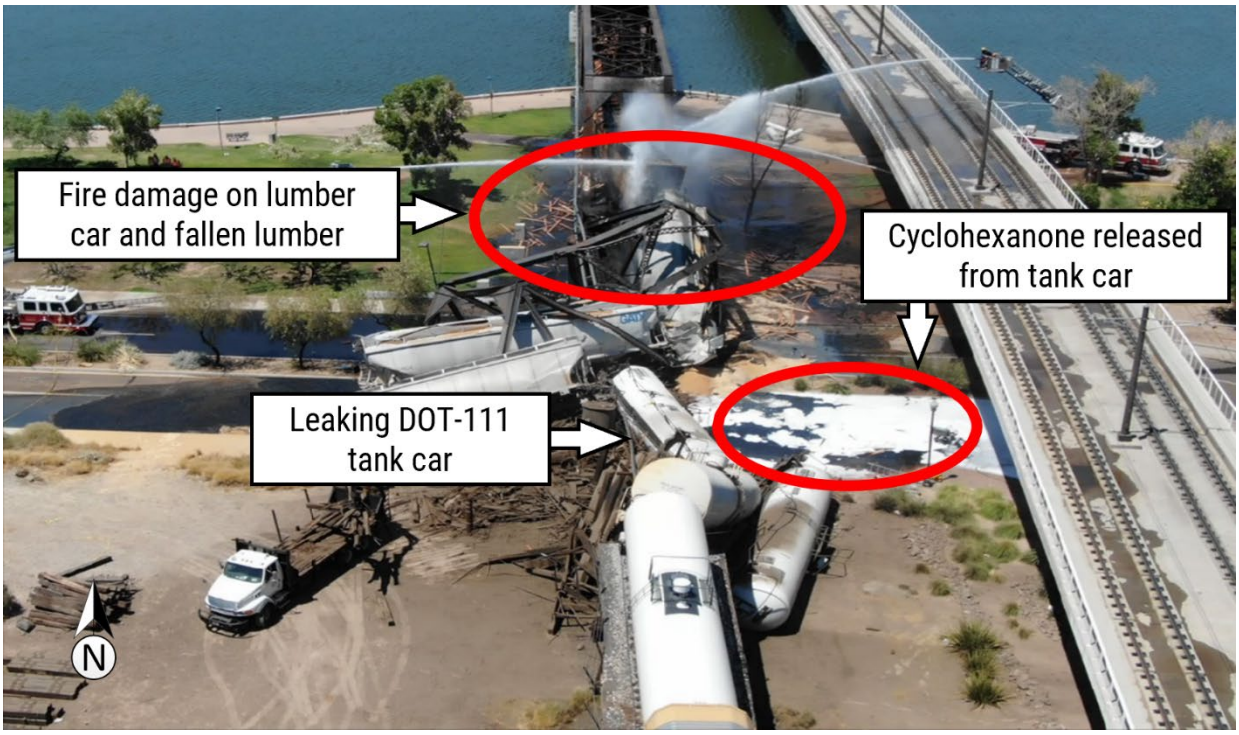

Figure 1. Aerial view of the derailment scene. (Photo courtesy of Union Pacific Railroad.)

On July 28, 2020, a UP crew (comprising an engineer, a conductor, and a brakeman) assumed control of train MTUPX-29 at the Tucson Yard in Tucson, Arizona, for an overnight trip to Phoenix, Arizona. National Transportation Safety Board (NTSB) investigators interviewed all three crew members. According to these interviews, train MTUPX-29 approached Tempe Town Lake Bridge the next morning from the south.[4] As the train approached the bridge, it began slowing from about 40 mph to about 23 mph

[4] The Tempe Town Lake bridge was a steel span bridge crossing over Rio Salado Parkway and Tempe Town Lake. The southern approach included a wooden trestle with a ballast deck. The bridge supported a single main line track.

in compliance with a permanent 25-mph speed restriction that began at milepost 915.8.[5] The train maintained a speed under 25 mph over the wooden trestle approach and onto the bridge itself. The head end of the train crossed the bridge without the crew noticing anything unusual. Event recorder data showed that shortly afterward, at 6:06 a.m., the train sustained an automatic emergency braking, slowing to a stop from a speed of 23 mph.[6]

NTSB investigators reviewed surveillance camera images from a southbound Valley Metro train crossing an adjacent bridge at the time of the derailment. These images showed a spark burst from an MTUPX-29 railcar striking a critical member of the bridge's first steel span on its east side.[7] After the initial strike, the top chord of the bridge buckled and the steel span collapsed. The failure spread up-track from the initial failure point, collapsing part of the wooden trestle. Subsequent images of the south end of the bridge showed derailed railcars colliding with each other and falling into the void opened by the bridge collapse. A single tank car, GATX 90208, began leaking cyclohexanone.

