TYRES – THEIR CONSTRUCTION & MAINTENANCE

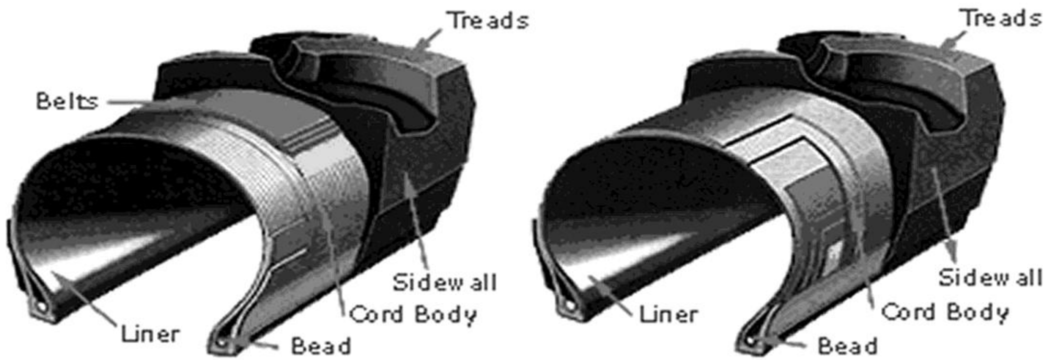
Pneumatic tyres are used on all types of vehicles, from cars to earthmovers to airplanes. Tyres enable vehicle performance by providing for traction, braking, steering, and load support. Tyres are inflated with air, which provides a flexible cushion between the vehicle and the road that smoothes out shock and provides for a comfortable ride quality.

The first practical pneumatic tyre was made by the Scot John Boyd Dunlop for his son's bicycle, in an effort to prevent the headaches his son had complained of while riding on the rough roads of the time. The pneumatic tyre also has a more important effect of vastly reducing rolling resistance compared to a solid tyre. Because the internal air pressure acts in all directions, a pneumatic tyre is able to "absorb" lumps and bumps in the road as it rolls over them without experiencing a reaction force opposite to the direction of travel, as is the case with a solid (or foam-filled) tyre. The difference between the rolling resistance of a pneumatic and solid tyre is easily felt when propelling wheelchairs or baby buggies fitted with either type.

Pneumatic tyres are made of a flexible elastomer material such as rubber with reinforcing materials such as fabric and wire. Tyre companies were first started in the early 20th century, and grew in tandem with the auto industry. Today over 1 billion tyres are produced annually, in over 400 tyre factories, with the three top tyre makers commanding a 60% global market share.

Basic Components /Tyre Construction

The construction of off-the-road depends, to a large extent, on the intended use of tyres. However, common components to all off-the-road tyres are the tread, carcass, beads, breakers, and sidewalls. Tubeless type tyres also have an inner liner.



Tread

The tread is the outermost covering of the tyre, and is the only part that normally comes in contact with the road surface. It, therefore, must be designed to protect the body of the tyre from cuts and wear. Depending on the intended use of the tyre, the rubber compound applied to the tread will be changed to customize cut tread pattern also has a large effect on the performance of the tyre. A number of tread patterns are available for different types of operations. These patterns feature excellent cut resistance, traction and longer serviceability. These factors are taken into consideration when recommending a tyre best suited for the operation.

Sidewall
The side walls are composed of flexible, crack resistant rubber, and protect the carcass from damage. For jobs where chuck holes, large rocks, etc. are a problem, tyres with high cut resistant sidewalls can be used. The sidewalls are designed to cushion the body plies from shock and cutting, while being able to flex and bend without cracking. The sidewall must also be able to withstand the ravages of the weather without deterioration.

Plies
A tyre is composed of a number of layers or plies. These plies are high tensile nylon cords which are loosely woven together and coated on both sides with a rubber compound. These layers of plies help contain the inflation pressure of the tyre in supporting the load. The high-tensile nylon cords have a greater resistance to shock, cutting and heat. This improves the durability of the tyre.

Carcass or Cord Body

The compressed air in a tyre supports the load placed on the tyre. The carcass forms a semi-rigid frame for the compressed air, but it is flexible enough to absorb some shocks and jolts. The carcass of the Bias tyre consists of a number of rubber-coated layers of fabric called "piles". The carcass determines the strength of the tyre and the ability to flex.

Bead

The beads fix the tyre to the rim to support the load.

Belts

In radial tyres stabilizer bias ply belts under the base rubber give added protection to the radial plies underneath and determine the shape of the footprint.

Liner

In tubeless tyres, this is composed of two or more layers of rubber, designed to retain air or liquid under pressure. The inner walls of tubeless tyres are lined. The liner is made of an air-impermeable rubber compound and is comparable to tubes used in tube type tyres. Tubeless tyre generally weigh less than comparable tube type tyres and are simpler to maintain tube and flap are eliminated.

Breakers

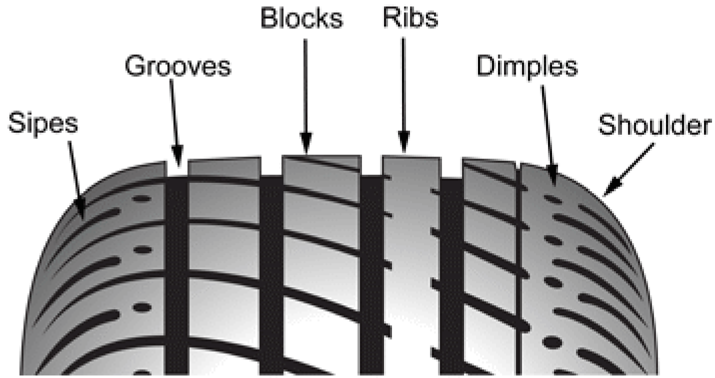
The breakers of Bias tyres are rubber-coated layers of cord between the tread and carcass, binding the two together. The breakers prevent cuts in the tread from reaching the carcass and absorb shocks.

Steel Breakers

The steel breaker tyre has steel cord breaker that give it very high cut resistance. It is especially useful where sharp rock is a problem, and is applicable t loader, dozer, dump truck, and occasionally earthmover type tyres. The adhesiveness between the steel cord and rubber is, however, more susceptible to heat damage than that of nylon cord and rubber. Accordingly, steel breaker tyres should not be subjected to conditions where heat generation is great. Because of the difficulty involved in retreading steel breaker tyres, they should not be used for jobs where more easily retreaded tyres can be used. Steel breakers that extend to the sidewall are also available for jobs where high side cut resistance is required.

A subset of tyre construction: tyre treads.

A proper tread design improves traction, improves handling and increases Durability. It also has a direct effect on ride comfort, noise level and fuel efficiency. Each part of the tread of your tyre has a different name, and a different function and effect on the overall tyre. Your tyres might not have all these features, but here's a rundown of what they look like, what they're called and why the tyre manufacturers spend millions each year fiddling with all this stuff.



Sipes are the small, slit-like grooves in the tread blocks that allow the blocks to flex. This added flexibility increases traction by creating an additional biting edge. Sipes are especially helpful on ice, light snow and loose dirt.

Grooves create voids for better water channeling on wet road surfaces. Grooves are the most efficient way of channeling water from in front of the tyres to behind it. By designing grooves circumferentially, water has less distance to be channeled.

Blocks are the segments that make up the majority of a tyre's tread. Their primary function is to provide traction.

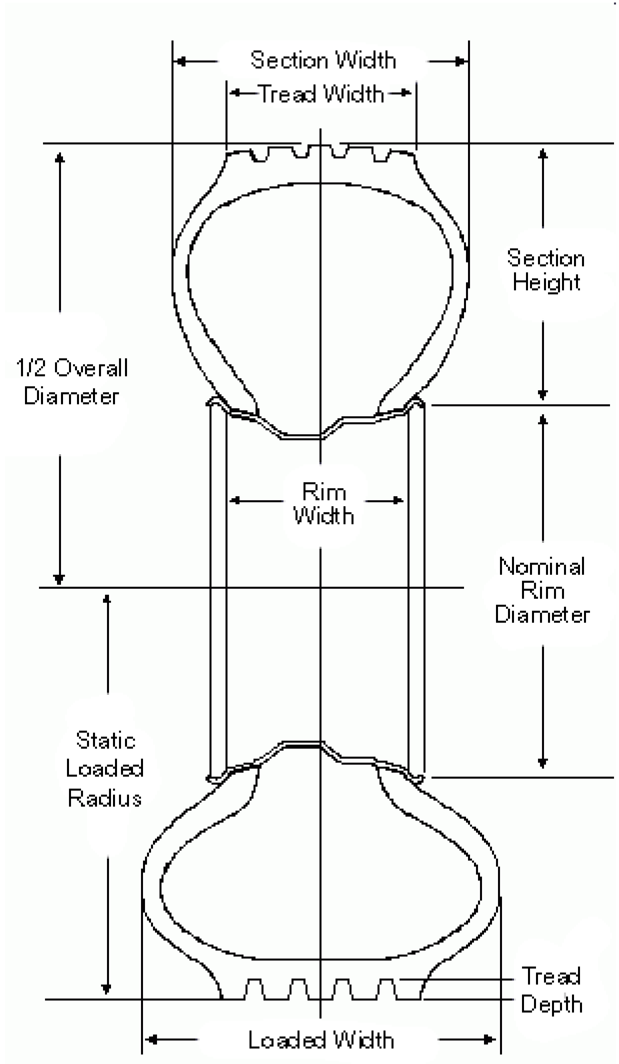
Ribs are the straight-lined row of blocks that create a circumferential contact "band."
Dimples are the indentations in the tread, normally towards the outer edge of the tyre. They improve cooling.
Shoulders provide continuous contact with the road while maneuvering. The shoulders wrap slightly over the inner and outer sidewall of a tyre.
The Void Ratio is the amount of open space in the tread. A low void ratio means a tyre has more rubber is in contact with the road. A high void ratio increases the ability to drain water. Sports, dry-weather and high performance tyres have a low void ratio for grip and traction. Wet-weather and snow tyres have high void ratios.

