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THE EFFECTIVENESS OF TANK CAR SAFETY VENT SURGE PRESSURE REDUCTION DEVICES

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Summary

There are significant differences in the performance of the various surge pressure reduction devices (SPRD) that are intended to prevent releases of hazardous materials from tank car safety vents. This conclusion is based on tests of the effectiveness of SPRDs in reducing pressure surges that can cause burst frangible discs, and of their effect on flow in an emergency pressure relief situation.

The leading cause of hazardous materials releases in rail transportation over the past five years has been burst frangible discs. These burst discs occur as a result of pressure surges in the safety vent during transportation. SPRDs are designed to protect the frangible disc from these surges. Prior to these tests there were no data to enable objective comparison of the effectiveness of SPRDs. The results of these tests will help tank car builders, owners, and operators improve their current equipment by installing cost-effective devices that will reduce non-accident-caused releases of hazardous materials and still function adequately to relieve pressure when necessary. The results will also provide a basis for setting SPRD performance and testing requirements and identify promising design elements for new SPRDs. These tests were conducted by the Association of American Railroads (AAR), with the support of the Chlorine Institute, the Federal Railroad Administration, and the Railway Progress Institute.

Suggested Distribution:

☐ Hazardous Materials
☐ Environmental
☐ Mechanical

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INTRODUCTION AND CONCLUSIONS

Burst frangible discs ("rupture discs") in tank car safety vents are among the leading causes of hazardous materials releases in rail transportation, accounting for 24 percent of such releases (1,379 of 5,863) during the past five years. Most disc failures are caused by momentary pressure surges in the safety vent nozzle that occur during transportation.

A variety of devices is available to attenuate these pressure surges. In a previous study it was found that tank cars equipped with surge pressure reduction devices (SPRD) had a significantly lower rate of release from the safety vent. This led the Association of American Railroads (AAR) Tank Car Committee to require SPRDs on new tank cars equipped with safety vents. However, the study did not permit evaluation of the effectiveness of different SPRD designs or their effects on flow rate. To address these questions, AAR, the Chlorine Institute, the Federal Railroad Administration and the Railway Progress Institute collaborated on two series of tests.

First, we conducted impact tests that measured each SPRD's effect on surge pressure in the tank car safety vent nozzle. A wide range of effects was found in both the average peak pressure and the maximum peak pressure observed. The tests were conducted on SPRDs designed for the three common safety vent nozzle diameters in use: 2 inch, 3 inch, and 6½ inch. The broadest range of effects was observed in the 6½-inch nozzle.

Second, we conducted tests that measured the effect of each SPRD on air flow through the nozzle. All of the devices reduced flow, but to varying degrees.

The Tank Car Committee is using the results of these tests to develop performance and testing requirements for SPRDs.

IMPACT TESTS

The impact tests were conducted at the ACF Industries laboratory in St. Charles, Missouri, to determine the effectiveness of each SPRD in attenuating surge pressures.

Test Car

The test car was a 100-ton, 20,884-gallon, DOT-111A100W1, general-service tank car loaded with water. The inside diameter of the safety vent nozzle used in the test was 6½ inches. To test SPRDs designed for the two smaller diameters, nozzle inserts with inside diameters of 2 inches or 3 inches were used.

The test car setup was designed to maximize surge pressures in the test nozzle while maintaining a controlled level of impact force. To ensure consistency in the test conditions, we controlled coupler force at approximately 1,000,000 pounds.[1] In order to obtain reliably high surge pressures in the safety vent nozzle, we used 0.5 percent outage and mounted the test nozzle about midway between the center of the car and the struck end.[2]

In place of a frangible disc, the safety vent on the test car was fitted with a steel disc equipped with a pressure transducer. This enabled us to obtain a continuous measurement of the pressure exerted at the location of the frangible disc and to compare the effects of the various SPRDs.

Test Procedure

In each test, the test car rolled down a ramp from a predetermined location and struck a standing car. We conducted these tests for 19 different SPRD setups. These included a control for each of the three nozzle diameters and each of the SPRD-nozzle combinations known to be in use. For each nozzle diameter, an experimental baseline, or control, was established by conducting 30 impacts with no SPRD in place. For each SPRD, at least 10 impacts were conducted. The sample size was selected using data on the variability in pressure surges obtained during earlier testing conducted using the same car at the ACF lab.

