Locomotive Braking Systems

Rationale

Why is it important for you to learn this material?

This module will help you set up and use the braking systems so that you can safely and effectively slow, control and stop locomotive and train movement.

Learning Outcome

When you complete this module you will be able to…

Detail the operation of the locomotive braking systems.

Learning Objectives

Here is what you will be able to do when you complete each objective.

1. Describe Dynamic Braking, its components and operation.
2. Identify the components of the locomotive air brake system.
3. Describe the operation of the independent brake.
4. Describe the operation of the automatic brake.
5. Explain the difference between the emergency brake and penalty application and the recovery procedures.

Prerequisites

- Locomotive Overview
- Locomotive Cab Controls and Equipment
- Locomotive Operations

OBJECTIVE ONE

When you complete this objective you will be able to…

Describe the components and the operation of the dynamic brake system.

Learning Activity

Complete each of the Learning Activities listed below.

1. Study the Learning Material.
2. Complete Exercise One.

Learning Material

What is Dynamic Braking?

Dynamic braking is a method of braking used to control train speed on descending grades and to reduce train speed when stopping. This is accomplished by changing mechanical power, developed by the momentum of a moving locomotive, into an effective retarding force. Electrical circuits are set up to change the traction motors into generators. It is characteristic of a generator (traction motor) to resist rotation when it is producing electricity. The resistance set up in each traction motor is a magnetic field through which the traction motor armature must rotate. The movement of the dynamic brake handle controls the strength of the magnetic field and the braking effort. Rotation of the armature through the magnetic field generates braking current. This current is sent to the resistor grids that are fan cooled, where the excessive electrical current is dissipated as heat.

Use of Dynamic Brake

Dynamic braking can often be used to effectively control train speed on descending grades during slow downs and stops. Because dynamic braking concentrates the retarding force at the head end of a train, similar to independent braking, there are practical limits to the amount of braking that should be done with the dynamic brakes. Extreme care must be exercised to avoid the development of excessive buff forces.

A heavy concentration of braking forces can also create high levels of lateral force which will, in effect, develop high L/V (lateral /vertical) ratios. Excessive forces developed by this may result in a derailment or gradual deterioration of the track structure. If the forces occur at turnouts, crossovers, points of sharp curvature, or other types of track irregularity, the impact magnifies. Train makeup can have a substantial impact on these forces and consequently merit attention by the engineer. Any combination of light cars, long cars, coupled to heavy short or long cars, or couplers misaligned, specifically at locations near the engines, will increase the possibility of damage or derailment if care is not exercised.

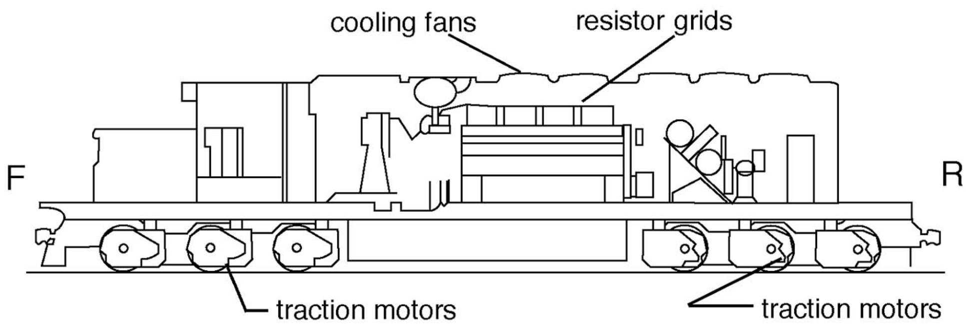

Figure 1 - Dynamic Brake Components

Dynamic Braking Control

The Locomotive Engineer controls the amount of dynamic braking by moving the dynamic brake handle. The load meter/tractive effort gauge shows how much amperage/retardation the traction motors are developing. The higher the amperage/reading-on-the-gauge, the more retarding force is being developed.

Components (See Figure 2)

1. Traction motor (gear driven by a turning wheel)
2. Dynamic brake control handle.
3. Resistor grids
4. Grid blower motor and fan (to cool resistor grids)

Figure 5 depicts DB capability of standard range locomotives, extended range locomotives, and also the capabilities of modern AC locomotives that we currently have in our fleet. It should be noted the ability of the AC locomotives to generate retarding forces down to zero miles per hour. This offers the engineer the option of using dynamic brake to control train operation during slow downs and stops on both level track and descending grade territories.

