16

Load Transfer – Stock Car

Asymmetric Load Transfer

(It's just not this simple!)

Despite its title, Chapter 16 is just as important for **road course** only race engineers as it is for oval track racers. All information in Book 1 is sequential i.e. you can't skip over any part of any chapter. Just because we are looking at a stock car chassis does not mean all of the asymmetric information is not just as important for road racers. As previously stated, under any time of dynamic acceleration, a road course chassis becomes asymmetric. Additionally, information presented in this chapter about how to work with Wan31 is not presented in any other chapter.

In Chapter 16 we will be looking at a three link live axle stockcar. The three-link suspension system is also used on many live axle GT type road course chassis. The chassis are found in the WinGeo3 software as Short Track Front, Short Track Rear. In Wan31A, the chassis is found under Short Track Stock Car in the Wan31A files.

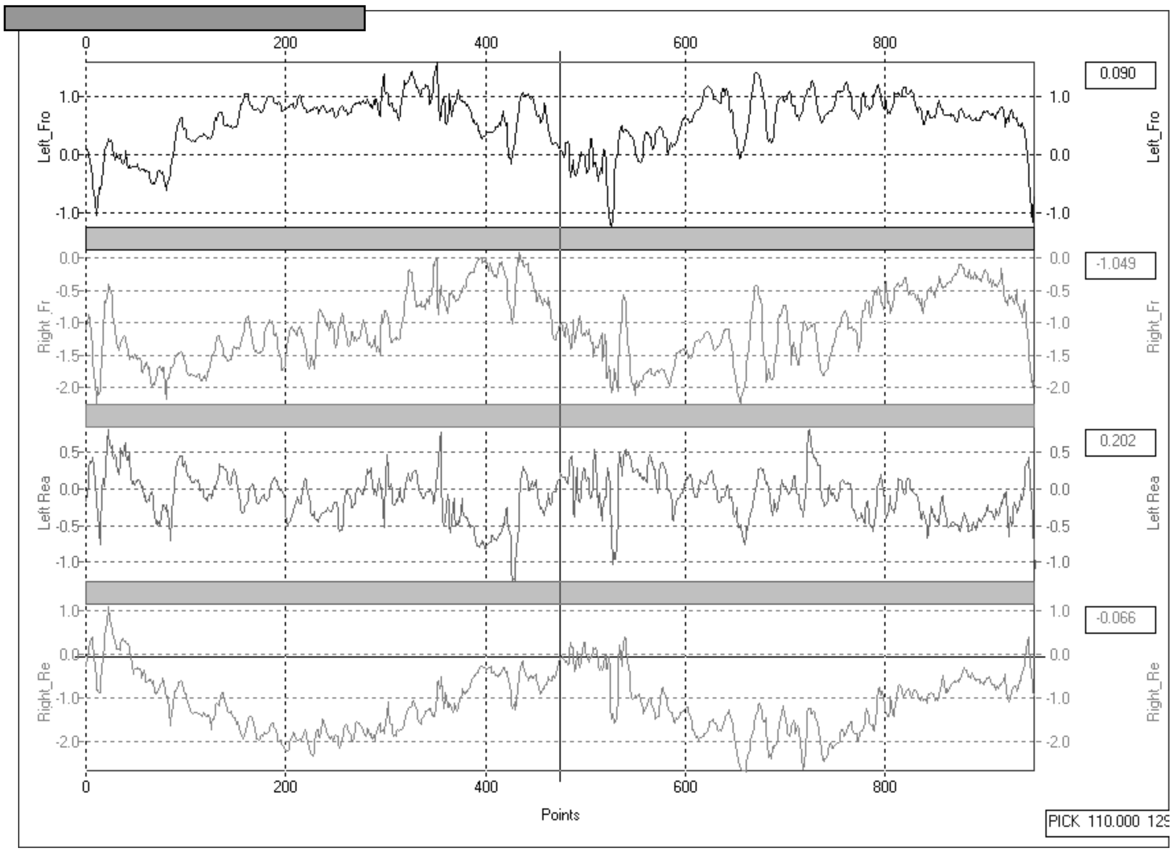
Oval track cars, in theory, only have to turn left and therefore are set up with a number of static and dynamic asymmetries that will help balance the dynamic left turn corner loads. Oval track cars are not necessarily more difficult than road course cars to set up but they certainly have considerably more set up possibilities.

