Developments in the Application of the Dowty Continuous-Control Method

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The Dowty system for the continuous control of freight car speeds in classification yards is based on hydraulic retarders and pneumatic booster-retarder units. Dowty retarders adopt the retard mode only for cars traveling faster than the preset control velocity; the booster-retarder units are adjusted to monitor speed and accelerate or retard as appropriate. Five examples of recent application developments are given: (a) Sentrarand Yard in South Africa, in which both retarders and booster-retarder units provide continuous speed control; (b) Trondheim Yard in Norway, in which the continuous speed-control system has been modified to facilitate clearing snow; (c) Nürnberg Yard in West Germany, in which the retarder system is a combination of existing clasp retarders and a modernized control system; (d) an electrohydraulic latch to hold the retarder capsule in the down position to permit high-speed train withdrawals toward the hump; and (e) use of hydraulic retarders to provide end-of-track arrester zones.

The principles of operation of the Dowty hydraulic retarder and the booster-retarder unit are widely appreciated by engineers involved with classification yards in North America. Therefore detailed descriptions of these two units are not incorporated within this paper; it is sufficient to explain that both units are speed sensitive.

The retarder (Figure 1) adopts the retard mode only for cars traveling faster than the preset control velocity; booster-retarder units (Figure 2) are adjusted to monitor car speed and to accelerate or retard cars as appropriate.

In application a continuous speed-control system may be made up of retarders only (i.e., where the running gradients are adequate to maintain the motion of cars with high rollability values) or of a combination of retarders and booster-retarder units to accelerate the cars with low rollability and retard the cars with high rollability to maintain constant car speed.

To study recent application developments five examples have been chosen to present a variety of facets:

1. Sentrarand Yard, South Africa: The overall design aspects for this South African yard are presented. This is an excellent example of a large, high-throughput yard equipped with both retarders and booster-retarder units to form the continuous speed-control system.
2. Trondheim Yard, Norway: Although small and with only a low throughput, this yard has been economically automated with a continuous speed-control system. The parameters and design features for this project are reviewed with a look at the method adopted for clearing snow, an important feature in this northern region.
3. Upgrading existing yards with classification-track control: The Dowty retarder installation in Nürnberg Yard, West Germany, is reviewed as a practical example of the adaptability of the Dowty system.
4. Equipment development: An electrohydraulic hold-down latch has been designed and developed for attachment to the Dowty retarder. The design, principles of operation, and application of the latch for retarder on-off operation are explained.
5. End-of-track control: A design study for economic end-of-track arrester zones based on practical North American parameters is reviewed.

SENTRARAND YARD

General Aspects

It has been planned to develop three complete yards in the Sentrarand complex; land is available for a provisional fourth module if it is required in the future. The first of these yards was completed and commissioned in autumn 1982 (Figure 3).

The module layout includes an arrival yard, two departure yards, and a main switching yard with two secondary hump yards appended (Figure 4). There is a dual-lead track over the primary hump to promote 5,000 cars per day switched into the 64 classification tracks. The designed humping velocity is 2.25 mph. Both secondary hump yards are arranged to include a herringbone track formation for the purpose of building block trains.

Figure 1. Dowty hydraulic retarders.

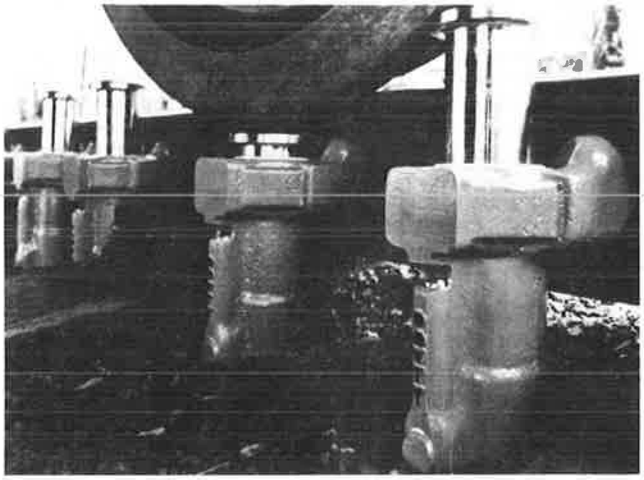


Figure 2. Dowty pneumatic booster-retarder units.

