On the Behavior of Long Cuts with Uneven Load and Axle Distribution in Classification Yards

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The behavior of long cuts being humped in classification yards is determined not only by rolling, curve, and wind resistance but also by load and axle distribution. Most retarder control algorithms keep cuts at a constant velocity notwithstanding rollability and cut makeup. This has been shown to cause simple and corner impacts. One method of overcoming such difficulties is continuous speed control combined with operative simulation of cut behavior shortly before humping when cut makeup is known.

The behavior of cuts being humped in a classification yard is generally thought to be determined by the rolling resistance, the curve resistance, and the wind resistance. Distribution of load and axles also plays an important role.

On September 6, 1979, in Limmattal Yard of the Swiss Federal Railways (SBB), which is a carefully designed automatic yard that has 64 tracks in the bowl and a capacity of 6,000 cars per day, a long cut suffered a corner impact and subsequent derailment. Examination in situ provided no clues as to the cause; the computer system controlling the retarders had evidently done what it had been programmed to do.

SBB tried to verify by means of computer simulation what had happened. The results of the simulation showed that the cut had accelerated ahead of the master retarder extraordinarily quickly, had accordingly been slowed down by the master retarder, and had then been caught by one of the following cuts. The reason for the extraordinary acceleration was uneven load distribution: The first cars of the cut were loaded, the following cars were more or less empty, and the loaded cars pulled the remaining cut over the hump.

Speed is controlled in hump yards by means of retarders of different types, for example, by clasp retarders or Dowty hydraulic retarder units. All retarders attack the rims of the wheels. If all other parameters of a cut, notably its length and weight, are held constant and for the moment the weight sensitivity of clasp retarders is ignored, the retarding action will be stronger if the cut has many axles than if it has few. Many European cars have only two axles and are nevertheless longer than or as long as bogie cars, and there are bogie cars that are nearly twice as long as standard ones. If the front of a cut has two-axle cars and the rear part has equally long bogie cars, such a cut will be slowed down in a retarder more gently at first and more strongly later. When the bogie cars are in the front of the cut and the two-axle cars are in the rear, the result will be the opposite. In both cases time-distance diagrams will be different.

Procedures intended to overcome the problems created by uneven load or axle distribution or both should not resort to splitting the cut because this causes a succession of cuts following each other immediately into the same classification track and requires a substantial reduction in humping speed given the probable error in nominal exit velocity from the retarders.

The most convenient means of studying cut behavior is computer simulation. The time-distance diagrams shown in this paper are the result of such simulations. They refer to Limmattal Yard. The hump layout of this yard is shown in detail in Figure 1.

INFLUENCE OF LOAD DISTRIBUTION

Figure 2 shows the time-distance diagram of a cut consisting of 14 bogie cars each 14 m long and weighing 60 t. The total length of the cut is 196 m; the total weight is 840 t. The load is evenly distributed. The cut is framed by two single-car cuts running into neighboring tracks and two other single-car cuts, the first two preceding and the other two following the cut of 14 cars. The singles are easily running cars (rolling resistance is 0.83 kg/t); the behavior of the cut of 14 cars is average (rolling resistance is 1.63 kg/t).

Because it is difficult to measure the true rollability of longer cuts, speed-control algorithms normally provide that they be kept at a constant velocity by master or group retarders or both, regardless of rollability.

