

Light Rail Transit Noise Control: A New Line For Tri-Met

Ken Kirse and Lisa Cobb
Tri-County Metropolitan Transportation District of Oregon (Tri-Met)
Portland, OR

Light Rail Transit Noise Control: A New Line For Tri-Met

Ken Kirse and Lisa Cobb

Tri-County Metropolitan Transportation District of Oregon (Tri-Met)
Portland, OR

ABSTRACT

Tri-Met's light rail system consists of 33 miles of double track. The system is run with high-floor Bombardier (Type 1) and low-floor Siemens (Type 2) cars on a day-base ten-minute headway. In the twelve years Tri-Met has been running trains, there have been noise complaints and Tri-Met was able to reasonably remedy the trouble areas. When trains started running on the Westside extension, however, complaints soared. Tri-Met doubled its efforts to reduce airborne noise for sensitive receivers, in some cases at very high cost.

Noise problems can be broken into three categories: squeal, screech, and roar. Squeal refers to high-pitch noise in tight curves, screech is high-pitched noise in wide curves or on a tangent track, and roar is train passing noise caused by rail corrugation. Tri-Met experiences all three types on various parts of the system.

Several strategies for the reduction of squeal are described and their effectiveness evaluated. These include the following: resilient wheels, car-borne surface conditioners and lubricants, wheel vibration absorbers, rail watering in tight curves, and profile grinding in tight curves.

"Roaring rail", where short-wavelength corrugation is evident, is shown to be eliminated by grinding and the noise levels reduced. A description of Tri-Met's ongoing noise reduction strategy is given.

INTRODUCTION

Tri-Met is the public transit agency for the three counties in the Portland, Oregon metropolitan area. The agency operates over 600 buses and a 33-mile light rail line with a fleet of 72 light rail vehicles (LRV's). The 15-mile eastern segment began

operating in 1986, and the 18-mile westside extension opened in September of 1998. Ridership for the entire rail line has already exceeded the projected 50,000 average weekday rides expected after one year of westside operation with January 1999 ridership averaging near 61,000 weekday rides on a 10-minute base headway.

The eastside rail line produced wheel squeal in a few tight curves that generated the occasional complaint, as did higher-speed running noise when rail became corrugated after about seven years of use. The line runs parallel to a freeway and then in street median for most of its length, and has only one mile where it runs between backyards. Most of the tight curves were in downtown areas that were not particularly noise-sensitive, and people became almost accustomed to the squeal.

The new westside line is geographically much different from the eastside. It runs from downtown through a three-mile long twin tunnel, traverses through residential and commercial areas on new right-of-way and abandoned railroad right-of-way. It also has many more curves of radius less than 500 ft. and long sections of grades up to 6%. When simulated operations began in August 1998 with trains running at 10 minute headway, the phones started ringing at Tri-Met's community relations office. Wheel squeal in the tight curves and normal running noise in some areas where homes are less than 50 feet from the track was irritating adjacent residents attempting to work and sleep.

There were 10 areas on the westside line that were the targets of noise complaints. The problems included wheel squeal, wheel flange noise and LRV interior noise in the tunnel. Canyons, tunnel portals and undercrossings seemed to be exacerbating the problems in a few areas. Tri-Met staff called transit agencies all over the country to learn how they dealt

with noise and wheel squeal. It was quickly discovered that not only are there no universal solutions, no two transit agencies use the same strategy for mitigation of wheel/rail noise. So feedback from other transit agencies did not provide a guaranteed solution, but the education was invaluable in formulating a Tri-Met strategy. The biggest challenge has been in isolating variables to test various methods in an environment where noise is not tolerated by sensitive receptors.

Several methods of mitigating wheel/rail noise will be described here, some track related and some vehicle related. The methods will be broken up in the way for the purpose of this paper, but it is worth mentioning that Tri-Met's civil and light rail systems engineers work together closely in a joint effort.

Track Related Noise Mitigation Efforts

During the design phase of the westside line, engineers recognized that the tight curves being introduced would produce wheel squeal. At the same time, girder rail was in need of replacement in our two most sensitive tight (82 ft) curves downtown. A rail weld embedment process called "Riflex and Eteka 5" has been used for wear and noise abatement in Europe and also at Metro in Washington DC and SEPTA in Philadelphia. The weld treatment was added to a new girder rail procurement for four tight curves, including two for westside and the two downtown curves. The weld material is very hard (450 BHN) and in theory would wear to a highly polished surface, like a ball bearing, to reduce friction. After bring in service for more than six months we find that this rail treatment has reduced wear, but has not reduced wheel squeal.

The track designers of the westside line also looked at the wear pattern on the eastside. In the girder rail sections there was a heavy wear on both the gauge corner and girder guard on both rails of tight curves. After examining the wheel/rail interface they decided to tighten the gauge by about 3 mm in girder rail curves of less than 150 ft radius. While the gauge tightening appears to have reduced wear, there has been no noticeable reduction in noise.