After the train stopped, the brakeman began to walk back along its length to identify the cause of the emergency braking. He saw smoke and burning lumber cars near the south end of the bridge. UP dispatch radioed the crew and told them that the Tempe Fire Medical Rescue Department was aware of the derailment and fire.

A witness near the scene called 911 at 6:07 a.m., and the Tempe Police Department began establishing a perimeter by 6:11 a.m. Subsequent emergency response also included the Tempe Fire Medical Rescue Department. Emergency response efforts focused on suppressing the fire, which involved parts of the bridge structure and the lumber spilled from derailed railcars, and on containing the spilled cyclohexanone, which did not ignite.

1.2 Before the Accident

[5] UP's 25-mph speed restriction includes both a curved section of Class 3 track (subject to a Federal Railroad Administration (FRA) limit of 40 mph) and the Class 2 track within the bridge limits (subject to an FRA limit of 25 mph). See Title 49 *Code of Federal Regulations* Part 213.9.

[6] A train can sustain automatic emergency braking when one of the air hoses that connects the air brakes on each individual car becomes disconnected. Train air brakes are designed to activate and apply maximum braking force on all railcars whenever railcars come uncoupled—in this case, during a derailment that split the train near its midpoint.

[7] A *critical member* is a tensioned part of a bridge whose failure is likely to cause part or all of the bridge to collapse.

The UP train crew reported for duty about 9:05 p.m. on July 28, 2020, at the Tucson Yard in Tucson, Arizona. They assembled MTUPX-29 and left the yard, bound for Phoenix, Arizona, with 3 locomotives and 102 railcars. After a brief stop in Magma, Arizona, the crew dropped off six railcars and picked up one in Randolph, Arizona. The train had 97 mixed freight railcars at the time of the derailment.

The NTSB's review of UP's records found that all derailed hazardous materials tank cars passed their pre-trip inspections.

1.3 Equipment Inspections and Rail Reconstruction

Railcars 49–60 (counting backward from the head of the train) derailed. While inspecting the derailed railcars, investigators discovered that railcars 48 and 49 had marks on their wheels consistent with having traversed a broken or damaged rail head.[8] (See figure 2.) Railcar 48 had a mark on the trailing axle and railcar 49 had marks on the leading two axles; the marks were on three consecutive axles across two railcars. The marks were all on the east wheels. Investigators found no other marks of this kind on the train's other wheels.

In reconstructing the damaged rails, investigators found rail-end batter on a rail segment from the eastern rail about 30 feet south of the first steel span, where the track was supported by a ballast deck over a wooden trestle.[9] (See figure 3.) The segment exhibited departing-end batter, and no other recovered segments exhibited rail batter of any kind. The NTSB's metallurgical analysis of the rail segment found no signs of rail fatigue or defects, but examination of the fracture face revealed a chevron pattern (shown in white in the figure) and micro features (marked with yellow arrows) consistent with overstress.[10]

[8] Railcar 48 was a loaded hopper car (TILX 518747), and railcar 49 was loaded tank car (NATX 160112).

[9] *Rail-end batter* is damage sustained when a wheel passes over a broken rail. The ends of the rail are referred to as the *departing end*, which is located on the up-track side of the break, and the *receiving end*, which is on the down-track side of the break. *Departing-end batter* is deformation at the vertical face of the rail end, and can occur when a misalignment or gap between the two rail ends allows the wheel to drop below the surface of the delivering rail. *Receiving-end batter* is corresponding deformation where the wheel strikes the receiving end.

[10] A *chevron pattern*, also known as a river pattern, is a pattern of marks that look like nested letters "V" or herringbone. A chevron pattern forms as a crack propagates from the origin of a fracture.