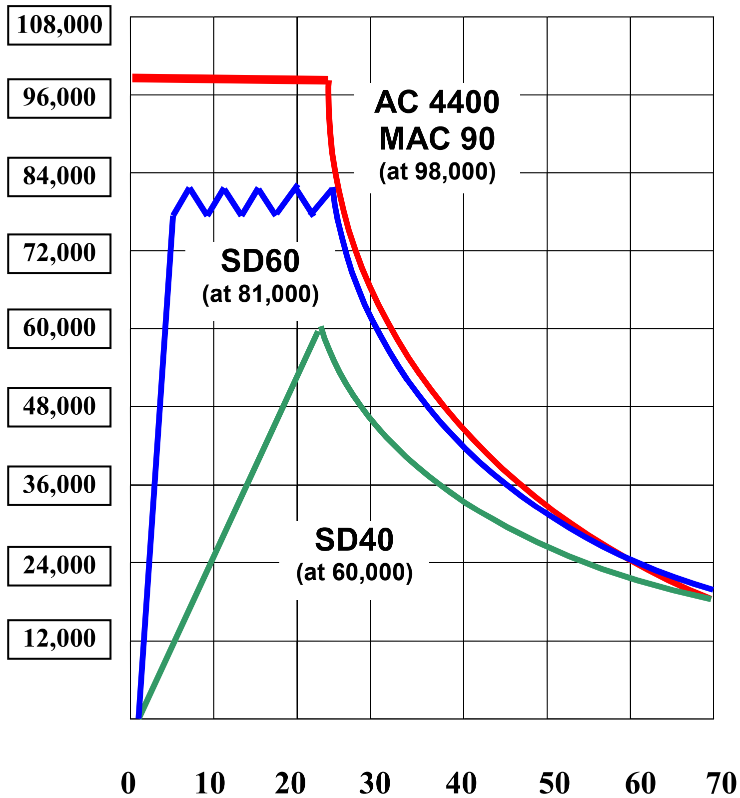

Figure 5 - Dynamic Braking capabilities of various locomotives

E. Length of the Train

You must be aware of the length of the train as it influences the application and release of the brakes, as well as the handling of the train on different grades.

> **Example:** A short heavy train will shift its weight rapidly as it interacts with the track structure while a long light train will take longer to shift its weight as it interacts with the track structure.

F. Weight of the Train

The weight of the train is affected by the following:

- The number of loads.
- The number of empties.
- The distribution of loaded or empty cars.
- The total tonnage of the train.
- The effect of the total train weight (same car count, different tonnage).
- The tons per operative brakes.

> **Example**: Gross tonnage divided by total number of cars with operative brakes equals tons per operative brake

6000 Tons / 100 cars = 60 Tons per Operative Brake

Tons per operative brake should be calculated before the start of each trip.

G. Braking Characteristics of the Train

Determining the braking characteristic of a train is essential as no two trains handle the same. Consider the following:

- The braking ratio (the total braking force available on the car divided by the weight).
- The percentage of operative train brakes.

Note:	When calculating the percentage of operative train brakes, include both locomotives and cars.

A. Draft Force

This is the tension that exists between the couplers when a train is stretched (as with the initial movement of starting a train). It is caused by tractive effort and also occurs when locomotives are pulling a train up an ascending grade or from stretching any slack condition.

B. Stringlining

This is the tendency of cars to pull to the inside of curves, attempting to create a straight line when in high draft conditions.

C. Buff Force

This is the compression that exists between couplers when the train is bunched. It is created by:

- a run-in of slack
- back up movements
- retarding forces in dynamic brakes
- retarding forces in air brakes, automatic or independent.

D. Retarding Force

This is any force which acts to retard the speed of your train, grade, curvature or wind. This can develop through the use of the dynamic brake or air brakes, which retard or slow the train. Retarding forces are measured in pounds. The retarding force from the dynamic brake varies. A retarding force due to the air brakes gradually increases as the speed decreases.

E. Vertical Force

The weight of the freight cars or locomotive(s) is transmitted to the rail by the wheels. The force that is created by this weight is called the vertical force and it is necessary for adhesion. In general, the wheel tread transmits the vertical force. Vertical forces between the wheel and the rail are measured in pounds of pressure.

F. Adhesion

Adhesion is used to describe the capability of the wheel to hold the rail without slipping.

