

MECHANIC MOTOR VEHICLE

NSQF LEVEL - 4

2nd Year

TRADE THEORY

SECTOR: AUTOMOTIVE

(As per revised syllabus July 2022 - 1200Hrs)



Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA



**NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI**

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : Automotive

Duration : 2 Years

Trade : Mechanic Motor Vehicle - 2nd year Trade Theory - NSQF Level - 4 (Revised 2022)

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Mechanic Motor Vehicle 2nd Year Trade Theory in Automotive Sector** under **Yearly Pattern**. The NSQF Level - 4 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Additional Secretary/Director General (Training)
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032

EXECUTIVE DIRECTOR

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material (**Trade Theory**) for the trade of **Mechanic Motor Vehicle 2nd Year NSQF Level - 4 (Revised 2022)** under **Automotive** Sector for ITIs.

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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 4 (Revised 2022) syllabus are covered.

The manual is divided into Eleven modules.

Module 1	Transmission System
Module 2	Steering and Suspension System
Module 3	Brake System
Module 4	Trouble Shooting
Module 5	Electronic Control System
Module 6	Charging and Starting System
Module 7	Lighting System
Module 8	Electrical Components Trouble Shooting
Module 9	Air Conditioning System
Module 10	Vehicle Information and Driving Practices
Module 11	Electric Vehicle Technology

The skill training in the shop floor is planned through a series of practical exercises centered around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual, a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Mechanic Motor Vehicle 2nd Year NSQF Level - 4 (Revised 2022) in Automotive**. The contents are sequenced according to the practical exercise contained in NSQF Level - 4 (Revised 2022) syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptual capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self-learning and should be considered as supplementary to class room instruction.

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Lesson No.	Title of the Lesson	Learning Outcome	Page No.
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LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No	Learning Outcome	Ref. Ex.No.
1	Plan & perform maintenance, diagnosis and servicing of transmission system. (Mapped NOS: ASC/N1404, ASC/N1405)	2.1.84 - 2.1.98
2	Plan & perform maintenance, diagnosis and servicing of Vehicle Control System. (Mapped NOS:ASC/N9437)	2.2.99 - 2.3.126
3	Troubleshoot vehicle Engine components and ascertain repair. (Mapped NOS: ASC/N9438)	2.4.127
4	Plan & service of electronic control system and check functionally. (Mapped NOS: ASC/N1438)	2.5.128 - 2.5.132
5	Diagnose & rectify the defects in vehicle to ensure functionality of vehicle. (Mapped NOS: ASC/N1438)	2.5.133 - 2.5.134
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11	Identify and study of Electricvehicle components and Performance comparison of EV and IC engine vehicles. (Components of Electric Vehicle such as Motor, Motor Controller, Battery Pack, Battery Management System, Charging System etc.) (Mapped NOS: ASC/N9439)	2.11.169 - 2.11.174