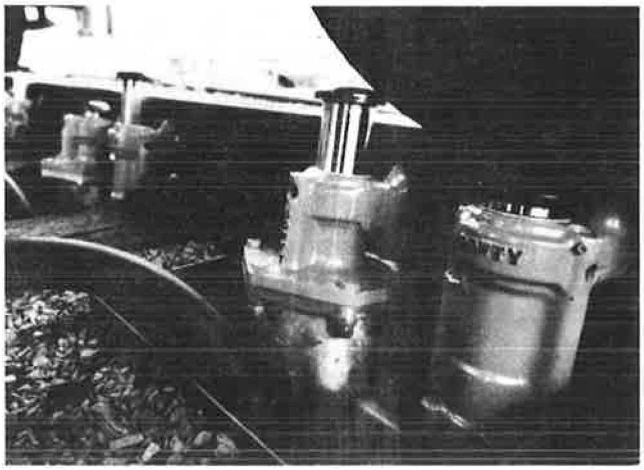


Figure 3. Sentrarand Yard.

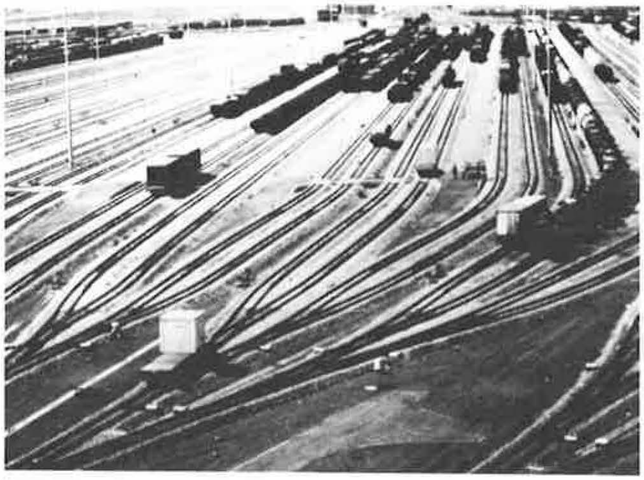
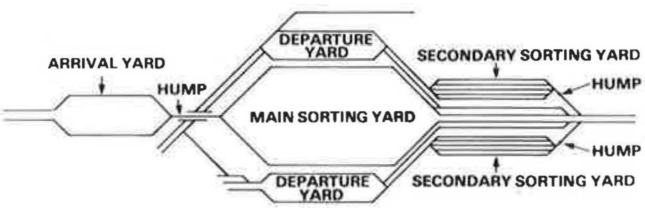


Figure 4. Layout of Sentrarand Yard.



Continuous Speed-Control System

The Dowty system for the continuous control of car speed is used throughout the main and secondary yards.

The speed-control system design was based on the following parameters:

Parameter	Amount
Axle loading	18.2 tons maximum, 3.6 tons minimum
Basic rollability bandwidth	0.001-0.018
Humping velocity (main yard)	2.25 mph
Car length	40 ft avg
Separation (main yard)	50 ft
Crest-to-clearance distance (main yard)	984 ft maximum

In the early design stages of the yard it was recognized by the engineers that particular problems were imposed by the need to cater to light cars combined with the wide rollability bandwidth specified. They also recognized that the ideal control system is one in which all cars, regardless of weight or rollability, are sustained at appropriate continuous velocities in the switching area to maintain separation and in the classification tracks to control the coupling speed.

To employ a control system based on retarder units alone would have imposed the need for unacceptable hump and gradient requirements. It was therefore determined, by using computer-aided design methods, that the optimum solution lay in the use of both retarders and booster-retarder units to supplement the gradients. In the final design of the main yard the hump height and vertical radius are equivalent to an accelerating gradient of 6.25 percent; boosters are added at a density of 0.88 unit/ft to accelerate all cars to the switching-area velocity of 11.2 mph.

In the switching area a gradient of 2.5 percent is used to keep the cars with high rollability in motion, and retarders are installed to hold the heavy cars with low rollability at 11.2 mph. The retarder densities vary between a maximum of 1.71 units/ft on tangent tracks to 0.4 unit/ft on curves and turnouts.

Deceleration zones are installed at the heads of the classification tracks to reduce the speed of the cars from the switching-area velocity of 11.2 mph to the classification-track control speed of 2.25 mph. These zones are equipped with a mixture of retarders and booster-retarder units; the retarders control the heaviest cars and the boosters and ensure that light cars with low rollability rapidly penetrate and clear the zone.