The design of the westside project included just over four miles of sound walls and other noise mitigation at residences at a total cost of \$5.3 million. Noise mitigation costs since opening have expanded by another \$2.5 million. One example of how this money has been spent is on one group of neighbors bordered by an 8 ft high sound wall. Measurements

showed maximum passby sound readings of over 80 dBA at some of the homes. A contract was issued to install a 4 ft wide band of noise absorption panels on the existing concrete sound walls. The objective is to absorb the sound so that it doesn't reflect off walls and vehicles. Tri-Met and the neighbors expect significant noise reduction, but as of this writing the absorptive panels have not been installed.

At the east portal of the Robertson tunnel the track is in a canyon with the retaining wall on one side. Residents at the top of this canyon, approximately 200 ft from the tracks, had noise levels in the high 70 dBA range. Tri-Met contracted the installation of sound absorption panels on the existing retaining wall, as well as panels between the tracks and along the outside of the far track to capture the noise and prevent it from reflecting off the concrete walls and the vehicle. The noise absorption panel work is due to be finished in March 1999.

Wheel squeal complaints during simulated revenue operations prompted Tri-Met to take immediate action. The design criteria specify the use of restraining rail in all curves less than 500 ft radius. In paved track, girder rail is used: open track has 115 lb tee rail. Wheel squeal was coming from three areas: the gauge corner, the top of the tail, and the restraining rail or girder guard as it contacts the back of the wheel flange. When the track was wet the noise disappeared. Watering systems were quickly installed at three of the most troublesome areas in open track. The systems are train activated with infrared switches and timers. They were installed in about three weeks and were running for the grand opening on September 12, 1998. The watering systems are effective in eliminating wheel squeal. Although these systems are still being used today, Tri-Met views them as temporary. There are only a few weeks of freezing temperatures a year in Portland, however, freeze plugs were ineffective this past winter when pipes were cracked at all three locations during the first freeze. Two of the three systems are on the direct fixation track with a concrete slab and drainage inlets. The third is in tie and ballast track. There is concern for the long term detrimental effect of wet ballast and sub-grade, electrical isolation of the rail from earth, and the possibility of rolling contact fatigue. This solution is also practically limited to open track.

Two other squealing locations were in paved track that could not be easily retrofitted with a watering system. Through our contacts with other transit agencies, we learned of a liquid modifier, HPF,

bring used to reduce wheel noise. This product seemed promising because it could be applied to the top of the rail, which is where it was made by the same company supplying Tri-Met with solid car-mounted sticks. We needed a product that could be put on top of the rail to eliminate the squeal yet not reduce the friction to the point of losing adhesion for braking and acceleration. Testing with this manually-applied product proved that the squeal could not be eliminated without causing major operational problems.

There were some problems associated with the friction modifiers, however. Tri-Met found that if the liquid was applied too heavily, trains could lose adhesion needed to climb a 5% grade. Automatic sanders were activated more frequently after application of the product. The biggest problem, though, in this situation, was the short life of the product. After a rain, the friction modifier required application after every other train. Most days, the product needed to be applied to 5 or 6 times to keep the wheels from squealing, in part because the headway between trains are too short to allow the product to dry. Tri-Met assigned crews full time to apply the material, which has proved to be a major expense. There was also a compatibility problem with the car-mounted sticks, which is detailed in the next section.

In October of 1998, Tri-Met contracted with a firm for technical advice in the area of wheel/rail interface. The consulting firm suggested a rail profile grinding program to deal with two separate issues: wheel squeal in curves and rail corrugation. In addition to the curve squeal, Tri-Met had also received complaints about the running noise in some other sensitive areas. The rail profile grinding program was designed to remove rail corrugation, reduce the contact band from about 1" to ½" in width, and to improve steering in curves. Steering was improved by grinding the rail so that the contact hand was moved to the field side on the low rail and to the gauge side of the high rail to take advantage of the natural rolling radius in the tapered wheel tread.

The rail profile grinding was performed at the select locations during December 1998 and January 1999. In the tight curves, the profile grinding has reduced the heavy contact at the gauge corner of the high rail. The objective of eliminating the wheel squeal in tight curves through rail grinding was not met, as wheel squeal noise measures the same level after grinding as it was before. Again most of the

squeal is believed to be coming from the top of the rail. In the segments that were ground to remove corrugation, sound tests before and after revealed a decrease in noise levels of about 3dB on average. It is believed that the healthier wheel rail interface will delay the return of the rail corrugation.

About the same time, Tri-Met learned that San Diego Trolley was successful in eliminating wheel squeal by using wayside rail lubricators. After a trip to San Diego to observe their lubrication practices, Tri-Met is in the process of procuring three similar wayside lubricators. The objective is to reduce the top rail coefficient of friction to a range of .25 to .35. Friction below this level will present braking and acceleration problems. Friction about this level correlates with wheel squeal. Tri-Met chose an electric wayside lubricator so that a precise amount of lubricant can be applied to the passing wheels. The lubricant is Teflon based, non-toxic, biodegradable, and non-polluting. The intention is to cover several noise-producing curves with on lubricator. San Diego has found that the lubricant will track for several miles. After installation of the lubricators, Tri-Met will be conducting braking and acceleration tests.

