# TRACK TRAIN DYNAMICS

# *Track Train Dynamics*

- VEHICLE DYNAMICS
  - LATERAL STABILITY
  - VERTICAL STABILITY
  - CURVING BEHAVIOUR

- TRAIN DYNAMICS
  - LONGITUDINAL TRAIN DYNAMICS
  - COLLISION BEHAVIOUR
  - YARD IMPACTS

# *Track Train Dynamics*

- Field Trials – Expensive and time consuming
- With fast digital computers available, studies now done using computer simulation models
- Some simulation programs –
  - NUCARS
  - ADAMS
  - AGEM
  - MEDYNA

# *Track Train Dynamics*

- VERTICAL DYNAMICS

  Wheel follows the vertical rail profile – hence behaviour in vertical mode can be simulated and predicted

- LATERAL DYNAMICS

  Wheel is not bound to follow the lateral rail profile – hence behaviour is rather random in nature and cannot be easily predicted

# LATERAL DYNAMICS

Hunting – refers to oscillations of a vehicle in lateral mode

Tread Taper – causes sustained lateral oscillations

- Axle/bogie may translate laterally
- Axle may rotate about vertical axis passing through centre of axle
- Bogie may rotate about vertical axis through centre pivot

## Hunting

- In extreme case, may cause flutter
- Some restraint provided by couplers
- Maximum oscillations on free end of last vehicle

  (Hence during oscillation trials, the free end of last vehicle is normally instrumented)
- Centre Pivot and side bearers provide damping to rotation

# VERTICAL DYNAMICS

## Undamped System

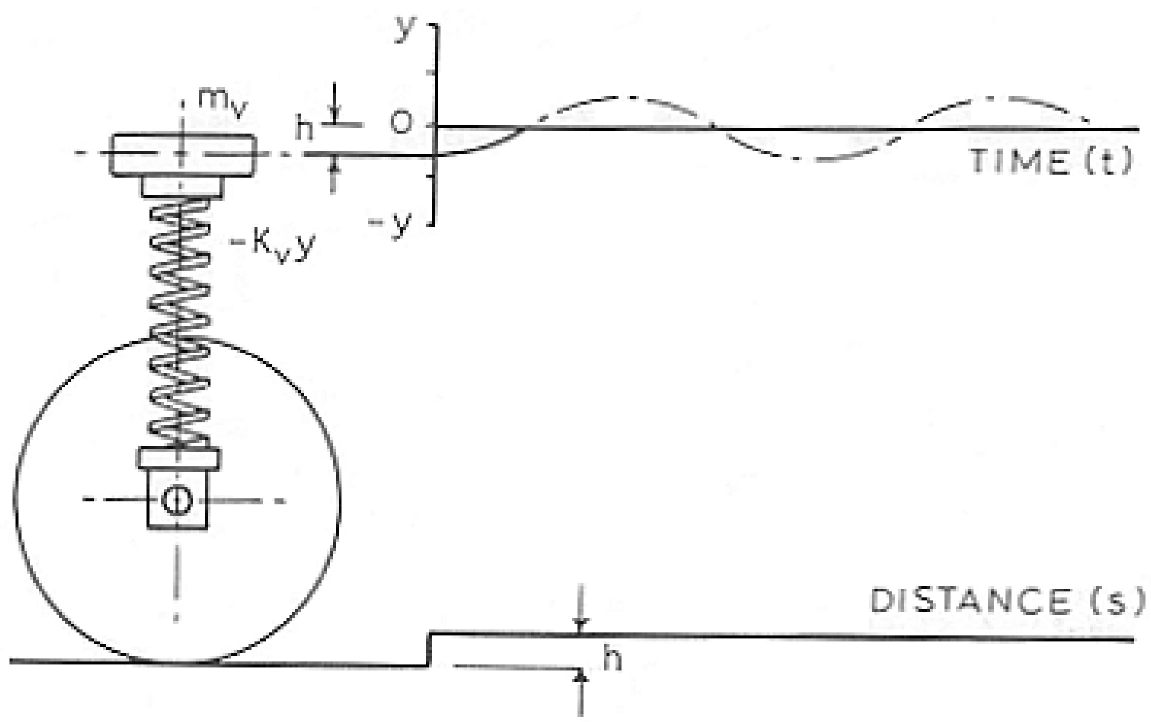
- Free Vibrations
- Forced Vibrations

## Damped System

- Free Vibrations
- Forced Vibrations

# Vertical Dynamics

## Undamped System – Free Vibrations



# Vertical Dynamics

## Undamped System – Free Vibrations

The Solution :