QR CODE

<p>Module 1</p>  <p>Ex.No. 2.1.85-88</p>	<p>Module 2</p>  <p>Ex.No. 2.1.96-98</p>	<p>Module 3</p>  <p>Ex.No. 2.2.99-101</p>	<p>Module 5</p>  <p>Ex.No. 2.3.118-126</p>
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SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 185 Hrs; Professional Knowledge 50 Hrs	Plan & perform maintenance, diagnosis and servicing of transmission system. (Mapped NOS: ASC/N1404, ASC/N1405)	<p>84. Identify different major components of Heavy vehicle and their function & placement study of different make lorry/busin Institute with different dealers or organizations. (18 Hrs)</p> <p>85. Practice on adjusting clutch pedal play- removing gearbox and clutch assembly from Light & Heavy Vehicle. (09 Hrs)</p> <p>86. Perform Dismantling clutch assembly, cleaning inspecting parts. (10 Hrs)</p> <p>87. Carryout Removing & fitting of new pilot bearing, removing & fitting of ring gear in fly wheel relining a clutch plate, checking condition of flywheel and pressure plate surface for reconditioning. (10 Hrs)</p> <p>88. Perform Assembling of pressure plate adjusting the fingers checking run out of fly wheel and aligning clutch assembly with flywheel. (08 Hrs)</p> <p>89. Perform Dismantling cleaning and assembling of gearshift mechanism changing oil in gear box. (10 Hrs)</p> <p>90. Practice Dismantling a synchromesh gear box, cleaning, inspecting parts replacing worn out defective parts assembling & testing for correct performance identifying noises from gear boxes and rectifying. (10 Hrs)</p>	<p>Introduction: Study of different major components & assemblies of heavy vehicle, and different make (indigenous). Name plate-constructural differences and their merits. leading manufacturers in Heavy vehicle Industry</p> <p>Clutches & Manual Transmissions-Clutch principles, Single-plate clutches, Multi-plate clutches, Dual mass flywheels, Operating mechanisms Clutch components- Pressure plate, Driven/ centre plate, Throw- out bearing.</p> <p>Manual transmissions- Gear ratios, Compound gear trains, Gear selection, Bearings, Oil seals & gaskets, Brief about Automated Manual Transmission (AMT)</p> <p>Gearbox layout & operation- Gearbox layouts, Transaxle designs, Gearbox operation, Baulk-ring synchromesh unit, Transaxle synchromesh unit. Gear shift mechanism. (18 hrs)</p>
		<p>91. Practice on Removing open type propeller shaft from vehicle, Practice on removing universal joints, cleaning replacing worn out parts, re- assembling & refitting to vehicle- and their alignment, including front wheel drive and all wheel drive of LMV. (15 Hrs)</p> <p>92. Practice on FWD Driveshaft Removal and Replacement. (15 Hrs)</p> <p>93. Practice on overhauling & inspection of rear axle. (15 Hrs)</p> <p>94. Practice on overhauling & inspection of differential assembly. (15 Hrs)</p>	<p>Final Drive & Drive Shafts - Basic layouts</p> <p>Front-wheel drive layout, Rear-wheel drive layout, Four-wheel drive layout, All- wheel drive layout, 4WD v/s AWD</p> <p>Front-wheel drive, Front- wheel drive shafts, Front- wheel final drives, Front- wheel differentials</p> <p>Rear-wheel drive- Propeller shaft, Type of Universal joints, Type of Constant velocity Joints, Rear-wheel final drives, Salisbury axles, Rear-wheel drive differentials, Limited slip differentials.</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		<p>95. Perform Trouble shooting - causes and remedy for clutch slip, clutch noise, clutch binding, hard clutch, gearbox noise, gear slip, rear axle noise, propeller shaft noise, universal joint noise, differential noise. (15 Hrs)</p>	<p>Four-wheel drive- Four-wheel drive shafts, Four-wheel final drive, Four-wheel drive transfer case, Freewheeling hubs, Four-wheel drive differentials All-wheel drive- four wheel final drives, All-wheel drive transfer case, Transfer case differential action. (18 hrs)</p>
		<p>96. Identify Automatic transmission components (5 Hrs)</p> <p>97. Check automatic transmission fluid and replace transmission fluid & filter. (10 Hrs)</p> <p>98. Practice on oil pressure control cable play adjustments, Inspection of shift lever switch, throttle position sensor, speed sensor and automatic transmission wiring harness coupler. (20 Hrs)</p>	<p>Automatic Transmissions - Torque converters, Torque converter principles, drive plate, Converter operation, Torque multiplication, Fluid flow, Heat exchanger, Lock-up converters, clutches.</p> <p>Planetary gearing- Planetary gears, Simple planetary gear sets, Compound planetary gear sets, Automatic transmission brake bands, Multi-disc clutches, Electronic control transmission - Electronic control Unit, Fully hydraulically controlled transmission, Electronic shift programs, Manual selection. Layout & operation for P,R,N&D (First & Second) Selector positions, Planetary gear set, High range power flow, Low range power flow Servos & clutches-Rear servo, Front servo, One way clutch, Multi-plate front clutch, Clutch pack, Rear clutch.</p> <p>Hydraulic system & controls- Hydraulic system components, Spool valves, Regulating or flow control valves, Control valves, Orifices</p> <p>Valve types & functions- Basic valve action, Regulator & control valves, Shift & governor valves</p> <p>Pressure regulation- The primary regulating valve, Line pressure variation, Modulator valve pressure, The governor, Governor pressure, Kick down pressure.</p> <p>Flow control- Gear position 1, 1-2 shift valve, 2-3 shift valve assembly, The servo orifice control valve, 3-2 kick down</p> <p>Continuously variable transmission (C.V.T.) - Continuously variable transmission, Drive or reverse, The steel belt, Secondary pulley shaft. (14 hrs)</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 245 Hrs; Professional Knowledge 62 Hrs	Plan & perform maintenance, diagnosis and servicing of Vehicle Control System. (Mapped NOS: ASC/N9437)	<p>Following practical to be Practiced On Light & Heavy Vehicle:</p> <p>99. Practice on removing the drop arm, Check and adjust the turning angle, align the drop arm and steering wheel with the front wheel. Check and correct toe-in. (08 Hrs)</p> <p>100. Practice on removing steering wheel, steering gearbox. (09 Hrs)</p> <p>101. Inspect and overhaul steering boxes, adjusting steering gear backlash, pre-load and adjust toe-in, toe-out, camber angle, castor angle, kingpin inclination and wheel run out. (08 Hrs)</p> <p>102. Check & top up power steering fluid, (5 Hrs)</p> <p>103. Carryout Pressure testing a power steering system, Flushing a power steering system, (10 Hrs)</p> <p>104. Carryout Inspecting & adjusting an engine drive belt, (5 Hrs)</p> <p>105. Carryout Servicing a steering system, (08 Hrs)</p> <p>106. Practice servicing wheel bearings. (07 Hrs)</p> <p>107. Perform Troubleshooting- Causes and remedy for abnormal wear of tyre, wheel wobbling, poor self centring, hard steering, and vehicle pulling to one side. (5 Hrs)</p> <p>Following practical to be Practiced On Light & Heavy Vehicle :</p> <p>108. Practice on visual Inspection of chassis frame for crack, bent and twists. (10 Hrs)</p> <p>109. Carryout Overhauling and Inspection of shackle, leaf spring, front & rear suspension. (09 Hrs)</p> <p>110. Practice on removing, inspection and assembling of shock absorber (09 Hrs)</p> <p>111. Practice Lubricating a suspension system. (08 Hrs)</p> <p>112. Perform Trouble shooting for Suspension system defects: Wheel hop, ride height (unequal and low), noises under operation, fluid leakage, excessive travel, bounce, worn dampers, worn joints/ damaged linkages, vehicle "crabbing". (09 Hrs)</p>	<p>Steering Systems: - Description and function of Steering systems, Principles of steering, Rack-and-pinion steering system, Recirculation ball & nut steering system, Four-wheel steering systems, collapsible steering system.</p> <p>Steering boxes & columns - Description and function of Steering columns, Rack-and- pinion gearbox, Helix, Variable ratio steering, Worm gearbox, Power Assisted steering, Steering process, Flow-control valve, Electric power assisted steering, Basic electric power steering operation</p> <p>Steering arms & components- Forward control vehicle steering, Steering linkages, Joints, Bushes/ bushings Wheel alignment fundamentals:- Basic principles of wheel alignment, wheel base, wheel track, king pin inclination, Caster, Camber, Scrub radius, Toe-in & toe out, Toe-out on turns, Turning radius, Thrust angle & centrelines. (15 hrs)</p> <p>Suspension Systems:- Principles of suspension, Suspension force, Unsprung weight, Wheel unit location, Dampening. Types of suspension- Suspension systems, Solid axle, Dead axle, Description, function and advantages of non independent suspension Independent suspension, Rear independent suspension, Rear-wheel drive independent suspension, electronically controlled air suspension (ECAS), Adaptive air suspension operation. Types of springs - Description and function of Coil springs, Leaf springs, Torsion bars, Rubber springs. Shock absorber types- Description and function of Hydraulic shock absorbers, Gas-pressurized shock absorbers, Load- adjustable shock absorbers, Manual adjustable-rate</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
			<p>shock absorbers, Electronic adjustable-rate shock absorbers, Automatic load- adjustable shock absorbers Front suspension types & components- Mc person Strut suspension, Short/long arm suspension, Torsion bar suspension</p> <p>Rear suspension types & components-Rigid axle leaf spring suspension, Rigid axle coil spring suspension, Independent type suspension, Rigid non-drive suspension.(15 hrs)</p>
		<p>113.Practice on removing wheels from light & Heavy vehicle, dismantling tyres and tubes checking puncture. (10 Hrs)</p> <p>114.Practice Assembling& inflating tyres to correct pressure. (10 Hrs)</p> <p>115.Check & adjust tire pressure by use of air or by Nitrogen(10 Hrs)</p> <p>116.Rotate the wheels in vehicle minor repairs to wheels and tyres, wheel balancing & alignment. (10 Hrs)</p> <p>117.Check for tyre wear patterns. (10 Hrs)</p>	<p>Wheels & Tyres-Wheel types & sizes Wheels, Rim sizes & designations, Types of wheels</p> <p>Tyre types & characteristics-Tyres, Radial ply tyres, Radial ply tyre sidewalls, Tyre pressure monitoring systems, Run flat tyres, Space-saver tyres, Tyre distortion, Center of gravity. Tyre construction-Tyre construction, Types of tyre construction, Tyre materials, Hysteresis, Tyre sizes & designations, Tyre information, Tyre tread designs, Tyre ratings for temperature & traction.</p> <p>Descriptions Tirewear Patterns and causes Nitrogen v/s atmospheric air in tyres (12 hrs)</p>
		<p>118.Practice on Adjusting brake pedal play, Overhauling and inspection of tandem master cylinder assembly. (5 Hrs)</p> <p>119.Perform Overhauling and inspection of front and rear brake assembly, overhauling and inspection of wheel cylinder assembly. (5 Hrs)</p> <p>120.Bleed hydraulic brakes & Disk brakes. (10Hrs)</p> <p>121.Carryout Overhauling and inspection of vacuum assisted brake assembly. (10 Hrs)</p> <p>122.Perform Overhauling and inspection of disc brake. (10 Hrs)</p> <p>123.Practice Adjusting Air brakes-repair to tank unit, air compressor, wheel brake adjuster- locating air leaks in the brake lines and</p>	<p>Braking Systems :- Principles of braking, Drum & disc brakes, Lever/mechanical advantage, Hydraulic pressure & force, Brake pad, Regenerative braking.</p> <p>Braking systems - Brake type - principles, Air brakes, Exhaust brakes, Electric brakes, Parking brakes, Engine brakes, Regenerative braking</p> <p>Braking system components-Park brake system, Brake pedal, Brake lines, Brake fluid, Bleeding, Master cylinder, Divided systems, Tandem master cylinder, Power booster or brake unit, Hydraulic brake booster, Electro hydraulic braking (EHB), Applying brakes, Brake force, Brake light switch</p> <p>Drum brakes & components -Drum brake system, Drum brake operation, Brake linings & shoes,</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		<p>rectifying - general maintenance and care. (10 Hrs)</p> <p>124. Perform Brakes service procedures-Checking & adjusting brake fluid, Replacing brake fluid, Checking brake pads, Replacing brake pads, Removing & replacing a rotor, Replacing brake linings, Adjusting a parking brake cable. (15 Hrs)</p> <p>125. Carryout Trouble tracing in braking system of a heavy vehicle adjusting all four wheel brakes, precautions to be observed while testing brakes points to be remember while preparing the vehicle for brake certificate. (15 Hrs)</p> <p>126. Practice of maintaining of ABS system. (05 Hrs)</p>	<p>Back plate, Wheel cylinders Disc brakes & components - Disc brake system, Disc brake operation, Disc brake rotors, Disc brake pads, Disc brake callipers, Proportioning valves, Proportioning valve operation, Brake friction materials Antilock braking system & components-ABS brake system, Antilock braking system operation, Principles of ABS braking, ABS master cylinder, Hydraulic control unit, Wheel speed sensors, ABS with EBD electronic control unit. The construction and operation of heavy vehicle Anti-Slip Regulation / Traction Control (ASR) system. Introduction to Electromagnetic retarder brake (EMR) and Engine exhaust brake.(20 hrs)</p>