To achieve the optimum performance in the zone, in which the heavy cars are fully decelerated and yet light cars and cuts clear the zone as quickly as possible, the deceleration in the zone is in stages, i.e., 11.2 to 10.0 mph, 10 to 7.8 mph, 7.8 to 4.5 mph, and 4.5 to 2.25 mph. A variety of unit densities is needed to provide this type of control for the full range of cars.

The classification tracks, which have a gradient of 0.4 percent, are equipped with retarders installed at 0.003 unit/ft and booster retarders at 0.2 unit/ft; both are set to a control speed of 2.25 mph. With this arrangement all cars fully couple in the classification tracks at a controlled maximum velocity of 2.25 mph.

Secondary Yards

Both secondary yards employ humped switching over an accelerating grade equivalent to 4.0 percent. Each of the yards includes five tracks built to a 0.75 percent gradient and equipped with retarders and booster-retarder equipment to continuously monitor and control the car speed. The center track is the hump lead and feeder line into the two flanking herringbone tracks and to the outer pair of parallel reserve storage lines; all these tracks are on a 0.75 percent gradient throughout.

The cars are continuously controlled to 9.0 mph while they are traveling down the center feeder line. When traversing the turnouts and switches, they are decelerated in stages (i.e., 9 to 7.8 to 6.7 to 5.6 to 2.25 mph) before they arrive in the herringbone tracks. Cars running in the outer tracks are controlled to a velocity of 2.25 mph. Operable skate retarders are installed at 330-ft intervals along the herringbone tracks to form five blocks in each track; these retarders are also installed in the outer tracks, dividing each of them into two long blocks. The operations of the yard are enhanced by this design of the secondary yards; formation of block trains and the preparation of short local trains are rendered simple and expedient.

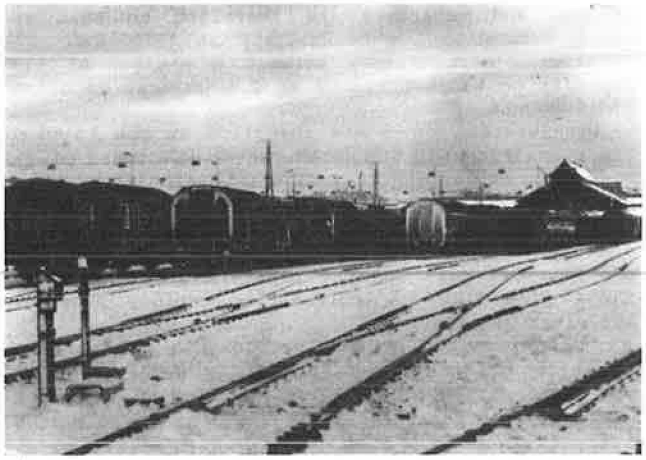
The specification for this type of operation is to sustain car separation down to the last switch, a distance of 1,880 ft in this case, and accommodate a wide rollability bandwidth. The cars must also run down to the end-of-block retarders and completely finish coupling in order to fill the blocks.

These parameters can only be met by using a speed-control system such as the Dowty system, in which retarders and booster-retarder units operate to continuously monitor speed and to adjust the motion of the cars by absorbing or dispensing energy as required.

Developments and Installations

It was the advent of this modern automated yard that promoted the design and development of the Dowty

Figure 5. Trondheim Yard.



booster-retarder unit. As mentioned previously, it was recognized early in the design stages that to achieve the maximum performance in car speed control and to avoid impractical gradients it would be necessary to employ mechanical feed equipment to impart energy to the cars with high rollability.

In the early 1970s trial systems of Dowty retarders were installed in the New Kaserne Yard for testing and evaluation. It was during this period that the head of the retarder capsule evolved into a mushroom shape to improve operation on tight horizontal curves.

These trials were extended in the mid-1970s to include the booster-retarder unit for equipment and system assessment. Cooperation among South African Transport Services, Telkor, and Dowty in the final development of the unit during this stage culminated in the production of approximately 18,000 units, to be installed with approximately 42,000 retarders to form the most extensive and complete continuous speed-control system ever derived.

Final costs quoted for the completed development of the yard are approximately $202,500,000 (1), of which $35,250,000 (2) was the approximate escalated cost for the speed-control system, including associated compressor plant and compressed-air reticulation.