Adhesion is affected by the condition of the rail, curves, weather and wheel wear.

G. Tractive Effort

Tractive effort is the force exerted by a locomotive on the track to get a train moving and to keep it moving. It is measured in pounds. It decreases as the speed increases in a given throttle position. Different locomotives develop tractive effort at a different rate.

Note:	Tractive effort developed by today's high horsepower locomotive(s) can be in excess of what draft gear can withstand.

H. Lateral Force

Lateral force is the force between the wheel and the rail at a right angle to the vertical force. It is the lateral force that causes a wheel to follow the rail around a curve. In general the wheel flange transmits the lateral force to the rail. The lateral force between the wheel and the rail is measured in pounds of pressure. Light or empty cars are more easily affected by high lateral force. Speed is the largest factor in developing lateral force.

I. Harmonic Rock and Roll

This is the side to side rocking motion that shifts the car weight alternately from one rail to the other. This problem primarily relates to high capacity/high center of gravity cars. This can cause load shift, derailment, and wear of the truck components. This most often happens on jointed rail, at speeds between 13 and 21 mph.

J. Truck Hunting

An unstable wheel set, weaving side to side along the track with the flange striking the rail. It occurs most frequently on empty, high center of gravity equipment operated over continuous welded rail at speeds above 45 mph.

K. Centrifugal

Centrifugal refers to the outward force that is transmitted to the outside wheel on a curve.

L. Jackknifing

A condition involving two coupled rail vehicles in which there is excessive center sill misalignment and coupler angularity. Jackknifing is caused by high buff forces in the train, such as when excessive tractive effort is used to shove a train or when excessive retarding force is used to slow a train.

M. Road Structure

In an effort to make sense of dynamic forces and their relation to your train handling strategy, you must also be aware of the road structure.

Road structure is the awareness of the track you are operating the train on. This includes being aware of approaching track grades or changes in grade, curvature, switches, speed restrictions etc.. A Track Profile provides you with an overview of the area of track you are operating on and specifies grade, curvature of the track, signal locations, mileage, etc.

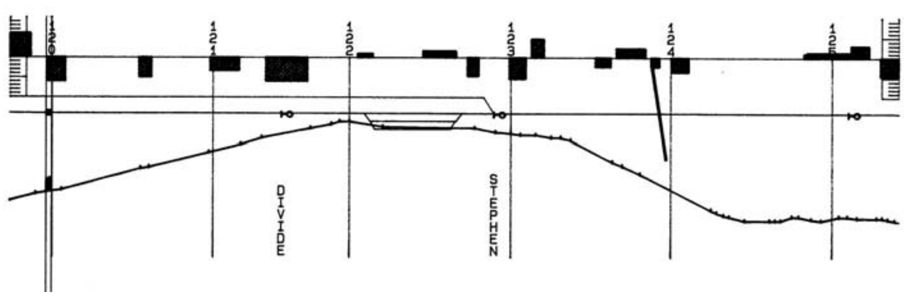

Figure 5 – Track Profile

N. Track Grades

Track grades influence the reaction of dynamic forces. The specific track grades are illustrated as follows:

Undulating Grade

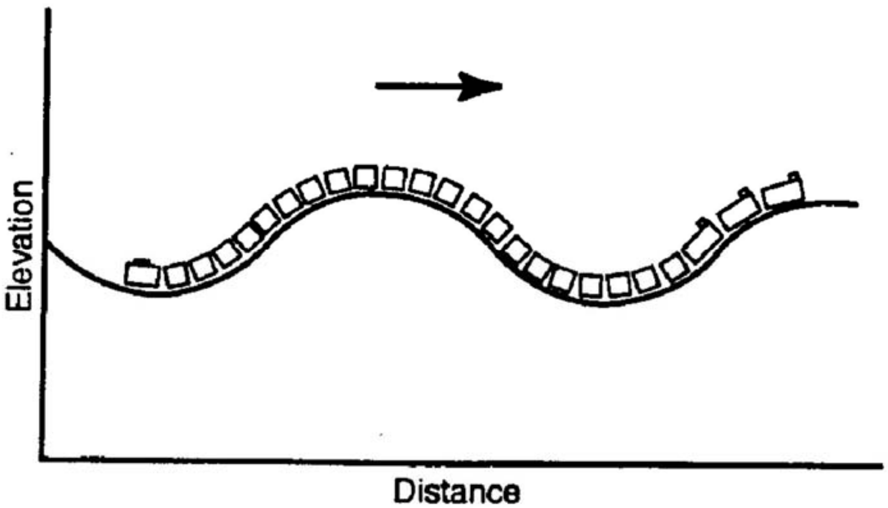

Figure 6 – Undulating Grade

An undulating grade refers to a track with grade changes so often that an average train passing over the track has some cars on three or more alternating ascending and descending grades. The train slack is always adjusting, as cars on the descending grades tend to roll faster than those on the ascending grades.