<p>Professional Skill 35Hrs; Professional Knowledge 05 Hrs</p>	<p>Troubleshoot vehicle Engine components and ascertain repair. (Mapped NOS: ASC/N9438)</p>	<p>127. Perform Trouble shooting Practice with Heavy vehicle for Engine Not starting - Mechanical & Electrical causes, High fuel consumption, Engine overheating, Low Power Generation, Excessive oil consumption, Low/High Engine Oil Pressure, Engine Noise. (35 Hrs)</p>	<p>Engine trouble shooting (5 Hrs)</p>
<p>Professional Skill 50Hrs; Professional Knowledge 24 Hrs</p>	<p>Plan & service of electronic control system and check functionally. (Mapped NOS: ASC/N1438)</p>	<p>128. Carryout Identification of Electronic control Unit. (10 Hrs)</p> <p>129. Perform Set up for testing, Testing of Electronic Control Circuit. (10 Hrs)</p> <p>130. Perform Identification of various sensors installed in engine & it's mounting. (10 Hrs)</p> <p>131. Check instruments & Gauges on dash board & replace defective gauges. (10 Hrs)</p> <p>132. Test Temperature sensor, Pressure sensor, potentiometer, magnetic induction sensor, cam shaft sensor, crankshaft position sensor. (10 Hrs)</p>	<p>Introduction to EFI Engine Management - EFI operation Modes of EFI, Electronic fuel injection, Idle speed control systems, Feedback & looping, Cold start systems, Air measurement, Air-flow monitoring, Variable intake manifold system, Electrical functions, EFI wiring diagram Electronic control unit (ECU) - EFI system ECU, Electronic control unit settings, Engine speed limiting, Malfunction indicator lamp. Importance of Diagnostic Trouble Code (DTC) & its general format. Use of scan tool and retrievals of codes. EFI sensors- Intake Temperature sensor, Mass airflow sensor, Manifold absolute pressure sensor, Air vortex sensor, Fuel system sensor, Throttle position sensor, Exhaust gas oxygen sensor, Crank angle sensor, Hall effect voltage sensor.(24 hrs)</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 25 Hrs; Professional Knowledge 10 Hrs	Diagnose & rectify the defects in vehicle to ensure functionality of vehicle. (Mapped NOS: ASC/N1438)	133. Carryout Diagnosis- Possible causes and remedy for Engine cranks, but will not or hard to start, Poor fuel economy or engine performance. (10 Hrs) 134. Practice Checking ignition timing, Checking & changing a spark plug, Identification and testing of Hall Effect sensor, Optical sensor. Tracing and testing of sensor circuits. (15Hrs)	Ignition principles and Faraday's laws, Primary and secondary winding of transformer, Ignition components, Spark plugs, Spark plug components, Vacuum & centrifugal units, Plug firing voltage, Induction, Inductive system operation, Induction wiring, Hall effect sensors, Hall effect operation, Optical type sensors Distributor less ignition systems, Insulated coils, Distributor less ignition system timing. (10 hrs)
Professional Skill 40Hrs; Professional Knowledge 10 Hrs	Carryout overhauling of charging system. (Mapped NOS: ASC/N1438)	135. Check charging system for the cause of undercharge, No charge, and over charge conditions. (10 Hrs) 136. Perform Removing & replacing an alternator, Inspection of rotor for ground, open circuit - field coil resistance, slip ring surface, Fan, bearing. Inspection of stator for ground, open circuit, Inspection of Drive end bearing rotation, Rectifier, brush length compare with service manual. Slip ring surface. (10 Hrs) 137. Practice Inspecting & adjusting an engine drive belt, Replacing an engine drive belt/ pulleys / Tensioner and their alignments. (10 Hrs) 138. Carryout Trouble shooting, possible causes and remedy for warning lamp does not glow when ignition switch is on, Warning lamp glows dim when ignition switch is on, warning lamp 'on' while the alternator is running, Warning lamp glows 'dim' while the alternator is running, warning lamp flickers considerably. (10 Hrs)	Charging system- The purpose of Charging system, charging system components, charging system circuit, Alternator principles, Alternating current, Alternator components, Rectification, Phase winding connections, Rotor circuit, Voltage regulation, System operating voltage, High voltage charging systems, Rotor, Stator, Alternator end frames, Slip ring & brush assembly, Rectifier assembly, Alternator cooling fan. (10 hrs)
Professional Skill 35Hrs; Professional Knowledge 10 Hrs	Carryout overhauling of starting system. (Mapped NOS: ASC/N1438)	139. Remove starter motor from vehicle, and carryout Performance test for pull-in test, Hold- in test, pinion (plunger) return test, No-load performance test. (15 Hrs) 140. Perform Trouble shooting, possible causes and remedy for starter motor not running, Starting motor running but too slow (small torque), starting motor running, but not cranking engine. Noise, starting motor does not stop running. Growler testing for rotors. (15 Hrs)	Starting system- purpose of starting system, Starting system components, Starter motor principles, study of starter control circuits. Starter motor construction, Starter magnet types, Starter motor engagement, Commutation, Switching, solenoid construction. (10 hrs)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		141. Check a starting system, Jump-start a vehicle. (5 Hrs)	
Professional Skill 85 Hrs; Professional Knowledge 20 Hrs	Troubleshoot electrical components of vehicle and ascertain repair. (Mapped NOS: ASC/ N1438)	<p>142. Trace the light circuit - test bulbs, align head lamps, aiming headlights. Changing a headlight bulb, checking of a head light switch and to replace if faulty. (5 Hrs)</p> <p>143. Perform Trouble shooting and remedy for turn signal and hazard warning lights -Flash rate high or one side only flashes, No Flashing, flash rate low. (5 Hrs)</p> <p>144. Perform Trouble shooting and remedy for clearance, tail and license plate lights - All lights do not light up, some lights do not light up. (5 Hrs)</p> <p>145. Perform Trouble shooting and remedy for fuel meter and fuel gauge unit - Fuel meters shows no operation or incorrect operation. (5 Hrs)</p> <p>146. Perform Trouble shooting and remedy for Engine coolant Temp (ECT) meter and ECT Sensor - Engine coolant temp meter shows no operation or incorrect operation. (5 Hrs)</p> <p>147. Perform Trouble shooting and remedy for oil pressure light - Oil pressure warning light does not light up when ignition switch is on at engine off. (5 Hrs)</p> <p>148. Perform Trouble shooting and remedy for brake and parking brake warning light- Brake warning light does not light up when fluid flow level, Brake warning light does not light up when parking brake pull up, Brake warning lights stay on. (5 Hrs)</p> <p>149. Perform Trouble shooting and remedy for interior light- Interior light do not light up. (5 Hrs)</p> <p>150. Perform Trace the wiring circuit of traffic signal flashers light circuit- tracing defects in the flasher circuits, replacing fuse bulb. (5 Hrs)</p> <p>151. Perform Trouble shooting and remedy for Horn- No horn operation, poor sound quality, horn sounds continuously and to replace the horn if faulty. (5 Hrs)</p>	<p>Lighting system, Lamps/light bulbs, Lamp/light bulb information, LED lighting, Headlights-description of standard sealed beam, halogen sealed beam, composite and High intensity discharge (HID) headlights.</p> <p>Headlight & dimmer circuits, Park & tail light circuits, Brake light circuits, turn signal circuit, Cornering lights, Fog lights circuit, interior lights- courtesy, reading and instrument panel lights, Smart lighting , Reverse lights (10 hrs)</p> <p>Accessories: Horn circuit, wiper circuit, power window components and circuit.</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		<p>152.Remove and install wiper motors and wiper switches. Checking & replacing wiper blades. (5 Hrs)</p> <p>153.Perform Trouble shooting and remedy for windshield wiper and washer - no operation, intermittent operation, continuous operation, and wipers will not park. (5 Hrs)</p> <p>154.Diagnose causes for improper operation of the windshield washer system and to replace the pump if faulty. (5 Hrs)</p> <p>155.Diagnose the power window system for - all power window motors do not operate, some switches do not operate. (5 Hrs)</p> <p>156.Diagnose the power door lock control for - All power door locks do not operate, only one power door lock not operate. (5 Hrs)</p> <p>157.Diagnose for remote keyless entry and immobilizer system. (5 Hrs)</p> <p>158.Diagnose automatic seat belt systems, Diagnose air bag system and service warnings. (5 Hrs)</p>	<p>Power door lock circuit, automatic door lock circuit, remote keyless entry system circuit, anti theft system, immobilizer system.</p> <p>Description and function of Airbags, Seatbelt, Vehicle safety systems, Crash sensors, Seat belt pretensioners, Tire pressure monitoring systems Integrated communications, Proximity sensors, Introduction to Hybrid & Electronic vehicle, Hydrogen fuel cell vehicle.(10 hrs)</p>
<p>Professional Skill 35 Hrs; Professional Knowledge 12 Hrs</p>	<p>Overhaul, service and testing Vehicle Air Conditioning system, its parts and check functionality. (Mapped NOS:ASC/N1438)</p>	<p>159.Identify Air conditioning components, Performance test on A/c unit, (5 Hrs)</p> <p>160.Check Charged state of refrigerant, Inspecting & adjusting an engine drive belt, Replacing an engine drive belt. (10 Hrs)</p> <p>161.Perform Refrigerant recovery - evacuating - charging of A/c system. Replenishing compressor oil level. Troubles diagnose and remedy for No cooling or warm air, Cool air comes out only intermittently, Insufficient cooling, (10 Hrs)</p> <p>162.Check abnormal noise from compressor, Magnetic clutch, condenser, evaporator, Blower motor. (5 Hrs)</p> <p>163.Carryout Diagnosis test for High pressure gauge - pressure high and low, Low pressure gauge for pressure high and low. (5 Hrs)</p>	<p>Heating Ventilation Air Conditioning (HVAC) legislation, Vehicle heating, ventilation & cooling systems, Basic air-conditioning principles, Air-conditioning capacity, Air-conditioning refrigerant, Humidity</p> <p>Description and function of Fixed orifice, Control devices, Thermostatic expansion valve system, Thermal expansion valves, Air- conditioning compressors, Condensers & evaporators, Receiver drier, Lines & hoses, TX valve construction, Temperature monitoring thermostat, Refrigerants, Pressure switches, Heating elements</p> <p>Air-conditioning ECU, Ambient air temperature sensor, Servo motors, Electric servo motors, Automatic climate control sensors, Evaporator temperature sensor, Blower speed control, Ventilation systems. (12 hrs)</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 50Hrs; Professional Knowledge 08 Hrs	Drive vehicle following Traffic Regulations and maintenance of good road conduct. (Mapped NOS: ASC/N14040)	Driving Practice : 164.Practice in straight driving on wide roads. (10 Hrs) 165.Driving through lanes and curves. (10 Hrs) 166.Practice in reversing. (10 Hrs) 167.Practice overtaking another vehicle. (10 Hrs) 168.Practice in driving through sand and wet surfaces. Practice in parking and Diagonal parking.(10 Hrs)	Traffic rules, Signals & controls. Locating vehicle information, Obtaining & interpreting scan tool data. (08 hrs)
Professional Skill 55 Hrs; Professional Knowledge 15 Hrs	Identify and study of Electric vehicle components and Performance comparison of EV and IC engine vehicles. (Components of Electric Vehicle such as Motor, Motor Controller, Battery Pack, Battery Management System, Charging System etc.) (Mapped NOS: ASC/N9439)	169.Study report on current adoption status of BEV,HEV, PHEV, FCEV type vehicles. (15 hrs) 170.Identify and study performance of Electric vehicles, in comparison to IC engine vehicles. (10 hrs) 171.Identification and study of basic components of EV (05 hrs) 172.Identify various gauges/ instrument on dashboard of an electric vehicle and identify differences in instrumentation panel with IC engine vehicle.(10 hrs) 173.Basic motor power calculation. (5 hrs) 174.Identify and test different types of Batteries, diodes and transistors (10 Hrs)	Introduction to Electric Vehicle Technology, EV Terminology Comparison of Electric Vehicle with IC engine vehicle based on emissions, range, fuel type. Types of electric vehicle, BEV, HEV, PHEV and FCEV. Architecture of Electric Vehicle, working principle of fully electric vehicle, Major component, performance parameter, Basics of Motors, Selection, sizing and characteristic of Motor, calculation for motor effort, electric transmission. Principle, working and operation of propulsion system, DC Motor - Drives Armature Voltage, chopper circuit, step up, Step down chopper, control strategy, chopper amplifier. Brushless DC Motor - principle working, features, speed control system of brushless DC motor, efficiency, calculation. Battery management system (15 Hrs)