TRONDHEIM YARD

General Aspects

Trondheim Yard is located in Norway 180 km south of the Artic Circle. Snow in this locality is a problem to be contended with each winter, and it was necessary during the planning stages to ensure that the retarder equipment selected and the snow-clearing methods adopted would be compatible. This yard, which was remodeled and commissioned in the autumn of 1982, is an example of how a low-throughput mini-yard can be economically equipped with a complete speed-control system to provide all the operating advantages of an automated yard.

There are 16 dead-end classification tracks to accommodate 1,200 cars per day over the hump. The specified humping velocity is 2.0 mph. All trains have to be withdrawn from the classification tracks via the switching area and hump bypass tracks (Figure 5).

Continuous Speed-Control System

The Dowty system for the continuous control of car speed is used throughout the yard. The speed-control system design was based on the following parameters:

Parameter	Amount
Axle loading	18.2 tons maximum, 3.7 tons minimum
Rollability bandwidth	0.001-0.007
Humping velocity	2.0 mph
Car length	42.6 ft
Separation	49.2 ft
Crest-to-clearance distance	675 ft avg

All cars are accelerated off the hump to a speed of 6.7 mph and this velocity is maintained throughout the switching area, which is graded to 1.2 percent.

The deceleration zones, situated at the head of each classification track, slow the cars from 6.7 mph to a coupling velocity of 3.4 mph. These zones commence 16 ft past the clearance markers and are installed across two gradients, 0.8 and 1.2 percent nominal. The location and gradients have been chosen to ensure that cars and cuts with low rollability move away from the clearance markers as quickly as possible. In the classification-track control area the speed is maintained at 3.4 mph on a 0.3 percent gradient.

The continuous speed-control system has been applied to this remodeled yard for less than $1 million, including spares, maintenance tooling, and commissioning. A gang of skatesmen has been released from their arduous and dangerous duty, and the car throughput has been greatly improved.

Snow-Clearing Operations

Before the final selection of the retarder system for use at Trondheim, snow-clearing trials were conducted at the existing Alnabru Yard near Oslo. The purpose of the trials was to evaluate the compatibility of the retarders and a suitable snow-clearing method.

During the trials snow-clearing machines with rotary brushes (Figure 6) were operated over the Dowty retarders. The rotating brushes were fitted with nylon-coated wire flails. This method was found effective in removing the snow and in no way affected the retarders mounted on the track.

The Dowty retarders and the brush method of snow clearing were adopted for use in Trondheim Yard; Figure 7 shows clearing operations in progress in the yard in February 1983.

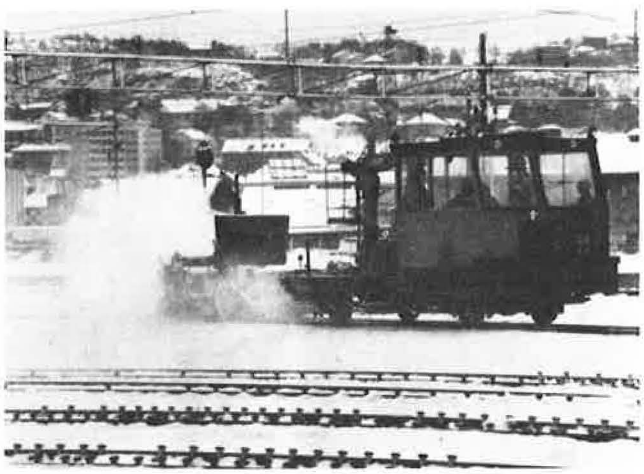
NÜRNBERG YARD: UPGRADING EXISTING YARDS

In many older yards the existing track gradients and speed-control system are not fully compatible with modern traffic and operations. A common problem in these yards is poor performance in the classification tracks because of excessive car speed. These conditions give rise to expensive freight and car damage, diminished safety due to high car speeds, and runouts at the trim end.

Nürnberg Yard in West Germany was built at the beginning of this century. In recent years plans were instigated for the remodeling of this important large yard. Work is already proceeding to produce a main yard with 72 classification tracks. After renovation the existing clasp retarders are to be retained in the switching area and operated via a fully modernized control system. A secondary hump yard is being designed for inclusion in the main

Figure 6. Snow-clearing machines, Alnabru Yard.

Figure 7. Snow-clearing machine at work, Trondheim Yard.



body of the yard. There are two further secondary switching yards located separately and to the north of the main yard.

Because of existing services, bridges, and so forth that have developed around the yard during 70 years of use, it has not been practical in the remodeling to greatly improve the gradients in many of the classification tracks. These classification-track gradients were constructed in the days when car rollability values were, on the average, much higher than those today, and therefore they present unacceptable accelerating grades to the majority of contemporary traffic.