Throughout Chapters 16 through 21 we will look at a number of different corner entry, apex and exit scenarios. The ten **generic** phases used in this chapter are as follows:

- **Corner Entry**
  - Phase One – Hard Braking and Rapidly Decreasing Throttle – B = 1.00 g - T_L = 0.0
  - Phase Two – Hard Braking, No Throttle and Slowly Increasing Steer Angle – B = 1.25 - T_L = 0.5 g
  - Phase Three – Moderate Braking with Rapidly Increasing Steer Angle – B = 0.6 - T_L = 1.0 g
  - Phase Four – No Braking with Slowly Increasing Steer Angle – B = 0.15 - T_L = 1.25 g
- **Corner Apex**
  - Phase Five – Constant Steer Angle with No Throttle – B = 0.05 - T_L = 1.53 g
  - Phase Six – Constant or Slowly Decreasing Steer Angle with Modulating Throttle – A = 0 - T_L = 1.37g
  - Phase Seven – Slowly Decreasing Steer Angle with Slow Pick Up on Throttle – A = 0.3 - T_L = 1.0 g

- **Corner Exit**
  - Phase Eight – Rapidly Decreasing Steer Angle with Slow Pick Up on Throttle – A = 0.4 - T_L = 0.7 g
  - Phase Nine – Slowly Decreasing Steer Angle with Rapid Pick Up on Throttle – A = 0.65 g - T_L = 0.5 g
  - Phase Ten – Full Throttle with No Steer Angle – A = 0.85 g - T_L = 0.0 g

Note: As shown below, in the four suspension graphs, actual on track suspension motion is mind bogglingly complex even if only measured every twentieth of a second i.e. actual chassis performance is a **great** deal more complex than the simplified examples used in Book One. However, when using on track data, I still normally break the corners into approximately ten phases were each phase contains multiple data points. Each lap will result in slightly different phase entry and exit points for each portion of the track (no two laps will ever be precisely the same). *It's just not that simple.*



Note: It has been a somewhat daunting exercise to determine what needed to be included and what could be left for the readers to ferret out for themselves in Chapters 16 through 21. Remember that just because a reader has carefully read through and understood the contents of a chapter, as well as having made the prescribed changes in the Wan31A model, it **does not**, in any way, mean they have gained all of the needed load transfer knowledge. In fact, these chapters barely introduce the static and dynamic set up possibilities. If we were going to cover each chassis type in detail, it would take ten thousand pages and probably that wouldn't even cover it ("*say it ain't so*"). I know this has already been stated ad infinitum, but becoming a knowledgeable race engineer takes a considerable amount of intestinal fortitude.

As the authors assume the reader possesses a modicum of intelligence, diligence and conviction to acquire the prerequisite knowledge, a great deal is left for the reader to discover on his/her own. In this regard, the reader will need to develop a great number of charts, graphs and tables on his/her own in order to understand the myriad of set up, static and dynamic load transfer combinations.

Wan31A – Short Track Stock Car

1) **Wan31A – Short Track Stock Car (Ride Height and Balance)**: Load the Wan31A Short Track Stock Car. **IMPORTANT**: Turn off all green anti/jacking cells and reset the LR spring preload to 1.373 and RR spring preload to 0.810. The change in rear preload is required to zero the Solutions Load Changes so the Solutions Corner Loads and Initial Loads match. The reason the preload needs to be changed when the anti/jacking forces are turned off is to compensate for a small amount of static track bar forces. The spring preload as the model is loaded is set for the anti/jacking forces engaged. Notice the initial corner loads, left side/rear bias and the wedge. As previously discussed, there is a very important relationship between the spring rates, corner loads, wedge and ride heights. Before the user starts working with this model, he/she should take time to look at all of the model's cells.

    - The left front wheelbase is 0.5" shorter than the other three wheelbases.

    - The tracks, as measured from the hub face, are LF = 32.50", RF = 33", LR & RR = 32.75". Even though the front and rear tracks are offset, they are both 65.5" in width.

    - The tire radii as measured on the set up pad are LF = 13.47", RF = 13.647", LR = 13.36" and RR = 13.853".

    - Spring motion ratios are LF = 0.473". RF = 0.455", LR &RR = 1.0"

    - Spring Rates are LF = 850 lb./in, RF = 900 lb./in, LR = 225 lb./in and RR = 200 lb./in.

