The Differential Gears Explained

By Dan Drommerhausen and Bob Nichols

Effective December 12, 2022

While some readers know what a differential is, others do not. First a fundamental explanation and then an explanation of the differential and its gears. Limited slip and four satellite gears differentials will be discussed. The steel (or alloy) wheel and tire will be called the "wheel" herein.

The vehicle engine turns and this rotation goes through a transmission and differential to transmit engine rotation at different ratios to the rear wheels via axles. In low gear about 10 or 11 engine rotations for every wheel rotation makes for easy starts. When in high gear about 3 to 4 engine turns for every wheel and tire rotation allow the car to cruise at highway speeds.

The Transaxle – The Covair combines the transmission and differential into one unit (that can be unbolted from each other).

The Transmission – Either a manual selected gear box engaged via a clutch, or a fully automatic hydraulic unit was installed in the Corvair. The transmission's job is to allow different gear rations to be selected so the engine rotations per wheel rotation can be changed to allow the vehicle to start easily from a stop, but reduce engine rotations with respect to wheel rotations so the vehicle can travel at a higher road speed.

The Axles – The axle(s) connects the rear wheels to the differential. The Corvair has two axles, one on the driver's side, and one on the passenger side

The Differential – It consist of a ring and pinion gear that are designed to take engine rotation, via the transmission, and turn it 90 degrees to rotate the axles and wheels. The ring is connected to a differential case containing a set of side and satellite gears. The differential assembly allows the vehicle to make a turn when the inner and outer rear wheels travel at "different" distances, or arcs. The ring and pinion, differential case, and axle yokes are contained in the differential carrier the transmission bolts to.

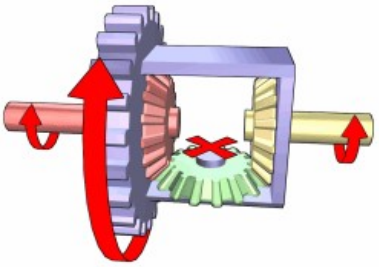
If both wheels and axles were connected without a differential, then each wheel would try to force the other to turn at the same rate in a turn. The result would be unbalanced forces negatively affecting handling and traction. During a turn the differential gears, via axles, allow the outer wheel to turn faster versus the inner wheel, but with equal force to each. In effect the differential side and satellite gears rotate to equalize the force to each wheel. This design is referred to as the "Open" differential and ensures either rear wheel cannot receive more force than the other. The design works well if both wheels have the same traction. If one wheel has less traction than the other a problem arises.

The "slipping wheel problem." – When one wheel losses traction it will slip and spin. This can happen on wet pavement, mud, snow, ice, or loose dirt. The force to the wheel with greater traction is reduced to about that of the low traction slipping wheel by the differential gears. This lack of force to the wheel with traction causes the car to accelerate poorly, if at all. There is an option to overcome this problem called a limited slip differential design that will be discussed here.

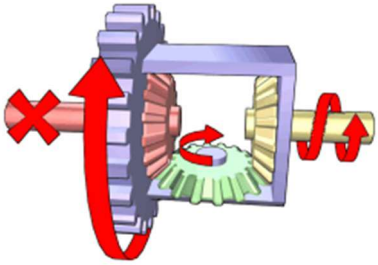
Ring and Pinion Gears – While the ring and pinion change transmission output rotation to the wheels by 90 degrees, they also operate at a ratio (typically in the 1960's at three or four input rotations from the transmission for every one rotation of the wheel). This came about during many years of early automotive design to minimize transmission gear size (and weight) and to allow a satisfactory sizing of the differential parts.

Side and Satellite Gears – the differential case gears allow one axle to turn at a different rotation rate versus the other axle. A side gear connects to each axle. The satellite gears are on a shaft mounted in the case that is driven by the ring and pinion housing. The satellite gears allow equal force to be applied to each side gear and axle.
NOTE: Different names are used for these gears.
Side gear called: Sun or Drive bevel gear.
Satellite gear called: Planetary, Spider, Pinion (not to be confused with the Ring and Pinion).

Refer to following simplified diagrams that better illustrate how a differential works. A more detailed illustration is in the Corvair Chassis Shop Manual.



The vehicle is traveling in a straight ahead. Both axles have the same traction and rotate at the same speed. The **green** satellite gear (via the **purple** ring gear and differential case and shaft into the **green** satellite gear) does NOT rotate and connects to the side **red** and **yellow** side gears that rotate at the same speed as the ring gear to turn the rear wheels.

