SECTION 2.4 HUMP CLASSIFICATION YARD DESIGN (FULL AUTOMATIC CONTROL)

2.4.1 GENERAL (2017)

a. A hump classification yard should be designed for the volume and character of traffic to be handled and should provide for continuous movement while humping with minimum loss of time between successive humping operations; also for the movement of cars by gravity from the crest to their proper tracks in the classification yard without damaging impacts.

b. Tracks at the outbound end of the classification yard should be connected to ladders so that classifications normally assembled in one train may be assigned to permit gathering from one ladder, thus providing for minimum movement of trim-end engines. A sufficient number of ladders, with lead connections to departure tracks, should be provided to permit working at least two trim-end engines where required with minimum interference. In many yards the throughput of the facility is determined by the rate you can remove cars from the classification yard; refer to Figure 14-2-1.

c. Where required, a set out track for cars with commodities that are not to be humped (inhalation hazard, explosive, etc.) as well as an escape track to release road locomotives should be installed.

d. Where a second locomotive set for continuous humping is desired a second track from the receiving yard may be required to ensure continuous operation.

e. If trains from two or more directions are to be humped in one direction over the hump, provision should be made so that cars can be moved into the end of the receiving yard next to the hump with minimum interference with humping operations.

f. It may be desirable to make up and dispatch trains from the classification tracks if local conditions permit, and such a method of operation usually expedites movements through the yard and reduces the expense. This requires that a sufficient number of classification tracks be long enough for each to accommodate a full-length outgoing train, or that lead tracks be provided at the outgoing end such that the combined length of a classification track and a lead track be sufficient for a full-length train, thus avoiding unnecessary doubling over or interference with hump operation. This may involve a temporary reassignment of classification during the inspection and preparatory time of a departing train.

g. Departure tracks may be required for making up and dispatching trains, depending on local conditions.

h. The gradient and geometry of a track leading to the crest of the hump should be such as to permit pushing the longest and heaviest train at humping speeds consistent with the proposed available power.

i. A good walkway surface should be provided at the hump crest on both sides of the track for the pin-pullers. If only one walkway for the pin-puller is provided it should be located on the right hand side when moving toward the hump. (It is desirable that cars be uncoupled from the right hand side so that the forward knuckle will be open, as the impact of normal coupling will often close the rear knuckle.)
j. Reference AREMA MRE Chapter 6 for lighting best practices.

k. Considerations for vehicle access should be given to access routes to switches, retarders and buildings within the yard.

l. Consideration should be given to maintenance of utilities supporting the hump operation. This could include electrical equipment, air valves, air tanks or signal equipment.

m. Two outer roadways running the length of the yard, and parallel with the tracks can be ideal to facilitate ease of vehicle movements from one end of the yard to the other.

n. Tracks can be set with extra wide centers between adjacent groups to give access for maintenance vehicles to move into the body of the yard.

o. The outer and inner roadways can be connected across the yard by constructing level grade road/rail crossings at the narrow ends of the track layout and where the minimum number of tracks need to be crossed.

p. For movement across the yard at the hump-end a tunnel may be constructed under the hump itself.

q. Grade crossings in classification yards, when necessary, should take into consideration type and volume of traffic.

r. Adequate car parking facilities for employee and company vehicles at the various office and workshop locations should be a consideration.

s. If the identification numbers of incoming cars are to be read and recorded by a video camera system, then special purpose high-density illumination should be provided at the camera location.

t. Modern automated hump classification yards fall into two principal categories, Intermittent Car Speed control or Continuous Car Speed control systems. A third category can be a hybrid system which combines Intermittent and Continuous control systems.

(1) Intermittent Car Speed Control System

(a) Intermittent car speed control systems in which powered, electronically supervised clasp retarders are located at discrete positions to control the velocity and progress of the cars traveling through the yard.
(b) The position and speed of the cars is constantly measured, monitored and predicted by the electronic supervisory system which commands the modes of the clasp retarders.

(c) The principal retarders, located in the switching area, are usually powered electrically or pneumatically.

(d) Other types of supplementary retarders may be needed such as tangent point retarders located at the entrances to the classification tracks, and operable skate retarders located at the exit ends of the tracks to provide securement other than tying hand brakes.