    - Once the corner loads and spring rates have been determined, the spring preload is adjusted in **A1** to rebalance the chassis loads in **A6** while also setting the static ride heights as close as possible to the designed heights. There are always a number of different ride height combinations that will balance the **A6** corner loads while also maintaining the wedge percentage. The **#4 Differences in Ride Height** calculator found on the **Splits and Changes** worksheet shows the relationships between the individual corner ride heights. For example, as the ride height is set when the model is first opened the difference between LF - RF is the same as LR - RR. If the RR preload is increased by 1" the chassis can be rebalanced by adjusting the preload at any of the other corners or at a combination of corners. Each type of adjustment will result in a ride height, pitch and roll change but LF-RF and LR-RR will still be equal. Adjusting preload is an extremely important tuning tool.

    - The original ride height is LF = 4.255", RF = 4.506", LR = 4.783" and RR = 5.034". The original static pitch is 0.680 degrees nose down while the original static roll angle is 0.257 degrees down to the left.

- If the RR preload is changed from 0.810” to 1.810”, the chassis can be rebalanced by one of the following:

    - Raising the LR preload to 2.368”. The new ride heights are LF = 4.566”, RF = 4.826”, LR = 5.509” and RR = 5.764”. The new static pitch is 1.213 degrees down and the new static roll is 0.261 degrees to the left. *Reset LR to 1.373*.

    - Raising the RF from –0.240” to 0.695”. The new ride heights are LF = 4.324”, RF = 5.431”, LR = 4.855” and RR = 5.961”. The new pitch is 0.683 degrees down and the new roll angle is 1.132 left. *Reset RF to 0.240.*

    - Lowering the LF from 0.17” To –0.300”. The new ride heights are LF = 3.642”, RF = 4.747”, LR = 4.585” and RR = 5.691”. The new pitch is 1.215 degrees and the new roll angle is 1.131 degrees. *Reset LF to 0.17.*

- Notice that in all three cases, the difference between the side to side splits (LF - RF) and (LR – RR) remains equal. When working with an infinitely rigid body with equal spring rates and motion ratios, as in the previous Chapter 14 **symmetrical model**, an increase of preload at the RR of 1” can be balanced by raising either the LR or RF by 1” or lowering the LF by 1”. This is a constant relationship even when working with a chassis having different spring rates and/or motion ratios. However, in this latter case, the different rates and ratios also need to be taken into consideration.

- In some cases, all four preloads will need to be changed a small amount, but, in most cases, the needed ride height ratios can be maintained by changing only the diagonal corners. However, you can seldom adjust the preloads to the exact prescribed ride heights while also maintaining the **A6** Solutions load balance (equilibrium of a rigid body). As chassis balance almost always takes precedence over small ride height irregularities, the static set up often ends up with the ride heights off a few thousandths. Nonetheless, if a stock car ride height setting is off more than 0.050”, a different set of preload combinations need to be tried unless, of course, the designated ride heights are completely incorrect in which case they need to be reconsidered.

- For many oval track races, the sanctioning body will require a minimum LF ride height and often a minimum RR ride height. Therefore, for oval track cars, the ride height relationship between the LF and the RR is the most important one. However, great care still needs to be taken not to unduly change the RF/LR balance, particularly with an aero sensitive chassis.

- The reader has no doubt already realized just how small a change in preload can be before it can alter the chassis balance. Racing is a rather exacting business when you consider a change of one or two pounds in corner load can move the balance from a loose to tight condition or vice versa.

2) **Wan31A – Short Track Stock Car (Wedge and Balance):** Changing the wedge percentage with preload while closely maintaining the ride height balance is an important shop set up procedure. Teams need to leave the shop already knowing how to change the various wedge percentages without upsetting the ride height balance, particularly with an aero sensitive chassis which is just about every modern chassis. Changing the static wedge percentage changes both the static loads and ride heights. Adjusting the wedge percentage, which, in turn, changes the ride heights, also results in a kinematic change. As we will discover shortly, a change in the kinematic IC co-ordinates can have a considerable effect on the anti and jacking forces.

