

Spiral Negotiation Requirements For New And Untried Freight Cars - Evaluation Tests

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SUMMARY

A good deal of controversy has surrounded the selection of spiral geometry for the certification of new freight cars. The spiral design originally incorporated in Chapter XI was questioned in terms of both rate of superelevation increase and associated change in curvature. A series of tests were conducted on the spiral section currently defined by Chapter XI requirements in addition to an alternative spiral design.

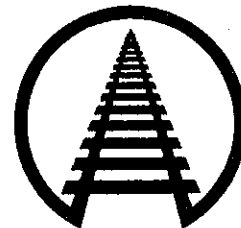
Test results showed that the existing spiral design, called the "bunched" spiral, and the alternative design, called the "limiting" spiral, both failed three (3) out of the four (4) car types. The car types failed in that they exceeded the allowable Chapter XI criteria limits for the measured wheel and axle forces.

Introduction of new designs of freight cars into general interchange service requires certification by the Association of American Railroads' Mechanical Division. Chapter XI, Service-Worthiness Tests and Analysis for New Freight Cars, of Standard M-1001 describes procedures to ensure that new and untried cars can operate without adverse dynamic behavior.

The tests were conducted under the direction of the Vehicle Track Systems' (VTS) Subcommittee on Mechanical/Track Standards. Four different car types were tested to evaluate the effect of the two spiral designs on car performance.

The results show that the "limiting" spiral is no worse as a test than the "bunched" spiral. This is based on the wheel forces measured during the tests. The three (3) cars which exceeded the criteria were equipped with typical 3-piece trucks and were a 70-ton 89 foot flatcar, a 100-ton covered hopper car and a 70 ton boxcar (RAILBOX). The car which successfully negotiated both spirals was an aluminum gondola equipped with premium trucks.

The results of these tests have been submitted to the Subcommittee which is reviewing alternative strategies toward providing practical yet representative spiral negotiation test procedures.



Association of American Railroads
Research and Test Department



INTRODUCTION AND CONCLUSIONS

Chapter XI of M-1001 of the Manual of Standards and Recommended Practices provides guidelines for testing and analysis to ascertain the interchange-service worthiness of new freight cars. One of the prescribed tests under the vehicle dynamics section is Spiral Negotiation. This test is designed to evaluate the performance of a vehicle in spirals with a rapid change in superelevation. The test track section for this test calls for a rate of change of superelevation of 1 inch in 20 feet, leading into a curve of *at least* 7 degrees and a minimum of 3 inches superelevation.

The test is presently conducted on the spiral to a 12 degree curve. Due to the rapid change in superelevation associated with this design, the test section is often called the "bunched" spiral. The spiral length is 200 feet, the first 50 of which has zero elevation change, the next 100 feet taking up the full superelevation of 5 inches. The change in curvature is taken up linearly from 0 to 200 feet, as in a standard spiral, into the 12 degree curve. Test speeds are 15 mph (3 inch underbalance), 25 mph (balance) and 32 mph (3 inch overbalance).

In 1990 the Car Construction Committee of the AAR Mechanical Division initiated a Task Force to review the "bunched" spiral test section and procedure. No clear reason for the selection of the 1 inch in 20 foot rate for Chapter XI was found. The review postulated that it may have resulted from committee discussions on the severity of spirals found in service. In view of the fact that the existing spiral may be too severe, as exhibited by the problems many car design types had while negotiating it, a less severe alternative was suggested. The alternative was to have a rate of change of 1 inch in 25 feet (FRA Class 3) of superelevation up to

5 inches leading to a 10 or 12 degree curve.

During the time of this review process the Engineering Division of the AAR showed a keen interest in the developments. The logical forum to accommodate the "track perspective" regarding the "bunched" spiral design was chosen to be the recently formed Subcommittee on Mechanical/Track Standards of the Vehicle Track Systems' Executive Committee.

The Subcommittee, in their review of the existing "bunched" spiral design, concluded that the portion of the spiral which had a zero change in superelevation for the first 50 feet, while the curvature starts to change, was highly unconventional and not representative of any spiral construction practice on revenue service trackage. At the same time they also concluded that the rate of change of superelevation of 1 inch in 20 feet was not the worst case encountered in revenue service, especially considering that FRA Class 2 standards allow a 1 inch in 17.7 foot rate of change.