Ascending Grade

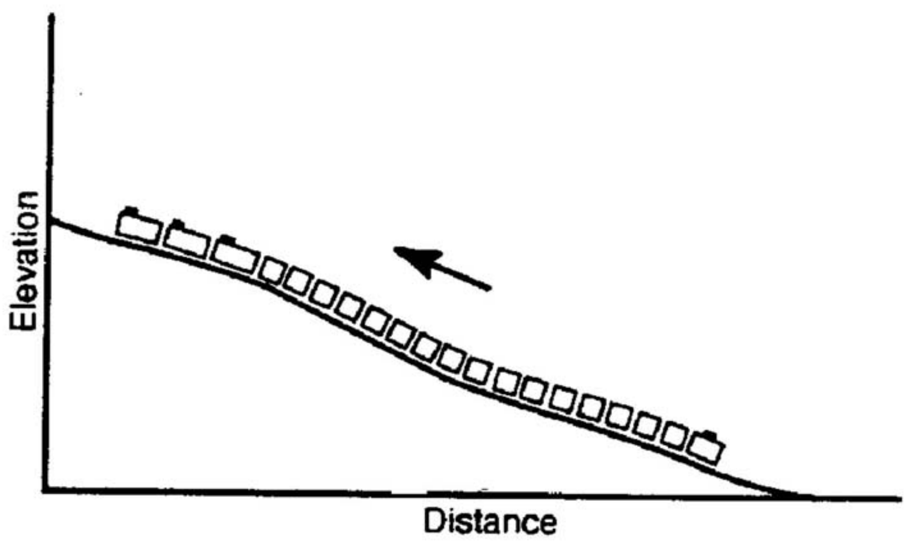

Figure 7 – Ascending Grade

An ascending grade describes track where elevation increases. An ascending grade is considered light when the grade is less than 0.8%, heavy when the grade is between 0.8% and 1.8%, and a mountain grade when the ascent is greater than 1.8%.

A 1% grade = a one foot rise in elevation for every 100 foot run of track.

Descending Grade

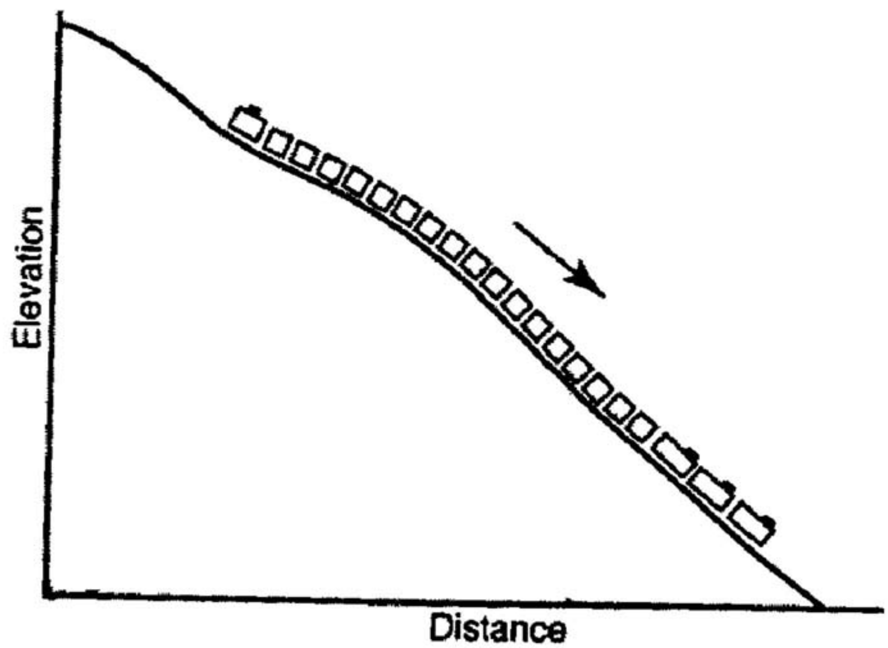

Figure 8 – Descending Grade

A descending grade describes a track where elevation declines. A descending grade is considered a mountain grade when the descent is greater than 1.8%, heavy when the grade is between 1.8 % and 0.8%, and light when the grade is less than 0.8%.