During each impact we recorded the pressure at the frangible disc location for several seconds following impact. Three representative time histories for the pressure in the 6½-inch nozzle are presented in Figure 1. The peak pressure at the frangible disc location was then identified as the highest pressure sustained for at least one millisecond.[3]

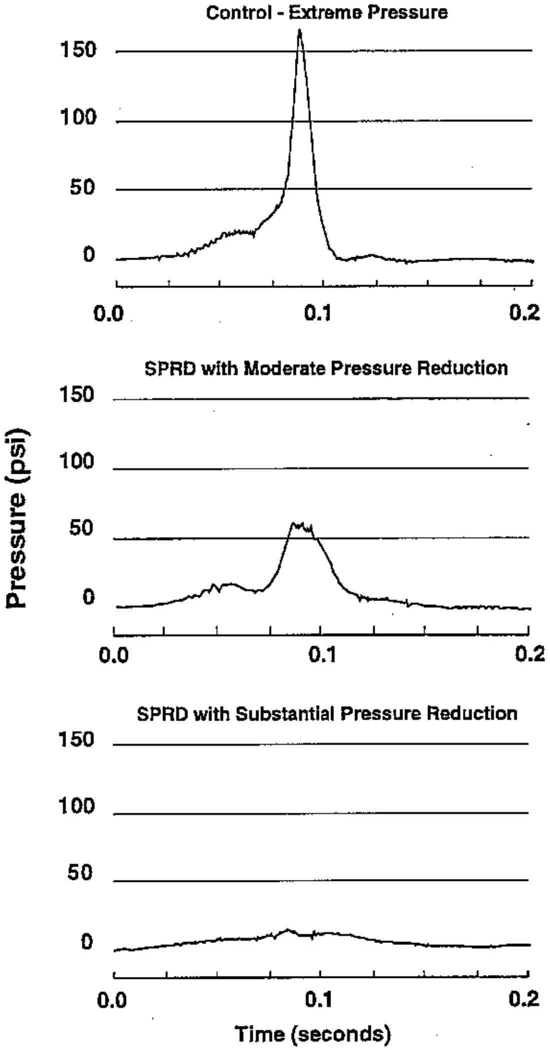

Figure 1. Representative time histories of the pressure in the 6½-inch safety vent nozzle under three different test conditions. (impact occurred at Time = 0.0)

Results

Figure 2 shows peak surge pressures for the 2-inch, 3-inch, and 6½-inch nozzles. The results for each nozzle diameter without an SPRD are in the left-hand column labeled 'CONTROL'. Each of the other columns represents the average peak pressure measured with the indicated SPRD configuration. The asterisks indicate the highest peak pressure observed and the error bars indicate one standard deviation above and below the mean. The highest peak pressure provides an indication of the possible range, but these test results do not reflect the full range of field conditions. For example, impacts with different draft gear on the struck car resulted in higher peak pressures than reported here.

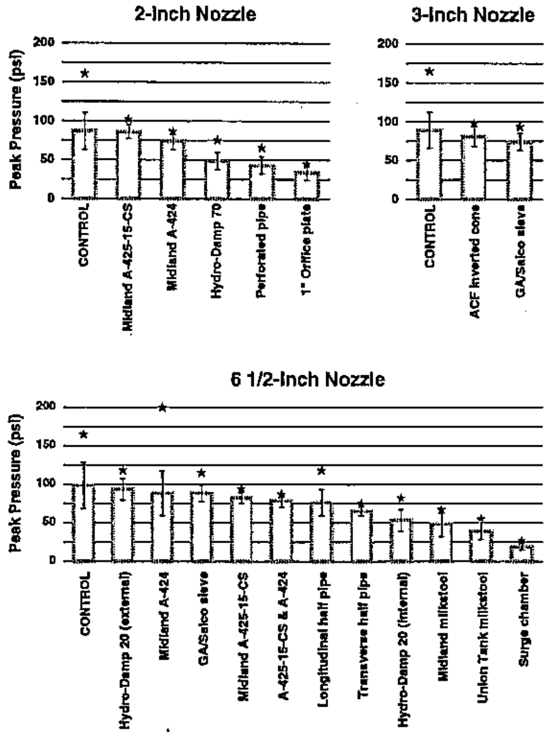

Figure 2. Effect of surge pressure reduction devices on peak pressure in 2-inch, 3-inch, and 6½-inch safety vent nozzles.