| | |
|---|---|
| $y = -h \cos \omega t$ | displacement of mass m |
| $a = h(k/m) \cos \omega t$ | acceleration of mass m |
| $f = \omega/2\pi$ | frequency of mass m |

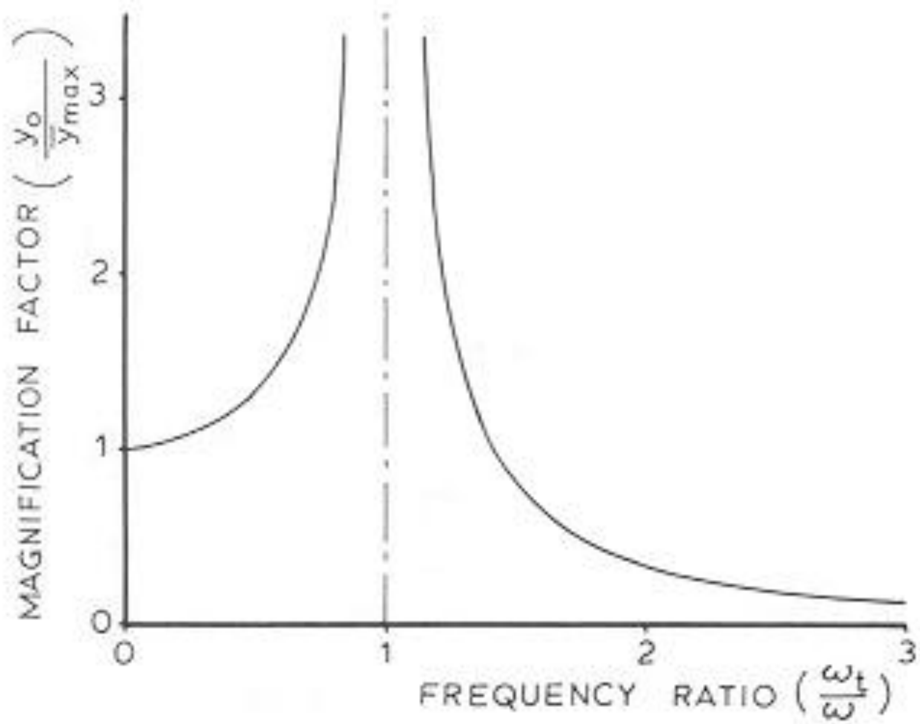
This is SIMPLE HARMONIC MOTION

Max. Accln of ‘m’ depends on k/m. Hence for this effect to be less, ‘k’ should be small i.e. spring should be soft