In 1976, 300 Dowty retarders were installed in one of the classification tracks for test and evaluation of their control capabilities. Following this satisfactory trial, 4,800 retarders were installed in six classification tracks during May 1979 to form continuous classification-track control systems developed from the original trial applications. At the head of track 22, one of six so equipped, an 81-ft-long deceleration zone made up of 148 retarders at a density of 1.83 units/ft was installed on a gradient of 0.66 percent. Three different speed settings (6.7, 4.5, and 2.25 mph) were used for staged deceleration in the zone to ensure that light cars and cuts with low rollability pass through as quickly as possible.

After leaving the deceleration zone, the cars are continuously controlled down the track at a maximum speed of 2.25 mph to finally stop on preset rail skates (Figure 8).

On track 22 the gradients and distances equate to a velocity head value of 9-10 ft for a car with high rollability; without continuous speed control it would not be feasible to switch into such a track and utilize its full length.

As the reshaping of this yard progresses during the next few years, more classification tracks will be equipped with continuous-control systems to meet development and operational needs.

ELECTROHYDRAULIC LATCH

To permit high-speed train withdrawals toward the hump, an electrohydraulic hold-down latch has been designed to hold the retarder capsule in the down (i.e., off) position during the passing of a train.

The latch assembly is a self-contained unit bolted onto the side of the retarder pot. It is retained against a positive location face on the pot by 2x10-mm H.T. steel bolts (Figure 9). The mechanism is actuated by a 12-W electrosolenoid, which can be remotely signaled to control the operating position.

With the solenoid energized, the first passing wheel flange depresses the capsule and the latch engages with the mushroom head to lock the retarder in the off mode for the duration of the train's withdrawal. The solenoid is deenergized to release the capsule, which then returns to the normal retarder on mode.

Operation

Solenoid Energized and Retarder Off

With the solenoid (2 in Figure 9) energized, the armature extends, pushing the ball valve (3) onto its seat, and closes the vent line from the piston chamber. On the downward stroke of the capsule, the latch tongue rotates against the torsion spring (8), allowing the capsule head to pass by. On the return or upward movement of the capsule, the head contacts the latch tongue but is prevented from pushing it away because the subsequent downward movement of the piston (5) creates a hydraulic lock when the ball valve (6) is forced onto its seat.

The capsule is therefore prevented from extending and will remain down, so that all subsequent wheels pass without significant engagement with the capsule as long as the solenoid valve remains energized.

Solenoid Normal and Retarder On

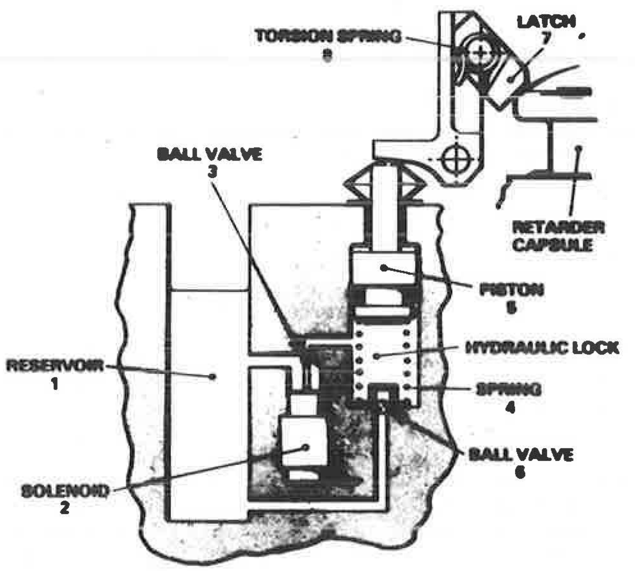
In the deenergized condition (Figure 10), the plunger of the solenoid (2) is retracted, allowing free flow of oil from the main piston chamber to the reservoir (1) via the ball valve (3).

Downward travel of the attendant capsule brings the mushroom head in contact with the latch (7), rotating its tongue against the torsion spring (8). This allows the capsule to complete its downward stroke.

Once the capsule head has passed the latch, the torsion spring (8) rotates and extends the latch tongue back into position above the capsule head. The return stroke of the capsule then brings it into contact with the latch tongue, causing the latch (7) to rotate about its fulcrum. This depresses the piston (5) into its chamber against the spring (4). At the same time, the ball valve (6) closes and oil from the chamber is vented to the reservoir (1).