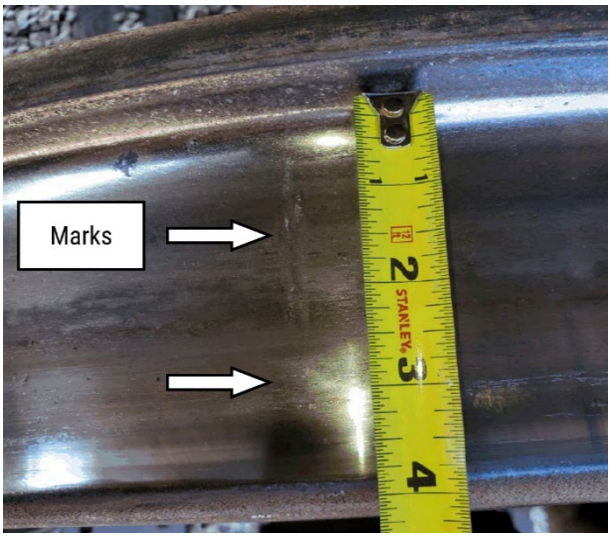

Figure 2. Marks from railcar 49. (Photo courtesy of the Federal Railroad Administration.)

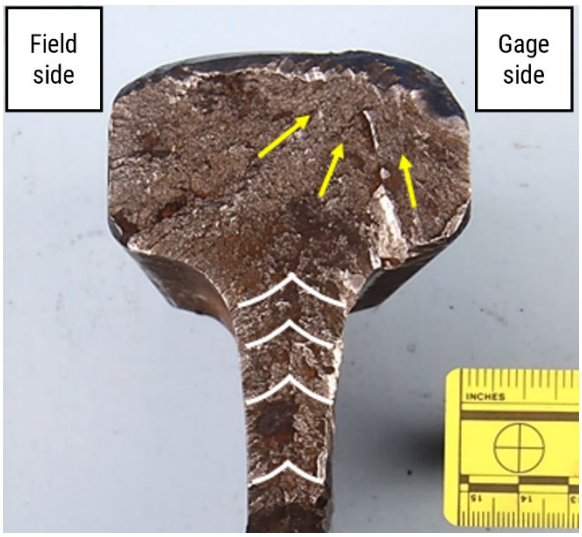

Figure 3. The facture face of a recovered rail segment.

NTSB investigators reviewed UP's track inspection records from the 2 months before the derailment and found that UP conducted its last inspection of the track near the derailment site on July 27, 2020.[11] (See section 1.4.1 for more information on the Federal Railroad Administration's regulations on track inspection.) UP's inspection identified no track defects near the derailment site. Investigators also examined images of the track and bridge captured by MTUPX-29's front-facing locomotive camera shortly before the derailment; no anomalies were apparent in these images. The images did show that the inner guard rail (IGR) on the Tempe Town Lake Bridge included a flare portion only north of the steel structure, not south of it.[12] With this IGR configuration, southbound trains derailing immediately before the steel spans would encounter an IGR, but northbound trains would not. Based on a review of UP's maintenance and inspection records, the south-end IGR flare portion had been removed for previous bridge work and not been replaced by the time of the derailment.

Investigators' examination of tank car GATX 90208 identified a damaged manway cover as the source of the leak; one of the six bolts designed to maintain pressure on the manway gasket had been sheared away, weakening the seal. Based on images from the Metro Valley surveillance cameras and the final disposition of the tank, GATX 90208 fell

[11] These inspections were conducted in accordance with FRA requirements under Title 49 *Code of Federal Regulations* 213.

[12] (a) An *inner guard rail* is a structure installed within the track gage meant to keep derailed equipment from moving laterally. (b) The *flare portion* of an inner guard rail is a tapered pair of in-gage rails that come to a point.

about 20 feet and first struck the ground with its B-end (the leading end), coming to rest on its left side. The missing bolt was on the left (ground-facing) side of the manway cover. GATX 90208 itself met the design specifications for a DOT-111 tank car. (See section 1.4.3 for details on the DOT-111 specification.)

1.4 Policies and Regulations

1.4.1 Track Inspection

Under Federal Railroad Administration requirements in Title 49 *Code of Federal Regulations* Part 213.233 Subpart F, railroads must visually inspect Class 2 track at least once each week and Class 3 track at least twice each week. UP inspected its main line tracks twice each week, including the track near the derailment site.

1.4.2 Union Pacific Inner Guard Rail Standards

UP engineering standards prescribe IGRs for several types of bridges, including through-truss bridges.[13] The Tempe Town Lake Bridge was a through-truss design. Diagrams accompanying the engineering standards show that an IGR flare portion should extend at least 50 feet beyond the bridge structure the IGR is meant to protect.

1.4.3 DOT-111 Tank Car Specification

Under Title 49 *Code of Federal Regulations* Part 179, a DOT-111 railcar is a non-pressurized tank car now being phased out in favor of the more robust DOT-117 standard; the three DOT-111 tank cars discussed in this report were scheduled for retirement in 2029. A DOT-111 has a thinner shell than the new DOT-117 standard, and it is not required to have head shields to protect the tank car's integrity during contact with adjacent railcars. The fittings and valves are not protected against being sheared off in a collision or other kinetic event. These tank cars are not fully jacketed with insulation and do not have a pressure relief device sized to protect against rupture in the event of a large fire.