(e) The automatic control of the switches, to route the cars into classification tracks, is controlled by the supervisory system along with other operational functions.

(2) Continuous Car Speed Control System

(a) Continuous car speed control systems in which speed sensitive hydraulic retarder units are distributed as necessary to tracks to automatically control the velocity of the cars traveling through the yard. Application in curves should be avoided if at all possible.

(b) This type of retarder is self-contained and needs no exterior power supply or electronic supervisory system.

(c) These retarders are mounted in close proximity along the tracks from the hump, through the switching area and for a selected distance down into the classification tracks.

(d) An electronic control system is needed for automatic switch operation and to supervise other operational functions.

(3) Hybrid System

(a) A hybrid system that combines an intermittent control system with a continuous control system, paragraph (1) and paragraph (2), can be employed to develop a yard having high car speeds in the switching area and accurate coupling speeds in the class tracks.

(b) In such a yard design the velocity and progress of the cars in the switching area would be controlled by an intermittent car speed control system. The function of this part of the hybrid system would be to ensure adequate separation between cars so as to permit movement of the switches for routing; and to predict, monitor and control the speeds for the cars arriving at the classification tracks.

(c) The velocity of the cars in the classification tracks would be controlled by a continuous car speed control system. The function of this part of the hybrid system would be to ensure a maximum allowable coupling velocity of the cars, to promote full car closure in the tracks and to prevent car runouts from the trim-end.

2.4.2 INTERMITTENT CAR SPEED CONTROL (2017)

2.4.2.1 Hump Control Tower and Buildings
a. A control building can be located near the hump to house operators and offices. This control building should contain video systems or other methods to allow the operators a good overall view of traffic movements throughout the yard.

b. The control building may need to accommodate a variety of facilities such as:

1. A control room, in which to locate a control panel for the manual operation and monitoring of signals, switches and retarders. Operational offices with associated communications, signaling and hump process control systems.
2. Hump process control room and electrical power supply equipment with their required cable routes and ducting.
3. Utility services equipment for the building.
4. Staff amenities accommodation.

See AREMA MRE Chapter 6 for additional information on building design considerations.

2.4.2.2 On Track and Trackside Equipment – Refer to Figure 14-2-2

To support a central process controller it may be necessary to install a variety of peripheral hardware at locations on the track.

2.4.2.2.1 Car Identification Equipment

This may be a video camera system or an Automatic Equipment Identification (AEI) system to interrogate car mounted identification.

2.4.2.2.2 Hump and Trim Signal

To control train movements toward the hump crest.

2.4.2.2.3 Car Characteristics Identification Equipment

a. Pole mounted photoelectric cells and track mounted wheel detectors to monitor car cut lengths.
b. A weigh rail installed in the track to measure axle loads.
c. Wheel Detector System or Radar System to form a rolling resistance test section.
d. Radar speed detectors to monitor car speed.

2.4.2.2.4 Track Scale

A weigh in motion scale for the commercial weighing of cars. Weight information can also be for input to car speed control system. The scale would need to be installed on a suitable foundation.
2.4.2.2.5 Car Speed Control

a. Primary, intermediate, group tangent point retarders mounted in the track to control the speed of cars at strategic locations. These can be electrically or pneumatically powered.

b. An electrical supply facility to power electrically powered retarders can be constructed in the vicinity of the retarders.

c. Air supply facilities for pneumatic retarders should be located in a position to limit piping run but far enough to prevent potential intake fouling.

2.4.2.2.6 Switches

Powered switches would be needed to route the cars from the crest into the classification tracks. Electrical track circuits or proximity loops, and/or wheel detectors can be included in the switching area to monitor the progress of the cars and provide switch movement protection as required.

2.4.2.2.7 Distance to Couple

The classification tracks may be equipped with electronic circuits to determine the distance a car must travel to couple.

2.4.2.2.8 Cable Routes

a. All the above signaling and monitoring equipment would require electrical cabling enclosed in trenches, troughs, conduits or directly buried.

b. Trackside electrical equipment cases may be needed at various locations.

2.4.2.2.9 End of Track Retarders
These may be used at the trim-end of the classification tracks to provide securement other than tying hand-brakes. Reference figure 14-2-4.