Figure 8. Rail skates, Nürnberg Yard.

Figure 9. Electrohydraulic hold-down latch: solenoid energized.



As the capsule's upward travel continues, its head disengages from the latch, allowing the spring (4) to extend and drawing oil into the chamber from the reservoir via the ball valve (6).

The cycle is repeated for each following capsule stroke as long as the solenoid valve remains deenergized.

Development

The general design for the hold-down latch was conceived in 1982, and during that year prototype units were produced and tested to prove the principles of operation.

Six prototype latch units were installed on a track in Seinajoki Yard in Finland in January 1983 to commence a 4-month winter test period (Figure 11). The objectives of the trial were to evaluate the operational integrity of the unit in a field environment when it was subjected to low temperatures and snow conditions.

During the trial period the ambient temperatures ranged from 10°C to 25°C and there were many snowfalls when the units were subjected to snow-clearing operations in which a high-speed rotary brush was used.

To test the effectiveness of the latch, test trains were driven at various approach and maximum velocities over the units; these speeds ranged from 9 to 21 mph. Low-voltage tests revealed that the solenoid could be effectively energized and held at 30 percent full DC potential.

At the end of April 1983, the latches were removed from the track, having successfully completed all trials. During the test period 15,400 axles had operated the retarders and the solenoids had electrically cycled on or off for 1,841 hr with a period of 12 min/cycle.

Figure 10. Electrohydraulic hold-down latch: solenoid normal.

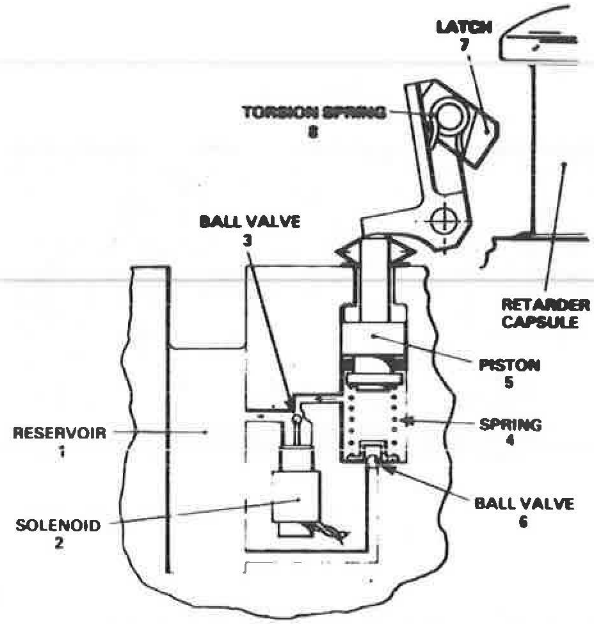
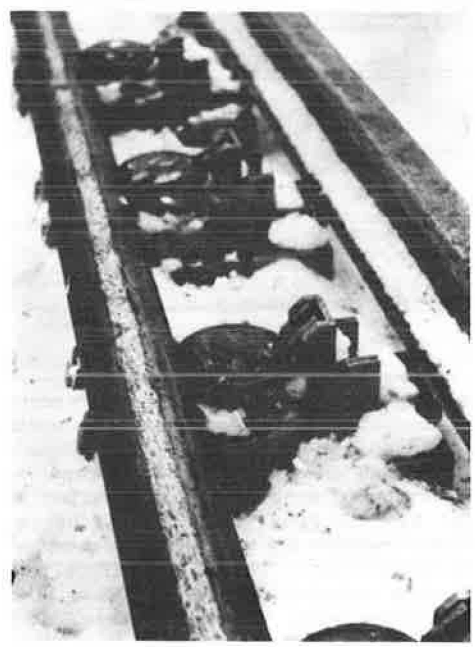


Figure 11. Prototype hold-down latches, Seinajoki Yard.



All six of these prototype units operated without failure under conditions of both snow and ice throughout the test period. They have since been completely dismantled and all components have been examined. From this investigation the only details calling for attention during the stage of making production drawings are to change the ball-valve seating material, improve the piston gaiter against a small leakage of moisture, and improve the method of excluding air from the piston seal during the assembly of the unit.

In parallel with the track trials a prototype latch was subjected to 1.0 million cycles of operation on a cycling test rig. A complete retarder was loaded into the rig so that the capsule could be stroked vertically in the normal operating method. During the 1.0 million cycles the solenoid was energized for one-sixth of the time and deenergized for five-sixths of the time to approximately simulate operating conditions.