Tread patterns

There are hundreds if not thousands of tyre tread patterns available. The actual pattern itself is a mix of functionality and aesthetics. In amongst all this, there are three basic types of tread pattern that the manufacturers can choose to go with:

- Symmetrical: consistent across the tyre's face. Both halves of the treadface are the same design.
- Asymmetrical: the tread pattern changes across the face of the tyre. These designs normally incorporates larger tread blocks on the outer portion for increased stability during cornering. The smaller inner blocks and greater use of grooves help to disperse water and heat. Asymmetrical tyres tend to also be unidirectional tyres.
- Unidirectional: designed to rotate in only one direction, these tyres enhance straight-line acceleration by reducing rolling resistance. They also provide shorter stopping distance. Unidirectional tyres must be dedicated to a specific side of the vehicle, so the information on the sidewall will always include a rotational direction arrow. Make sure the tyres rotate in this direction or you'll get into all sorts of trouble.

Tyre Dimensions


Section Width
Tread Width
Section Height
1/2 Overall Diameter
Rim Width
Nominal Rim Diameter
Static Loaded Radius
Tread Depth
Loaded Width

Aspect ratio

This is the the ratio of the section height of the tyre's cross-section to its section width. An example of this might be 65, which means that the height is equal to 65% of the tyre's width. To calculate the aspect ratio, multiply the section width (e.g. 215) by 0.65 to get the section height as 215x.65=139.75 in mm. This is the height of the rubber from rim to tread on one side of the tyre.

Overall diameter

The measurement of the distance of an unladen tyre from tread surface to tread surface on opposite sides of the tyre.

Overall width

Measurement of the cross section of an unladen tyre including ribs and protrusions. Usually the same as section width on radial tyres.

Section width

Measurement of the cross section of an unladen tyre across the casing only—not including ribs or protrusions.

Tread width

Distance across the tread face of an unladen tyre.

Tread depth
Distance from tread surface to major groove base at designated measuring point.
Section height
Distance from the bead seat to the tread surface of an unladen tyre.
Rim width
distance between the rim flanges.
Nominal rim diameter
Diameter of the rim from bead seat to bead seat in inches.
Static loaded radius
Distance from the center of the axle to the ground of a loaded tyre under maximum dual load and inflation as stamped on the sidewall of the tyre.
Loaded width
The maximum section width of a loaded tyre under maximum dual load and inflation as stamped on the sidewall of the tyre.
Minimum dual spacing
The minimum allowable distance between the wheel center lines in a dual arrangement.

Revolutions per mile (rpm)
The number of tyre revolutions in one mile measured at a speed of 55 mph at maximum dual load and inflation as stamped on the sidewall of the tyre.

Load Rating
Tyres are specified by the manufacturer with a maximum load rating. Loads exceeding the rating can result in unsafe conditions that can lead to steering instability and even rupture. This is a number corresponds to the maximum load in pounds that a tyre can support when properly inflated.

Inflation pressure
Tyres are specified by the manufacturer with a recommended inflation pressure that permits safe operation within the specified load rating.

Speed rating
The speed rating denotes the maximum speed at which a tyre is designed to be driven for extended periods of time. The ratings range from 99 mph (160 km/h) to 186 mph (300 km/h).

Construction
R indicates the tyre is a radial type tyre. B indicates the tyre is a bias ply type tyre.

PR (Ply Rating)
The word "Ply" refers to the number of cords which form the carcass of a tyre. When cotton cord was used the strength of the casing was shown by the actual ply of cotton cords. Today, the cord material has changed from cotton to nylon, steel and others, so the ply rating is used to indicate strength, and not necessarily the number of cord plies in the tyre.

Tyre Use Classifications

Tyres are classified into several standard types based on the type of vehicle they serve. Since the manufacturing process, raw materials, and equipment vary according to the tyre type it is common for tyre factories to specialize in one or more tyre types. In most markets factories that manufacture passenger and light truck radial tyres are separate and distinct from those that make aircraft or OTR tyres.

Passenger and Light Truck

High Performance tyres, Mud and Snow tyres, all-season tyres, all-terrain tyres are typical passenger & light truck tyres.

Run-Flat Tyre

Several innovative designs have been introduced that permit tyres to run safely with no air for a limited range at a limited speed. These tyres feature still load supporting sidewalls and often plastic load-bearing inserts.

Heavy duty truck tyres

Heavy duty tyres are also referred to as Truck/Bus tyres. These are the tyre sizes used on vehicles such as commercial freight trucks, dump trucks, and passenger busses.

Off-the-Road (OTR)

The OTR tyre classification includes tyres for construction vehicles such as backhoes, graders, trenchers, and the like; as well as large mining trucks. These tyres are built with a large number of reinforcing plies to withstand severe service conditions and high loads. OTR tyres are used in rather low speed conditions.

Agricultural

The agricultural tyre classification includes tyres used on farm vehicles, typically tractors and specialty vehicles like harvesters. High floatation tyres are used in swampy environments and feature large footprints at low inflation pressures.

Racing

Racing tyres are highly specialized according to vehicle and race track conditions. Tyres are specially engineered for specific race tracks according to surface conditions, cornering loads, and track temperature.

Industrial

The Industrial tyre classification includes pneumatic and non-pneumatic tyres for specialty industrial vehicles such as skid loaders and fork lift trucks.

Bicycle

This classification includes all forms of bicycle tyres, including racing tyres, mountain-bike tyres, and snow tyres.

Aircraft

Aircraft tyres are designed to withstand heavy loads for short durations. The number of tyres required for aircraft increase with the weight of the plane. Aircraft tyre tread patterns are designed to facilitate stability in high cross-wind conditions, to channel away water to prevent hydroplaning, and for braking traction. Aircraft tyres are usually inflated with nitrogen gas in order to minimize the expansion and contraction due to the extreme changes in temperature experienced during flight. Aircraft tyres generally operate at high pressures, up to 200 psi for airliners and higher for business jets.

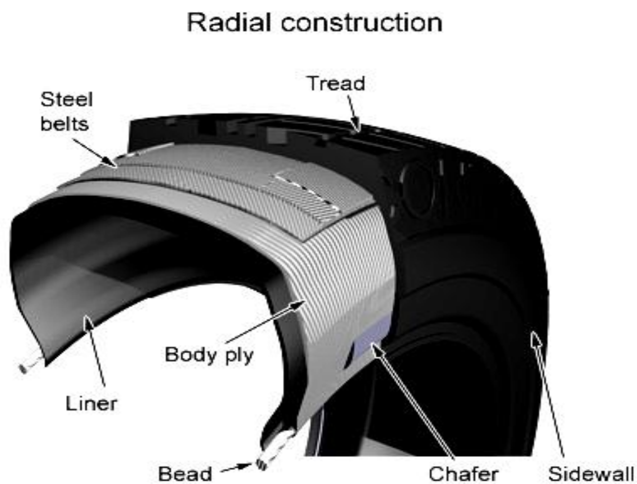
Motorcycle

Motorcycle tyres are available in different flavors - Sport Touring, Street, Sport street tyres, Track/Slick tyres.

Bias/Crossply & Radial types of Tyres

RADIAL TYRES

The radial is a type of tyre that is constructed with rubber coated, reinforcing steel wire belts that are assembled parallel and run from side to side, bead to bead at an angle of 90 degrees to the circumferential centerline of the tyre. They constrict the radial ply cords and stabilize the tread area. This makes the tyre more flexible which reduces rolling resistance to improve fuel economy. Then numerous rubber coated steel belts are then constructed into the "crown" of the tyre under the tread to form a strong stable two-stage unit.