FLOW TESTS

The flow tests were conducted at the Colorado Engineering Experiment Station in Nunn, Colorado. We used the same SPRD configurations, safety vent and nozzle diameters as in the impact tests, with two exceptions. First, the half-pipe baffles were not tested because the flow area available through the two entries into the half pipe is substantially larger than the inlet to the safety vent nozzle itself. Consequently, we assumed that the effect of the half pipe on flow is negligible. Second, the combination of Midland A-424 and A-425-15-CS was flow-tested on the 2-inch nozzle as opposed to the 6½-inch nozzle.

We conducted the flow tests of the SPRDs in accordance with standard procedures for flow-testing tank car pressure relief vents and valves. The performance of each system was tested for pressures of 100 pounds per square inch (psi) and 165 psi by determining flow at 110 percent of both pressures (110 psi and 181.5 psi, respectively). Flow was also determined at two intermediate pressures, 135 psi and 160 psi, to investigate the pressure-flow relationship in more detail.

The flow test results for the controls and the SPRDs are presented in Table 1. The relationship between pressure and flow was linear (regression $R^2 > 0.998$ in all cases), and the percent reduction in flow caused by any one SPRD relative to the control for the same nozzle diameter was constant regardless of pressure. Table 1 shows the flow at 181.5 psi, the percent reduction in flow relative to the corresponding control, and the discharge coefficient C_d (the ratio of the actual flow to the flow through an ideal conduit with the same orifice area) for each configuration.

Table 1. Flow Test Results

2-Inch Nozzle	Flow Rate (scfm)*	Percent Drop	Estimated C_d
CONTROL	10,125	n/a	0.87
Midland A-425-15-CS	7,027	30.6%	0.65
Midland A-424	6,553	35.3%	0.61
A425-15-CS & A-424	5,768	43.0%	0.54
Hydro-Damp 70	4,186	58.7%	0.66
1-inch orifice plate	2,464	75.7%	0.86
Perforated pipe	2,318	77.1%	0.36
3-Inch Nozzle			
CONTROL	11,412	n/a	0.97
GA/Salco sieve	6,135	46.2%	0.67
ACF inverted cone	6,032	47.1%	0.66
6½-Inch Nozzle			
CONTROL	11,456	n/a	0.98
Union Tank milkstool	8,842	22.8%	0.64
Midland milkstool	8,812	23.1%	0.72
Midland A-425-15-CS	7,337	36.0%	0.68
Midland A-424	6,818	40.5%	0.64
Surge chamber	6,764	41.0%	0.75
GA/Salco sieve	6,221	45.7%	0.67
Hydro-Damp 20 (internal)	2,792	75.6%	0.53
Hydro-Damp 20 (external)	2,300	79.9%	0.44

* scfm = standard cubic feet per minute. These flow rates were measured at a gauge pressure of 181.5 psi at ambient temperature and barometric pressure and were adjusted to a standard temperature of 519.68°R (=60°F) and a standard barometric pressure of 14.696 psi.

CONCLUSION

This test indicates that SPRDs can be used to substantially reduce pressure surges in tank car safety vent nozzles and thereby help prevent the release of hazardous materials. The results from this testing are being used by a task force of the AAR Tank Car Committee to develop performance requirements for SPRDs. The major issues the task force is considering include:

- What is an appropriate level of performance for SPRDs?
- Can a bench test be developed to measure SPRD performance and what should be its design?
- What is an appropriate approach to retrofit of tank cars already in service?

The data developed in this test will be needed to validate possible bench test designs. This will help facilitate the acceptance and implementation of SPRDs in the North American tank car fleet.

Note: Contact Todd Treichel at (202) 639-2262 if you would like a copy of the AAR technical report on the surge suppression system testing or have any questions or comments about this document. E-Mail: TTREICHEL@LMS.AAR.ORG

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[1] This force was typically developed in the range of impact speeds from 6.8-7.2 mph, which is in the upper range of normal service experience.

[2] "Outage" is the term used to measure the percentage of the tank volume not filled by liquid. Other data from this test, as well as those from previous tests, showed that the lower the outage, the higher the surge pressures in the nozzle. We also had data that showed that the closer the nozzle was to the struck end of the car, the higher the resultant surge pressure.

[3] Data supplied by a frangible disc manufacturer indicated that this is the minimum duration of pressure at or above the burst-pressure rating that might burst a standard, newly installed disc.