Cresting Grade

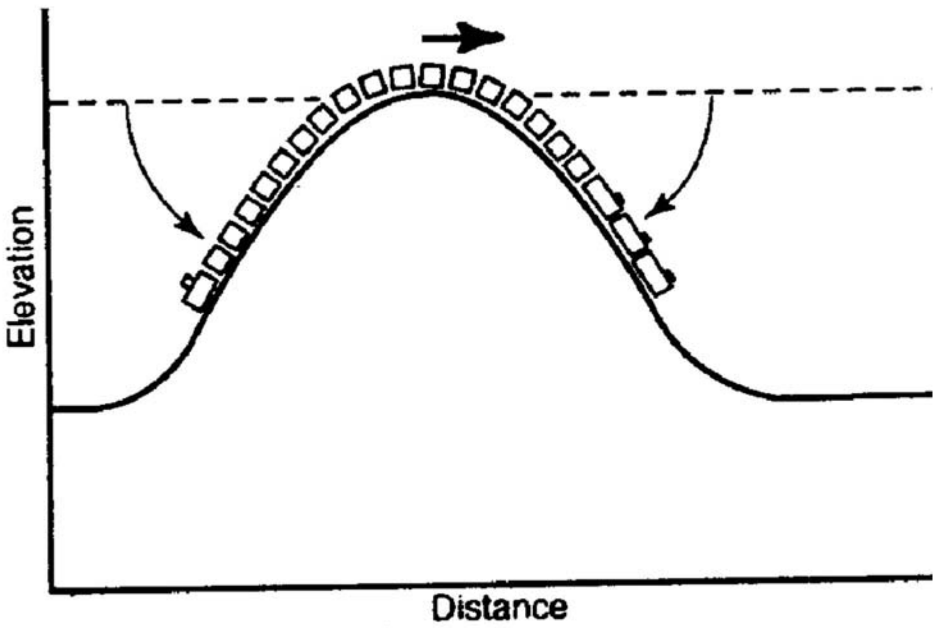

Figure 9– Cresting Grade

A cresting grade is a long ascending grade which rapidly changes to a long descending grade, both of significant magnitude, (usually on heavy grades), requiring a change in the train handling strategy when the grade is topped.