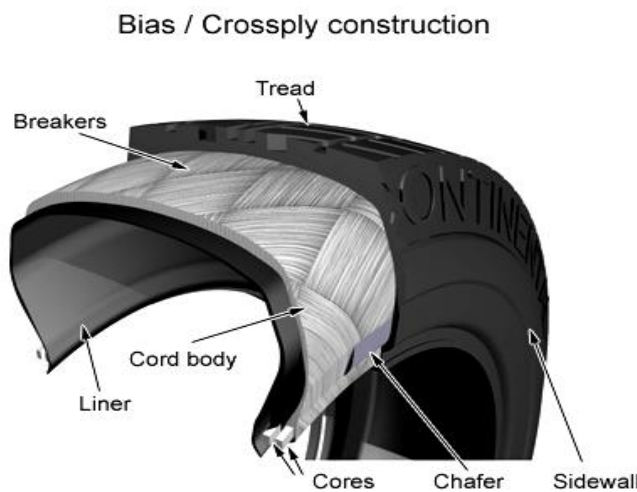
Radial tyres are the preferred tyre of choice in most applications for several key reasons.

- The combination of steel stabilizing belts in the single-layer radial casing allows the tread and sidewall to act independently. The sidewall flexes more easily under the weight of the vehicle and its cargo, while the tank-track type tread provides even contact with the ground. Greater vertical deflection is achieved with radial tyres. This is desirable because extreme flexing greatly increases resistance to punctures.
- To increase a radial tyre's strength, larger diameter steel wires are used. Larger steel wires can help reduce punctures, tears and flats. Larger steel wires also help distribute heat, resulting in a cooler running tyre and improving fuel economy. Unlike bias ply tyres larger steel cables have little negative affect on performance.
- The parallel stabilizing steel belts of the radial minimize tread distortion. As the sidewalls flexes under load, the belts hold the tread firmly and evenly on the ground or object and thus minimizing tread scrub and greatly increasing tread life.

- When cornering the independent action of the tread and sidewalls keeps the tread flat on the road. This allows the tyre to hold to its path.
- When off road, the radial tyre's stabilizing steel belt design aids in greater traction by holding the tread evenly over obstacles allowing the tread of the tyre to have a better chance of finding traction.
- Radial tyres lay all of the cord plies at 90 degrees to the direction of travel (that is, across the tyre from lip to lip). This design avoids having the plies rub against each other as the tyre flexes, reducing the rolling friction of the tyre. This allows vehicles with radial tyres to achieve better fuel economy than vehicles with bias-ply tyres. It also accounts for the slightly "low on air" (bulging) look that radial tyre sidewalls have, especially when compared to bias-ply tyres.

BIAS /CROSS PLY TYRES

The bias ply tyre construction utilizing rubber-coated layers known as plies composed of textile cords, usually nylon and sometimes Kevlar. The plies layered diagonal from one bead to the other bead at about a 30 degree angle. One ply is set on a bias in one direction as succeeding plies are set alternately in opposing directions as they cross each other and the ends are wrapped around the bead wires, anchoring them to the rim of the wheel. The layers of plies are them covered with more rubber to form the tread of the tyre. Bias ply tyres are sometimes called cross-ply tyres.



The reasons for this limited use of bias tyres are:

- The bias-ply tyre casing is constructed to form one working unit. When the sidewalls deflect or bend under load, the tread squeezes in and distorts. The distortion affects the tyres footprint and can decrease traction and increases wear depending on the terrain. The tread distortion also causes abrasion from the ground surface, which reduces the life of the tyre. These factors are why bias ply tyres are not idea for passenger car tyres or as tyres that my see highway use unless used as tyres for a towed trailer.
- Bias Ply Strength - The way to increase the strength of bias-ply tyres is by increasing the number of plies and bead wires. More plies means more mass which, increasing heat retention and reducing tyre life.
- Because of the bias ply inherent construction, sidewall strength is less than that of a radial tyre's construction and cornering is significantly less effective. This is probably one of the main reasons bias ply tyres are not used for passenger cars and trucks.

- However because of the bias ply construction and inherent strength of a properly inflated tyre, the bias ply is idea for straight line towing.

Comparison of Radial vs. Cross-ply construction

<table>
<tr><th>Cross-ply components</th><th>Radial components</th></tr>
<tr><td colspan="2">The tread consists of especially compounded/vulcanized rubber which can have unique characteristics ranging from wear resistance, cut resistance, heat resistance, low rolling resistance, or any combination of these. The purpose of the tread is to transmit the forces between the rest of the tyre and the ground.</td></tr>
<tr><td colspan="2">The sidewall is a protective rubber coating on the outer sides of the tyre. It is designed to resist cutting, scuffing, weather checking, and cracking.</td></tr>
<tr><td>The chafer protects the bead and body from chafing (wear from</td><td>The chafer of a radial tyre acts as a reinforcement. It increases the overall stiffness</td></tr>
</table>

<table>
<tr><td>rubbing) where the tyre is in contact with the rim.</td><td>of the bead area, which in turn restricts deflection and deformation and increases the durability of the bead area. It also assists the bead in transforming the torque forces from the rim to the radial ply.</td></tr>
<tr><td colspan="2">The liner is an integral part of all tubeless pneumatic tyres. It covers the inside of the tyre from bead to bead and prevents the air from escaping through the tyre.</td></tr>
<tr><td colspan="2">The bead of a cross-ply tyre consists of bundles of bronze coated high tensile strength steel wire strands which are insulated with rubber. A cross-ply tyre designed for off-road use typically has two or three bundles. A radial on-road tyre normally only has one. The bead is considered the foundation of the tyre.</td></tr>
<tr><td>The cord body is also</td><td>The body ply of a radial tyre</td></tr>
</table>

known as the tyre carcass. It consists of layers of nylon plies. The cord body confines the pressure, which supports the tyre load and absorbs shocks encountered during driving. Each cord in each ply is completely surrounded by resilient rubber. These cords run diagonally to the direction of motion and transmit the forces from the tread down to the bead.	is made up of a single layer of steel cord wire. The wire runs from bead to bead laterally to the direction of motion (hence the term "radial plies"). The body ply is a primary component restricting the pressure which ultimately carries the load. The body ply also transmits the forces (torque, torsion, etc.) from the belts to the bead and eventually to the rim.
The **breakers** are also known as belts. They provide protection for the cord body from cutting.	The **belts** are layers of steel cord wires located between the tread and the body ply. Off-road tyres can have up to

They also increase tread stability which resists cutting. Breakers can be made of nylon, aralon, or steel wire.	five belts. The steel wire of the belts runs diagonally to the direction of motion and increase the rigidity of the tread which increases the cut resistance of the tyre. They also transmit the torque forces to the radial ply and restrict tyre growth which prevents cutting, cut growth and cracking.

Comparison of Radial vs. Cross-ply performance

This little table gives you some idea of the advantages and disadvantages of the two types of tyre construction. You can see the primary reasons why radial tyres are almost used on almost all the world's passenger vehicles now, including their resistance to tearing and cutting in the tread, as well as the better overall performance and fuel economy.

	Cross-ply	Radial
Vehicle Steadiness	√	X
Cut Resistance - Tread	X	√
Cut Resistance - Sidewall	√	X
Reparability	√	X
Self Cleaning	√	X
Traction	X	√
Heat Resistance	X	√
Wear Resistance	X	√
Flotation	X	√
Fuel Economy	X	√

Solid tyre

Many tyres used in industrial and commercial applications are non-pneumatic, and are manufactured from solid rubber and plastic compounds via molding operations. Solid tyres include those used for lawn mowers, golf carts, scooters, and many types of light industrial vehicles, carts, and trailers. Solid (non-pneumatic) tyres have also been designed for automotive use using special compounds of polyurethane, although have not yet been delivered for broad market use.

Difference between Tubeless & Tube type tyres

In place of the tube in a normal tyre, the tyre and the rim of the wheel form an air container in a tubeless tyre. To 'seal in the air', in this tyre-rim compartment, the inner wall of the tyre is throughly lined with an impermeable, air-tight membrane. This performs, in essence, the important chore of substantially reducing the permeation of air, as compared to the natural rubber inner liner, a function of which is why we use a butyl tube in a tubed tyre.

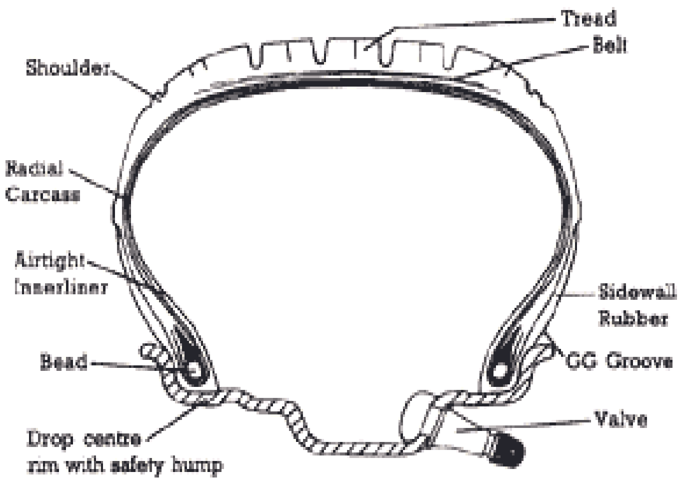
Let us see where the construction difference lies. Apart from the basic construction, which remains the same, the main difference lies in the application of the inner liner of the carcass. Whereas in a tube-type construction the inner liner acts as a medium for reducing friction between the cord body and the tube, in a tubeless construction this is the tube itself. Thus the inner liner in a tubeless tyre is made up of a Halogenated Butyl rubber like Chlorobutyl or Bromobutyl for better air impermeability together with high heat and weather resistance.

