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Assessment Methods for Freight Train Builds

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Key Findings:

- Class 1 railroads employ their own combination of tools to proactively assess a proposed train's expected safety performance depending on its characteristics and routing.
- Typical assessment methods include some combination of the following factors:
  - Train makeup and handling rules.
  - A review of relevant historical performance.
  - Knuckle strength.
  - Analysis and simulations.
  - Physical testing.
  - Other considerations such as siding length.
- Industry requirements regarding train builds are not practical given the myriad combinations of interacting variables possible in North American service.

As part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) program, Transportation Technology Center, Inc. (TTCI) is conducting a study of train build assessment methods. This study is a collaboration with North American Class 1 railroads, which have provided descriptions of their internal procedures. In summary, the Class 1 railroads have individually developed and currently utilize a variety of proactive evaluation methods to operate safely given various service constraints on a subdivision-by-subdivision basis. These variables include topography, track condition, train handling, power configuration, train makeup, car load status, car component selection and condition, adjacent car length, car blocking, and general weather conditions. Therefore, rather than draw conclusions from a limited analysis, this *Technology Digest* is intended to communicate the evaluation methods that railroads employ in order to assess the safety of their train builds.

BACKGROUND

When new train service designs are formed, or changes are made to an existing plan, each one is evaluated using some combination of train makeup and handling rules, a review of relevant historical performance, knuckle strength, simulations, physical tests, and other considerations. A railroad may use some or all of these methods depending on the characteristics of the train and its routing. Frequently, the assessment will continue after the new or modified service begins, and it will include a review of event recorders and any service disruptions (e.g., broken knuckles).

Historically, railroads have safeguarded train operations through train makeup and train handling rules. These rules may limit the size of trains, the placement of certain equipment within trains, the speed of trains, tractive and dynamic braking effort, power placement in trains, or some mix of all the above. These rules are often developed through some combination of

operating experience, train dynamics simulation, and field testing/observation. A simulation of train dynamics can quantify expected performance in terms of static and dynamic coupler forces and estimated lateral-to-vertical wheel force ratio (L/V) values—a key predictor of derailment. The rules may be system-wide or subdivision/segment-specific.

TRAIN MAKEUP AND HANDLING RULES

Each railroad has internal instructions for train makeup pertaining to the number of powered or dynamic braked axles, the train length, the train tonnage, the distribution of tonnage and empties within the train, placement of distributed power (DP), and the placement and quantity of cars with end-of-car cushioning (EOCC). The instructions issued by each railroad are similar in many respects, but may differ significantly in detail. Likewise, railroads also issue their own internal instructions for train handling with and without DP operations.

The distribution of power, tonnage, and particular car types within trains can be important for minimizing problems with slack action, as well as lateral forces resulting from coupler angularity combined with large coupler loads. Multiple railroads have detailed rules specifying that certain cars should not be placed near locomotives when contributing factors such as trailing tonnage and/or grade would be expected to result in large coupler forces.

Some railroads speed-restrict or size-restrict specific trains based on lading, car type, or other factors. Speed restrictions can reduce the severity of an accident should one occur; however, these restrictions do not necessarily reduce in-train forces.

REVIEW OF RELEVANT HISTORICAL PERFORMANCE

New or revised train blocking plans often share important characteristics with one or more trains already being operated over similar territory. The important train characteristics to be considered are the placement of loads relative to empties (tonnage profile) and the location of EOCC equipment relative to the blocks of tonnage.

If similar trains have operated successfully with tonnage on the head end and EOCCs on the rear, then a new blocking plan calling for more loads on the head end will not be a concern. However, if the plan is to pick up empty cars equipped with EOCC on the head end, the train may be subject to trailing tonnage restrictions or DP requirements.

Territory is important as grades, undulations, curvatures, and allowable speeds define the in-train forces that are likely to develop. Railroads know from past performance which train characteristics can be problematic in a given territory.

Data from past derailments and the analysis performed to determine the causes of these derailments supply railroads with additional information that can be taken into consideration when creating trains for a specific territory. Train makeup may or may not have been a contributing factor for any specific derailment.