Major systems and its components

Objectives: At the end of this lesson you shall be able to

- **define heavy vehicles**
 - **specify various components and its purpose**
 - **identify major manufacturers and products.**
-

Introduction

Any road vehicle combination of road vehicles with a gross vehicle weight rating (GVWR) of 4,500 kg or more is considered a heavy vehicle. Further to classify that there are heavy commercial and heavy passenger vehicles on roads. Passenger vehicles given due importance to passenger safety, where as commercial vehicles are built keeping the load and torque aspects. Being a life line of the economy, these vehicles are an integral part of the commercial activity of any country and these vehicles are usually deployed in the long haul distance and in transportation of materials at the ports as also in the extraction of natural resources like iron or coal etc.

Major components of heavy vehicles and their purpose (Fig 1)**1 Engine**

It is a power pack of any automobile vehicles where in which the power is developed by means of combustion of a fossil fuel. In heavy vehicles the major fuel is high speed diesel oil. Simply we can say diesel. All most all the engines are now a day's internal combustion engines. Few decades ago the external combustion engines were also exist in practice. The engines are capable of propel larger loads with considerable speed. So that the constructions are heavier when compare with the passenger cars and other utility vehicles.

Present days popular engines are as under

- NA engines- Natural aspirated engines
- TC engines- Turbo charged engines
- TCAC engines- Turbo charged after cooled engines
- CRDI engines- Common rail diesel injection engines

2 Power trains

Power trains are arranged in such a way that the transmission is conducted smoothly from engines to wheels. Wherein which we have various types of clutches, various types of gear boxes, propeller shaft, differentials and final drive and axles. In an axle there are single, double and multi axles are fitted to serve various purpose.

3 Control systems

The brakes should be sturdy and efficient to stop the vehicles with heavy loads speed. So that the manufacturers go with various brakes such as servo,

power and single line, dual line air brakes. ABS brakes are anti lock brakes which prevents skidding of vehicles.

The steering system is a group of parts that transmit the movement of the steering wheel to the front wheel, and sometimes the rear, wheels. The primary purpose of the steering system is to allow the drive to guide the vehicle. When a vehicle is being drive straight ahead, the steering system must keep it from wandering without requiring the drive to make constant corrections. The steering system must also allow the drive to have some road feel (feedback through the steering wheel about road surface conditions). For maximum tire life, the steering system should maintain the proper angle between the tires both during turns and straight-ahead driving. The drive should be able to turn the vehicle with less effort, and with proper control. Power steering provide this facility.

4 Chassis and frames

A vehicle frame or chassis, is the main structural element of a motor vehicle to which all other components are fastened. Another term for this design is body-on-frame construction. It has to hold carry and support the whole vehicle to move smoothly.

Also it has to deal with static and dynamic loads, without undue deflection or distortion.

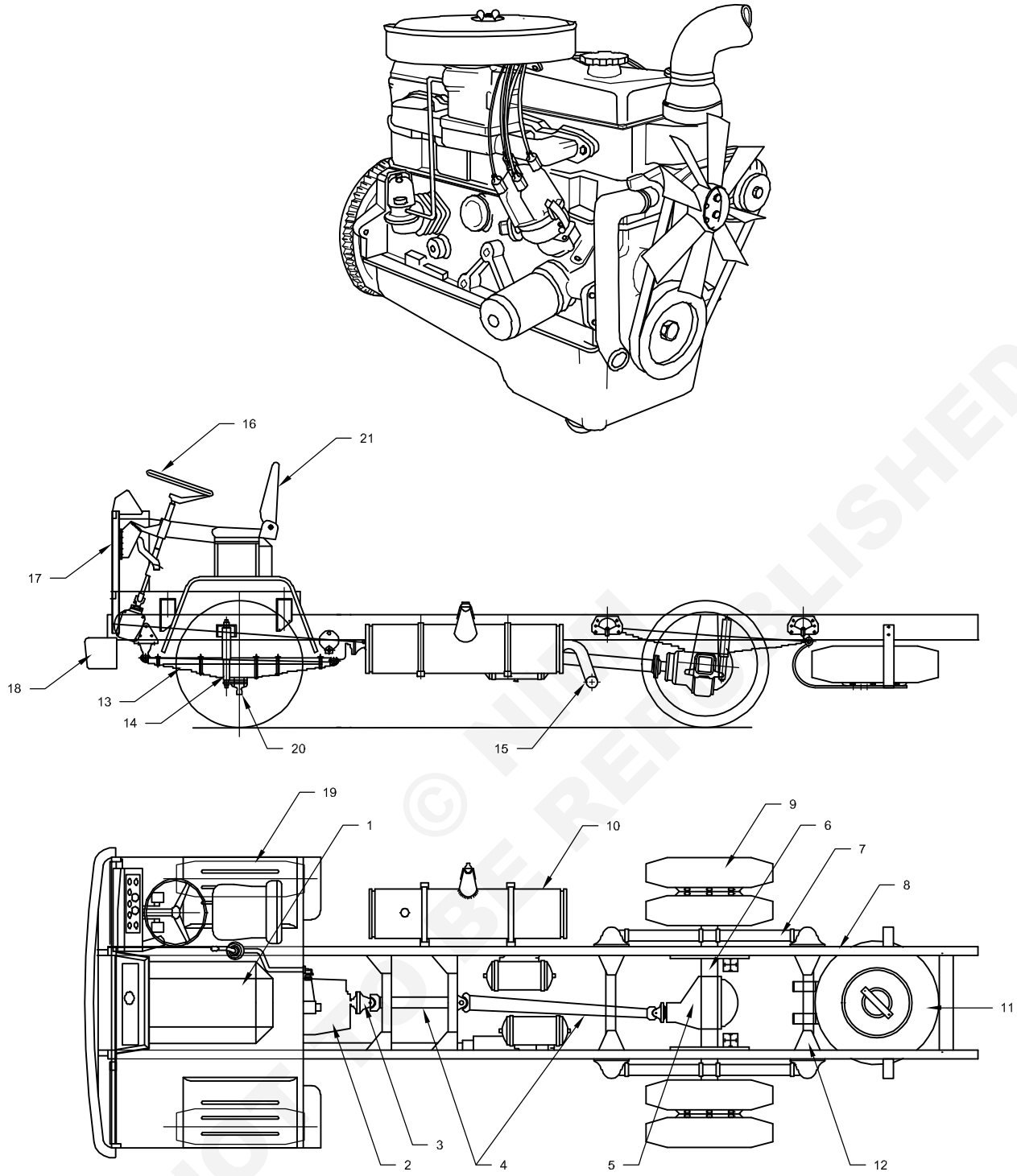
These include

- Weight of the body, passengers, and cargo loads.
- Vertical and torsional twisting transmitted by going over uneven surfaces.
- Transverse lateral forces caused by road conditions, side wind, and steering the vehicle.
- Torque from the engine and transmission.
- Longitudinal tensile forces from starting and acceleration, as well as compression from braking.
- Sudden impacts from collisions.
- Three important classifications are C frame and box frames.