Another major difference lies in the bead area of the tyre. While considering a radial tyre both type of tyres have a flexible yet rigid bead, where the bead bundle is very thin and the stability of the tyre is enhanced by the bead apex or bead filler controlling it, in a tubeless it also has to maintain the air pressure within. Thus the bead heel in the tubeless sits more tightly within the flange of the rim, and to ensure this tight fitting most tyre manufacturers add an extra wrapping over the bead area. This enhances high-speed performance while achieving a better cornering ability on the tubeless.

The other advantages are the absence of a tube make the tyre lighter in weight, thus has less chance of vibrations, which means that it leads to a better fuel saving. Even the rolling resistance in a tubeless radial is lower when compared to a tube type radial. This is due to the fact that the tubeless tyre sidewall is more supple as there is no internal body to create a friction. This also helps the tyre to run cooler as it eliminates heat generation caused by the internal shuffling of the tube.

The inner liner also acts as an absorbent during a nail penetration making the nail act like a plug and therefore the tyre has a slow leak and not a sudden deflation as it occurs on a tube- type tyre. This can be illustrated by a simple example. Pierce an ordinary balloon with a pin and it disintegrates, while sticking a cello tape on the balloon would enable the pin to penetrate without it bursting. Thus, come what may, a tubeless tyre never goes flat all of a sudden and hence is more safe.

As there is no tube, and, hence, no tube valve, a specialized valve is employed for increasing/reducing the air pressure in a tubeless tyre. The valve (check out the line drawing to see how it mounts) sits on the tyre rim and is ingeniously sealed by a large high quality rubber seal which is easy to mount.



TUBELESS	TUBE TYPE
The inner tube is integral within the tyre, known as inner liner. The valve is	Components: Tyre, Tube with Valve and Rim.

permanently fixed to the rim. THE ASSEMBLY IS AIRTIGHT.	
In case of a puncture, loss of air is very slow, since air can escape only through the narrow gap made by the penetration of a nail.	Instant air leakage after getting punctured. The air under pressure finds a way between the tube, tyre and through the rim hole.
High-speed performance while achieving a better cornering ability.	High speed performance cannot be achieved.
The absence of a tube makes the tyre lighter in weight. Better fuel efficiency.	Heavier tyre, less fuel efficient
Sidewall is more supple as there is no internal body to create a friction. This eliminates heat	More heat generation during traveling.

generation	
Tubeless tyres can flex over an object, giving it a better impact resistance than a tube type one.	Cannot flex easily over an object. Hence lesser impact resistant.

Regulatory Bodies

Of the many regulatory bodies for tyre design, applications, etc in the world, the Tyre and Rim Association, Inc is the most important regulatory body for all OTR tyres.

The Tyre and Rim Association in the United States has established a liaison with the following other international tyre and rim organizations:

- Associacao Latino Americana De Pneus E Aros, San Paulo, Brazil
- European Tyre and Rim Technical Organization (ETRTO), Brussels, Belgium
- Indian Tyre Technical Advisory Committee, New Delhi, India

- The Japan Automobile Tyre Manufacturers" Association (JATMA), Tokyo, Japan
- The Tyre and Rim Association of Australia, Hawthorn, Australia

Tyre performance metrics

- **Tread wear :** Friction between the tyre and the roadway causes the tread rubber to wear away over time. Government standards prescribe the minimum allowable tread depth for safe operation. There are several types of abnormal tread wear. Poor wheel alignment can cause excessive wear of the innermost or outermost ribs. Over inflation can cause excessive wear to the center of the tread. Under inflation can cause excessive wear to the outer ribs. Tyre manufacturers have mutually established standards for tread wear testing that include measurement parameters for tread loss profile, lug count, and heel-toe wear.

- **Dry traction :** Dry traction is measure of the tyre's ability to deliver traction, or grip, under dry conditions. Dry traction increases in proportion to the tread contact area. Dry traction is also a function of the tackiness of the rubber compound.
- **Wet traction :** Wet traction is measure of the tyre's ability to deliver traction, or grip, under wet conditions. Wet traction is improved by the tread design's ability to channel water out of the tyre footprint and reduce hydroplaning.
- **Force Variation :** The tyre tread and sidewall elements undergo deformation and recovery as they enter and exit the footprint. Since the rubber is elastomeric, it is compressed during this cycle. As the rubber deforms and recovers it imparts cyclical forces into the vehicle. These variations are collectively referred to as Tyre Uniformity. Tyre Uniformity is characterized by Radial Force Variation (RFV), Lateral Force Variation (LFV), and Tangential Force Variation. Radial and Lateral Force Variation is measured on a Force Variation Machine at the end of the

manufacturing process. Tyres outside the specified limits for RFV and LFV are rejected. In addition, Tyre Uniformity Machines are used to measure geometric parameters including Radial Runout, Lateral Runout, and Sidewall Bulge in the tyre factory at the end of the manufacturing process as a quality check.

- **Balance :** When a tyre is rotated it will exert a centrifugal force characteristic of its center of gravity. This cyclical force is referred to as balance, or imbalance or unbalance. Tyres are checked at the point of manufacture for excessive static imbalance and dynamic imbalance using automatic Tyre Balance Machines. Tyres are checked again in the auto assembly plant or tyre retail shop after mounting the tyre to the wheel. Assemblies that exhibit excessive imbalance are corrected by applying balance weights to the wheels to counteract the tyre/wheel imbalance.
- **Centrifugal Growth :** A tyre rotating at high speed will develop a larger diameter due to centrifugal forces that force the tread rubber away from the axis of rotation. As

the tyre diameter grows the tyre width decreases. This centrifugal growth can cause rubbing of the tyre against the vehicle at high speeds.

- **Rolling resistance :** Rolling resistance is the resistance to rolling caused by deformation of the tyre in contact with the roadway. As the tyre rolls, tread enters the contact area and is deformed flat to conform to the roadway. The energy required to make the deformation depends on the inflation pressure, rotating speed, and numerous physical properties of the tyre structure, such as spring force and stiffness. Tyre makers seek lower rolling resistance tyre constructions in order to improve fuel economy in cars and especially trucks, where rolling resistance accounts for a high amount of fuel consumption.
- **Stopping distance :** The use of performance oriented tyres, which have a tread pattern and rubber compounds designed to grip the road surface, usually has slightly shorter stopping distances. However, specific braking tests are necessary for data beyond generalizations.

TRA Classification of OTR Tyres

Off-the-road tyres are classified as follows by the Tyre and Rim Association, Inc. (TRA). The purposes of the TRA include the establishment of interchangeability standards for tyres, rims and allied parts for the guidance of manufacturers of such products, designers and manufacturers of motor vehicles, aircraft and other wheeled vehicles and equipment, and governmental and other regulatory bodies.

<table>
<tr><th>Application</th><th>TRA Code</th><th>Tread Type</th><th>Application</th><th>TRA Code</th><th>Tread Type</th></tr>
<tr><td rowspan="4">EARTHMOVER TYRES (Dump Trucks and Scrapers)</td><td>E-I</td><td>Rib Regular</td><td rowspan="2">GRADER TYRES (Motor Graders)</td><td>G-2</td><td>Traction Regular</td></tr>
<tr><td>E-2</td><td>Traction Regular</td><td>G-3</td><td>Rock Regular</td></tr>
<tr><td>E-3</td><td>Rock Regular</td><td rowspan="2">COMPACTOR TYRES (Tyre Rollers)</td><td rowspan="2">C-1</td><td rowspan="2">Smooth</td></tr>
<tr><td>E-4</td><td>Rock Deep</td></tr>
</table>

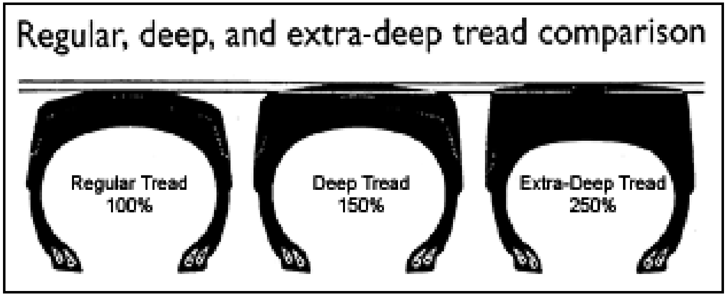
		Tread			
	E-7	Flotation			
LOADER AND DOZER YRES (Front-End Loaders and Tyre Dozers)	L-2	Traction Regular			
	L-3	Rock Regular			
	L-4	~Rock Deep Tread			
	L-5	Rock Extra Deep Tread			
	L-4S	Smooth Deep Tread			
	L-5S	Smooth Extra Deep Tread			

Tread Thickness/Depth
Tread depth is a vertical measurement between the top of the tread rubber to the bottom of the tyre's deepest grooves. According to the Tyre and Rim Association, there are three general classifications of tread thickness for off-the-road tyres: regular, deep, and extra deep. Deep and extra deep and 1.5 are 2.5 times thicker than regular, respectively. The thicker treads have greater cut and wear resistance.