Sag or Dip

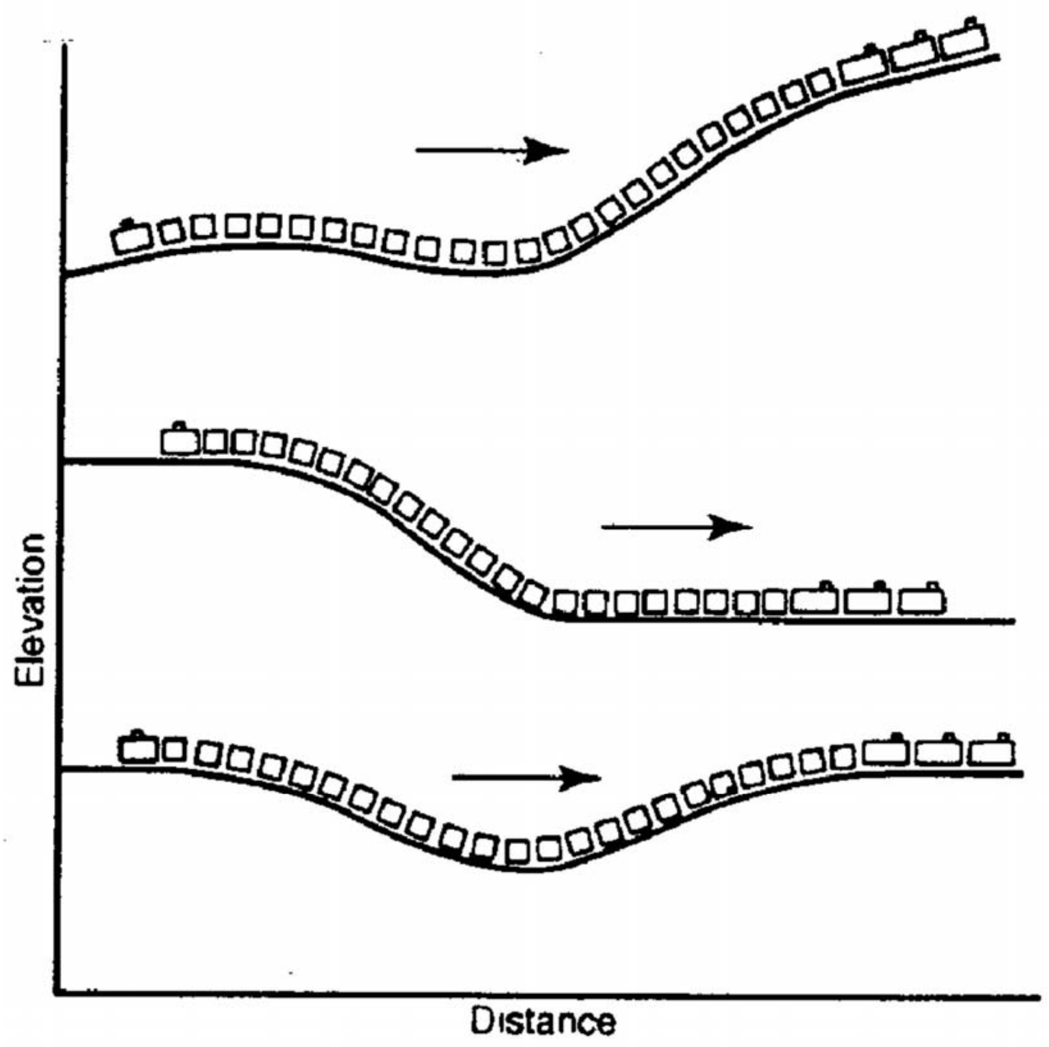

Figure 10 – Sag or Dip

A sag or dip refers to a track with a rapid decrease in grade followed by an increase in grade sufficient to result in abnormal slack adjustment.

Exercise Two

1. Explain the difference between an undulating grade and a cresting grade.

2. An ascending grade is considered light when it is less than _________%.

3. A descending grade is considered heavy when it is between __________% and _________%.

4. A descending grade is considered a mountain grade, when the descent is greater than _________%.

5. Tractive effort developed by today's high horsepower locomotive(s) can exceed the limits of draft gear.

   True   False

1) Automatic Brake

Whenever practicable, to ensure the release of all freight train brakes after a brake application, the total brake pipe reduction should be 10 psi or more before the release is made. An overall reduction of less than 10 psi should therefore be increased to 10 psi or more before releasing.

During service automatic air brake application, the locomotive independent air brake must not be allowed to apply.

Should the locomotive brake pipe pressure be reduced below 48 psi during service brake operation, the train must be stopped and the brake system recharged.

When commencing a service application and the train air brake system is fully charged, the initial equalizing reservoir reduction must not be less than 5-7 psi.

To avoid an undesired release of train brakes, when commencing a service application and the train air brake system is NOT FULLY charged, one of the following methods must be used:

a) Determine the amount of false gradient, reduce equalizing reservoir pressure 7 psi plus the amount of false gradient

Note:	The following explains the true and false gradient concepts. **True Gradient**: After charging or recharging, if brake pipe pressure (BPP) on the rear car has stopped rising, then the train air brake system is considered fully charged (true gradient). For example, the rear car has reached 88 psi and will not increase any more. **False Gradient:** During charging or recharging, if BPP on the rear car is still rising, then the train air brake system is not fully charged (false gradient). For example the rear car has reached 85 psi, but the pressure is still rising. False gradient is anytime the rear car of the train is not fully charged.

Amount of False Gradient: equals true gradient minus false gradient.

For example:

88 psi	highest/normal rear car BPP	(true gradient)
- 85 psi	current rear car BPP	(false gradient)
= 3 psi		(amount of false gradient)

Example: The amount of false gradient is 3 psi (see above explanation). When you reduce the equalizing reservoir pressure 7 psi plus the amount of false gradient, the result is 7 +3 = 10 psi.

OBJECTIVE THREE

When you complete this objective you will be able to…

Determine the operating conditions that will affect your selection of the safest, most effective train handling strategy.

Learning Activity

Complete each of the Learning Activities listed below.

1. Study the Learning Material.
2. Complete Exercise Three.

Learning Material

After you have considered the equipment you are working with and evaluated the dynamic forces present in your working environment, you must determine how each of these will interrelate with one another, affecting the overall operating conditions. Knowledge of all of these elements and how they relate will help you to develop a successful overall train handling plan.