5 Suspension system

The purpose of the complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. I must also keep the tires in contact with the road, regardless of road surface. A basic suspension system consists of springs, axles, shock absorbers, arms, roads, and ball joints. The spring is the flexible component of the suspension. Basic types are leaf springs, coil springs and torsion bars.

Fig 1



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With independent suspension, the wheels can move independently of each other, which reduces body movement. This prevents the other wheel from being affected by movement of the wheel on the opposite side, and this reduces body movement. When a wheel strikes a bump, there is a reaction force, and energy is transferred to the spring which makes it oscillate. Oscillations left uncontrolled can cause loss of traction between the wheel and the road surface.

Shock absorbers dampen spring oscillations by forcing oil through small holes. The oil heats up, as it absorbs the energy of the motion. This heat is then transferred through the body of the shock absorber to the air. When a vehicle hits an obstruction, the size of the reaction force depends on how much unsprung mass is at each wheel assembly. Sprung mass refers to those parts of the vehicle supported on the springs. This includes the body, the frame, the engine, and associated parts. Unsprung mass includes the wheels, tires, brake assemblies and suspension parts not supported by the springs.

Vehicle ride and handling is improved by keeping unsprung mass as low as possible. Wheel and brake units that are small and light follow the road contours without a large effect on the rest of the vehicle.

6 Electrical system

The heavy vehicle has the following electrical systems:

- a Storage system (Battery)
- b Starting system
- c Charging system (Alternations)
- d Lighting system and Accessories
- e HVAC system

7 Storage system

It provides the DC power source for the various systems used in the vehicles. It deals about batteries generally 24v battery system is used for heavy vehicles.

8 Starting system

It is used to start the vehicle. It deals about starter, starter, relays, sharring switch, solenoids etc.

9 Charging system

It deals about the alternators, voltage controllers etc. It is used to charge the battery source.

10 Lighting system and Accessories

The vehicle requires many lights during night travel and day travel. The lighting system deals about head lights, tail light, stop light, brake light, cabin light, fog light, pairing light TVM Indicator lights, number plate light, reverse light etc.. It also deals about wiper, washer, horn, uses, circuit breakers, instrument cluster, GSP etc..

11 HVAC System

It is used for making the drive cabin comfortable for driving. It deals about A.C compressor and other A.C components and Heater.

12 Major manufacturers in India

- 1 Tata motors
- 2 Ashok Leyland
- 3 Mahindra & Mahindra
- 4 MAN-Trucks India Ltd.
- 5 Eicher motors
- 6 Volvo motors
- 7 Premier motors
- 8 Swaraj Mazda
- 9 Benz motor

Products

- Passengers segment
- Goods segments

Different products in goods segments are

- a 2-axle vehicles,
- b Multi axle vehicles,
- c Tippers,
- d Tankers,
- e Special purpose vehicles (Concrete mixture, scooter carries, car carrier etc..)

13 Name plate-Constructional differences and their merits

Motor name plates enable installation and maintenance personnel to quickly understand and recognize exactly find the procedure. Name plates primarily serve an informative function.

- Frame size
- Design letter
- Service factor
- Full load efficiency
- Certification code
- Manufacturer serial number
- Symbols and logos
- Manufacturer, name and address
- Rated horse power

Clutch

Objectives: At the end of this lesson you shall be able to

- state the principle of clutch
- state the need for a clutch in a vehicle
- list out different types of clutch
- state the function of the clutch
- state the various types of clutch actuation systems
- explain the function of mechanically operated clutch.

Principle of clutch

The clutch works on the principles of friction. When two friction surfaces are brought in contact with each other and pressed, they are united due to the friction between them. The friction between the two surfaces depends upon the area of the surfaces, pressure applied upon them and co-efficient of friction of the surface materials. The two surfaces can be separated and brought into contact when required. One surface is considered as driving member and the other as driven member. The driving member is kept rotating when the driven member is brought in contact with the driving member, it also starts rotating, when the driven member is separated from the driving member, it does not revolve. This is the principle of a clutch operation.

Need for a clutch

While shifting gears, the speed of the sliding sleeve and the respective gear on the main shaft should be synchronized to avoid gear collision noise. This is achieved by disconnecting the transmission of power from the engine flywheel to the gearbox shaft with the help of the clutch. The clutch is used to connect and disconnect transmission of power from the engine flywheel to the gearbox drive shaft.

Different types of clutches

They are:

- Cone clutch
- Dog clutch
- Single plate clutch with coil spring
- diaphragm clutch
- Multi-plate dry wet clutches
- Semi-centrifugal clutch
- Fully centrifugal clutch
- Fluid coupling.

Function of the clutch

The clutch should connect and disconnect the power from the engine to transmission smoothly and gradually without affecting the other components.

It should damp vibrations and shocks during operation.

It should not slip under high torque transmission.

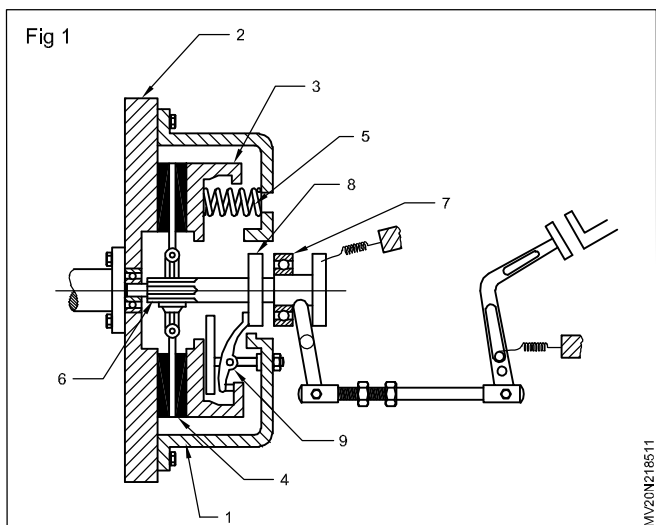
Torque transmission by clutch depends upon the:

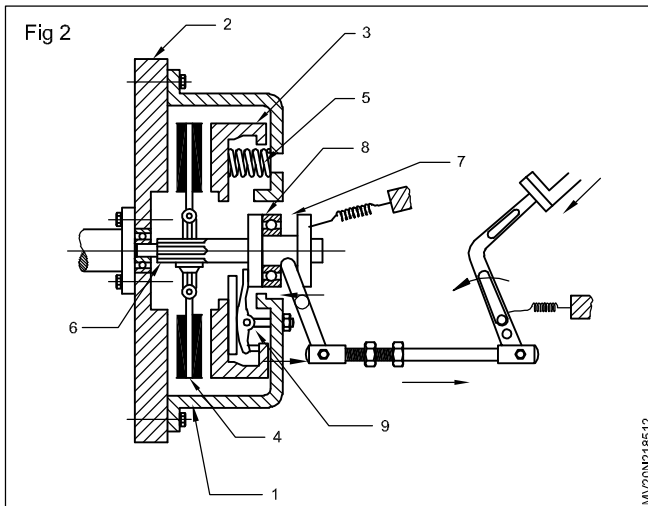
- size of the clutch plate
- coefficient of friction
- spring pressure, and
- number of clutch plates used.