The TRA tread codes are classified as follows:

- Extra Deep Tread L-5, L-5S
- Deep Tread E-4, L-4, L-4S
- Regular Tread E-2, E-3, G-2, G-3, L-2, L-3

Although thicker treads give greater wear and cut resistance, they also generate and retain more heat. Accordingly, work conditions for thick tread tyres should be thoroughly evaluated to prevent heat separation and other heat related damage. Deep and extra deep tread tyres have almost the same overall diameter which is larger than regular tread tyres. When replacing regular tread tyres with deep or extra deep tread tyres, the larger- overall diameters of the thicker tread tyres should be taken into consideration.



Size Identification & Aspect Ratio

The size of an off-the-road tyre is normally indicated by tyre width, rim diameter, and ply rating. The nomenclature for this is as follows:

Tyre Width	Rim Diameter	Ply Rating
21.00(inches)	35(inches)	36PR(Narrow base)

26.5 (inches)	25 (inches)	20PR(Wide base)

A narrow base tyre has an aspect ratio (tyre height/tyre width) of 96-98%, and a wide base tyre has an aspect ratio of 80-82%, Widths of narrow and wide base tyres of the same diameter are shown below:

13.00-15.5	21.00-26.5
14.00-17.5	24.00-29.5
16.00-20.5	27.00-33.5
18.00-23.5	30.00-37.5

For example, the overall diameters of 18.00-25 E3 and 23.5-25 E3 are 63.5 inches and 63.8 inches: almost the same. According to TRA guidelines, tyres with an aspect ratio of 65-70% are called *super low profile tyres* and provide high flotation and stability and are usually indicated as follows: *Tyre width/aspect ratio-rim diameter* (40/65-39). Some low profile tyres are also indicated by *overall diameter x tyre width-rim diameter* (42 x 17-20). A suffix, NHS, TG or K, may be attached. These are TRA designations used to differentiate between tyres requiring certain conditions. NHS: Not for highway service, TG:Tractor-grader tyres, not for highway use, and K: Compactor tyre for use on 5° drop center or semi-drop center rims having bead seats with nominal minus 0.032 diameter.

Ton-Kilometre per Hour (TKPH)

Earth-moving and mining tyres have become increasingly important with the development of ultra large construction vehicles. The primary task of these heavy-duty tyres is to haul maximum loads faster, over longer distances. The inevitable consequence of heavy hauling is heat buildup in the tyres. As tyres have limited resistance to heat, deterioration of the tyre may begin at any early stage of operations. Accordingly it is necessary, when selecting tyres, to determine the amount of work which will keep the tyre within a safe range to avoid over-heating.

The amount of work done under the given conditions and within a safe range is known as "Ton-Kilometre-Per-Hour" (TKPH) and can be calculated in a number of ways.

Method 1

TKPH = (Mean Vehicle Load * Work Day Average Speed * % Axle Load Distribution) / (Number of tyres per axle * 100)

Method 2

TKPH = Mean Tyre Load (tons) * Work Day Average Speed (km/h)

Mean Tyre Load = 1/2 (Loaded Mass + Empty Mass) of tyre being examined.

Work-day Average Speed = (Round trip distance in kilometers * number of trips per day)/(total hours of operation per day)

Load calculations
Refer method 1

Weigh the vehicle one axle at a time for each load to be weighed. Determine the mean loaded mass of the vehicle by adding the individual axle masses for each load. Determine the empty mass of the vehicle by weighing the individual axles and then adding them together. The percentage load distribution can then be determined by establishing what percentage of the load is carried by the front axle and rear axle(s) individually.

Mean vehicle load

Refer method 1

The mean vehicle load is the average mass of the vehicle during its working shift (or day). This is determined as follows:

Mean Veh. load = (Mean Gross Veh. Mass + Empty Vehicle Mass) / 2

Mean tyre load

Refer method 2

The mean load is the average load carried by the tyre during its working day, and is calculated as follows:

Mean tyre load = Average vehicle load * % load distribution of tyre

(% Load distribution is calculated below but here the individual tyres, not axles, are weighed)

% Load distribution

Refer method 1

The percent load distribution is the portion of the load carried by each individual axle. This is determined as follows:

% Load Distribution = (Mean Axle Loading * 100) / Mean Gross Vehicle Mass

Please note: All wheels on one axle must be on the scale for Axle load distribution and only one wheel must be on the scale for Tyre Load Distribution.

Calculation of Working Day Average Speed (WDAS)
There are two methods of calculating the WDAS:
(1) Measure the total distance covered by the vehicle in one shift or day, (km). Determine the total hours worked by the vehicle per shift per day.
WDAS = Total Distance Covered / Total Hours Worked
(2) Measure the round trip distance, (km). Determine the number of trips per shift or day. Determine the hours worked by the vehicle per shift or day.
WDAS = (Round trip distance * No. of Trips) / Total Hrs Operated

Formula limitation
Tests have shown that the TKPH formula does not apply:
- When tyres are loaded 20% above their capacity.
- On hauls of more than 32 kilometres.

Effective Tyre Selection

In selecting the tyre to meet your specific requirements, the factors which may influence the tyre must be taken into account. Conditions such as severe climatic changes and operational hazards, (for instance heat and cutting) make the selection of a tyre more difficult. In these cases the tyre must be selected for the worst possible conditions. Listed below are factors which must be considered when selecting a tyre.

Type of Dumper/Truck:

- Make, model and horsepower
- Maximum carrying capacity
- Maximum speed
- Tyre size design and ply rating

Operating Conditions:

- Climate
- Haul roads
- Speed (Mean & Maximum)

- Load
- Ton kilometre per hour
- Maintenance

Once the above factors have been considered, decisions on the following must be made in order to select the right tyre for the job.

- Correct tyre size, ply rating, type and tread pattern.
- Correct inflation pressures and loads.

Inflation Dynamics

The inflation pressure of a tyre is probably the most critical feature of tyre performance. It is also one of the most neglected aspects of tyre maintenance. It must be remembered at all times that it is the air inside the tyre that carries the load. One of the best means of reducing your tyre costs is to introduce a strict pressure maintenance program. Earthmoving tyres are designed to carry a specific load at a specific inflation pressure when mounted on a specific width rim. When these conditions are met, the deflection of the tyre carcass is in the optimum range and maximum tyre performance can be expected. If the combinations of these design dynamics are altered for any reason, tyre performance is reduced.

Inflation pressures should be checked daily. Recommended inflation pressures based on total load on tyres should be used. For accurate inflation, use a special low-pressure gauge with 10 kPa graduations. Gauges should be checked occasionally for accuracy. Always use sealing valve caps to prevent loss of air.

To determine the true operating pressure for a liquid filled tyre. The valve should be at the top of the tyre. Tyres filled with water or air-and-water should be tested when the tyres are cold, since the pressure rises somewhat as the fluid increases in temperature. A tyre that has sufficient pressure when it is hot may be under-inflated when it cools down.

Tyre overload and under inflation

Tyre overload or under-inflation have the same effect of over-deflecting the tyre. Under such conditions the tread on the tyre will wear rapidly and unevenly, particularly in the shoulder area. Radial cracking in the upper sidewall area will be a problem. With under-inflated drive tyres in high torque applications, sidewall buckles will develop, leading to carcass breaks in the sidewall. While an under-inflated drive tyre may pull better in some soil conditions, this is not generally true and not worth the high risk of tyre damage that such an operation invites.

Over inflation

Over-inflation results in a higher ground bearing pressure due to a reduced contact area. This results in excessive wear in the crown area of the tyre, reduced traction and flotation. The smaller ground contact area results in an increase in spinning, skidding, vibrations and bead damage due to the harder ride. The likelihood of reinforce flex breaks, impact fractures and cuffing is increased due to the higher tension in the tyre cord body and tread.

Load and Speed

Load

The load carried by each tyre should be within the TREDCO recommendations for the particular tyre size-ply rating and inflation pressure. The operator responsible for loading the vehicle must spread the load evenly across the pan to ensure a uniform load distribution on the tyres. In all cases, the prescribed load should not be exceeded. When determining the load to be carried the following must be borne in mind:

- The load on each vehicle must be kept within the limits specified for the vehicle. Overloading must be avoided.
- To determine the maximum permissible load, refer to the load inflation table for the particular tyre size, ply rating, cold inflation pressure and speed.