2.4.2.3 Trim-End Tower or Building

a. In large yard developments with extended classification tracks, a trim-end building may be required to house signal and traffic control room from which operations in the departure end of the yard may be supervised. See AREMA MRE Chapter 6 for additional information on building design considerations.

b. The trim-end building may need to contain a number of facilities such as:
   1. A signal and control room with signaling and communications equipment.
   2. An electrical power supply equipment room with their required cable routes.
   3. Utility services equipment for the building.
   4. Staff amenities accommodation.

2.4.3 CONTINUOUS CAR SPEED CONTROL (2017)

2.4.3.1 Hump Control Buildings

a. A control building can be located near the hump to house operators and offices. See AREMA MRE Chapter 6 for additional information on building design considerations.

b. The functions of this building could be similar to that described in Article 2.4.2.1 with the following exceptions:

1. There is no manual or automatic control of this type of retarder.

2.4.3.2 On Track and Trackside Equipment – Refer to Figure 14-2-3

a. Car identification equipment as per Article 2.4.2.2.1.

b. Hump and trim signals as per Article 2.4.2.2.2.

c. Multi-unit Hydraulic Retarder system consists of self contained, hydraulically operated devices that require no external power source and bolted to rails at close intervals throughout the tracks as per Article 2.4.1.1t(2).

d. Switches as per Article 2.4.2.2.6.

e. Cable routes. The signaling and track circuit equipment would require cabling as per Article 2.4.2.2.8.

2.4.3.3 Trim-End Building

In large yard developments a trim-end building may be required as described in Article 2.4.2.3.
2.4.4 HYBRID CAR SPEED CONTROL SYSTEM (2017)

2.4.4.1 Hump Control Buildings

a. A control building can be located near the hump to house a control tower, operators and offices.
b. The description and functions of this building would be similar to that described in Article 2.4.2.1.

2.4.4.2 On Track and Trackside Equipment

a. To support the Intermittent Car Speed Control part of the system it may be necessary to install in the switching area a variety of peripheral hardware at locations on the track.
b. For a description of the type of equipment that may be included refer to Article 2.4.2.2.

NOTE: Article 2.4.2.2.9, end of track retarders may not be required.
c. For the Continuous Car Speed Control part of the system hydraulic type retarders would be needed in the classification tracks as described in Article 2.4.3.2c.

2.4.4.3 Trim-End Building

In large yard developments a trim-end building may be required as described in Article 2.4.2.3.

2.4.5 OBJECTIVE (2017)
a. The objective for constructing and equipping an automated hump yard is to facilitate an efficient and expedient method of automatically routing free rolling cars into designated classification tracks for the formation of outbound trains.

b. To achieve this objective it is necessary to meet certain design criteria within the overall concept.

2.4.5.1 Design Criteria

a. To provide a hump of sufficient elevation to ensure that all cars, having a practical rolling resistance value will penetrate far enough into the classification tracks to achieve a high percentile of closed couplings. It may be necessary to relax this requirement under severe weather conditions such as extreme cold, snow or high winds; but the minimum need is for all cars to run beyond the clearance points.

b. To form accelerating gradients from the hump that will promote separation between successive cars to facilitate the operation of switches between cars.

c. To form a series of gradients throughout the switching area of the yard so that the car speeds are compatible with the specified humping rate (car throughput) and with the chosen retarder system.

d. To automatically control the velocity and destination of the cars by providing car retarder and route selection systems respectively.

e. To form gradients in the classification tracks that will assist the cars to penetrate the tracks fully and couple at 4.0 mph maximum.

2.4.5.2 Design Methods

a. Although it is a range of rolling resistances that influence the gradient profile of a yard, it is the retarder system that assumes the primary role in yard design by the fact of measuring and monitoring the car speeds to achieve the desired throughput, controlling acceleration, maintaining separation in the switching area and determining car performance in the classification tracks.

2.4.5.3 Typical Retarder Control Systems

2.4.5.3.1 Intermittent Control System

2.4.5.3.1.1 Automatic Yard

a. In an automatic yard employing intermittent retarders and a process controller system the cars are weighed and classified after leaving the crest of the hump. Rolling resistance measurements are taken at one or more test section locations. This information is stored for reference in predicting the car exit velocities from the group and/or tangent retarders.

