Train Derailment at a Broken Switch Rail

Two train rail elements at a switch location broke as part of a locomotive derailment. Preexisting cracks present in the elements most likely had developed as a result of wear in the switch system. The cracks were not the principal reason for the system failure, but they did define a plane of weakness. No other material defects were noted. The steel elements were severely deformed, but the final breaks included some brittle character, most likely a result of a high rate of loading during the incident. The rolling wheels were already outside of the constraints provided by the wheel flange and track configuration in order to cause the twisting and rolling deformation of the leading ends of the thin switch rails, which then led to breaking and separation of the pieces. Nondestructive examination was performed on an additional 199 switch rails. Cracks and/or linear indications were found on 27 switch points or switch point protectors. The flawed or damaged rails were removed, and spare rails that had passed the examination were substituted.

Background

In the summer of 2002, a locomotive that was shoving a flat car derailed the tracks at a switch in a storage yard at the Savannah River Site (Fig. 1). Pieces of rail from the switch point and the switch point protector were broken and recovered at the site. These pieces are elements of the switch rail and are designed to smooth the transition to the connecting rail (Fig. 2). Materials consultants participated in the investigation to determine whether material defects in the rails could have contributed to the event. The flat car did not derail, no damage occurred to the flat car, and no equipment, other than the locomotive, was compromised.

Field Observations

Two elements of railroad track that had broken from the switch point at the derailment location were examined metallurgically to determine the role of material defects in the failure process. The rail pieces were from the top leading edges of the switch point and the switch point protector (Fig. 2). These pieces are designed to guide or lead the wheels onto the second track during the switching process. Both pieces exhibited extensive deformation, thus the mating surfaces of the broken rails did not fit together well after the failure. The fracture surfaces showed severe tearing, evidence of brittle separation, and evidence of prior cracking. The pieces were examined optically and in the scanning electron microscope (SEM).

The entire switch point protector element was twisted (rotated) and bent down, probably as a result of the incident. It appeared that the switch point rail was struck first by a wheel, and then that wheel and others rolled up and over the element to cause the twist. At the time of initial contact with the wheel, the point protector rail probably
was displaced and not touching the main rail. This displacement allowed the protector rail to be loaded in this manner.

The tracks at the location showed substantial disturbance for 15 m (~50 ft) in the vicinity of the derailment. The majority of this disturbance could be related to rolling of the locomotive across the wooden ties after the derailment. The deformation of the steel tie bars joining the switch rails prevented determination of the extent of wear, clearance dimensions, gap sizes, and the extent of misalignment or misfit. All of these are typical of service-induced changes in the rail system and probably existed at the transition point on the track immediately prior to the incident. The rail system is approximately 50 years old, and some wear and relaxed clearances might be expected, although adjustments are made as a part of regular maintenance. Track gage was reported as satisfactory—56 ⅞ ± ¼ in.—shortly before and immediately after the incident.

The main rail showed considerable wear at the switch site. The crown formation on the rail was flattened for 20 cm (~8 in.) precisely at the transition location. This crown flattening could affect the rolling transition at the switch point.

Excess metal associated with the crown formation usually overhangs and extends the length of new rails. The overhang tends to wear away on the inside of the track due to rubbing of the wheel flange. In this instance, it was essentially missing for approximately 60 cm (~2 ft) at the approach to the switch. This may have affected the approach to, and the smoothness of, the transition at the switch. The wheel flange design minimizes the possibility of striking the point rail head-on and maximizes a smooth transition in the change of direction during rolling. However, the vertical ends of the point rail and the point protector rail both had head-on damage, possibly associated with direct hits by the train wheels.

The age of the track system suggests that tightness or tolerances may have suffered. However, an analysis of the system in January 2002 had suggested a low probability for derailment. (The results of the analysis summarized here suggest that the earlier analysis did not consider wear and deterioration of switching points.) It is significant that the track gage did not change with the incident, and no relative displacement of the fixed rails occurred.

Laboratory Observations

It was suspected that pre-existing cracks probably contributed to the failure. The cracks were marked by the presence of graphite in the crevices and on the fractured surface. Graphite lubricant becomes coated on many track components over time. The newly fractured areas showed bright metal and/or slight rust.

The broken section of switch point rail (Fig. 3) was approximately 15 cm (6 in.) long. The prior crack was approximately 54 mm (2 ⅛ in.) along the fractured surface. This crack was also 6 mm (~¼ in.) deep,