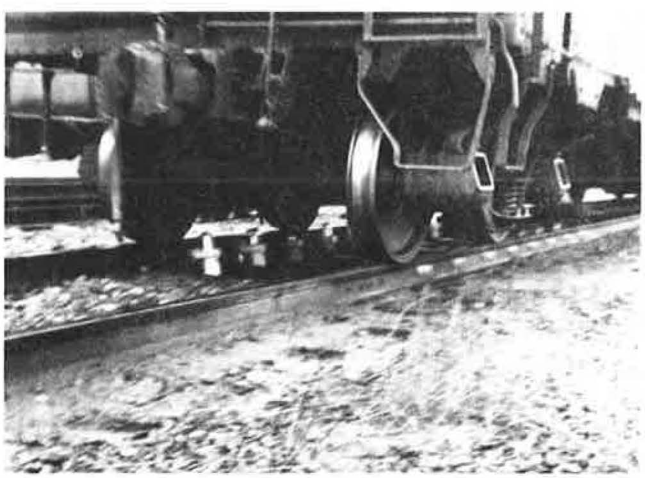
Future

Following these most satisfactory test results, production drawings and specifications are being prepared for the manufacture of latches. The six prototype units are being rebuilt and are destined for a further trial period in the Alnabru Yard in Norway, where on-site trials will be conducted with a view to future applications. Trials with the latch in Finland will of course continue until the time that the application of hold-down latches in new yards will be required.

With the advent of the hold-down latch, an operable Dowty retarder can now be offered for special applications where there is an operational need for unrestricted train withdrawal speeds.

The hold-down latch could advantageously be applied to Dowty arresters to form an operable unit. It would then be possible to turn the arresters off when trains are being pulled or in trimming movements to permit unrestricted speed coupled with an extensive working-life expectancy for the arresters.

Figure 12. Arrester zone, De Butts Yard.



END-OF-CLASSIFICATION-TRACK CONTROL

Efficient Design of Arrester Zones

Dowty arresters, i.e., hydraulic retarders in which the speed-sensitive valves are set to zero during manufacture, are installed in yards to provide end-of-track arrester zones.

In the past the arresters have been installed to form a dense bank of units situated on the change of grade, i.e., at the start of the end-of-track reverse gradient. Figure 12 shows an arrester zone in the De Butts Yard.

Because these zones, with their ease and rapidity of installation, lack of retarder squeal, immunity to wheel contamination, economic maintenance needs, and ability to operate without controls, offer an attractive alternative to skate retarders, a design study has been made of this type of application.

It was determined that an efficient and economic arrester zone can be achieved by distributing the arresters along the reverse gradient track so as to take advantage of the energy absorbed from the cars moving through a distance and the track elevation. In this manner, the kinetic energy of the car will be absorbed by

1. The rolling-resistance value times distance traveled,
2. The elevation gained by the car, and
3. The activation of the arresters by each axle of the car.

In adopting this method it is necessary to determine first the density of the arresters needed to prevent the cars from accelerating down the gradient in the reverse running direction (Figure 13).

The arrester density can be calculated from

$$d = (G - R)/E_A \qquad (1)$$

where

d = arrester density (units/ft),

Figure 13. Arrester-zone diagram.