# Vertical Dynamics

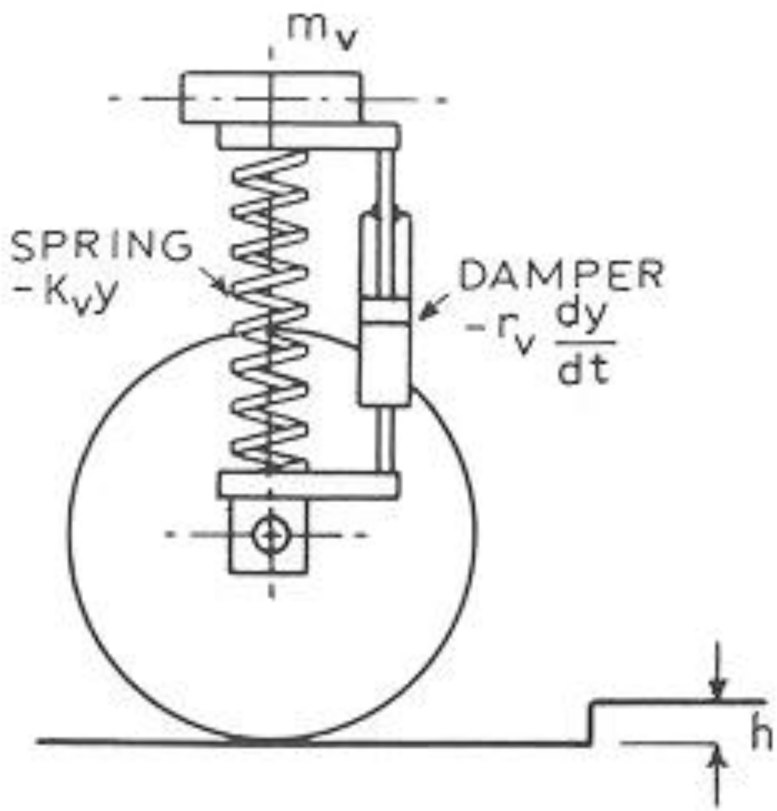
## Undamped System – Forced Vibrations

Forcing frequency : $\bar{y} = \bar{y}_{\max} \sin \omega_t t$



## Vertical Dynamics

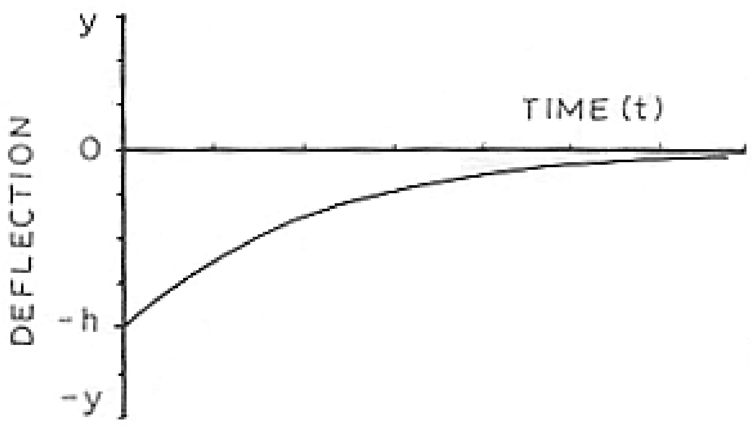
Damped System

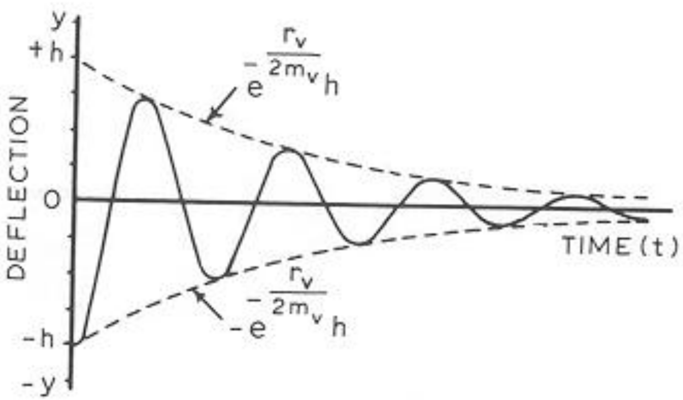


# Track Train Dynamics

## Vertical Dynamics

Damped System – Free Vibrations



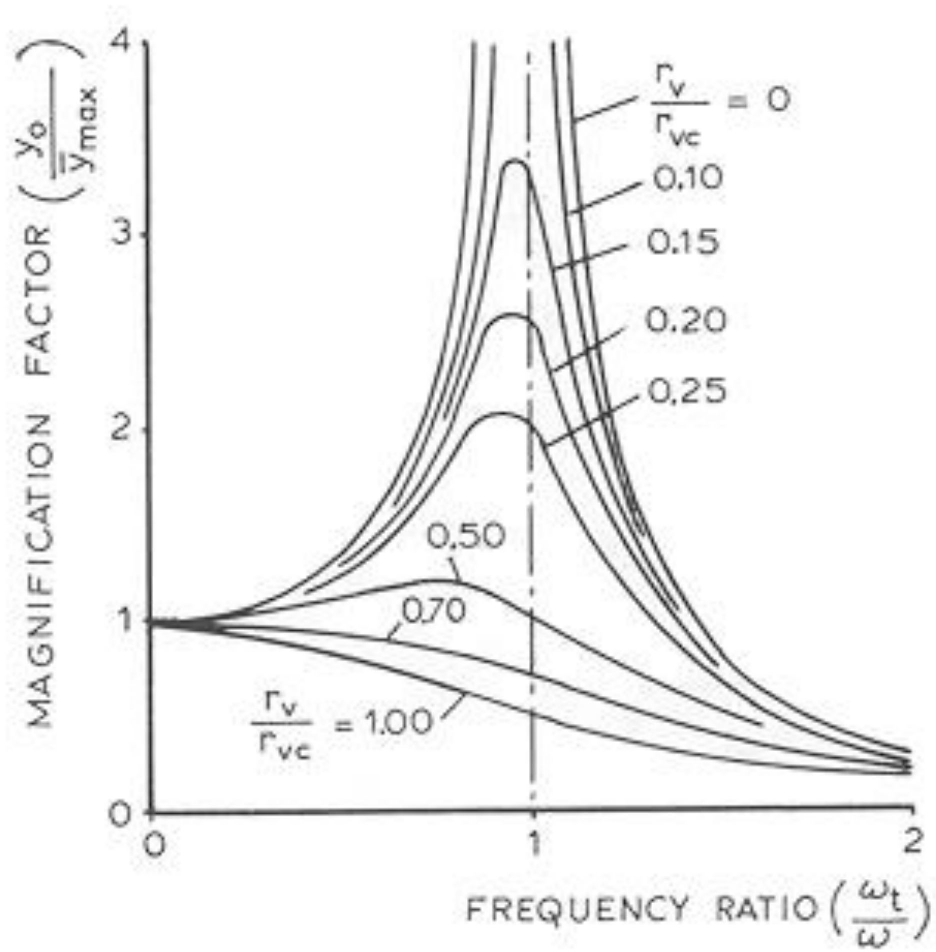

Overdamped System