    - Static wedge can be increased by adding preload to the RF and/or LR or by decreasing preload at the LF and/or RR. Decreasing wedge is just the opposite. No matter what corner or combination of corners from which the preload is adjusted, a given change in wedge percentage will always result in the same amount of static load transfer. The ride heights will change depending on where the preload change(s) are made but the corner loads will not change for any given wedge percentage. Adding preload at one corner will increase the ride height at that corner and that corner's two opposite corners while decreasing the ride height at its diagonal corner. The opposite happens if the preload is decreased.

- <u>Changing the **Static** wedge from 53.6% to 55.8%</u>: At 53.6% the ride heights are LF = 4.255", RF = 4.506", LR = 4.783" and RR = 5.034". Chassis pitch is 0.680 degrees nose down and the roll is 0.257 degrees to the left.

- Increase the LR preload from 1.373" to 2.020". Wedge has changed to 55.8% and the resultant change in load transfer is approximately 32.3 lb. per corner. The new ride heights are LF = 4.505", RF = 4.464", LR = 5.171" and RR = 5.131". Chassis pitch is 0.858 degrees nose down and the roll is 0.042 degrees to the left. *Reset to base*

- Increase the RF preload from 0.240" to 0.209". Wedge has changed to 55.8% and the resultant change in load transfer is plus approximately 32.9 lb. per corner. The new ride heights are LF = 4.349", RF = 4.866", LR = 4.745" and RR = 5.262". Chassis pitch is 0.510 degrees noise down and the roll is 0.529 degrees to the left. *Reset to base.*

- Decrease the RR preload from 0.810" to 0.150". Wedge has changed to 55.8% and the resultant change in load transfer is approximately 32.9 lb. per corner. The new ride heights are LF = 4.303", RF = 4.255", LR = 4.698" and RR = 4.650". Chassis pitch is 0.509 degrees nose down and the roll is 0.049degrees to the left. *Reset to base.*

- Decrease the LF preload from 0.17" to –0.140". Wedge has changed to 55.8% and the resultant change in load transfer is approximately 32.8 lb. per corner. The new ride heights are LF = 3.899", RF = 4.414", LR = 4.568" and RR = 5.084". Chassis pitch is 0.862 degrees nose down and the roll is 0.528 degrees to the left. *Reset to base.*

- Take time to explore the relationships as the result of a wedge change, between the changes in ride height, pitch and roll. Remember changing the wedge **does not** change the left side and rear bias.

3) **Wan31A – Short Track Stock Car (Spring Changes)**: As with the symmetric chassis, any time a spring change is made, a preload change will also have to be made in order to reset the corner load balance and ride heights. As with a road course car, spring changes are made to change the roll, dive, squat and ride height balance in addition to the load transfer balance. Unlike a road course car, these changes are normally asymmetric in nature to help left turn performance. More on this shortly.

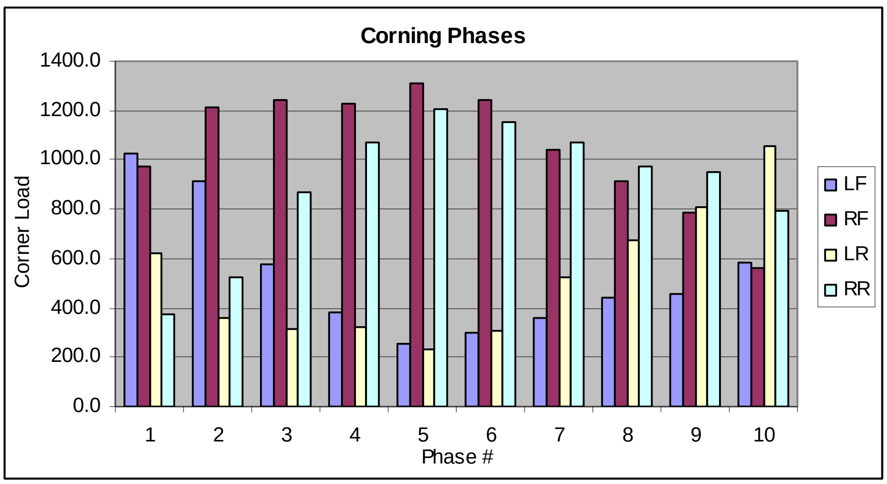
Load Transfer through the Ten Cornering Phases (Springs)

Table 16-1 and its accompanying graph represents a generic left turn scenario. It shows the dynamic corner loads as a result of ten base cornering phases. There are many different types of cornering scenarios but even the classic, get all the braking done in a straight line, late apex line is never that cut and dried.