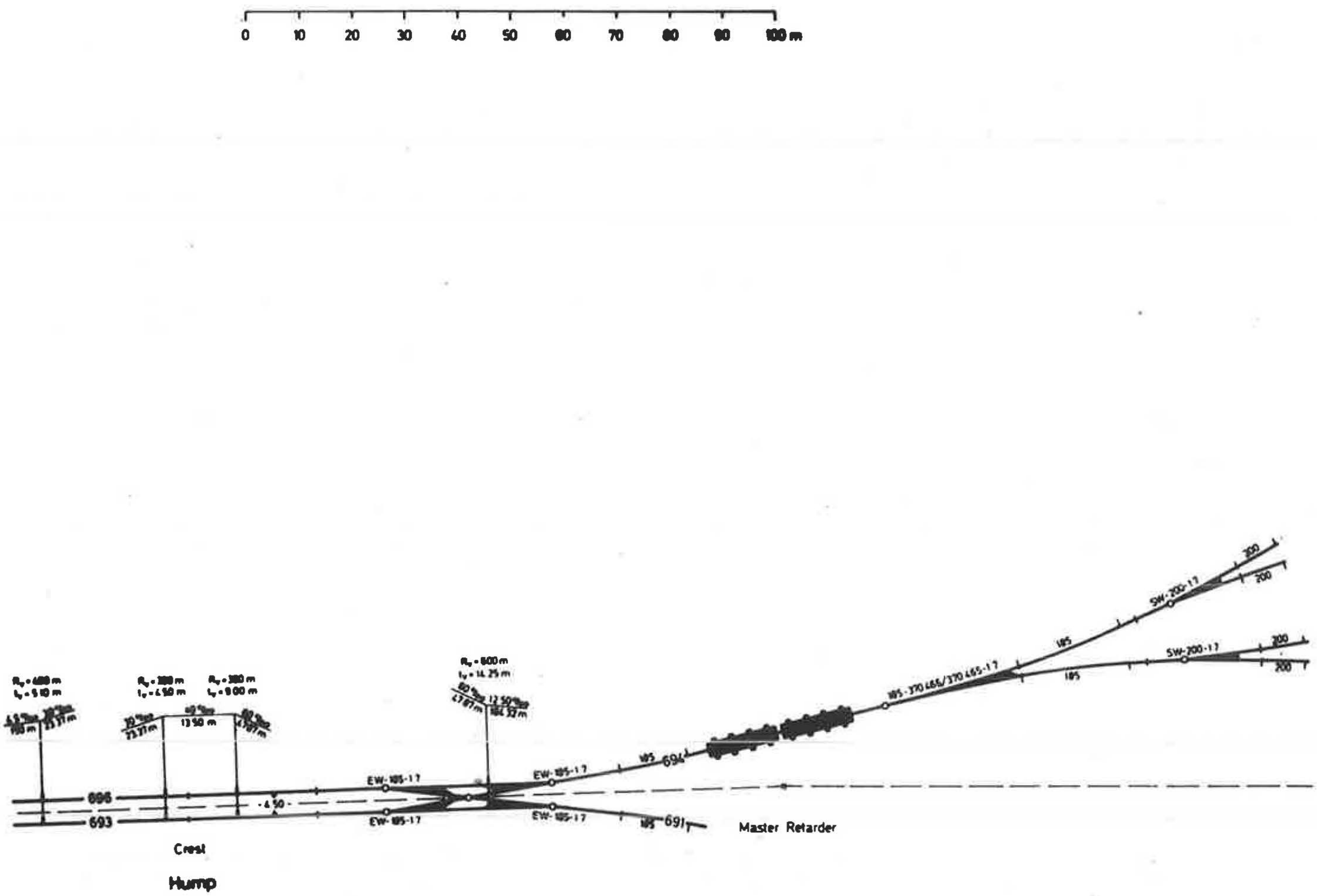
To show the influence of load distribution only, it is assumed that the optimal exit velocity of both master and group retarders is known; the long (14-car) cut then will be filed optimally between the preceding and the following singles as shown. Because these are easily running cars, they would be slowed down even with target shooting in the bowl to a more or less safe coupling speed (in Europe, buffing speed) of 1.5 m/sec. Spacing in Figure 2 is by definition excellent.

Figure 3 shows the same cut succession as that in Figure 2 except that the loaded cars are now in the front of the 14-car cut and the empties are in the rear. Total cut weight is the same as that of the 14-car cut in Figure 2. The long cut accelerates much better than before. For purposes of easy comparison the hatched curve gives the rear coupler of the cut, which has an even load distribution. It may be observed that spacing is no longer optimal. The cut of 14 cars is now much nearer the preceding single after being slowed down by the siding retarder (the term "siding retarder" is used intentionally; in Limmattal Yard the siding retarders are situated only 10 m behind the clearance marker of the last switch and not at the tangent point, which is 90 m farther down). Nevertheless, the cut behavior in this situation causes no conflicts.

The situation becomes dramatically worse when the loaded cars are in the rear part of the cut (Figure 4). This cut starts to accelerate from humping speed (1.4 m/sec) fairly late and then only to 1.44 m/sec; by then the empty cars have passed over the hump with the remainder of the cut. The loaded cars then enter the hump access gradient. The cut decelerates from 1.44 to 1.35 m/sec and the rear coupler again touches the front coupler of the rest of the train. With the old European side buffers and screw couplers this would have no consequences but with automatic couplers it does; they engage anew, provided they had not been put in the locked position. Normally this would make no sense because automatic couplers should engage when the cuts arrive in the bowl. Finally, when enough empty cars are in the accelerating gradient, the cut accelerates strongly. It is then kept at the same speed as the cut that has an even load distribution and later slowed down to safe coupling speed.