Damage due to over-loading

Overloading a tyre results in the tyre experiencing the combined effects of over- and under-inflation. The tyre will be susceptible to excessive tread and sidewall movement, cord tension and bead stress resulting in excessive heat generation. Tyre life will be adversely affected and early life failures, such as separations, impact fractures, penetrations and reinforce flex breaks, can be expected. Overloading reduces the life of a tyre. Overloading will cause permanent tyre damage.

Tyre damage due to over-loading

- Separation due to excessive heat.
- Cord and bead damage due to excessive deflection.
- Uneven wear due to excessive tread movement.
- Cut and impact damage due to increased cord tension.

Speed

The operator of the vehicle must adhere to the speed limits laid down by the management. The maximum speed permitted should not exceed the maximum speed classification of the tyres stipulated by the tyre manufacturer. In the interests of safety the operator of the vehicle should always take the prevailing conditions such as climate, haul road conditions, gradient and visibility into account.

Damage due to excessive speed

Excessive speed results in higher heat generation due to the increase in the rate of flexing that takes place. This can result in tyres failing due to heat separations, impact fractures and penetrations. The life of the tyre will be adversely affected due to increased rate of wear caused by excessive braking and sliding while cornering.

Correct working speed

The correct speed is determined from both the vehicle's maximum speed and the conditions prevailing on site. The following is a list of recommended maximum speeds under ideal conditions.

Vehicle	Tread Type	Distance (one	Max Speed

		way)	
Earthmovers		5 km	50 km/h
Graders		Unlimited	40 km/h
Dozers/Loaders:	L2,L3 type tread	600m	25 km/h
	L4 type tread	250m	25 km/h
	L5, L5S tyre tread	80m	8 km/h

Tyres used on Loader/Dozer are fitted with special abrasive and cut resistant tread compounds. These tread compounds are suited for slow moving vehicles in rough underfoot conditions and not for haulage type operations Machines in load-and-carry operations should not exceed these limits.

Effective Tyre Usage

Operating hints for prolonged tyre life

Haulage

- Avoid sharp turns
- Avoid Overloading
- Avoid abrupt starts and stops
- Avoid Rough and hard operation
- Do not exceed the speed limit
- Maintain correct inflation pressures
- Avoid stones and rocks
- Avoid oily and greasy surfaces
- Avoid sudden and hard braking
- Inspect the vehicle and its tyres before starting work.

Load and Carry

- Minimize wheel spinning
- Avoid rough and hard operation
- Avoid abrupt starts and stops
- Avoid overloading and spilling the load
- Use the bucket to clean the path to the materials being moved

- Maintain correct inflation pressures
- Avoid oily and greasy surfaces
- Avoid excessively forceful shoveling

To achieve optimum performance your tyres must be used correctly. Tyre abuse will result in rapid tread wear and reduce tyre performance, increasing costs. The following points must be observed by your staff members if tyre costs are to be contained.

Factors to be monitored

- Specified inflation pressures
- Specified load
- Specified vehicle speed
- Proper vehicle maintenance
- Haul road maintenance

Proper road maintenance

Off-the-Road Tyres are used on unpaved roads and these are often littered with objects which could easily damage a tyre.

The cleaning of the haul roads is the responsibility every person on site and not simply that of the haul road maintenance staff.

- Constant care of the haul roads and removal of any obstructions.
- Rock and spillage must be removed from the curves, loading and dumping areas.
- The road surfaces must be graded continually to improve drainage, filling up holes, and eliminating corrugations and partially protruding rocks.
- Haul roads must be watered regularly, but not excessively, to eliminate dust.
- Haul roads should be wide enough to accommodate four of the widest vehicles in the operation side by side.
- Super elevation (or banking up) of haul road corners is recommended to eliminate load transfer during cornering.

Haul road conditions

Haul road grade

Steep gradients cause tyre slippage, resulting in rapid tyre wear, increased fuel consumption and reduced work efficiency. gradients should never exceed 10%.

%Gradient = Vertical distance / Horizontal distance

Haul road contour

Correct drainage of haul roads is essential to prevent the accumulation of water on the road. The road contour should have a 3% crown and ditches on the sides to allow for drainage and water dispersion. The haul road should be built to be 4 times the width of the haul vehicles.

Poor Roads and Tyre Damage

Road Condition	Tyre Damage
Spillage, rock and other obstacles on the haul roads.	Impact fractures, penetrations and cuts
Irregular surfaces and pot	Irregular tread wear

holes.	and impact fractures
Adverse gradients	Shortens tyre life. Cuts and cut-separations.

Proper tyre maintenance

Tyres in most operations are the second highest cost item after fuel. In view of this fact it is on fitting that a strict tyre maintenance program be instituted to contain tyre costs. The right tyre must be used in the correct application and maintained properly. The neglect of tyres can result in increased costs and down time. The maintenance of tyres involves a daily inspection routine and all personnel who are associated with tyres have their part to play.

Tyre inspection

Off the road tyres are subjected to abnormal abuse due to the severity of the operating conditions. This leads to premature damage such as cutting, impact fractures, separations and penetrations. For safety and economic reasons daily inspection routines, including the following, should be carried out:

- Inflation pressure checks
- Tyre appearance
- Tyre valve and rim components appearance

Tyre inflation pressure inspection

While the tyre is in operation heat is generated. This causes the pressure to increase in the tyre. (Sometimes the pressure increase is in excess of 25% of the cold inflation pressure). The tyre must not be bled to reduce the pressure increase. If the pressure increase is in excess of 35% the tyre should be allowed to cool and be rechecked, or removed for inspection.

Inflation pressure should be checked daily before using the vehicle. If this is not possible, hot pressure checks should be recorded daily An analysis of the pressure recordings will show up possible leakers and other problem tyres before they are too extensively damaged.

Inflation pressures must be checked (and corrected when necessary) before operating the vehicle. This ensures that the tyres start working at the recommended COLD INFLATION PRESSURES as stipulated by the manufacturer. When the internal temperature of a tyre is the same as the ambient temperature, the pressure reading obtained is called the "cold pressure".
Pressure gauges must be accurate and should be checked against a master pressure gauge regularly. The master gauge should be examined frequently by the manufacturer and are calibrated by the SABS on a regular basis.

To maintain proper inflation pressures:

- Use proper rim components
- Check your pressure gauge against a master gauge
- Check tyre appearance and check for air leaks
- Check inflation pressure daily

Tyre appearance

A visual inspection of all tyres should be carried out daily Early discovery of tyre damage can reduce expensive tyre repairs at a later stage. Listed below are ways of reducing the loss of a damaged tyre if discovered early enough.

Damage	Action
Foreign matter in tread	Remove and repair
Separation	Remove and inspect
Tread cuts into the body	Remove and repair
Tread groove cracks	Check inflation history and run
Uneven wear	Check alignment and inflation

Oil impregnation	Clean
Tyre touching vehicle	Report to maintenance and inspect

Mechanical defects such as misalignment, cause rapid tyre wear. Daily inspections will help to highlight any mechanical defects so that corrective action can be taken early and quickly.

Tyre valve and rim components

The tyre rim components play a vital part in the performance of a tyre. Leaks due to faulty rim components will cause excessive heat build up due to under inflation. If left the tyre will fail due to a run flat condition. Daily checks on valve caps and extensions, and rim condition must be conducted during pressure checks.

Rim Maintenance:

- Rims must be free of rust. If rusted, then remove the rust by wire-brushing or sand blasting. Once free of rust, rims must be painted with an etching primer.
- Handle rims carefully to avoid damaging the bead seats and are distorting the rim-flanges.
- Care should be taken not to damage the valve hole.

O-Rings:

- O-rings should be stored in a cool, dry place.
- Use a new O-ring whenever a tyre is mounted on a rim.
- Ensure that the correct size O-ring is used.
- Take care not to damage the O-ring during fitting.

Matching of tyres

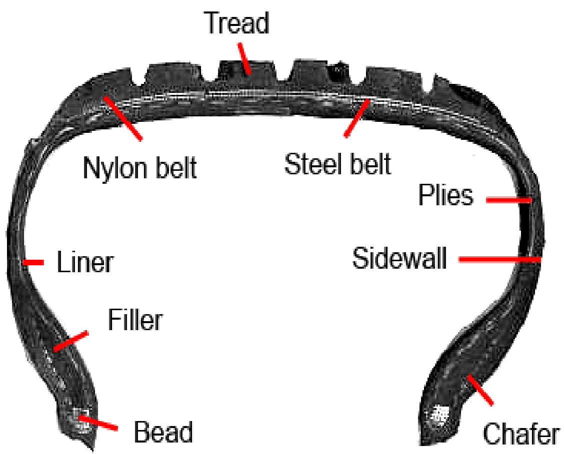
As a general rule, when two tyres are to be fitted on the same axle, tyres of the same type, and overall diameter should be used by preference Mismatched combinations will result in rapid tread wear on the smaller tyre and mass displacement onto the larger tyre. This is due to the larger tyre being forced to carry more of the load until its centre is the same height above the road as the smaller tyre. The smaller tyre is therefore dragged by the larger tyre through its foot print area to make up the distance traveled for each rotation. Careful attention to the following will assure maximum serviceability.