1.5 Postaccident Actions

When UP rebuilt the Tempe Town Lake Bridge, it included IGR flare portions extending at least 50 feet north and south of the structures that require protection. The

[13] Union Pacific Railroad, "Double Inside Guard Rail for Open Deck Bridges," *Union Pacific Engineering Standards*, Revised September 29, 2009.

new IGR configuration aligns with UP's engineering standards as discussed above. These flare portions are designed to keep derailed equipment in-line with the track, preventing contact with critical members even when a derailment occurs south or north of the steel spans themselves.

2. Analysis

Train MTUPX-29 was operating on a single main track at 23 mph while crossing the Tempe Town Bridge when 12 of its 97 railcars derailed. One of the derailed railcars struck the bridge structure, causing part of the bridge to collapse, temporarily shutting down Rio Salado Parkway. Derailed lumber railcars spilled lumber, feeding a fire on and below the bridge. One tank car released about 2,200 gallons of cyclohexanone, which did not ignite, creating a pool below the damaged bridge.

2.1 Hazardous Materials

Five DOT-111 tank cars carrying hazardous material derailed. Two, both carrying cyclohexanone, fell into the void opened by the bridge collapse. One of these fallen tank cars, GATX 90208, released cyclohexanone from a damaged manway cover. GATX 90208 passed its pre-trip inspections and was within legal specifications; it failed only after being subjected to a highly unusual derailment scenario: a fall of about 20 feet that sheared a bolt upon contact with the ground. The DOT-111 specification is currently being phased out in favor of the more robust DOT-117.

2.2 Point of Derailment

The first physical evidence of abnormal operation is a mark on the rearmost east-side wheel of railcar 48, which indicates that it traversed a broken rail end. The lack of marks on wheels up-train of railcar 48 indicates that the first 47 cars traversed the rails normally, without encountering any rail breaks.

Marks on the first two east-side wheels of railcar 49 show that they too rolled over the broken rail end. Subsequent wheels did not exhibit similar marks, indicating that the train had derailed far enough that wheels were no longer traversing the broken rail end.

Rail reconstruction identified a single segment of rail, about 30 feet from the bridge's first steel span, that showed rail-end batter, a type of damage inflicted by wheels traversing a broken rail end. Given the wheel marks and the single rail segment exhibiting rail-end batter, physical evidence places the initial point of derailment at this broken rail. Forty-seven railcars traversed the rail normally before it broke under the 48th. The final two east-side wheels of railcar 49 (and all the wheels of 11 subsequent cars) derailed far enough that they were no longer traversing the broken rail end, as shown by their lack of marks.

2.3 Rail Breakage

Metallurgical analysis of the rail near the derailment point did not identify any signs of fatigue or flaws. The fracture pattern is consistent with overstress, suggesting that the rail broke due to forces applied immediately before the derailment.

2.4 Bridge Strike and Collapse

A review of surveillance images showed that, during the derailment, railcars moved laterally (east) until one struck the first steel span. The strike compromised a critical member, leading to the bridge's partial collapse. Although the track over the steel spans featured an IGR, the track over the trestle portion of the bridge did not. The derailment occurred on this unprotected stretch of track just south of the steel structure. As a result, derailed railcars were able to move laterally until they encountered the bridge itself.

After rebuilding the bridge, Union Pacific installed a flare portion of IGR at both ends of bridge in accordance with their engineering standards to mitigate derailments by keeping derailed equipment in-line with the track. If kept in-line, equipment is less likely to strike the bridge structure and cause damage or a collapse.

3. Probable Cause

The National Transportation Safety Board determines that the probable cause of the Union Pacific Railroad freight train derailment and subsequent bridge collapse on July 29, 2020, was a broken rail located on the ballast deck portion of the wooden trestle approach about 30 feet from the steel bridge. Contributing to the severity of the derailment was the absence of an inner guard rail preceding the steel bridge structure, which allowed the derailed equipment to move laterally into the bridge structure and cause its collapse.

The National Transportation Safety Board (NTSB) is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, and pipeline safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974, to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties … and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)).

For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID RRD20LR005. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting–

National Transportation Safety Board

Records Management Division, CIO-40

490 L'Enfant Plaza, SW

Washington, DC 20594

(800) 877-6799 or (202) 314-6551