Because the cut is late, much later than the cut

Figure 1. Limmattal Yard: northern half of main hump.



with loaded cars in the front was early, it is caught in a corner impact by the immediately following single car, the destination of which is the neighboring track. In Europe corner impacts with cars that have side buffers usually cause derailment.

Even the second following single-car cut, the destination of which is assumed to be the same track, catches the cut of 14 cars. Under European conditions (screw couplers) the catching car would stop immediately due to the ratio of mass of both cars involved (88 versus 840 t) because there is no more gradient in the lower part of the switch area. Thus the catching car would be an obstacle and perhaps cause further problems.

INFLUENCE OF AXLE DISTRIBUTION

It is not easy to show the influence of axle distribution on the behavior of cuts isolated from any other influence, notably load distribution, because if cuts are made up simply of long and short bogie cars and if all cars have the same axle load, then load distribution would vary with car arrangement. Evidently it must be assumed that longer cars have a higher axle load, so load per unit of length would be the same for all cars.

Problems in this case may even arise from internally weight-responsive retarders. The influence of low axle density would be offset by higher clasp pressure generated by the higher axle load.

Externally weight-responsive retarders are often controlled by setting the clasp pressure proportional to the mean axle load of the whole cut; this pressure is kept constant for all axles of the cut. This procedure is applied in Limmattal Yard. There is no risk that the wheels will climb the rail because there is a fairly wide margin between the clasp pressure needed for retardation and that needed to prevent climbing so that even short cuts made up of a leading empty car and a trailing loaded car (the worst case, because the first axle of the empty car has to cut the clasp) are treated without the occurrence of climbing.

Figure 5 shows the behavior of another cut 196 m long but made up of six short cars (each 14 m long) and four long cars (each 28 m long). Car distribution is such that axle density is nearly even: Each half of the cut consists of a short, a long, another short and another long, and finally a short car. Cut succession is the same as that in Figures 2 to 4 as is the exit velocity from master and group retarders. Spacing, indeed, is optimal.