2.4.5.3.1.2 Primary Retarder

a. The primary retarder is used to adjust the velocity of the cars in order to maintain adequate separation between them; and to assist the speed control function of the group retarders by providing suitable exit velocities from the primary retarder.

b. As a car passes through the primary retarder, the braking shoes are applied at no more than the maximum pressure allowable for the car’s weight category. Radar units measure the speed of the car moving through the retarder and transmit information to the process controller in the form of a constant feedback loop to continuously monitor car speed and determine the retardation force required.
2.4.5.3.1.3 Group Retarder

a. The speed control method is the same through the group retarders as for the primary retarder except that in this case the exit velocities must be adjusted for the cars running varying distances down the classification tracks to finally couple at a maximum 4 mph.

b. The rolling resistance value of the car, based upon the information collected at the test sections, is modified in accordance with track and car characteristics. The track resistance characteristics are determined from computer models and practical tests made prior to the system being operational.

c. The classification tracks are equipped with electronic distance to couple circuits which monitor the positions and speeds of the cars and transfer this information to the process controller; from this the exit velocity from the group retarder is determined for each car. This exit velocity will be automatically and continually modified during switching operations to strive to achieve the maximum performance in cars coupled not exceeding 4 mph.

2.4.5.3.1.4 Tangent Point Retarders

a. For some yards, where the distance from the group retarder to the tangent points, and the distances to couple are extensive or increased throughput is desired, it is necessary to employ tangent point retarders to attain the required car performance in the tracks.

b. The exit speeds from the group retarder are then controlled so that the cars arrive with predicted velocities at the tangent point retarders. These retarders, being radar equipped will monitor and control the car speed in accordance with the distance to couple information.

2.4.5.3.1.5 Clasp Type Retarders

a. The clasp type of retarders used in intermittent car speed control systems act upon sides of wheels. The brake shoes apply a frictional force to slow the wheels of the car; this force is controlled in increments that are proportional to the car weight classes.

b. Variations of these types of retarders are:

(1) Pneumatically powered.

(2) Hydraulically powered.

A primary or group retarder can be of various lengths and is installed on a well-constructed and consolidated foundation. The mechanical components and associated steelwork are integrated in assembly with special ties that have custom made supports on which the running rails are attached within the retarder. This type of retarder, due to the frictional action at the brake shoe to wheel interface can in some instances emit loud noise levels of high frequency. Dependent upon location, it may be an environmental requirement to construct acoustical barriers in close proximity to the retarders. Maintenance and lighting should be considered in the design of acoustical barriers.

2.4.5.3.1.6 Typical Gradients

Typical gradients associated with this type of yard are illustrated in Figure 14-2-4. In the design of the track profile for a classification yard, the gradients will depend upon factors such as car throughput, range of car rolling resistance values, track curvature and turnouts, and local weather conditions. Due to the steep grades at the crest, it may be desirable to add a short section of +0.50% grade between the approach grade to the crest and the -2.5% grade descending into the classification yard. This will reduce the amount of binding in the knuckles and allow easier uncoupling of the cars. Final design of the gradients in the yard should be modeled to ensure optimal performance for all car mixes.
2.4.5.3.2 Continuous Control System

a. In a yard employing the continuous control method the car velocity for the switching area, i.e. from the hump to the tangent points, is selected during the yard design stage. This switching area velocity is dependent upon the humping rate, separation between cars, range of car rolling resistance values, range of wheel diameters, the track characteristics and the length of the switching area. The hydraulic retarder units are then calibrated during manufacture to control all cars constantly at this selected velocity.

b. Hump.

   i. The hump, for this type of yard will compromise concurrent concave and convex vertical curves and finish at the first switch.

   ii. The hump is used to accelerate cars to the switching area velocity and the installation of the retarder units commences in the sag curves at the point where the minimum rolling resistance car attains the switching area velocity.