Properly Damped System

## Vertical Dynamics

Damped System –

Forced Vibrations



# LONGITUDINAL TRAIN DYNAMICS

- Study of development of longitudinal coupler forces
- Longitudinal forces develop from operation of vehicles coupled by spring assemblage (draft gear, cushioning device etc.)

## Problems due to longitudinal forces –

- Coupler breakage
- Bunching

Factors affecting longitudinal forces –

- Physical
  - Available tractive effort
  - Weight of locomotive(s) and other stock
  - Grades, curves in section
  - Characteristics of Braking System
  - Type of draft gears and cushioning units

Factors affecting longitudinal forces –

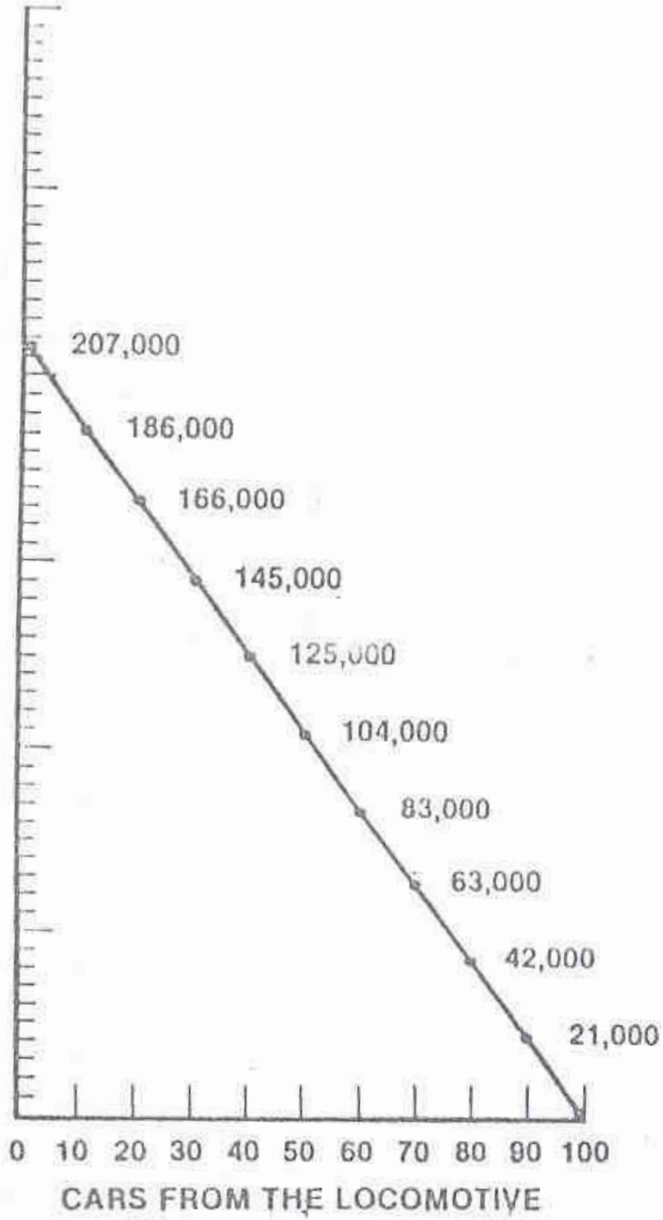
- Operational
  - Train make-up - No. of locomotives, cars and their positions
  - Train Handling - Types of throttle and brake manipulations used by drivers