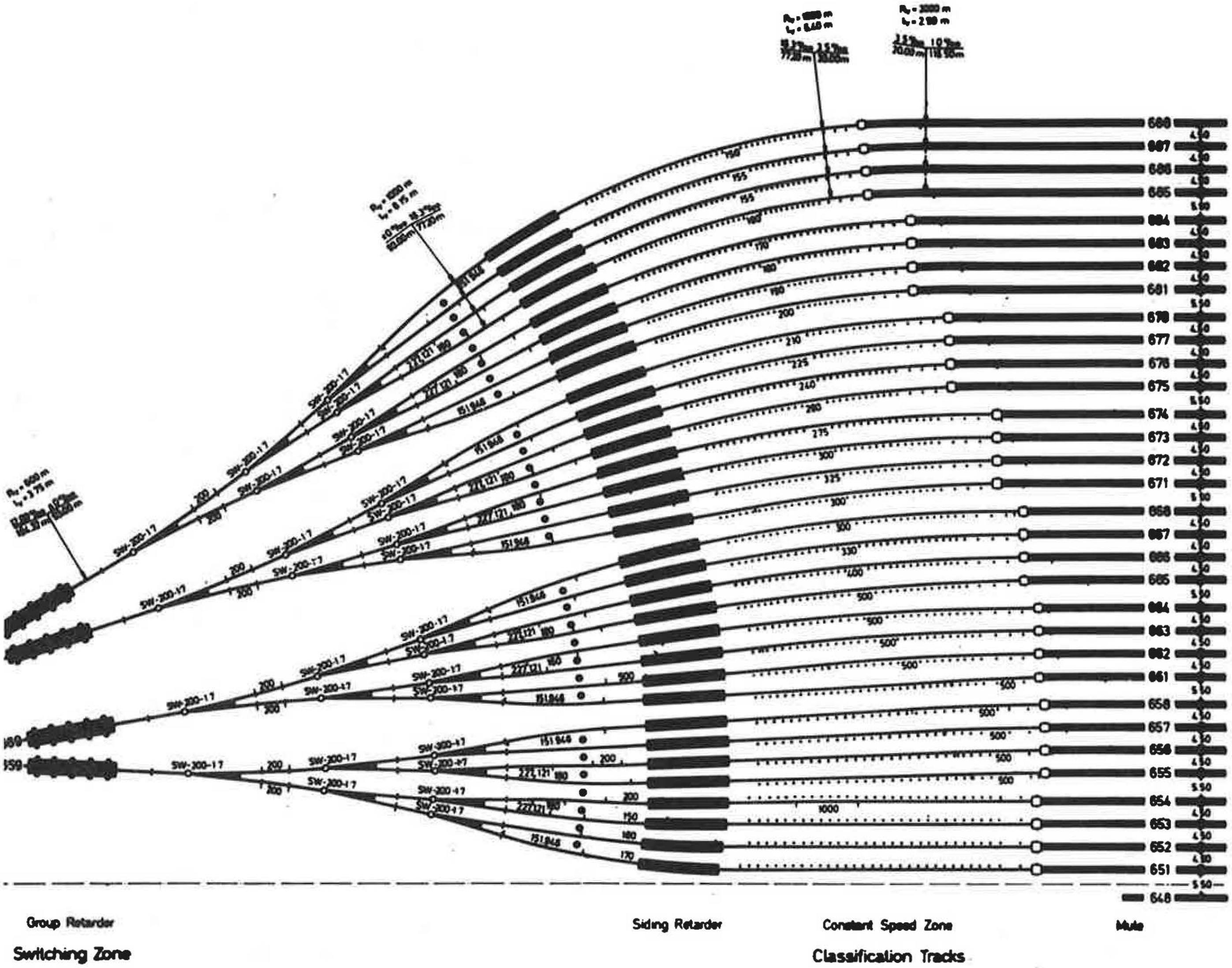


Figure 6 shows the same cuts except that the four long cars are now in the front of the long cut and the six short cars are in the rear. Until the cut is slowed down by the siding retarder, this new configuration does not behave significantly differently; the hatched curve of the cut that has even axle distribution closely resembles the curve of the cut considered here. This is because both master and group retarders keep the cut at a constant speed without really having to slow it down. It is only in the siding retarder that curves begin to diverge; lack of axles in the front part of the cut slows it down late. The final difference between the curves is appreciable; the 14-car cut nearly catches the second preceding single-car cut, assumed to run into the same track of the bowl. Should the exit speed from master, group, or siding retarder of this preceding car accidentally be less than the nominal calculated value, then an impact could occur. Such errors in exit velocity do occur with a certain frequency.

Figure 7 shows the same cuts, but now the six short cars are in the front of the long cut and the four long cars are in the rear. Of course, the cut is now slowed down early by the siding retarder as compared with the cut with even axle distribution. But even in this case no corner impact or simple catching occurs if the following single cars are treated correctly by master, group, and siding retarders. Yet there is not much tolerance left.

Effects of load and axle distribution may interfere with proper positioning of the car. Such effects may be partly or completely cancelled or amplified. It should be mentioned that all cases given here are not the worst cases. Still longer cuts with still more uneven loads or axle distributions do occur.

CONCLUSIONS

Control schemes for clasp retarders usually take the acceleration measured ahead of the retarder to calculate the exit velocity needed for adequate spacing of single cuts and shorter groups. For longer groups a constant suitable velocity is chosen. This procedure cannot deal adequately with longer cuts in high-capacity yards.

In an algorithm called F*DELTV, SBB uses a more integrated measure for rollability--the speed ahead of the retarder (1). This procedure is capable of filing cuts of any length and rollability more or less optimally between preceding and following cuts,

provided that load and axle distributions are fairly even. The only parameter needed is length of the cut.

It is tempting to see whether a still more integrated measure of rollability--the time needed by the cut to run from the crest of the hump to the retarder--would be able to space cuts of any makeup correctly. Simulations show that the time for running from the crest of the hump to the retarder is a measure of rollability and perhaps load distribution also (but not axle distribution). However, exit velocity would have to be calculated with the length and mean axle load of the cut as parameters. Therefore this procedure would be somewhat troublesome. Many simulations would be needed to cover the whole range of length and axle load and that would only

Figure 2. Cut of 14 bogie cars, load evenly distributed.