Types of clutch actuation

Types	Features	Advantages
Mechanical Actuation	Pedal effort is transmitted by linkage to withdrawl bearing	Less maintenance and easy to repair.
Hydraulic Actuation	Pedal effort is transmitted through fluid to withdrawl bearing.	Less pedal effort to engage & disengage and clutch

Working of a clutch (Single plate, dry, coil spring type) (Figs 1 & 2)

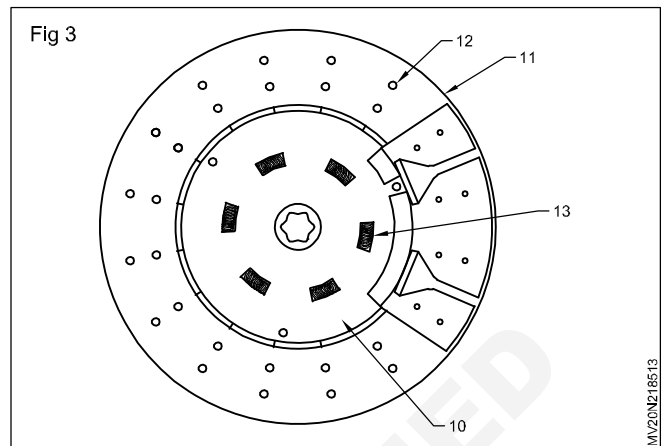




A clutch consists of driven and driving components. A clutch cover (1) is mounted on the flywheel (2) by a set of screws. In the clutch cover, a pressure plate (3) presses the clutch plate (4) against the flywheel (2) by the pressure of springs (5). The clutch plate hub (4) is splined on the gearbox drive shaft (6). The clutch plate (4) rotates along with the flywheel (2), and power is transmitted to the drive shaft (6).

When the clutch pedal is pressed, the withdrawal bearing (7) pushes the withdrawal plate (8) through the linkages. The withdrawal plate (8) pushes the clutch finger (9). The clutch finger (9) swivels and moves the pressure plate (3) away from the flywheel (2). The springs (5) are compressed. Now the pressure plate (3) does not exert pressure on the clutch plate (4) and the clutch plate (4) does not transmit power from the flywheel (2) to the drive shaft (6).

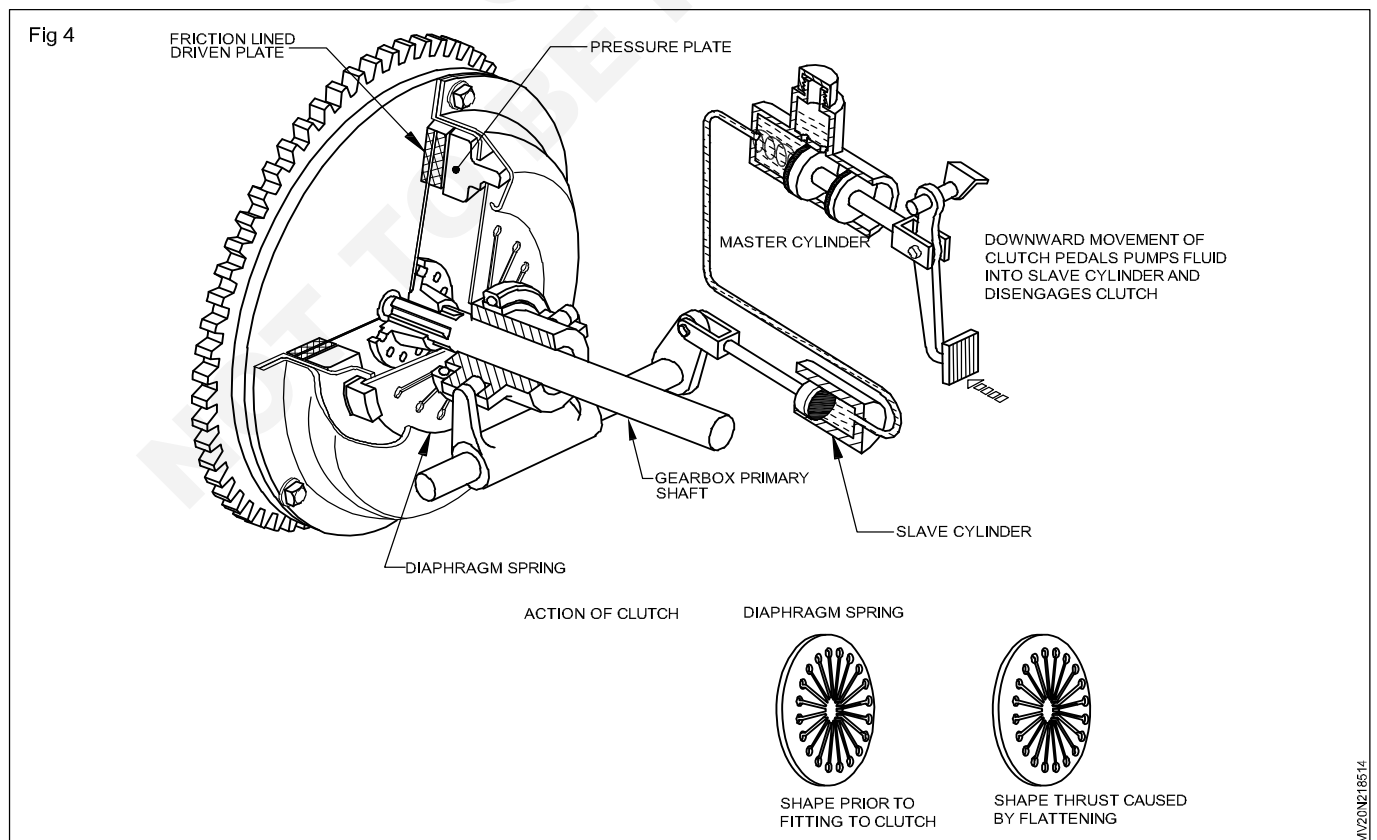
The clutch plate (Fig 3) consists of a torque plate (10), and the clutch lining (11) made of frictional material, is fixed on the torque plate (10) by rivets (12). Damper springs (13) are fixed in the torque plate to dampen shocks during clutch operation.



Operation of a single plate hydraulic clutch (Fig 4)

In light and heavy vehicles with a single dry plate the spring force becomes excessive and it becomes difficult for the driver to release the clutch. So a hydraulic mechanism is added to the transmission which minimizes the force required by the driver to operate the clutch.

When the clutch pedal is pressed, hydraulic fluid from the master cylinder reaches slave or servo cylinder. As the fluid is under pressure it actuates the slave cylinder push rod which releases the clutch release fork, thereby disengaging the transmission.

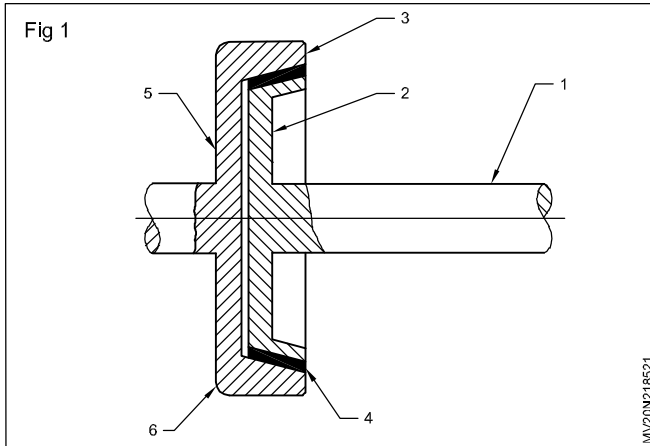


Function of different types of clutch

Objectives: At the end of this lesson you shall be able to

- state the function of
 - multi-plate clutches
 - dry clutches
 - wet clutches
- state the functions of a semi-centrifugal clutch
- state the functions of a fully centrifugal clutch
- state the functions of fluid coupling.

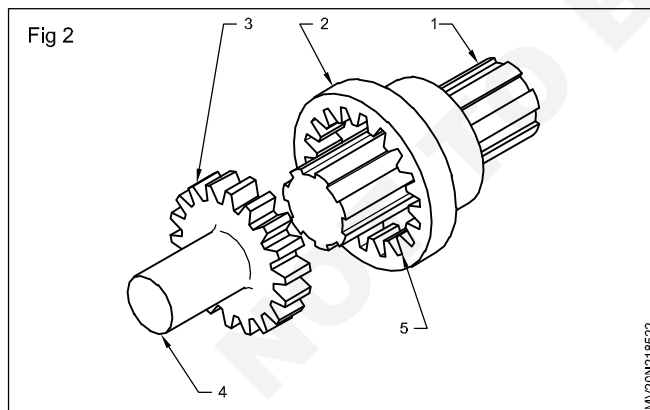
Cone clutch (Fig 1)



When the clutch is engaged the friction surfaces (4) of the male cone (2) on the clutch shaft (1) engage with the female cone (3) on the flywheel (5) due to the force of the spring. When the clutch pedal is pressed the male cone slides on the splines of the clutch shaft against the spring force.

It gives more frictional area and is simple in construction. It is practically absolute and the same principle/device is used in the synchronizer unit in a synchromesh gearbox.