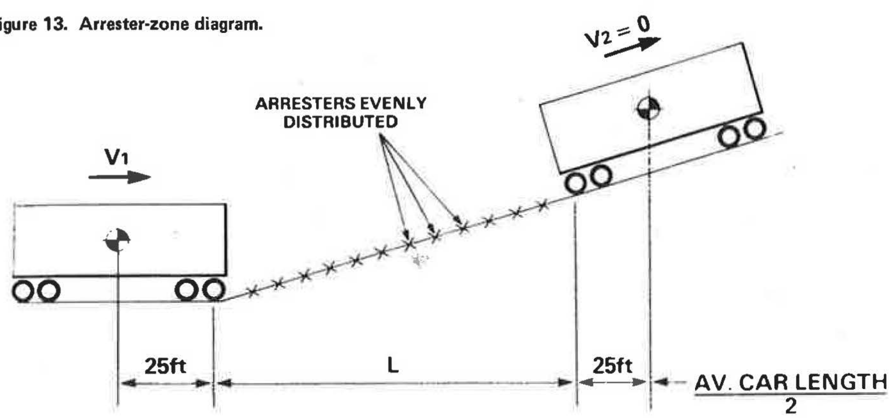
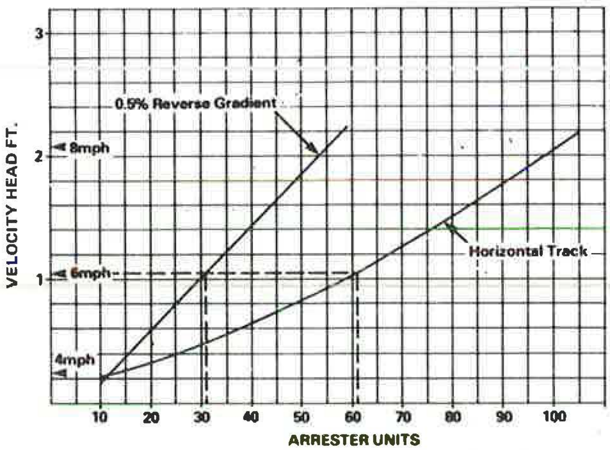


Figure 14. Velocity head versus arrester quantity for 135-ton car.



G = gradient coefficient,
R = rollability coefficient, and
E_A = arrester energy head value (ft).

Once the unit density has been determined, it is then possible to calculate the distance (L) by using Equation 2, and from this the length of the arrester zone and the minimum quantity of units can be found:

$$VH1 = VH2 + (E_A \times d \times L) + G(L + 25) + R(L + 50) \quad (2)$$

where

VH1 = initial velocity head (ft),
VH2 = final velocity head = 0, and
L = distance traveled (ft).

The value of E_A used in determining the arrester density is not the same as the E_A value used in the final equation. In the first case the energy value is appropriate to a low-speed car, and in the second case it is appropriate to the mean velocity-head value, which is dependent on the initial car velocity; the unit energy value increases with car speed.

Arrester-Zone Example

In the graph shown in Figure 14 a typical curve of velocity head versus arrester quantity has been plotted for a gradient of 0.5 percent. For this example the following parameters were used:

Parameter	Amount
Car weight	135 tons
Rollability	2 lb/ton
Arrester density	0.31 unit/ft
Car length	50 ft

For comparison purposes the curve of velocity head versus arrester quantity for horizontal track has been included to illustrate the effectiveness of the up grade. When this type of arrester zone is designed, it is necessary in some cases to temper the mathematical solution slightly by considering the desired ultimate stopping point for the car, i.e., at the top of the grade or a specified distance before.

This consideration is most pertinent where gradients are shallow or initial car velocities are high; e.g., an 8.0-mph car requires an arrester zone of 258 ft on a 0.30 percent gradient; in some cases this could bring the car close to the top of the gradient with little margin of safety. It is possible, by applying some small adjustment to the unit density value, to restrict the final length of the arrester zone and achieve a compromise quantity of units.

CONCLUSION

The developments mentioned in this paper have in the main taken place outside the North American continent. They are, however, applicable to possible projects in the United States and Canada.

Sentrarand Yard is equal in magnitude to the scale of yard developments still planned on the American continent. Its design and equipment present an excellent model of engineering for a high-throughput yard needing accurate separation in the switching area with precisely controlled speed and coupling in the classification tracks.

The method of clearing snow adopted with the Dowty retarder installation in Trondheim must, because of the nature of North American winters, be of interest. The design for Trondheim Yard illustrates how it is possible to bring the benefits of automation to miniyards, and there are those within the American railroad industry who think that there may be more of these in the future. To expand on this view, one might ask what the operating possibilities are in a miniyard that includes some herringbone track arrangements. Surely a formula should be considered for reducing the switching operations and the time spent by cars in yards.

With about 120 automated hump yards in North America, of which about 45 percent are more than 20 year old, there could exist opportunities for updating them with the Dowty classification-track control system.

The electrohydraulic hold-down latch, although designed to meet a specific yard-operating requirement, will find a wider range of uses in the future. For some installations there could be advantages in using operable arresters in order to comply with the required operating needs; retarders that can be signaled on or off could enhance the control capabilities of the Dowty systems employed in industrial terminals, where low car speeds and accurate spotting are often needed.

Arrester zones have already been installed in American yards, and engineering design proposals for planned installations are currently being considered by a number of railroad companies. These zones can also be profitably merged with classification-track control zones when yard improvements are made.

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