Summary: Report on tests performed at Largo Central RailRoad (LCRR) 02/03/09 File: (LCRR test revision 020804 (Text).doc)

The purpose of the test was to find how far an aluminum or steel rail track can be tilted one rail higher than the other, before the wheels of a rail truck would slide down towards the lower rail. Two short sections of track were used, placed four rails together on wooden ties, (known as "Interlaced track") correct to gauge.

The experiments were performed first on a pair of aluminum rails then repeated on a pair of steel rails. The aluminum rails were already clean. At first the steel rails were somewhat rusted, so the experiment was done on the rusty rails, then the rails were sanded to clean off the rust, and the third test was done on the sanded steel rails.

Three different trucks were used, one with new cast iron wheels, a second with worn cast iron wheels, and the third with new steel wheels.

Instruments were used to measure the angle by which the track was tilted at the moment that slip occurred.

The lowest angle was 13.8^0 with new cast iron on aluminum rails.

The lowest angle with new cast iron on steel rails was 14.81^0

The greatest angle of tilt was with both worn cast iron wheels and new steel wheels on sanded steel rail, when both had the same angle of 16.23^0.

Applying these figures to standard gauge of 56½", the smallest superelevation at 13.8^0 would be 13.5". The largest would be 15.8". By extension, these figures represent the lift that should be tolerable on the outer rail of standard gauge track before wheels would slip down from flange contact at the high rail.

The preliminary work of Sky Train Corporation has been designed around the angle of 10.0^0, or an equivalent lift of 9.81". Compared with the lowest figure of 13.5" from cast iron on aluminum rail, this has the ratio of 1.375, a margin of 37.5%. The lowest figure on steel rail was with new cast iron wheels, angle of 14.81^0, equivalent lift of 14.4", ratio 1.47, or a margin of 47%. The highest figure with both worn cast iron and new steel wheels on steel rails was 15.8", ratio 1.61, or a margin of 61%.

Two of the smallest values pertained to new cast iron wheels. The figures for steel wheels were consistently higher, if not highest. In view of the margins in angles of slip found in this experiment, it is quite reasonable to continue using 10^0 for calculating purposes. Apparently using 10^0 of superelevation is quite conservative.

The modern use of steel wheels in Sky Train's OSLR might permit use of even greater superelevation. Experience with full-scale vehicles may confirm that larger angles of superelevation could be applied to curves in Sky Train tracks, which would permit faster curving speeds in services where this could be advantageous.

Report of tests of rail trucks on tilted track

The Experimental Equipment

The experiment was performed on the grounds of the Largo Central RailRoad (LCRR) in Central Park, Largo, Florida.
LCRR is a railroad to a scale of 1/8th full size. On North American railroads, standard gauge is 4ft81/2inches, or 561/2inches. At 1/8 scale, the gauge of the LCRR is 71/2inches.

LCRR provided a table with screw jacks at the four corners so that the table may be tilted. Picture # 1 shows the tilting table with the screw jacks and with three trucks on it.

Members of LCRR prepared two examples of railroad track, one in aluminum and the other in steel. Segments of rails were laid on ties to the proper gauge, so that the segment comprised four rails in total. Picture #2 shows the dual track on the tilted table

LCRR made available three types of rail truck in the same scale; the differences were in the materials of the wheels. They were: cast iron in new condition; cast iron in worn condition; and steel in new condition.

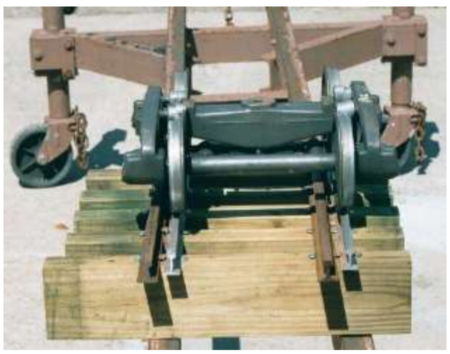
Picture #3 shows the three trucks on the tilting table, each truck with the different wheel materials.

Sky Train personnel provided measuring devices to measure the angle of tilt. These comprised: a carpenter's spirit level of length 172mm; a steel square to establish the correct 90^0 angles; a steel rule calibrated in mm; a length of 4"x2" lumber carrying a length of steel straight edge to stiffen the instruments; and a grade indicator calibrated in degrees of slope.

Experimental procedure

In preparation for the measuring stage, a first step was to place the tilting table on a firm concrete surface and set it level in both the longitudinal and transverse directions. For this purpose, the spirit level was used lying on the straight edge. The table was brought into the level position by adjusting the screw jacks at the four corners.

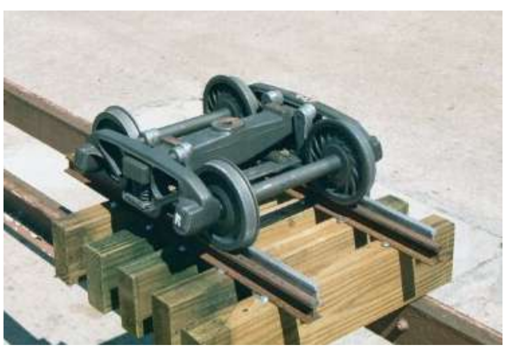
The grade indicator was placed on a railroad tie in a transverse direction, to give a preliminary indication in degrees of the angle of tilt.