A. Throttle Operation

1. Initial Movement

The initial movement refers to starting trains. Factors to be considered when doing so are:

- Tractive effort of locomotives in consist.
- The throttle response characteristics of the locomotive consist.
- The weight and length of the train.
- The amount of slack in the train.
- The weather conditions.
- The grade of the track.
- The conditions of the rail.
- The proximity of curves in relation to the head-end of the train.
- The marshalling of the train.

b) When the rear car brake pipe pressure is known, make an equalizing reservoir reduction of at least 7 psi below the rear car brake pipe pressure.

c) When the rear car brake pipe pressure is not known, use the equalizing reservoir gauge, and measure at least a 7 psi reduction from the point where the heavy service exhaust starts to blow.

Note:	In Locotrol operation, the sound of the heavy service exhaust must not be used to measure a service reduction.

Note:	In the application of paragraphs (a) and (b) above, if TIBS fails to display rear car brake pipe pressure and it is necessary to apply the brakes with the train air brake system not fully charged, and equalizing reservoir reduction of at least 5 psi more than the last reduction must be made.

Do not make a running release if excessive brake pipe leakage is indicated or severe slack action occurs on the brake application.

The speed at which a running release may be satisfactorily made depends on conditions such as the amount of the brake pipe reduction, grade conditions, brake pipe leakage, and the number of cars in the train.

After a running release has been made and the speed of the train has been reduced to the point that it is evident the train will stall, an additional service brake application must be made to stop the train.

When making running releases of service applications, it is important to allow sufficient time for the release of the brakes throughout the train before increasing the power. Applying too much power too soon after initiating the release can result in a break-in-two if the slack conditions are not favorable.

Reporting Undesired Brake Releases

Locomotive Engineers are responsible for reporting undesired brake releases immediately to the RTC/Dispatcher and to record the location of the occurrence by subdivision and mile, as well as by the description of the use of the automatic brake prior to the release, for furtherance to the Road Manager/Road Foreman.

Minimizing Sticking Brakes

To minimize sticking brakes:

- The train brake system must not be overcharged above the standard pressure for that train, unless otherwise specified as per special instructions.

- The brake pipe pressure on the locomotive handling cars to be placed in the rear portion of the train during switching operations, should be 15 psi or less than the standard pressure for that train.

- Whenever an angle cock is closed in a train such as when changing a defective air hose, a build up of brake pipe pressure in the cars ahead of the closed angle cock will result. In order to eliminate this build up of pressure (overcharge condition) from causing sticking brakes, a full service brake pipe reduction must be made before the angle cock is closed.

- When a running release of the train brakes is to be made, have the brake pipe pressure reduced at least 10 psi and the brake pipe exhaust stopped at least 20 seconds before releasing.

- When air brakes are used to stop a train, if a 15 psi brake pipe reduction has not been made, it must be increased, when practicable, to that amount before releasing the train brakes. The brakes should not be released until at least 20 seconds after the brake pipe exhaust has stopped.

Emergency and Penalty Brake Applications

An emergency brake application must not be made unless it is necessary. In cases that require stopping in the shortest possible distance, such as to avoid imminent contact with someone or something that could result in harm to members of the public, employees or property, or when contact has been made, an emergency brake application must be made.

Emergency application must be made by placing the automatic brake handle into the emergency position, activating the Emergency Switch on the head end display unit and opening the emergency brake valve on the conductor’s side of the locomotive cab.

You must activate the Emergency Switch on the head end display unit even if the head end display unit indicates no communication.

When an emergency brake application occurs from any source, the Locomotive Engineer must immediately place the automatic brake valve handle in the emergency position and leave it there until the movement stops. On trains so equipped, the TIBS emergency brake feature must also be activated.

In the event of a penalty or emergency brake application occurring while moving, the Locomotive Engineer must regulate the locomotive brake cylinder pressure to obtain the shortest possible stop required by the situation. Care and good judgment must be exercised to avoid locomotive wheel slide and severe in train forces. Excessive locomotive brake cylinder pressure may degrade or nullify the extended range of the dynamic brake.

Excessive Speed on Descending Grade

All crew members on trains operating on the grades listed in the following table must take action to stop the train with an emergency application of the brakes should the train exceed the maximum authorized speed by 5 MPH.