Dog clutch (Fig 2)

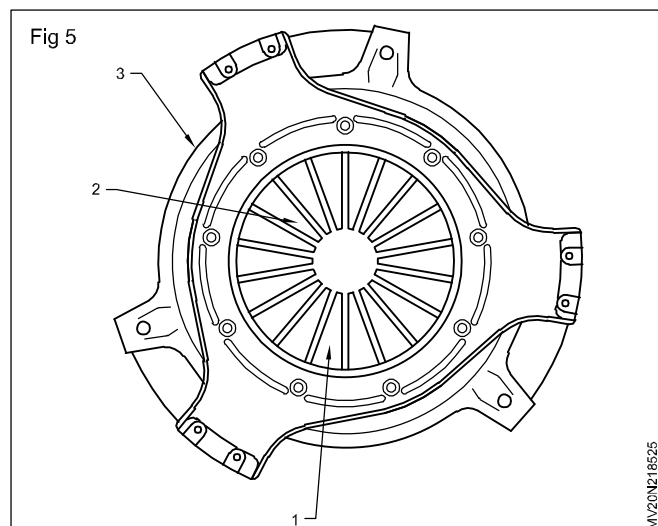
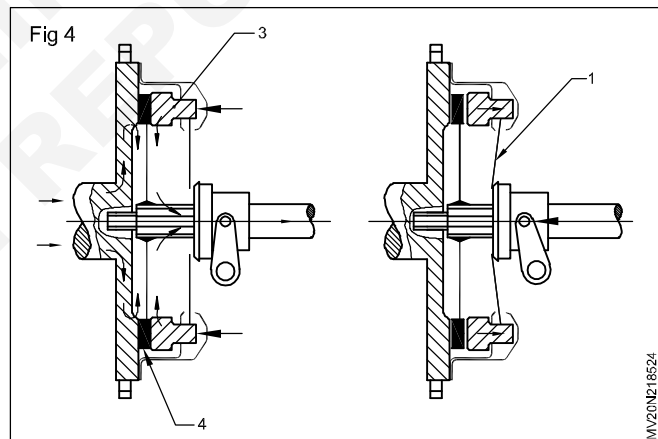
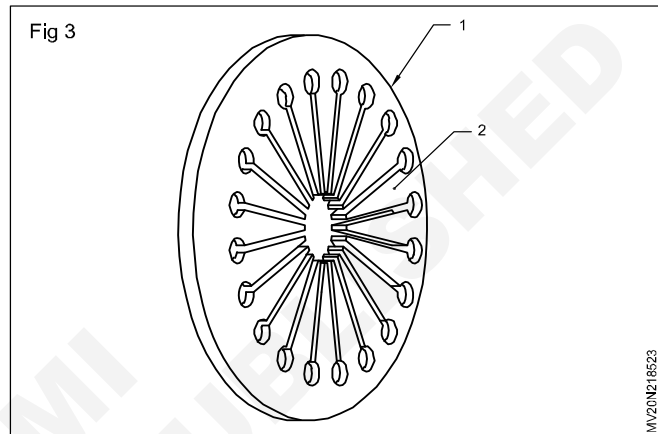


This type of clutch is used to lock two shafts together or to lock a gear to a shaft. When the sleeve (2) slides on a splined shaft (1), its internal teeth (5) match with the dog clutch (3) teeth of the driving shaft, (4) and the clutch is engaged.

In this type there is no possibility of a slip as both the shafts revolve exactly at the same speed.

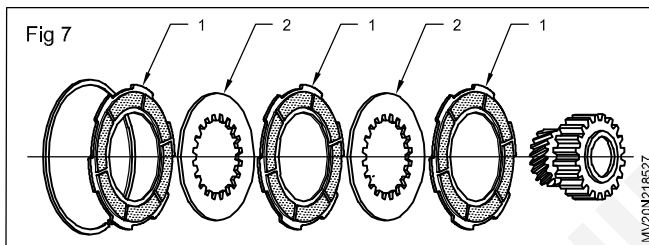
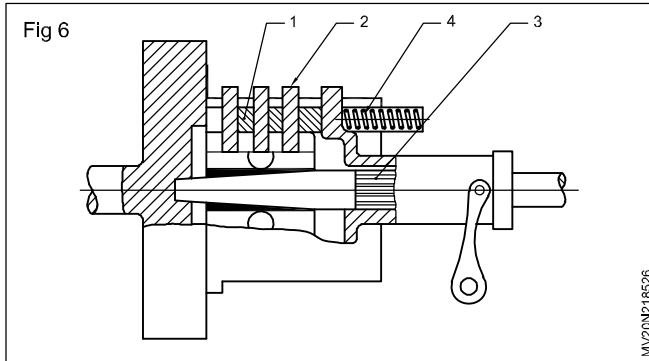
This type of clutch is used in constant mesh gearboxes with and without a synchronized unit.

Diaphragm spring type (Figs 3, 4 & 5)



In some modern vehicles, instead of using coil springs a conical dish-shaped steel plate diaphragm spring (1) is used. It exerts force on the pressure plate (3) to press the clutch plate (4) firmly for engaging the clutch. It does not have release levers. The slots start from the centre of the diaphragm to form a number of release fingers (2). It requires very little pedal effort to disengage the clutch, and it works noise-free.

Multi-plate clutch (Figs 6 & 7)



To transmit more torque, instead of using a bigger flywheel and clutch plate, two or three small clutch discs are used to increase the frictional area. The pressure plates (2) and clutch plates (1) are alternatively arranged on the clutch shaft (3) and compressed by a number of pressure springs (4). This type works in the same way as a single plate clutch does.

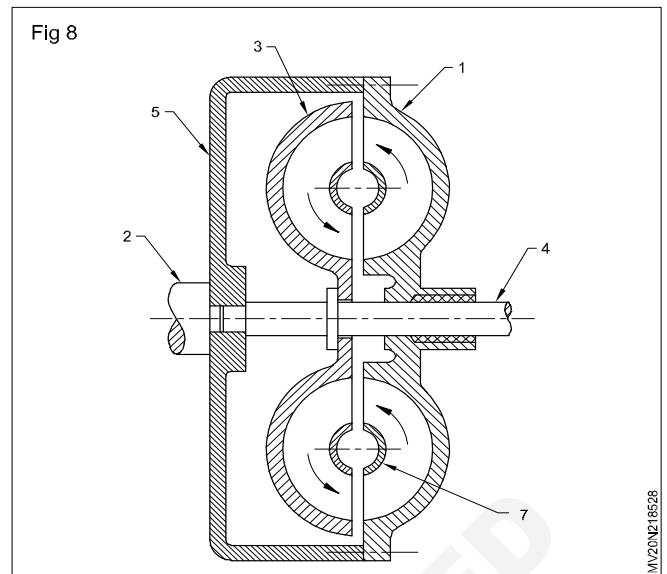
These clutches may be dry or wet. When the clutch is operated dry it is called a dry clutch, but where the oil is used in the clutch it is called a wet clutch.

The wet clutches are generally used along with or as a part of automatic transmission.

These types of clutches are mostly used in scooters, motorcycles, heavy commercial vehicles, earth moving machines, race cars etc.

Fluid coupling (Fig 8)

Fluid coupling enables the driver to use the clutch and gear with less skill and fatigue than the conventional clutch. Wrong clutch engagements or selection of improper gear will not produce any sound. Any sudden load is cushioned and absorbed by the fluid coupling so that dynamic stresses or breakages of the gear teeth of the mechanism and final drive are reduced. Fluid coupling is used with the epicyclic gearbox as the output shaft (drive shaft) is always in motion.



Fluid coupling consists of two half shells fitted with interior fins (7) which rotate from the hubs. These units are mounted very close to each other with their open ends, so that they can turn independently without touching each other. A housing (5) surrounds both units to make a complete assembly. Inside, the assembly is filled with 80% of fluid.

The driving unit impeller (1) is linked to the crankshaft (2) and gets the oil into motion when the crankshaft (2) rotates. The driven impeller (3) is mounted on the driven shaft (4). Due to the movement of the oil, the impeller (3) rotates and transmits torque to the driven shaft (4).

Fly wheel

The flywheel mounted on the engine crank shaft large ring gear is attached the fly wheel. The fly wheel is bolted to a cover which carries a pressure plate, pressure springs and releasing levers. The entire assembly of the fly wheel and the cover rotate all the times, when an automatic transmission is used the torque converter assembly acts as the fly wheel.

The flywheel stores energy during the power stroke and supplies it to the crank shaft during the idle stroke i.e suction, compression and exhaust the size of the flywheel depends upon the number of cylinder and general construction of the engine.