c. A constant gradient is formed from the first switch to the tangent points in the classification tracks. This gradient is designed for a modified rolling resistance value comprising car rolling resistance plus air, wind and track characteristic resistances. These characteristics, together with the maximum car weight will determine the quantity of retarder units needed to provide continuous speed control.
d. At the tangent points, or in some instances the clearance points, deceleration zones are used to slow the cars from the switching area velocity to a 4.0 mph coupling velocity and are situated on the initial gradients at the beginning of the classification track.

e. The quantity of retarders needed for each zone will depend upon the change of velocity required, the maximum car weight and the initial classification track gradient.

f. Typically, the initial classification track gradient can continue for approximately one third of the total track length with retarders installed along the track to prevent the heavy, low rolling resistance cars from accelerating above 4 mph. This initial gradient will assist the penetration of cars down into the tracks and provide a high percentile of coupling.

g. The hydraulic retarders used in continuous control systems are relatively small units installed at close intervals along the tracks. They are fixed to the inside of the running rails and actuated by the wheel flange.

h. Typical gradients associated with this type of yard are illustrated in Figure 14-2-5. In the design of the track profile for a classification yard the gradients will depend upon factors such as car throughput, range of car rolling resistances, track curvature and turnouts, and local weather conditions.

![Figure 14-2-5. Track and Profile Diagram (Continuous Control)](image)

2.4.5.3.3 Hybrid Control System

a. The formulation of a hybrid system of car speed control is based upon the use of the clasp type of retarders, with process controller, in the switching area to perform the duties of maintaining separation and controlling the group retarder exit speeds; and a continuous control system that commences with deceleration zones in the classification tracks and continues with coupling speed control zones.
b. The intermittent control system in the switching area would be as described in Article 2.4.5.3.1.1, Article 2.4.5.3.1.2, Article 2.4.5.3.1.3 and in some cases Article 2.4.5.3.1.4 with a modification to the group retarder exit speed requirements, and the distance to couple circuits would not be needed for speed control. The last active retarder exit velocities would be controlled to provide a bandwidth of velocity for the cars arriving at the deceleration zones, with the lower limit of velocity being applied to the low rolling resistance cars and the higher limit to the high rolling resistance cars in order to ensure good penetration of the light cars through the zone.

2.4.5.4 Design Parameters

In preparing for a classification yard design it is necessary to ascertain the parameters.

Car throughput, the rate at which cars will be expected to pass over the hump. This can be expressed as the humping velocity. For example 2 mph = 3 - 60' cars per minute.

a. The vertical convex and concave curves for the hump profile should be specified in order to ensure adequate clearance from the car structures, prevent binding of car knuckles and insure adequate cut separation.

b. The maximum and minimum car weights should be stipulated in association with car types, length and wheel diameter.

c. Details of the weigh scale length should be ascertained, with the minimum response and record times, in order to be able to specify the minimum time that a car must occupy the scale to produce valid recordings before first point of control.

d. One of the most important parameters is the range of rolling resistance values for the variety of cars to be humped. Detailed research and analysis should be undertaken to determine practical values. A good source of information is the printouts from existing control systems that are already operating in established yards. The basic tangent rolling resistance values for the total car population should be ascertained and specified.

e. In the event of a catch-up between leading and following cars, the movement of the automatic switches is locked in position to prevent derailments. Various types of electrical switch protection circuits can be employed to guard the switches. In order to be able to specify the minimum separation distance between cars it is necessary to ascertain details of the circuits, such as occupation length and response time, along with the response and operating times for the switch machines.

f. Where clasp retarders are used, a retarder of sufficient length should be designed to stop the heaviest good rolling car in the event of an emergency (assuming application of braking throughout the entire retarder). Designing for either primary or group retarders alone to be capable of stopping a car can cater to this requirement. Another option is to design for the primary and group retarders in unison to have sufficient total retardation to stop the heaviest good rolling car (assuming application of braking throughout the entire retarder). The preferred requirement should be specified.

g. The geometric data of curves and turnouts for all tracks will need to be specified for a well-designed yard layout. The layout for curves and turnouts are designed to make the distance from crest to clearance point as short as possible. This will reduce the height of the hump, which
reduces the amount of retarders required. The shorter distance also improves yard performance by shortening the time a car is in the switching area and reduces the chance of catch-ups.

h. Additional gradient, to compensate for curve resistance, may be added with advantage to the long curves that lead to the outer groups of tracks.

i. Standard turnouts should be preferred to any of special design as these may not be readily available in a future emergency if a replacement switch panel is needed.

j. End of track retarders in combination with a prevent rollout gradient, should be considered to avoid car run outs. The retarder capacity must be designed to stop a heavy car at a specified maximum velocity.