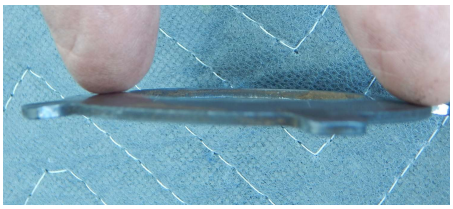


The vehicle has one wheel turning faster than the other. The illustration shows how the **green** satellite gear rotates when the **red** side gear and axle shaft moves slower than the **yellow** side gear and axle shaft. The **red** axle has greater traction than the **yellow** axle and causes the **green** satellite gear to rotate with the **yellow** side gear and axle to equalize force to each side gear and axle.

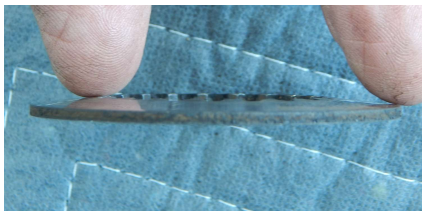
Limited slip differential – Initially this design was meant to ensure that if one wheel had far less traction than the other a minimum force would still be transmitted to the axle with greater traction. The intent was to provide some traction on slippery surfaces, but they found great favor with racing folks and off-road enthusiasts to get a lot of engine power to BOTH wheels for greater traction. This resulted in more robust locking differential designs that were never used by the Corvair and will not be reviewed here.

The Corvair Positraction limited slip differential. – Chevrolet offered a limited slip differential called "Positraction" for the Corvair. It is a modification of the "open" differential gear system using friction plates (clutch) that bind each axle together via a preset torque (the Corvair shop manual specifies a minimum 50 ft lbs. at the axle) The limited slip clutch connects both axles to the ring and pinion carrier to ensure a minimal force of 50 ft lbs. is transmitted to the wheel with greater traction when the other wheel has less traction. Yes, this is a compromise of how the open differential works in a turn, but overcomes the slipping wheel problem when one wheel loses traction on a slippery surface. Most driving is straight ahead, that minimized clutch slipping and heat build-up that only occurs during vehicle turns or when one wheel in on a slippery surface.

The Corvair Positraction limited slip clutch. – Unlike some Chevrolet Positraction clutches that use a friction material on the clutch friction plates, the Corvair clutches are solid metal with no friction material attached. Some of the plates are curved and some are flat. The plates either connect to the differential ring case via four outer protrusions, or they have inner small protrusions that the axle side gear fits into. The plates are assembled (refer to Chassis Shop Manual) so they fit together under pressure and have friction between them. Refer to images.



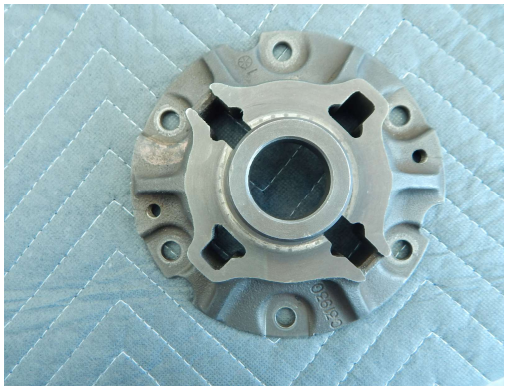
Curved clutch plate with outer protrusions to fit into ring gear differential case slots.



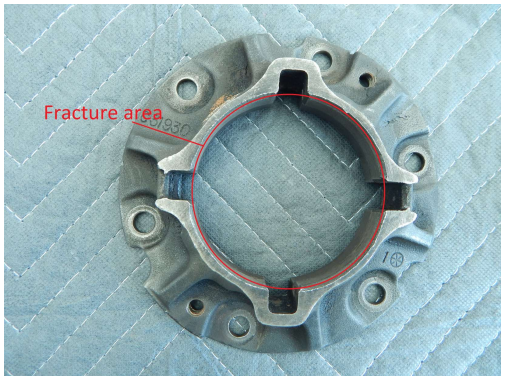
Curved clutch plate with inner protrusions to fit onto side gear ridges.

flat clutch plate with outer protrusions to fit into ring gear differential case slots.

Early vs. late Positraction – The early design was an option on model years 1961 - 1964, then a more robust design was used for the option during model years 1965 - 1969. The early design case side cover has a history of occasionally failing. Chevrolet improved the design for the 1965 models. The most obvious difference is the early design was assembled with six bolts while the latter design was assembled with nine bolts. Refer to illustrations of good earlier carrier versus one that has failed.



Early POSITRATION case side cover.



Early failed POSITRATION case side cover fractured and separated.

Corvair Positraction lubrication – Some limited slip differentials require lubrication additives for proper functioning of the clutches. The Corvair 1961 through 1965 model year shop manuals make no recommendations about adding Positraction lubricant additives to the gear oil.

The Corvair 1966 and 1967 model year shop manual supplement states NOT to add limited slip additive to the gear oil as follows: **On vehicles equipped with Postraction axles use the above mentioned lubricant** *(equivalent of GL-4 80W90 gear oil)*, **as** *(adding)* **Special Positraction lube will cause hard shifting on standard transmissions in cold weather.** Others have reported gear clash while shifting when limited slip differential lube was added.