Tyre matching procedure

- Dual mounting of the same brand of tyre is ideal; if this is not possible then tyres of different brands, but of the same construction and type, and of the same diameter, should be used together.
- Dual mounting of tyres with different section widths is not recommended, even if they meet minimum values of dual spacing, because of differing deflection.
- Bias/Cross ply and radial ply tyres must not be mounted on the same axle.

Tyre manufacturing

Tyre manufacturing is a complex process, starting with the raw materials which pass through several processes to arrive at the finished tyre. The scope of this article is to include both current materials and processes together with a tyre manufacturing history.



- Beads made of high tensile steel wire. They anchor the tyre to the rim. Bead are usually coated with Bronze (Cu : Sn) or Brass Coating (Cu: Zn) for achieving adhesion with rubber.
- Fillers are triangular strips of hard rubber, applied above the beads, to give stiffness to the lower sidewall.
- Liner is made of halo butyl rubber. This replaces the inner tube in case of "Tubeless Tyres".

- Plies, made of rubberized textile fabric. The earliest textile used was cotton; later materials include rayon, nylon, polyester, and Kevlar™. These gives the tyre its strength. Small tyres have a single ply, larger tyres have more plies. The radial tyre construction shown here gives more strength than the old cross-ply, so that one radial ply is the equivalent of two crossed plies. The cords cross the carcass at 90 degrees, i.e. "radially".
- Steel belts (or formerly, textile) belts made of rubberized cord. They provide reinforcement to the tread. The cords cross at approx. 15 degrees.
- Nylon belts applied above the steel belts to improve the rigidity of the structure. The nylon cord is applied at zero degrees.
- Tread are made of rubber compounds designed to give high mileage, together with good traction on wet and dry roads. Since there is a conflict between these requirements, tread compounding uses a combination of rubbers and blacks designed to give the best compromise.

- Sidewalls protect the tyre carcass and uses compounds which give resistance to cutting and cracking.
- Chafers protect the tyre beads against the rim. They can be made of rubberized fabric, or hard rubber compound.

The Manufacturing Sequence

The sequential manufacturing sequence consists of :

Raw Materials and Semi-Manufacturing.
Mixing the Rubber Compounds.
Calendering and Extruding.
Assembly (Tyre Building).
Vulcanization (Curing).

Raw Materials and Semi-Manufacturing

Rubber is the best known material in tyres. The term rubber describes the physical properties of the material, rather than its chemical composition. Synthetic rubbers can be "tailor made" to provide the required properties.

Today, natural rubber is still used in large quantities, mainly because of its low heat build-up properties.

- Syrene/butadiene co-polymer is the most common synthetic rubber, usually abberviated to SBR. In the 1970's, oil extended SBR was used for the tread compounds, taking advantage of the better wet grip provided. Its lower cost was a big factor in its popularity. The trade-off was that this type of rubber gave lower mileage.
- Polybutadiene is used in combination with other rubbers because of its low heat build up properties.
- Halobutyl rubber is used for the tubeless inner liner compounds. The halogen atoms provide a bond with the carcass compounds which are mainly natural rubber. This inner liner replaces the butyl inner tube.

Ingredients must be added to achieve the desired properties in the cured rubber compounds.

- Carbon black, forms a high percentage of the rubber compound. This gives reinforcement and abrasion resistance.
- Silica, used together with carbon black in high performance tyres,as a low heat build up reinforcement.
- Sulphur cross-links the rubber molecules in the vulcanization process.
- Accelerators are complex organic compounds which speed up the vulcanization.
- Activators assist the vulcanisation. The main one is zinc oxide.
- Antioxidants prevent sidewall cracking, due to the action of sunlight.
- Textile fabric reinforces the carcass of the tyre.

Early tyres were made of layers of square woven cotton fabric, coated with rubber. Hence the expression that the tread was "worn down to the canvas". In 1918 a new type of cord fabric was introduced, where the cross threads, or "weft" were replaced by a few light strands of cotton called "picks". These were just there to hold the fabric together until it could be stabilized with a rubber coating in the Calendering Process. By 1938, cotton was being replaced by rayon, although its use continued until the 1960s on high speed cross ply tyres. This was because the cotton fibres provided a better bond to the rubber, and avoided ply separations at high speed. By 1958 rayon was being replaced by nylon. This had cost advantages. Because of nylon's greater strength it was possible to reduce the number of plies in most tyres from four to two. This brought about the introduction of the term "ply rating" , for example "4 PR". Modern radial tyres are normally monoply. This takes advantage of the fact that the 90 degree cord path is more efficient.

Polyester has been in and out of favour since the 1980s. It has a better strength/cost factor than nylon, but in the early stages there were problems with bonding polyester to the rubber compound in the cured tyre. Catastrophic failures could occur if the tyre overheated and the bond could then break

down and leave the cords on the failed tyre to be totally exposed like white spaghetti.
Steel cord fabric is used in truck tyres for the single ply of the steel cord carcass. Also the belts under the tread of radial tyres are made of steel cord. This steel cord consists of many fine filaments of brass coated steel wire, twisted together to give a cord like structure. The brass coating serves not only to protect the steel from rusting, but also assists the rubber to metal bonding in the curing process. Here the copper in the brass cross-links with the sulphur in the rubber, to combine as copper sulphide.

Mixing the Rubber Compounds

Typical percentages of the Synthetic Rubber and Natural Rubber mix in various types of tyres:

Passenger tyre 55% 45%
Light Truck tyre 50% 50%
Race tyre 65% 35%
Off-highway tyre(giant/earthmover) 20% 80%

The raw rubber, whether natural or synthetic is called the polymer. The process of combining this with the other ingredients is called mixing. Within the industry, the terms mixture and compound are synonymous. This may seem strange, but the mixing and subsequent curing of the rubber and its ingredients is analogous to baking a cake.

The rubber polymer used to be mixed with the other ingredients on a series of open mills. However, modern tyre factories use large internal mixers. The Banbury Internal Mixer manufactured by Farrel is typical of these.

Mill mixing comprised a series of machines with pairs of large steel rollers, rotating with a small gap between them, called a "nip". As the rubber was forced through the nip it provided shearing forces to masticate and work the rubber. Natural rubber required the input of a lot of energy to break it down, so it was first fed into a mill with corrugated grooves cut into it. This is called a "cracker mill". Carbon black for mill mixing was normally obtained as a master batch (pre-mixed with rubber) from an external source, to avoid the handling

problems of the fine powder. The curing ingredients are added as late as possible, to avoid the compound curing up.
With Banbury mixing, the process is better controlled. The mixing is done in three or four stages to incorporate the ingredients in a logical order.
The finished rubber compounds are sheeted off and stacked on pallets awaiting subsequent processing.

Calendering and Extruding

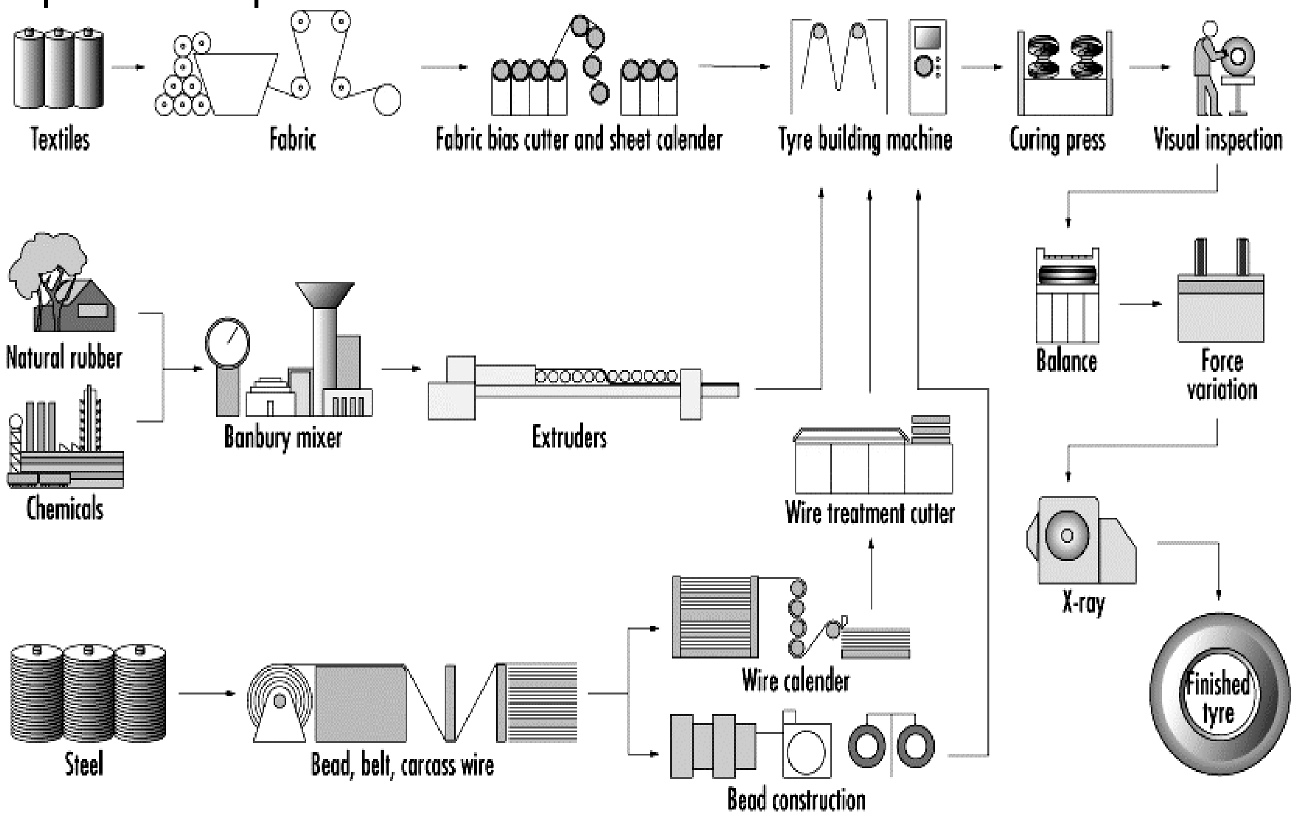
The fabrics and rubber compounds undergo a number of semi-manufacturing processes, before being assembled together on the building machine.