2.4.5.5 Theory

2.4.5.5.1 Car Velocity

a. The velocity of a car traveling along a gradient can be determined at any point by the equation

\[ V^2 = 2gh \]

where:

- \( V \) = car velocity, ft/sec
- \( g \) = gravitational acceleration, i.e. 32.2 ft/sec^2
- \( h \) = energy head, ft

b. The energy head, \( h \) can be the potential energy, due to the elevation on a gradient, that will accelerate a car to velocity, \( V \) (ignoring resistance losses); or it can be the velocity head, in which case it is the energy invested in the car velocity; for clarity, let \( H \) feet = velocity head and \( h \) foot = potential head, refer to example Article 2.4.5.5.4.

c. This basic energy equation needs to be modified to include two coefficients that affect the movement of a car, these are:

- The rolling resistance coefficient, \( R \).
- The coefficient \( k \), to allow for the inertia of the wheel sets.

2.4.5.5.2 Rolling Resistance

a. The rolling resistance of a car can be expressed as a coefficient, a force per weight ratio or an equivalent percentage gradient, i.e. 0.003 = 6.0 lb/ton = 0.3%. This expression states that a car with a rolling resistance coefficient of 0.003, or 6.0 lb/ton resistive force, would travel with constant velocity on a 0.3% gradient tangent track. The total rolling resistance value for a car is the sum of the tangent rolling resistance + curve and turnout resistance + air and wind resistance.

b. Typical rolling resistance coefficients are:
Tangent rolling resistance = 0.0005 min. to 0.006 max
Curve resistance = 0.0004 to 0.0005/degree

Air/Wind resistance is heavily dependent on car configuration and environmental geometry. Modeling may be used to determine numbers.

NOTE: In a Continuous Speed Control system an additional factor must be introduced to allow for the idling resistance of the retarder units when operating below their threshold control speed.

2.4.5.5.3 Wheel Inertia

a. The coefficient:

\[ k = 1 + \left( \frac{X wr^2}{WD^2} \right) \]

where:

- \( X \) = number of axles * 2
- \( w \) = weight of wheel set, lbs
- \( r \) = radius of gyration of wheel set, in.
- \( D \) = wheel tread diameter, in.
- \( W \) = Car weight, lbs

b. For an estimate of car performance on a given gradient a simplified value for \( k \) can be determined from:

\[ k = \frac{W + 4000}{W}, \text{ for a 4-axle car} \]

c. Typical car weights are 40,000 lbs. to 315,000 lbs.

2.4.5.5.4 Change in Velocity

a. To determine change in velocity refer to Figure 14-2-6.

let:

- \( V_0, V_1, \text{ and } V_2 = \text{velocity, ft/sec} \)
- \( H_0, H_1 \text{ and } H_2 = \text{velocity head, ft} \)
- \( h_1, h_2 \text{ and } h_3 = \text{potential head, ft} \)
- \( D_1 \text{ and } D_2 = \text{distance, ft} \)
- \( G_1 \text{ and } G_2 = \text{gradient coefficient} \)
b. To determine $V_1$:

\[ V_1^2 = \frac{(2gH_1)}{k} \]

\[ H_1 = H_0 + h_1 - (D_1R) \]

Also $H_0 = 0$ and $h_1 = (D_1G_1)$

subs. $H_1 = D_1(G_1 - R)$

Then $V_1 = \sqrt{\frac{(2gH_1)}{k}}$ ft/sec

c. To determine $V_2$:

\[ V_2^2 = \frac{(2gH_2)}{k} \]

\[ H_2 = H_1 + h_2 - (D_2R) \]

also $H_1 = V_1k / 2g$ and $h_2 = (D_2G_2)$

subs. $H_2 = H_1D_2(G_2 - R)$

then $V_2 = \sqrt{\frac{(2gH_2)}{k}}$ ft/sec
2.4.5.5.5 Car Separation

The lengths of the Intermittent Control retarders and the weigh scale, and the operation of the switches make it necessary to predetermine the separation of the cars as they travel from the crest of the hump to clearance points in the class tracks.