One of the trucks was placed on the segment of aluminum rails, with the flanges touching one side rail.

Picture #4 shows the truck on the aluminum track.

Two members of LCRR started to turn the screw jacks to raise the rail on that side only, synchronizing their movements to ensure maintaining level in the longitudinal direction. Both LCRR and Sky Train personnel observed closely the position of the flanges to detect the instant when the wheels started sliding away from the high rail. At that instant lifting was stopped, and the process of measuring the angle of tilt was commenced.



The process was repeated twice for each truck and on both the aluminum and the steel rails. The experimental results proved to be repeatable. Each second test simply yielded the same measurements.

Picture # 5 shows the truck on the steel rails

Measurement technique

The straight edge was laid transversely across the tilted rails. One end of the spirit level rested on the upper part of the straight edge, while the other end was raised slowly to bring it horizontal. The steel square was placed at right angles on the straight edge to measure the distance from the straight edge to the bottom corner of the spirit level. This method composed a right angle triangle, with the length of the spirit level forming the hypotenuse and the measured distance being the perpendicular. The ratio perpendicular divided by the hypotenuse gives the sine of the angle of tilt, to be converted into degrees of tilt from mathematical tables of angles.

Picture #6 shows measuring in progress.

The process was repeated twice for each truck and on both the aluminum and the steel rails. The experimental results proved to be repeatable. Each second test simply yielded the same measurements.

Observations: There are four specific phenomena observed.

While watching for the moment when the flange first slid away from the upper rail, the movement was not sudden. The wheels moved only slightly. This was the effect of the coning of the wheels. The slight movement down towards the lower rail caused the lower wheel to move on to a larger diameter. Effectively the wheel lifted itself upwards, diminishing the effect of the tilt.

The angle at which sliding developed was such that the upper end of the spirit level tended to slide down the surface of the straight edge. An Assistant from LCRR held the upper end of the spirit level in place touching the straight edge so that measurements could be taken.

Two persons observed the process of adjusting the bubble of the spirit level while bringing it into the horizontal position, affording a crosscheck to confirm that it was truly level.

A third person used the steel ruler along the steel square to measure the height from the straight edge to the bottom corner of the spirit level. There were no problems in measuring this.

Measurements:	**Perp.mm**	**Hypo.mm**	**Sine**	**Angle**
New cast iron wheels:				
On aluminum rails	170.0	712.0	0.2387,	13.81^0,
On rusty steel rails	197.0	712.0	0.2767	16.06^0
On sanded steel rails	182.0	712.0	0.2556	14.81^0
Worn cast iron wheels:				
On aluminum rails	188.0	712.0	0.2640	15.3^0,
On rusty steel rails	188.0	712.0	0.2640	15.31^0
On sanded steel rails	199.0	712.0	0.2794	16.23^0
New steel wheels:				
On aluminum rails	194.0	712.0	0.2724	15.8^0
On rusty steel rails	200.1	712.0	0.2810	16.32^0
On sanded steel rails	199.0	712.0	0.2794	16.23^0

Accuracy

The length of the spirit level was measured by the steel rule at 712.0mm. The human eye can detect closer than 0.5mm, so the accuracy there should be better than 99.9%.

The distance of separation was measured by steel rule, also to 0.5mm, on lengths that varied between 170.0mm to 200.1mm. The accuracy there also should be better than 99.7%. The resulting ratio should be within an accuracy of 99.6%.

Accepting that the accuracy of measurement should be within 99.6%, the smallest sine above could lie between 0.2377 and 0.2396. The corresponding angles are 13.75^0 and 13.86^0. This is a margin of 0.11^0, barely measurable in the field.

Conclusion:

Two of the smallest values pertained to new cast iron wheels. Use of cast iron wheels was discontinued long ago due to inferior wear characteristics. The figures for steel wheels were consistently higher, if not highest. The lowest steel wheel angle of slip was 16.23$^{0.}$ Operating up to 10^0 of superelevation uses only 62% of this range (10/16.23). If at any time the angle of slip might be exceeded, the flanges would slide towards the rail and the slip will be controlled by the flanges of the wheels. Although rail stability must be taken into account, in view of the margins in angles of slip found in this experiment, it is quite reasonable to continue using 10^0 for planning purposes. Apparently using 10^0 for superelevation and for outward swing is quite conservative.

The modern use of steel wheels in Sky Train's OSLR might permit use of even greater superelevation. Experience with full-scale vehicles may confirm that larger angles of superelevation could be applied to curves in Sky Train tracks, which would permit faster curving speeds in services where this could be advantageous.

Wilfred Sergeant, Vice-President, Planning and Operations April 22, 2002