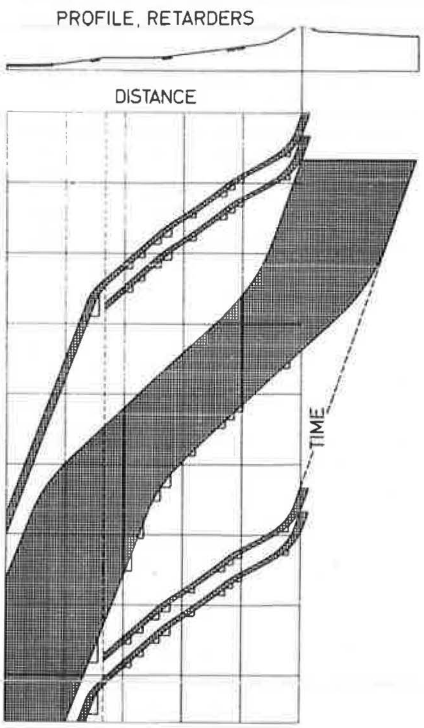


Figure 3. Cut of 14 bogie cars, load in front part.

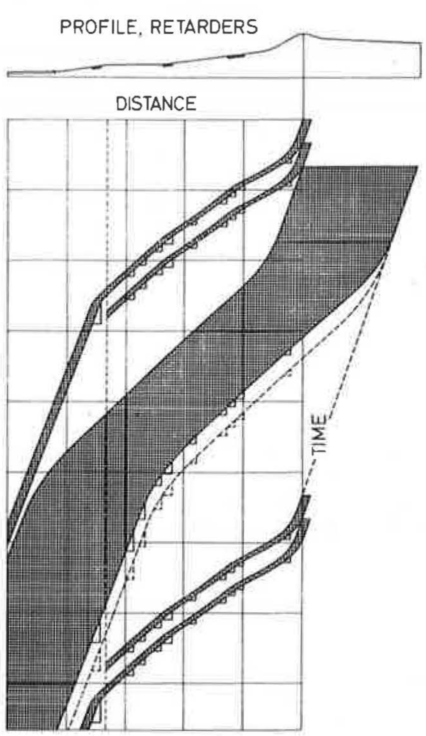


Figure 4. Cut of 14 bogie cars, load in rear part.

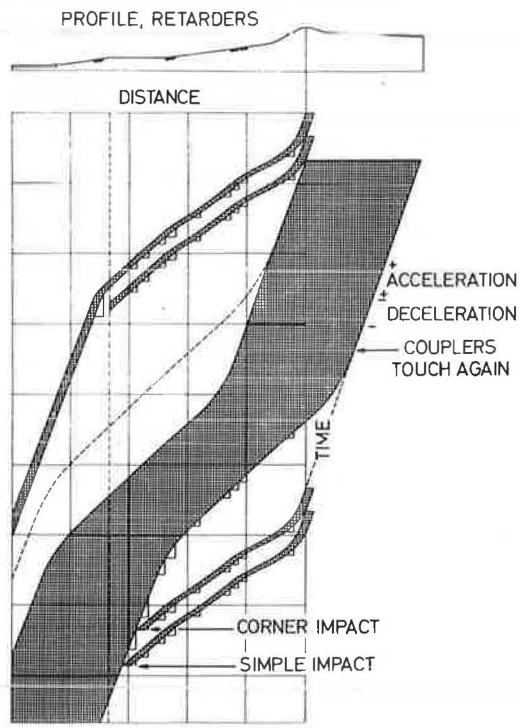
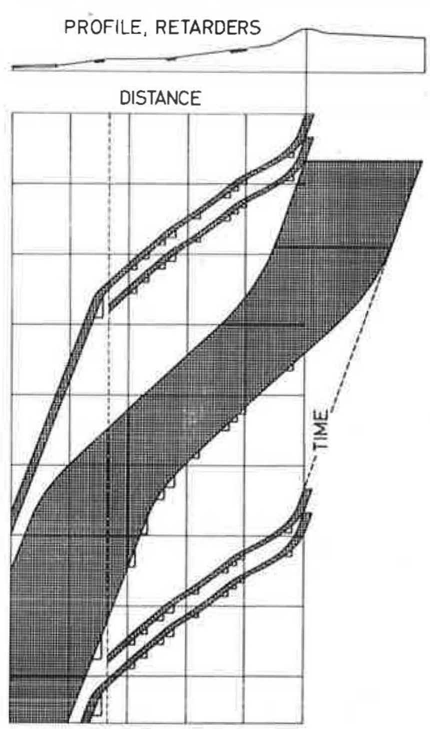


Figure 5. Cut of 10 bogie cars, long and short mixed.