Corner Loads with Base Spring Rates:

	Load	Load	Load	Load
	LF	RF	LR	RR
#1 B = 1.0g - T_L = 0.0g	1028.8	977.0	618.0	377.3
#2 B = 1.25g - T_L = 0.5g	910.2	1210.2	359.0	521.6
#3 B = 0.6g - T_L = 1.0g	576.7	1242.7	313.4	868.2
#4 B = 0.15g - T_L = 1.25g	380.1	1231.1	320.2	1069.6
#5 B = 0.05g - T_L = 1.53g	256.3	1308.2	232.1	1204.4
#6 A= 0.0g - T_L =1.37g	301.4	1240.3	307.9	1151.4
#7 A =0.3g - T_L =1.0g	361.7	1042.1	526.7	1070.4
#8 A = 0.4g - T_L = 0.7g	444.8	913.3	670.3	972.6
#9 A = 0.65g - T_L = 0.5g	456.5	786.6	809.4	948.5
#10 A =0.85g - T_L =0.0g	587	564.5	1056.5	793

Table 16-1



The above table and graph of the ten cornering phases gives us an overview of how much the loads shift between each phase. The fastest car, all other things being equal, will have the best dynamic set up compromises through each phase. Mess up one phase and it doesn't matter how good the next ones might have been. Likewise, a killer set up through the first two phases doesn't help at all if it results in the third stage set up being all wrong. **There is no perfect set up, only compromises**.

Note: Chapters 16 & 17 look at corner loads, amounts of load transfer plus side to side and front to rear load splits. Until the tire models are added in Chapters 20 & 21, we won't really know whether a change in balance will help or degrade the chassis' ultimate performance. Further to this, a balance change for any given tire map may help one driver's performance while hurting a less talented driver's performance.

The Four Corner Entry Phases

1) **Phase One – Corner Entry - Hard Braking and Rapidly Decreasing Throttle (B = 1.0g – T_L = 0.0g)**: This first set of corner phases sees all of the load transfer passing through the **springs**. For this example there is still no anti roll bar, damper or kinematic reaction to the load transfer.

- Load the Short Track Stock Car, zero all of the green anti/jacking cells and reset the LR spring preload to 1.373 and the RR spring preload to 0.810. The static corner loads are LF = 790 lb., RF = 754 lb., LR = 855 lb. and RR = 602 lb. Load transfer is zero. Ride heights are LF = 4.255", RF = 4.506", LR = 4.783" and RR = 5.034".

- Enter 1g of braking.

  - The new Phase One base set up loads are LF = 1028.8 lb., RF = 977.0 lb., LR = 618.0 lb. and RR = 377.3 lb.

    - Notice that the percentage increase in LF load is slightly higher than the percentage increase in RF load. At first glance this may not make sense because, as we learned while working with the symmetrical chassis in Chapter 14, the stiffest spring will receive the highest percentage of load transfer. However, we also learned that a stiffer spring will also **lose** a higher percentage of load transfer in rebound. What this tells us is, when looking at load transfer, we always need to look at all four corner wheel rates, or, in this case, spring rates and motion ratios. We can't just look at one end of the chassis.

      <u>A quick load transfer review (Pure Braking)</u>:

      - A stiffer RF wheel rate during braking will see a higher load at the RF and LR and a lower load at the LF and RR.

      - A stiffer RR wheel rate during braking will see a lower load at the RR than the LR and a lower load at the LF than the RF.

      - The reader may want to review the spring versus load transfer tables presented in Chapter 14.

    - Some of the increased load seen at the LF is a result of the narrower LF track and shorter LF wheelbase but the majority of the increase, beyond the static bias offset, is the result of the spring rates and motion ratios.

      - The static wheel rates are LF 850 * 0.494 = 420 lb./in, RF 900 * 0.460 = 414 lb./in. **Surprise**, **surprise!** The LF wheel rate is actually higher than the RF with its higher spring rate but lower motion ratio. The rear corners have a 1/1 ratio so the spring rate and wheel rate will both be the same. This tells us that making a rear spring change, for any given rate change, will have a larger influence over load transfer than the front springs with their much lower motion ratios. Further to this, the LF, with its slightly higher motion ratio, will influence load transfer more than for the same change at the RF.