KNUCKLE STRENGTH AND DISTRIBUTED POWER

An important criteria in evaluating train tonnage and power configuration is the capacity of the knuckles to withstand the pulling forces to which they will be exposed. Knuckles act as a mechanical fuse for the train with the intention that the knuckles will fail at lower loads than other draft system components and can be replaced relatively quickly on the line-of-road. Knuckles can fail in gross overload or as a result of fatigue loading.

With modern alternating current (AC) traction locomotive units capable of up to 200,000 pounds of starting tractive effort,[1] and Grade E knuckles rated at 400,000 pounds,[2] a locomotive consist that is compliant with a railroad's powered axle rules can damage a knuckle in a steady-state force condition. Dynamic in-train forces add to the stress environment. Distributed power is a common and effective solution to this condition because it distributes and reduces the peak coupler forces in the train; it also tends to reduce in-train dynamic forces by acting as a control node within the train.

Railroads have introduced a number of DP operating rules that both govern its safe use and modify conventional powering rules to take advantage of DP benefits. An

example of the former would be to prohibit lightweight cars within 10 cars of the DP units. An example of the latter would be an easing of trailing tonnage limits when operating with DP.

ANALYSIS AND SIMULATIONS

Train consist analysis and computer simulation tools allow railroads to evaluate trains on different levels. At minimum, a consist analysis is essentially an automated rulebook application that determines if a given train is in compliance with operating rules. If a proposed train falls outside the scope of existing rules, it can be evaluated using computer simulation tools. These tools account for parameters such as car geometry, weight, and track condition while generating expected performance in terms of parameters such as coupler forces, speed differences between cars in the train, fuel consumption, run time, and L/V values. The simulation results need to be interpreted to determine if the train can be deemed safe to operate under the proposed conditions.

The assessment approach can vary widely in design, scope, and application depending on the railroad and the situation. Many railroads use locomotive simulators to estimate the dynamic coupler forces and the effect of slack action on specific trains over specific routes. Restricted equipment trailing tonnage rules may then be adjusted regarding new train builds.

One railroad assigns each area of its territory to one of a handful of track categories based on grades, curvatures, and undulations. Then, rules regarding train makeup and handling are adjusted for each track category. These rules were developed and improved using a variety of means, including an analysis of wayside detector data and train dynamics simulation results. An electronic system then performs calculations for each mixed train to evaluate the expected coupler forces.

Another railroad is experimenting with the use of a matrix of hundreds of output runs from TTCI's Train Operation and Energy Simulator (TOES™). These simulations are comprised of various loads, empties, tonnage, and length characteristics operated over a range of grade profiles and speeds to form a lookup table of maximum buff and draft forces. An internally developed computer algorithm finds the best simulated-train match for the proposed train, and then reports the maximum expected coupler forces for the intended operation.

PHYSICAL TESTING

On-track testing provides an opportunity to supplement the information gathered from simulations. Instrumentation is placed at critical locations on the consist in order to measure accelerations and, on rare occasions, coupler forces. Consists used in standard revenue service can be instrumented to get baseline measurements without interrupting operations. Physical testing increases the accuracy of the modeling results and instills confidence in the steps being taken to mitigate risk in new consists. Railroads also use supervised pilot trains or test trains with transportation officers on board the locomotive as well as a review of event recorder data from new trains as additional forms of physical evaluation.

OTHER CONSIDERATIONS

There are some other factors that must be accounted for when evaluating train length, including:

- Track siding lengths.
- Air brake performance—this may be affected at colder ambient temperatures, so brake pipe lengths are shortened and/or additional sources of air are added.
- Reliable wireless communication range between head end power, DP units, and end-of-train device.

CONCLUSIONS

During the long history of railroading in North America, well-established processes have been developed to assess the safety of train builds. With the advent of computer simulations and the availability of digital route and train consist information, railroads have begun to characterize individual trains based on expected performance. By combining the information gained from simulation tools with more traditional rules-based means of assessing train service design, railroads are more fully capturing the benefits of the technologies that are currently available such as DP and onboard locomotive handing software, enabling a wider variety of train builds to operate safely.

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