**NOTE:** In a Continuous Control system only the separation needed to operate the switches has to be considered.

2.4.5.5.6 Time/Distance Curves

a. Each car must be accelerated away from the hump to produce adequate separation distance between cars and this distance must be maintained at a minimum length throughout the switching area. In order to study and analyze the car’s performance and separation it is necessary to compute Time/Distance curves and to introduce retardation at critical points in order to adjust speeds and maintain separation.

b. In order to design for a worse case situation it is necessary to take into consideration the separation changes between a light, high rolling resistance car when followed by a heavy, low...
rolling resistance car, each routed to adjacent class tracks. There must be adequate separation down to the last level of switches; and finally, a following car must not coincide with a leading one until after the clearance points.

c. For Intermittent Control systems, retarders must be located at the critical points of the Time/Distance curves in order to adjust car speeds and prevent catch-up between cars of varying rolling resistance values. The exit speeds from the last active retarder must be varied to match the distance the cars must run to couple in each class track; when a track is nearly full these exit speeds will be relatively slow and this must be allowed for in the Time/Distance curve by plotting a heavy, low rolling resistance car followed by a light, high rolling resistance car that may need to run un-retarded; refer to the sketch of Time/Distance curves in Figure 14-2-7.

d. In Continuous Control systems the car velocity, after initial acceleration, will be nearly constant with little change in separation; it is however, necessary to allow for a speed control bandwidth due the variation in wheel diameters; refer to the sketch of Time/Curves in Figure 14-2-8.

![Figure 14-2-7. Sketch of Time vs. Distance Curves (Intermittent Control)](image)
2.4.5.7 Retardation

a. A typical intermittent retarder yard will comprise a primary retarder and a number of group retarders: the primary will be situated near the hump and its function is to adjust speeds for separation control. The groups, located at the end of the switching area gradient, control the speeds of cars entering the class tracks; their prime function is to release cars at predicted speeds in order to achieve 4.0 mph coupling at varying distances down the tracks. This method of operation is often referred to as target shooting and employs Distance to Couple circuits in the tracks, combined with computed exit velocities from the groups. If tangent point retarders are used at the entrance to the tracks, then the groups will target shoot to these and the tangent point retarders will then control the final distances and coupling speeds.

b. In a Continuous Speed Control system the retarder units are installed at regular intervals throughout the switching area and for distances down into the class tracks. The quantities of retarders needed to provide speed control are dependent upon the control velocity, and are directly proportional to the effective gradient (gradient minus total rolling resistances) and the maximum car weight.

\[
Retarder \text{ density} = \frac{A \times (G - R_{\text{min}})}{E}, \text{ units / ft}
\]

where:

\[
A = \text{Maximum axle load, ton}
\]
G = Gradient coefficient

R_{min} = Minimum total rolling resistance coefficient

E = Retarder energy, ft ton / unit at specified control velocity

c. At the tangent points the retarders are installed in dense banks, forming deceleration zones to slow the cars from the switching area velocity down to a 4.0 mph coupling speed.

Quantity of retarders / zone = A \left( V_{SA}^2 - V_{CV}^2 \right) \cdot k / (2gE)

where:

\( V_{SA} \) = Switching area velocity, ft/sec

\( V_{CV} \) = Allowable coupling velocity, ft/sec

d. As a slight accelerating gradient is usually extended down into the class tracks it is necessary, in order to maintain a coupling speed of 4.0 mph maximum, to continue with a speed control section comprising an appropriate quantity of retarder units. The retarder density can be determined by applying the formula used above to calculate unit density in the switching area.

2.4.5.7.1 References

References used in this Part are located at the end of this chapter. See Reference 1, 2, 3, 4 and 5.

References

The following list of references used in Chapter 14, Yards and Terminals is placed here in alphabetical order for your convenience.

1. *Assessment of Classification Yard Speed Control Systems*, SRI.


2.4 Hump Classification Yard Design (Full Automatic Control) ........................................ 14-2-7
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