# Train Make-Up

- Deals with positioning of locomotives and cars in the train
- Weakest draftgear component – knuckle : intentionally so designed for ease of replacement

# Draw Bar Forces

- Max in the 1st car
- Decrease in magnitude upto last car
- Under steady state, DB forces decrease uniformly for equally loaded cars


207,000
186,000
166,000
145,000
125,000
104,000
83,000
63,000
42,000
21,000
0
10
20
30
40
50
60
70
80
90
100
CARS FROM THE LOCOMOTIVE

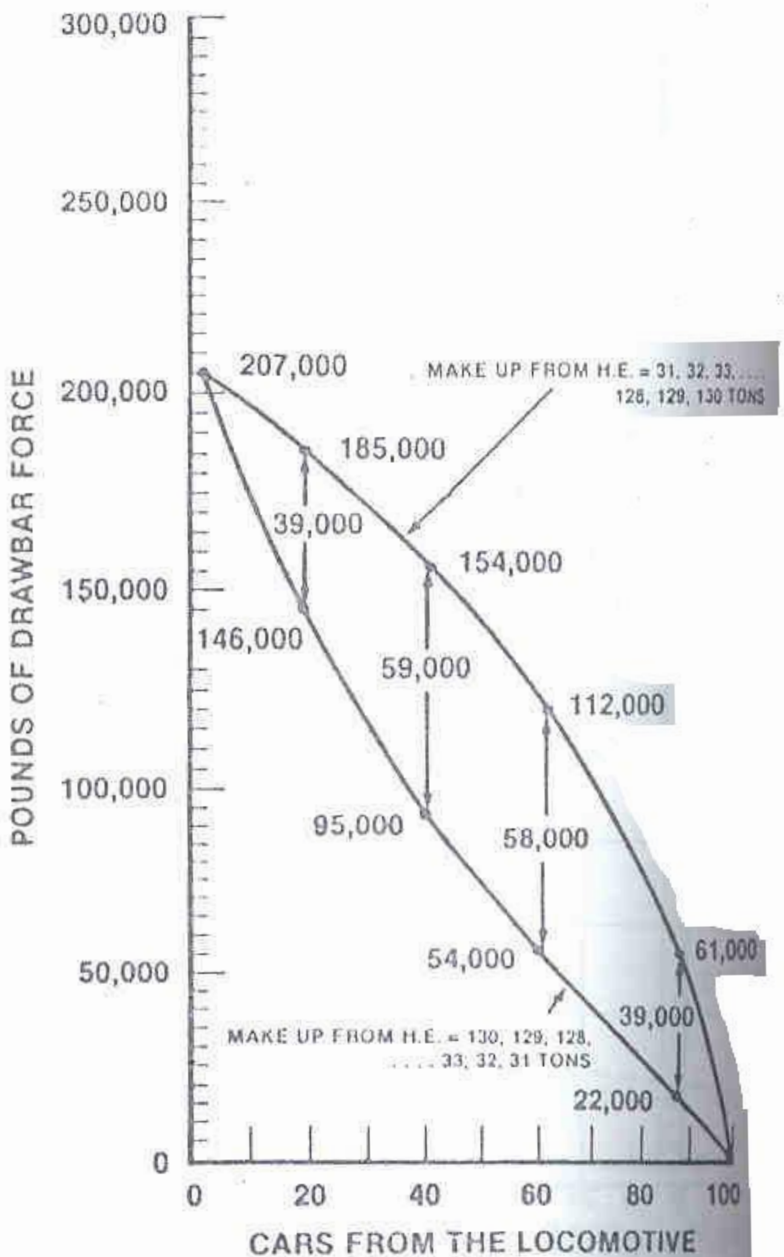
## Draw Bar Forces

- Cars not loaded uniformly – how should they be positioned ?
- In general – heaviest car in the front followed by successively lighter cars towards the end

# Reasons for heavy cars in the front –

(From DB Forces point of view)

- Except for the first car, drawbar forces will be lower
- Highest drawbar forces transmitted through fewer cars – thus lessening the probability of train separation



300,000
250,000
200,000
150,000
100,000
50,000
0
POUNDS OF DRAWBAR FORCE
0
20
40
60
80
100
CARS FROM THE LOCOMOTIVE
207,000
185,000
154,000
112,000
61,000
146,000
95,000
54,000
22,000
39,000
59,000
58,000
39,000
MAKE UP FROM H.E. = 31, 32, 33, . . . . 128, 129, 130 TONS
MAKE UP FROM H.E. = 130, 129, 128, . . . . 33, 32, 31 TONS

# Reasons for heavy cars in the front –

## (From Dynamic Stability Point of View)

- Under full brake power, front portion will decelerate at a lower rate compared to rear, keeping the train a little stretched – a desirable condition
- Due to brake application time lag, front cars start braking early but their higher weight somewhat compensates for difference in deceleration rate from rear, reducing effects of bunching
- Due to lighter cars at rear, bunching will be with lesser force

There is nothing inherently unsafe in handling trains with mixed distribution of heavy & light cars or with heavier loads at the rear, so long as proper train handling procedures are followed and draw bar forces are within limits.

How to determine draw bar forces ?

Methods of determining draw bar forces -

Field Trials :

Couplers are removed from vehicles, strain gauged, calibrated and re-fitted

Limitations –

- Only a few couplers can be instrumented
- Expensive
- Very time consuming
- Generally only the lead coupler is instrumented - this is also used to verify tractive effort of locomotive

Computer Simulation Models

Generally two types of models:

a. Complete data is fed into the computer including braking data – computer outputs coupler forces for the particular set of data

b. The computer is interfaced with traction and brake controllers – data is obtained from look-up tables

   The brake controller may be linked to test rack in a brake lab to obtain more realistic brake data

   Depending on the train length, time step etc., coupler forces may or may not be available in real time.

Advanced Version : Loco Simulator

In IR, computer software for calculation of coupler forces not available.

Software available only for vehicle dynamics – ADAMS

# Dynamic Stability

- On curves, coupler forces and coupler angle cause lateral forces at wheel rail contact point
- If L/V ratio is more than 1.0 – tendency to derail
- L can be calculated by coupler/car geometry and max permissible DB forces may be prescribed accordingly
- Coupling of long car with short car causes max coupler angle – hence not dynamically stable

## Placement of Motive Power

- If all locos are at the head, tractive forces will be higher and so also the DB forces
- Nodes
  - These are points of zero stress where the draft gear is neither in compression nor tension
  - Train is in draft mode ahead of the node, in buff between node and helper and in draft behind the helper