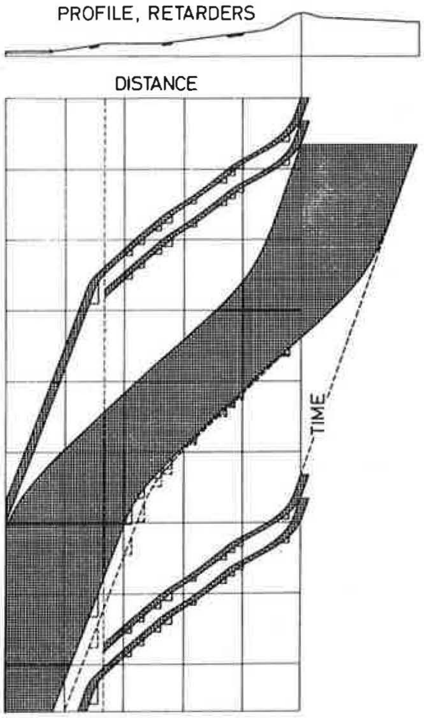


Figure 6. Cut of 10 bogie cars, long cars in front part.

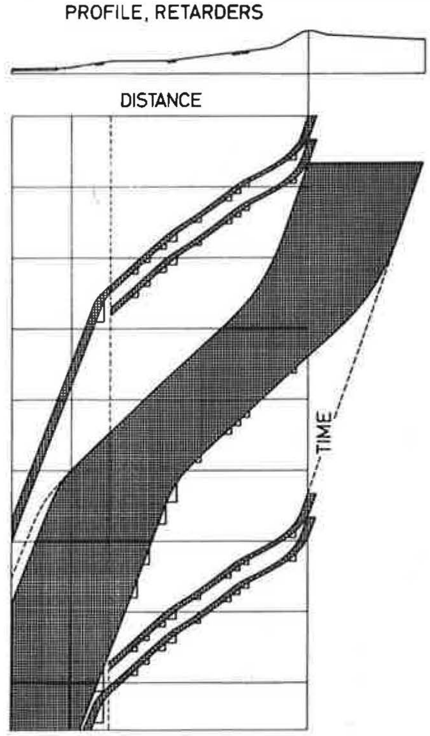


Figure 7. Cut of 10 bogie cars, short cars in front part.

determine the coefficients of the equations for calculation of exit velocity.

But at least for yards equipped with continuous speed control throughout from hump to bowl (by Dowty retarders, for example), a far more elegant method has been found: simulation of cut behavior shortly before humping when cut makeup is known. This procedure, which might be called operative simulation, governs not only load distribution but also axle distribution. Research conducted so far appears to show that operative simulation is feasible with respect to computer hardware and software and time needed for simulation. The first application is envisaged for the Vienna central classification yard in Austria (48 classification tracks, 6,000 cars per day). It could probably be applied to conventional speed control by clasp retarders also.

REFERENCE

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Empirical Results from Freight Car Rollability Study

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A knowledge of freight car rolling resistance is critical in the design and operation of rail freight yards, yet published data on this subject have been scant in the past. In a project sponsored by the Transportation Systems Center and the Federal Railroad Administration, SRI International gathered data on freight car rollability at five rail yards. Complete data were obtained only from Hinkle Yard (Union Pacific) and DeWitt Yard (Consolidated Rail Corporation). In the empirical approach used, the distributional characteristics of rolling resistance were obtained for the two yards during the winter and the summer. These samples were combined and the results of a regression analysis exploring the underlying causal factors are presented. Generally, resistance was found to depend on those factors frequently cited in the literature, although some notable deviations were found.

An understanding of car rolling resistance (rollability) is critical in the design and operation of railroad hump yards. Because cars are accelerated by gravity, design engineers must have a knowledge of rolling resistance to determine the hump height, classification-track grades, and the placement and length of retarders to ensure proper switching between successive cars on the hump and to control coupling speeds on the classification tracks.

Despite this need, however, rolling resistance has not been well understood, and an industrywide