Deliberations of the Subcommittee led to a consensus that an alternative spiral design be constructed over which several car types be tested. The objective of this task was to obtain test data from four different car types, while negotiating the "bunched" and "limiting" spirals, to help in the decision of defining an appropriate alternative test requirement under Chapter XI. The alternative, called the "limiting" spiral, was to be 88 feet in length at one end of a 10 degree curve. The rate of change of superelevation was 1 inch in 17.7 feet (FRA Class 2) up to 5 inches. Both the superelevation and curvature were to be changed linearly from 0 to 88 feet. Test speeds for the "limiting" spiral are 17 mph (3 inch underbalance), 27 mph (balanced) and 34 mph (3 inch overbalance).



**Exhibit 1. Aluminum Gondola Car in Test
Consist at TTC.**

Based on the conduct and results of these tests the following conclusions can be drawn regarding the spirals:

- *As an alternative spiral design the "limiting" spiral is definitely no worse. In fact in some cases it is marginally easier to negotiate than the "bunched" spiral.*
- *Although no more difficult to negotiate than the "bunched" spiral, the "limiting" spiral still presents a problem to three out of four car types tested.*
- *The car types which exceeded the Chapter XI criteria did so in both the "bunched" and "limiting" spirals.*

SPIRAL NEGOTIATION TESTS

The car types tested were a 70-ton 89 foot flatcar, a 100-ton covered hopper, a 70-ton boxcar and a 100-ton aluminum gondola. These car types were chosen to provide a wide range of truck centers, torsional rigidity, and weight. Wheel/Rail forces measured by instrumented wheelsets were the primary source of test data used in analyzing test results. The existing criteria for unacceptable performance under Chapter XI for the wheel L/V ratio is a value of

1.0 measured for a period of 50 milliseconds or more. An additional criteria to be satisfied is an axle sum L/V ratio of 1.4 for a period of 50 milliseconds or more. A preliminary review of the data was conducted for the entry and exit test runs at the under- and overbalance speeds.

In order to reveal the worst case values measured during the tests, most of the data presented is from test runs conducted at the 3 inch underbalance speeds of 15 and 17 mph exiting the "bunched" and "limiting" spirals, respectively. Exhibit 2 is a table of maximum values of measured lateral over vertical wheel force ratio (L/V) from the tests for the 89 foot flatcar, covered hopper car and aluminum gondola.

Car Type	Maximum Wheel L/V Ratio	
	Bunched Spiral	Limiting Spiral
89 ft Flatcar	1.05*	1.15*
Covered Hopper Car	1.4*	1.15*
Aluminum Gondola	0.7	0.6
* 50 millisecond values		

Exhibit 2. Maximum Wheel L/V Ratios for "Bunched" and "Limiting" Spirals - Measured on High Rail During Exit of Curve.

The maximum values for 50 milliseconds in Exhibit 2 were calculated from continuous time history measurements of the wheel L/V ratio of the wheel on the high rail, between the point where the cars exited the curve (negotiated the spiral) and the point where they were back on tangent track. Exhibit 3 shows similar values of wheel L/V ratios, but also shows the effect of speed on the maximum values measured. These



are maximums and have not been corrected for 50 milliseconds, but judging from the high values, it is safe to assume that they will not meet the criteria.

Speed	Maximum Wheel L/V Ratio	
	Bunched	Limiting
3" Under-balance	1.8	1.7
Balance	1.7	1.50
3" Over-balance	1.45	1.3

Exhibit 3. Maximum Wheel L/V Ratios for 70-ton Boxcar - Measured on High Rail During Exit of Curve.

Although the axle sum L/V ratio (instantaneous sum of the absolute value of the left and right wheel L/V) data are not presented, it was found that in all cases when the wheel L/V exceeded the criteria so did the axle sum L/V.

As can be seen from the data presented, the only car to comply with the criteria is the aluminum gondola.

Point worthy of note is that the aluminum gondola, although being the lightest car, was the only car equipped with premium trucks as opposed to the others being equipped with typical three piece trucks.

The following trends were observed after analyzing the data from all four car types:

1. Exiting both the spirals generates higher wheel and axle sum L/V ratios along with minimum vertical wheel loads than when entering the spirals. The high L/V is associated with a decrease in vertical load rather than an increase in lateral load.
2. The measured wheel and axle sum L/V ratios for three out of the four car types exceeded the current Chapter XI criteria. The exception was the aluminum gondola with premium trucks. The highest values during the exit runs were measured at the wheel in the lead axle of the lead truck, on the high rail.
3. The measured wheel vertical loads, calculated as a percentage of their respective vertical static loads, did not exceed the current Chapter XI criteria of 10%.

Note: Contact F. D. Irani at (312) 808-5830 with questions or comments about this document.

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