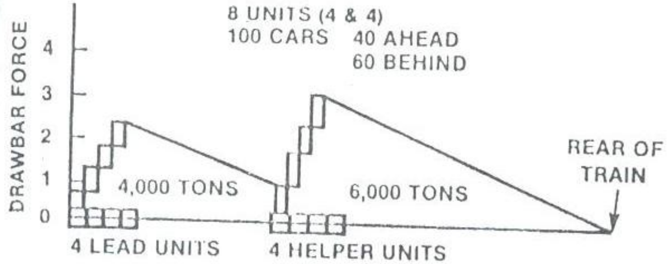



**Figure 3-12**
Helper Placemer
Situation One

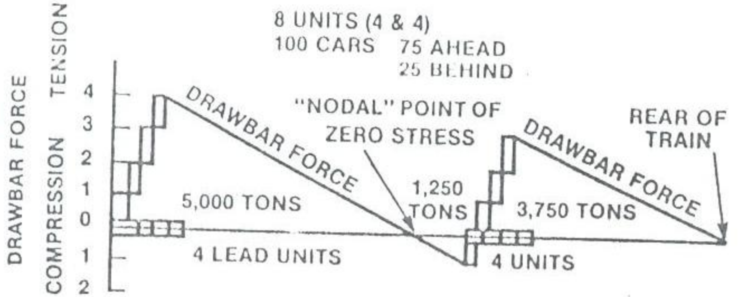



**Figure 3-13a**
Helper Placemen
Situation Two

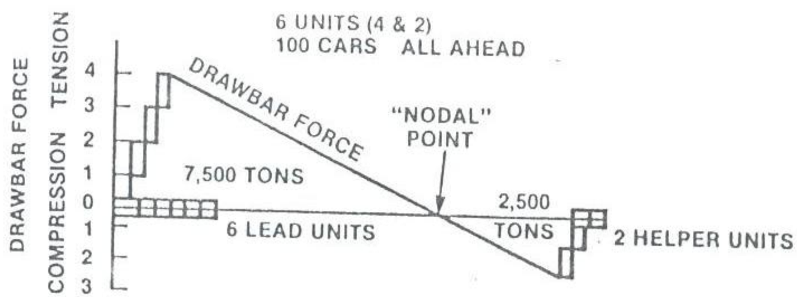



**Figure 3-13b**
Helper Placement
Situation Two
(Rear)

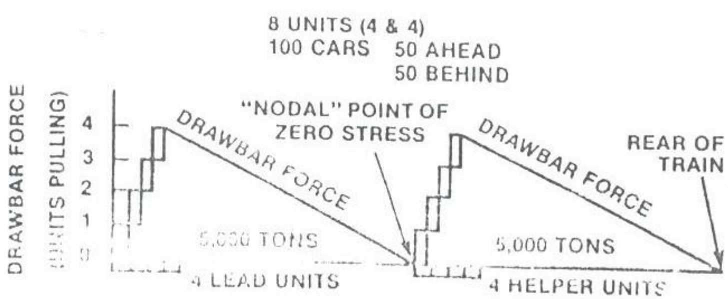



**Figure 3-14**
Helper Placement
Situation Three

# Operational Considerations

- In a fully graded section, locomotives may be suitably placed at the time of train formation itself.
- In a section with part grade, helper can be attached only at the rear or front

There are no hard and fast rules about positioning of locomotives in a train except that :

- The draft and buff forces should be within prescribed limits
- The DB forces may also be limited by the max curvatures in the section

In general, optimum location of loco may be determined for the particular territory of operation by using computer simulation models

# Train Handling : Some Considerations

- At start, loco brakes may be used to restrict the train speed upto about 1.5 km/h until the entire train has started moving – particularly important if heavier loads are at the rear
- All changes (notching up or braking) should be made slowly to prevent shuttling due to slack

Train handling – Slowing & Stopping

Two Methods :

- Slack Stretched Method

  Minimum train brakes should be applied while working power – throttle should be reduced after brakes become effective throughout the train

- Slack Bunched Method

  By the use of dynamic brakes and train brakes

## Train handling – Slowing & Stopping

- If heavier loads are at the rear, slack stretched method may cause problems at low speeds – heavier cars may run-into lighter cars – in such cases, slack bunched method may be used with care
- The optimum manipulations of throttle, dynamic brakes, loco brakes and train brakes may be determined for a particular type of territory by using simulation models and drivers may be trained accordingly

*Thank You !*