  - <u>Changing Spring Rates</u>: With 1g of inertial braking forces, the base load transfer is LF = 238.8 lb., RF = 223.0 lb., LR = -237.0 lb. and RR = -224.7 lb. Notice that the LF has gained more than the RF while the RR sees less load loss than the LR. If one corner sees a higher load transfer percentage than its opposite corner, its diagonal corner will, in turn, see less load transfer than its opposite corner. Increasing the LF corner load percentage will also increase the RR corner load percentage.

Note: Fundamental Truth – As previously discussed, stiffening a corner in compression will result in a load increase at that corner and its diagonal corner in addition to a load decrease at the opposite diagonal corners. The opposite is true when the corner is softened. Stiffening a corner in extension/rebound will result in a load decrease at that corner and its diagonal corner in addition to a load increase at the opposite diagonal corners. The opposite is true when the corner is softened.

- Increase the LR spring from 225 to 250 and rebalance the chassis by changing the preload to 1.045. The new load transfer is LF = 244.2 lb., RF = 217.5 lb., LR = -242.5 lb. and RR = -219.3 lb. The LR saw a larger amount of load transfer than the RR while the RF saw less load transfer than the LF. Using a stiffer LR spring resulted in a higher load at the LF and RR as seen in the corner loads. Corner loads are LF = 1034.2 lb., RF = 971.5 lb., LR = 612.5 lb. and RR = 382.7 lb. The dynamic wedge is decreased from 53.6% to 52.8%.

  - Base set up ride heights at 1g braking were LF = 4.255", RF = 4.506", LR = 4.783" and RR = 5.034".

  - The new ride heights are LF = 3.684", RF = 4.045", LR = 5.150" and RR = 5.511".

  - *Reset the springs and preloads to the base set up.*

- Decrease the LR from 225 to 200 lb. and rebalance the chassis by changing the preload to 1.780. The new load transfer is LF = 232.4 lb., RF = 229.3 lb., LR = -230.6 lb. and RR = -231.1 lb. Notice that the amount of load transfer is quite balanced with this spring combination. Corner loads are LF = 1022.4 lb., RF = 983.3 lb., LR = 624.4 lb. and RR = 370.9 lb. The dynamic wedge is 53.6%, the same as the static wedge percentage. Using a softer LR spring decreases the dynamic LF and RR loads while increasing the dynamic RF and LR loads.

  - Ride heights are LF = 3.776", RF = 4.030", LR = 5.292" and RR = 5.546".

  - *Reset the springs and preloads to the base set up.*

- Decrease the RR spring from 200 lb. to175 lb. and rebalance the chassis by changing the preload to 1.155. The new load transfer is LF = 246.5 lb., RF = 215.3 lb., LR = -244.8 and RR = -217.0 lb. Corner loads are LF = 1036.5 lb., RF = 969.3 lb., LR = 610.2 lb. and RR = 385.0 lb. The dynamic wedge has moved from 53.6% to 52.6%. Decreasing the RR spring rate has increased the LF and RR corner loads while decreasing the RF and LR loads.

- *Reset the springs and preloads to the base set up.*

- Increase the RR spring from 200 to 225 and rebalance the chassis by changing the preload to 0.543. The new load transfer is LF = 232.4 lb., RF = 229.3 lb., LR = -230.6 lb. and RR = -231.1 lb. Corner loads are LF = 1022.4 lb., RF = 983.3 lb., LR = 624.4 lb. and RR = 370.9 lb. The dynamic wedge is the same as the static wedge of 53.6%. Decreasing the RR spring rate has increased the LF and RR corners while decreasing the RF and LR loads.

- *Reset the springs and preloads to the base set up*

- Table 16-2 illustrate the changes in corner load at 1g of braking as the result of rear spring changes. The base springs are LF = 850, RF = 900, LR = 225 and RR = 200. Notice the relationships between the diagonal corners.