Grades		
Subdivision	Railroad	MP Location
Merriam Park Subdivision	CPR	MP 416 to MP 410
Midway Subdivision	BNSF	MP 5.0 to MP 430
St. Paul Subdivision	BNSF	MP 5.0 to MP 430

Table 5-11 Grades

Dynamic brakes on locomotives are not to be considered as superseding the requirements for automatic or independent air brakes. Dynamic brakes must not be relied upon to stop or slow a light locomotive as failure of the dynamic brakes would create a hazard.

When entering a siding or crossover and the dynamic brake factor of the lead locomotive consist is 14 or greater, the dynamic brake handle must not be placed in a position higher than No. 5 when reaching the turnout and not increased until at least half of the train has entered the siding or crossover.

When entering temporary speed restrictions and the DB factor of the locomotive consist is 14 or greater, the DB handle must not be placed in a position higher than No. 5 one half mile prior to reaching the beginning of the restriction and while moving through the restriction.

This instruction also applies when moving on any yard track in Canada

I the US when moving through yards the DB handle cannot be in a position higher than 5.

When operating through turnouts, crossovers, passing tracks curves and temporary speed restrictions particular care must be exercised to control the amount of dynamic braking effort. The high dynamic forces involved may easily derail cars and for this reason, the speed should be reduced to the maximum permissible speed, or lower if necessary, prior to the start of the restriction, so the dynamic brake level can be reduced while passing through these locations. This is particularly important when the dynamic brake alone is used entirely for controlling the speed of the train and the train has empties, light loads or long overhang cars on the head end, and heavy loads, on the rear end.

When cresting a grade the throttle should be decreased as the head end crests the grade. Speed should be below maximum to allow the Locomotive Engineer time to adjust slack gently when making the transition from power to braking.

Changes in power output or retardation effort within the limits of curves should be made very cautiously, as any change could possibly result in undesirable dynamic forces.

The total braking effort from the dynamic and air brakes should be kept at the lowest practical level when slowing or controlling a train in curved territory.

When slowing or controlling trains using the dynamic brakes or the dynamic brakes and the automatic air brakes, the maximum dynamic brake factor can never be over DB20.

When changing from motoring to dynamic braking when the train is in motion, pause for ten seconds with the throttle in idle.

When moving into the braking zone, pause at the minimum braking position long enough to adjust the train slack, then move the handle slowly within the braking zone to obtain the desired braking effect.

After releasing the dynamic brake in preparation for applying power, the throttle must be advanced with care to ensure gradual adjustment of the train slack.

When commencing the descent of grades with the train slack stretched and it is **known** that both the dynamic brake and the automatic air brake will be used to control the train, automatic air brakes must be applied first. The degree of the application is to be sufficient to control the train speed throughout all but the steeper portions of the descent where the dynamic brake is to be increased to whatever degree is required to provide the additional braking needed to control the train speed.

4) Braking System Combination

The automatic air brakes and the dynamic brake may be used in conjunction with each other. To avoid skidding locomotive wheels during this operation, the locomotive brakes must be bailed off.

When the release of an automatic air brake application is to be followed by a dynamic brake application or an increase in the dynamic braking effort:

- The dynamic brake should be applied before releasing the automatic air brake.
- The train speed should be reduced, allowing for the dynamic brake to be reduced for at least two minutes after releasing the automatic air brake which prevents heavy run-in of slack.

The high dynamic forces produced by the dynamic brake at the head end of a train may also be present when the independent brake valve is used. For this reason, the use of the independent brake valve must be used with caution to prevent the build-up of excessive brake cylinder pressure. The potential of high head-end forces increase with the number of axles in the locomotive consist.

Particular care must be taken when stopping in curved territory because various combinations of curvature, dynamic or automatic air brakes, and train marshalling will generate lateral forces during deceleration. The total braking effort from the dynamic brakes and the automatic air brakes should be kept at a practical level when stopping in curved territory.

C. Control of Train Speed

Speed has the greatest influence on stopping distances. This is because the stopping distance versus the deceleration of a train does not take place at a constant rate.

Compliance with speed restriction (either permanent or temporary) has been established for many reasons. These include operating, legal, and technical considerations, such as limitations of the equipment, track or structures. Permanent speed restrictions are usually listed in the timetable. Temporary speed restrictions are applied because of track or bridge repairs, emergency situations, equipment considerations, etc., and are generally imposed by GBO or a track bulletin.