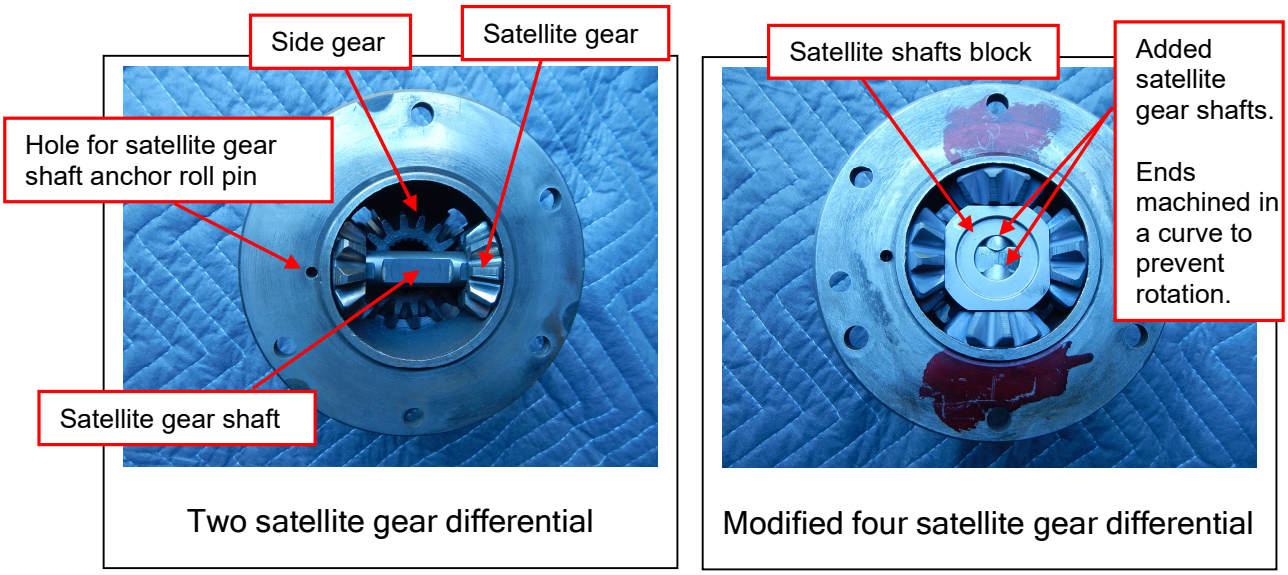
The 1969 shop manual supplement states: **CAUTION: With Positraction rear axles use special Positraction lubricant.**

What to do? Dirty, worn, or improper lubricant will cause the clutch disks to overheat and wear during turns or when driving on slippery surfaces. The audible symptoms are “squealing” or noisy “chattering” when the vehicle is in a turn. If this happens the consensus is to add a limited slip additive. Once the clutch packs are silent during a turn, change the gear lube without an using an additive.

It is suggested that Positraction equipped Corvair, should have the transaxle lubricant changed every 10,000 miles, more often if the car is raced, to prevent damage to the clutch plates. This may seem overly cautious, but transaxle lubricant is less costly versus rebuilding a differential clutch pack.

The FOUR satellite gear modification. – The Corvair differential design used two satellite gears. The purpose of adding two additional satellite gears is to reduce force on individual satellite gear teeth that could cause them to fail. Either the open or limited slip differential can be modified to four satellite gears.

The Corvair differential has an undeserved reputation for satellite gear failures. A common cause of satellite gear failure is worn out lubricant causing gear, shaft, and thrust washer wear. Another cause is aggressive driving, like engaging the clutch rapidly at high engine RPM. If you are going to drive your Corvair aggressively, or race it, then modifying the differential from two to four satellite gears is warranted. Refer to the following illustration showing four satellite gear installation.



Two satellite gear differential

Modified four satellite gear differential

Adding two extra satellite gears requires:

- Two additional satellite gears
- Two additional satellite gear thrust washers
- A block to hold the two additional satellite gear shafts
- Two additional satellite gear shafts
- Machining the differential case

Over the years there have been several four satellite gear modifications offered for the Corvair differential. Not all are the same. For best function and reliability, the following features are recommended:

- Prevent case wear by satellite gear shaft rotation. The main satellite gear shaft is anchored by a split pin (see illustration). To prevent rotation of the added satellite gear shafts they should be machined to fit the curvature of the original satellite gear shaft or anchored by another method. See illustration.
- The differential case should be machined, in a manner like the original satellite gears and thrust washers, to hold the additional satellite gears thrust washers.
- Worn or damaged satellite gears should be replaced with new or re-manufactured (examined for fractures and typically re-coated).