Calendering

The raw carcass materials made of textile or steel are coated with rubber. This is done by passing them through a machine called a calender which has a series of rollers in a stack, normally four. The rollers are called boles. The fabric passes between the middle rollers and rubber is fed from above and below. The thickness of the rubberized fabric is controlled by the gap between the rollers. This gap is called the nip.

Extruding

The profiled slabs of rubber which go to make up the tread and sidewall of the tyre are produced using an extruder. This machine forces the green rubber through a die to give the required shape.



Assembly

In the days of cross ply tyres, all the components were assembled together on a tyre building machine. The assembly was done on a building drum. The carcass plies were applied with the cords running at an angle, each layer in the opposite direction. Hence the term cross ply.

The change from cross ply to radial tyres happened more slowly and this change of manufacturing process was known in the industry as metalisation.

With radial tyres the assembly is carried out in at least two stages.

- First stage building is done on a flat collapsible steel building drum. The tubeless liner is applied, then the body ply which is turned down at the edges of the drum. The steel beads are applied and the liner/ply is turned up. The chafer and sidewall are combined at the extruder. They are applied together as an assembly. The drum collapses and the tyre is ready for second stage.
- Second stage building is done on an inflatable bladder mounted on steel rings. The green first stage cover is

fitted over the rings and the bladder inflates it, up to a belt guide assembly. The steel belts are applied with their cords crossing at a low angle.

Often a nylon zero degree belt is applied above the steel belts, to make the structure work more efficiently.

The tread rubber is then applied. The tread assembly is rolled to consolidate it to the belts and the green cover is detached from the machine.

For popular sizes, the tyre building process has been automated. Each component is applied separately along a number of assembly points. Such process has a high initial investment, but gives good quality and productivity.

Curing and Finishing

The term curing is preferred to vulcanization in tyre manufacturing. The meaning is the same. The green (uncured) tyres are molded in a curing machine also known as a vulcanizer, or a press. The tyre is placed over a butyl curing bladder which expands the cover to meet the mold surfaces as the press closes. Here the tread pattern is molded onto the tyre. Originally, tyre molds were in two halves. With radial tyres, the tread elements are split into segments to avoid distortion to the steel belts as the mold is closing. The sidewall plates are engraved to provide the inscriptions of size etc. on the cured tyre.

The tyre is cured with high pressure hot water inside the butyl bladder. This has replaced steam as the curing medium, since pure steam at the pressures required would give too high a temperature for an even cure. The mold sidewall assembly is fixed to steel plates which are heated by steam.

After curing, the tyres pass to the finishing department, where they are inspected for defects after which they are run on balance machines and the heavy spots marked. They then undergo other uniformity controls on a force variation machine. This measures the tyres for radial run out, lateral run out and consistency.

Retreading of Tyres

Retreading is a process that provides tyres with a second life by giving a new tread to a worn tyre. Retreading is the generic term for tyre reconditioning which extends the useful life of a worn tyre for its original purpose by the addition of new material.
In the majority of cases the tread rubber is the only part of a tyre to wear away. The structure of the tyre remains intact. As the tyre construction has been produced to be capable of more than one life, to use this potential by replacing the worn tread makes sound environmental and economic sense. Whilst a car tyre is retreaded only once, OTR tyres are often retreaded two or three times and aircraft tyres many, many times.
It is essential that casings are carefully inspected before retreading, to ensure that there is no casing damage that could reduce the safety and performance of the retreaded tyre. When the casing has been approved, the worn tread is buffed away and a new tread is bonded to the tyre casing. There are two different process techniques (hot and cold), but both are

similar to the manufacture of a new tyre, bonding a new tread through the application of heat and pressure for a predetermined time. Retreaded tyres are manufactured to high standards, using highly sophisticated machinery. There is no doubt that professionally-made retreads are as safe as new tyres. With lower production costs than new tyres, retreads have a purchase price that is normally between 25 % and 50% lower than comparable new tyres.

Retread Process

First of all, a careful inspection of the casing is made by an experienced operator in order to check the casing for obvious appearance defects on both in- and outside – using a pressure testing machine, to inflate the casing to tyre operating pressure, to test its structural integrity. Furthermore the Shearography technology is used to expose hidden flaws of the casing.

Then, the operator carries out a precise and careful removal of the old tread-rubber from the casing (Buffing) on the buffing-machine – through circumferential rotation of a cylindrical rasp-head against the rotation-direction of the tyre. Then he makes an investigation and a clean-up of all penetrations through the surface-rubber to the casings belt-package, by means of pneumatic grinding-tools.

A rubber-cement is then applied by means of an airless spray-gun, in order to reach every part of the texturized surface and later provide good bonding with the cushion-gum, which connects the Pre-cured tread (PCT) with the casing through vulcanization.

Skiving-craters are filled with unvulcanised repair-gum by means of a hand-extruder, in order to create an even surface-plain, on which cushion-gum can be applied. Next the PCT is selected in a width, corresponding to the width of buffed surface on the relevant casing, and then is cut to a length corresponding to the circumference of the buffed casing.

An unvulcanised cushion-gum is applied, either in form of a thin sheet, cut to required width, directly onto the buffed surface of the casing, or alternatively applied as a thin layer of hot-extruded compound by means of a cushion-gum extruder. The prepared PCT-strip is applied onto the casing on a building-machine, by means of a tread server, which controls the level of stretch of the PCT against the pulling force of the casing, which rotates through 360 degrees from the starting point.

Then the built Retread is wrapped in a so called “envelope” and “inner-lope”, which is necessary as preparation for curing of the Retread in the Autoclave (curing-chamber). The Retread must me cured (vulcanised) in the Autoclave for ca. 3.5 hours at a differential pressure of 6 bar chamber-pressure and 4.5 bar pressure between envelope/innerlope and tyre-surface at a temperature of between 100 and 120 degrees Celsius. To finish, the operator unloads the Autoclave – removal of envelope/innerlope, and makes the final visual inspection and the final Quality Control of the finished Retread.

Why are Tyres Black?

Left alone, tires dry out, discolor and eventually crack and split. The major factor degrading tires and other synthetic and rubber products is ozone. When combined with ultraviolet light a reaction occurs that attacks the tire polymer.

To protect against ozone and UV damage, a stabilizer molecule called a "competitive absorber" is blended with the tire polymer. Competitive absorbers work by capturing and absorbing UV radiation and converting it to heat which is dissipated harmlessly. All tire manufacturers use the same competitive absorber, **carbon black**. This is why all tires are black...why tires are not available in designer colors.

These absorbers are sacrificial; they expend themselves in performing their function of changing UV to heat. As carbon black loses its ability to perform, it turns gray. This is one reason why black tires discolor as they age.

To protect from further ozone damage, tire manufacturers add a wax compound to their formulas. Tires flex when they are in motion, causing the wax molecules to migrate to the surface. This forms a protective barrier between the air (ozone and oxygen) and the tire polymer. In the tire trade this is called "blooming".

When tires are parked for extended periods, blooming does not occur and ozone starts attacking the polymer. With UV light and ozone working in concert, the degradation is accelerated, resulting in drying, discoloration and cracking.

This article has been compiled from various articles/notes downloaded from the various *websites.*