Short Track Stock Car		1g Brake				Short Track Stock Car		1g Brake		
Spring	Load	Load	Load	Load		Spring	Load	Load	Load	Load
Changes	LF	RF	LR	RR		Changes	LF	RF	LR	RR
Base	1028.8	977.0	618.0	377.3		Base	Base	Base	Base	Base
LR 250	1034.2	971.5	612.5	382.7		LR 250	Increase	Decrease	Decrease	Increase
LR 200	1022.4	983.3	624.4	370.9		LR 200	Decrease	Increase	Increase	Decrease
RR 175	1036.5	969.3	610.2	385.0		RR 175	Increase	Decrease	Decrease	Increase
RR 225	1022.4	983.3	624.4	370.9		RR 225	Decrease	Increase	Increase	Decrease

Table 16-2

Set Up Scenarios: There are two primary reasons why a chassis would be set up to have higher left side loads under pure braking:

- A higher LF load would tend to bias the braking force to the left front over the right front, thereby producing a tendency for the chassis to begin to turn left before a steer angle is introduced.

- To help balance the left to right lateral acceleration load transfer as the chassis begins to turn left. Because the side to side balance during a turn is so important, teams take every opportunity to add as much **static** and **dynamic** left side bias as they can. Getting the right amount of dynamic bias is the tricky bit.

2) **Phase Two – Corner Entry - Hard Braking, No Throttle and Slowly Increasing Steer Angle (B = 1.25g – T_L = 0.5g)**: This first set of corner phases sees all of the load transfer passing through the springs. There is no anti roll bar, damper or kinematic reaction to the load transfer.

- Enter 1.25g of braking and 0.5g of left turn acceleration.

  - The new base set up corner loads are LF = 910.2 lb., RF = 1210.2 lb., LR = 359.0 lb. and RR = 521.6 lb. The load transfer is LF = 120.2 lb., RF = 456.2 lb., LR = -496.0 lb. and RR = -80.4 lb.

    - This first stage of corner turn in sees some of the most abrupt changes in side to side corner loads - it all happens quite quickly. If the chassis doesn't get through this phase well, the rest of the corner is pretty well downhill from this point. If the chassis takes a set and stays balanced front to rear, there is much time to be saved in this phase. If the **chassis** or **driver** has trouble taking or keeping a set through this stage, the lost time can never be made up throughout the rest of the corner even if the driver is able to regain chassis balance later in the turn.

      - From the time steer angle is introduced, it should only take about one and a half to four revolutions of the tires for the load transfer to settle in (find its balance), depending on how stiff the chassis is (roll and pitch rate). As previously discussed, load transfer is pretty well instantaneous, but, depending on the spring, bar and damper rates, it takes a certain amount of time for the chassis to find its state of equilibrium. As we will discover shortly, the build and shaft velocity of the shocks play a major role in how long it takes for the load transfer to balance (reach equilibrium).

    - The stiffer the chassis is, the faster the chassis will pass through this first stage. However, for a heavy stock car, even for an extremely talented driver, slowing the transitions down slightly in this phase can help set up the rest of the corner. As long as the ride heights are changing, be it ever so slightly, the race engineer can exert a modicum of dynamic control through the set up options. More on this later in the chapter.

- The Phase Two ride heights are LF = 4.384", RF = 3.095", LR = 6.090" and RR = 4.800". How quickly the ride heights change over a given time determines the shaft speed and rate of acceleration of the shock. When we add the shocks into the load transfer calculations, we find many more ways in which the race engineer can control the chassis dynamic load transfer and balance. Of course, that also gives us many more ways to go astray.

- If the RF ride height changes more than the LR ride height for a given amount of time, then the RF shaft velocity will be higher than the LR. *It's just not that simple*.

- Notice that the wedge has moved from 53.1% during Phase One to 52.3% in Phase Two. The chassis has dewedged, which, in turn, will help the front balance and degrade the rear balance. This is confirmed by looking at the front and rear load splits where in Phase One they were front = 51.8 and rear = 240.7 while in Phase Two the splits are front = -300.0 and rear = -162.6.

Making Changes

- As in Phase One, we can change the static wedge (preload changes) and/or dynamic wedge change (changing spring rates) to adjust the front to rear balance. We can also change the actual amount of load transfer by changing the tracks, wheelbases and/or the CG.

    - CG Height: We can change the CG height by changing the static and/or dynamic ride heights. If we soften the right side springs, the chassis will roll down, thereby slightly lowering the CG (the right side ride heights move down more than the left side ride heights move up). If we stiffen the right side springs, the chassis will roll up, thereby slightly raising the CG (the left side ride heights will move up more than the right side ride heights move down). Once we introduce the shocks into the calculation, we are able to further exaggerate the extent of roll up or roll down.