Transit Cooperative Research Program Project (TCRP) C-3A is titled "Field Testing of Wheel/Rail Noise Control Technologies". Wilson, Ihrig, & Associates were aware of Portland's noise problems and asked Tri-Met to participate in a demonstration of a rail vibration absorber, along with a test of wheel vibration absorbers. Tri-Met has agreed and will be testing this new rail technology in June 1999. The device is a small damper that is clamped to the rail between the fastenings. They have apparently been used successfully in Germany, but this will be the first test in the U.S.

Vehicle Noise Mitigation Efforts

On the vehicle side, Tri-Met has tried or is in the process of considering several things to reduce squeal and running noise. These include LRV side skirts, truck-mounted surface conditioners, wheel vibrations absorbers, atomized liquid flange lubrication and a new wheel profile. All Tri-Met LRVs are equipped with resilient wheels. While still in the design phase of the westside project, Tri-Met conducted tests to determine if the addition of side skirts on the older "Type 1" LRVs would reduce wayside noise. Prototypes were built and showed a 2dB reduction in 55-mph passby noise level at 50 ft.

This was considered to be beneficial, and all 26 Type 1 cars were fitted with locally made side skirts at a cost of \$250,000.

Tri-Met has been using truck-mounted stick surface conditioning products called HPF and LCF for some time. The Type 1 cars have HPF and LCF. The tread product, HPF, is designed to reduce squeal while not reducing adhesion. The LCF is a more traditional solid lubricant product designed for the wheel flange. LCF and HPF have been installed on the center truck wheels, both axles, on the Type 1 cars since 1995. LCF was added to the back of the wheel flange in 1998. The low-floor Type 2 cars, which have been in service since September 1997, have LCF on the flange face and HPF on the tread, leading and trailing axles of the car.

The sticks have been useful in reducing wear on the wheel flanges, and they did reduce squeal noise levels on the two most sensitive curves downtown when only Type 1 cars were running. However, this noise-reducing effect has not been maintained with the introduction of the Type 2 cars, which coincided with the installation of new rail with Reflex as discussed in the previous section. Wheel squeal has re-emerged as a problem at the two sensitive 82 ft radius curves downtown, as well as at curves on the westside line. Adhesion problems have also emerged in a curve where we have been using the liquid HPF discussed in the track section. According to the manufacturer, Tri-Met is using too much liquid HPF, and this is combining with the stick HPF causing the cars to lose adhesion and discharge sand on the track exiting Jefferson Station.

Engineering staff have notices that HPF appears to wash off in the rain, as evidenced by the prevalence of squeal noise in dry periods immediately after a rain. A similar phenomenon was also observed in Denver after a snow, where staff reported it takes a few days for the HPF to build up on the rail from the sticks after the precipitation. The rain/dry cycles Portland experiences in spring and fall make maintenance of a good film on the rail difficult. The maintenance of the sticks themselves has been a problem for a well-worked car maintenance crew, and continuation of their use is under review.

Liquid flange lubrication is being considered as an alternative to the solid lubricants. The system will consist of a reservoir of liquid, an air compressor, detector and microprocessor. It is designed to deposit the lubricant through a nozzle, at a pre-determined rate, only on curves smaller than a given radius. It is

expected, based on the experience of Valencia, Spain, that systems would not need to be added on more than half of the fleet, though this is unproven. It has been reported that Valencia has lubrication units on fewer than 25% of its Duewag cars. Migration of the lubricant to the tread of the rail is also a concern. Procurement of two systems to fit on the center trucks of the Type 2 cars is underway and are due to be tested in the fall of 1999. A major challenge of a test program will be in separating the various noise-reducing products without disturbing our sensitive receptors, that is, people. Some transition will be necessary to determine how many units would be needed to keep the fleet quiet on tight curves.

Wheel vibration absorbers are due to be fitted to one Type 1 care and tested in summer, 1999. This is also a TCRP project with Wilson, Ihrig Associates. The wheel vibration absorbers consist of specially-tuned plates bolted to the LRV wheels, which absorb characteristic squeal frequencies. The applicability of this technology to the Type 2 cars is uncertain, due to lack of clearance around the tires.

Tri-Met is also considering a change in its wheel profile to better fit the rail profiles. Tri-Met currently uses a non-standard 1:30 wheel profile and two rail profiles, 115RE and R159. A long-term approach of having a single matched rail profile (possibly with some special curve profiles) with a well-matched wheel profile is desirable. This is currently under review.

CONCLUSIONS

In the Portland area, people expect their transit agency to make rail operations extremely quiet. This is a particularly challenging task because new construction has been built very close to people's homes. Mitigation measures can be very expensive. In this low-tolerance environment the effectiveness of individual methods is difficult to assess because it is not always possible to separate variables without noise levels increasing. Tri-Met will continue to apply techniques used successfully on other properties and experiment with new technologies in the on-going search for effective economical noise control measures.