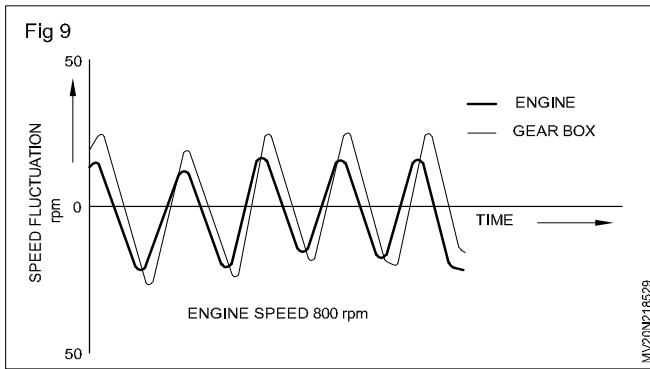
Dual-mass flywheel

This is intended to damp torsional vibrations which are generated by the periodic cycle of the four strokes and the firing order in the crankshaft and a conventional flywheel.

At certain rotational speeds torsional vibrations can result in gearbox noises (gearbox rattling) and body droning.

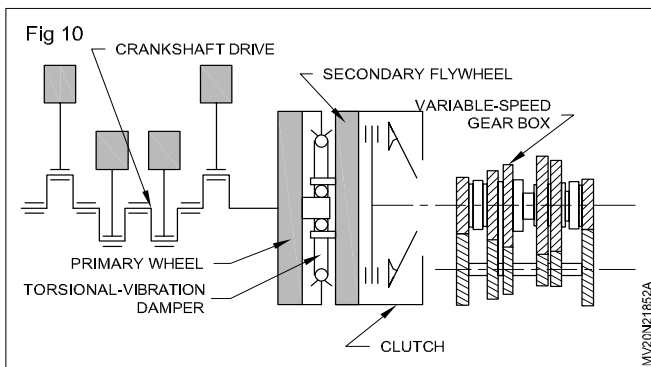
The conventional flywheel mass of an internal combustion engine consists of the crankshaft-drive components, the flywheel and the clutch.

In the diagram (Fig 9) the speed fluctuations of the engine and the gearbox at full load are plotted against time.



The vibrations of the engine output and gear box input have virtually identical amplitudes and frequencies. In the event of superposition (resonant range), this results in gearbox noises and body droning.

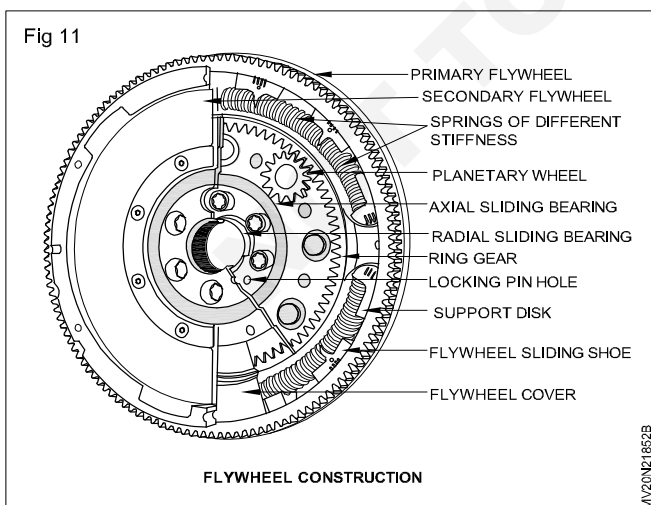
Design (Fig 10)



The conventional flywheel mass is divided into the **primary flywheel** (crankshaft drive, primary flywheel) and the **secondary flywheel mass** (secondary flywheel, clutch).

A torsional-vibration damper connects the two flywheel masses. The function of this damper is to isolate the flywheel-mass system of the engine from the gearbox and the drive train. A clutch disc without a torsion damper can therefore be used for the clutch.

The dual-mass flywheel (Fig 11) consists:

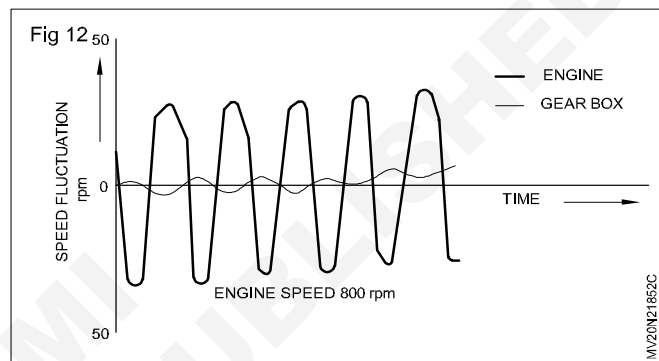


- Primary flywheel
- Secondary flywheel
- Inner damper
- Outer damper

Operating principle

Dividing the flywheel mass into the primary mass on the engine side and the secondary mass on the gearbox side increases the mass moment of inertia of the rotating gearbox parts. In this way, the resonant range is below the engine's idle speed and thus not in the engine's operating range.

The diagram (Fig 12) shows that the vibration curves of the engine output and gearbox input are clearly far removed from each other.



In this way, the torsional vibrations generated by the engine are isolated from the gearbox, and gearbox rattling and body droning no longer occur.

Advantages

Reduction of gearbox and body noises (rattling, chattering, droning).

Protection of power-plant components.

Lower synchronmesh wear.

Clutch disc does not requires a torsion damper.

Throw out bearing

A throw out bearings is a part of an automobile clutch system. It is provided between the clutch release fork and clutch finger / diaphragm spring. It is a thrust bearing with the inner race contacting the clutch deactivation finger. It is used to release the pressure plate by applying thrust force while pressing the clutch pedal to disengage the engine power from flywheel to clutch disc.

Gear shifting mechanism

Objectives: At the end of this lesson you shall be able to

- state the various types of gear shift mechanism
- state reasons for the gear slip.

The gear shift lever is located either on the steering column or on the floor board (Fig 1)

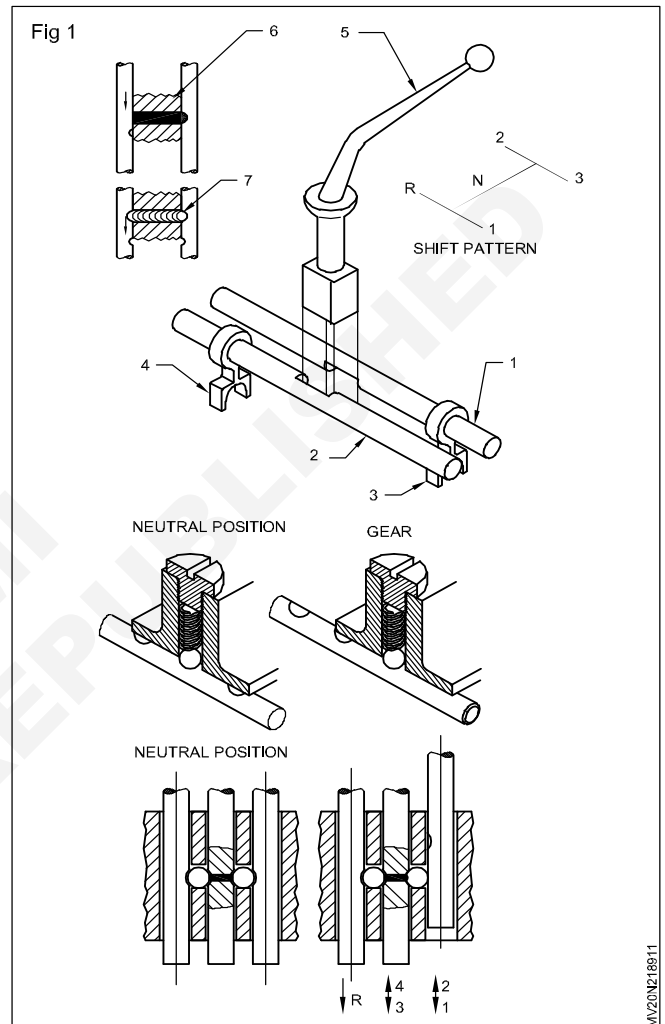
To engage the gear, the gear shift lever, moves the selector rods 1 & 2. The gear shift forks 3 & 4 are fixed on the selector rod. The shifting forks 3 & 4 sit in the slot of the sliding dog clutch or gear. When the selector rod moves, the shifting fork also moves and pushes the respective sliding dog clutch or gear to engage the respective gear.

When the selector shaft is moved, it forces the pin (6) into a groove cut in the opposite rail and the lock or spring loaded ball (7) hold selector shaft in locking position.

Gear slip

The following are the reasons for the gear to slip.

- Wrong adjustment of gear lever/selector rod.
- Weak lock spring.
- Worn out locking ball/pin.
- Excessive end float of gear.



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Gearbox

Objectives: At the end of this lesson you shall be able to

- state the need for a gearbox
- state the various resistances in vehicles motion
- calculate gear ratios
- state the different types of gearboxes
- describe the various components and their functions in a sliding mesh gearbox
- describe the various components and their functions in a constant mesh gearbox and its advantages
- state reasons for gear noise.

Gearbox (Manual transmission)

A gearbox is used to get different torques and speeds which are required to overcome the following resistances.

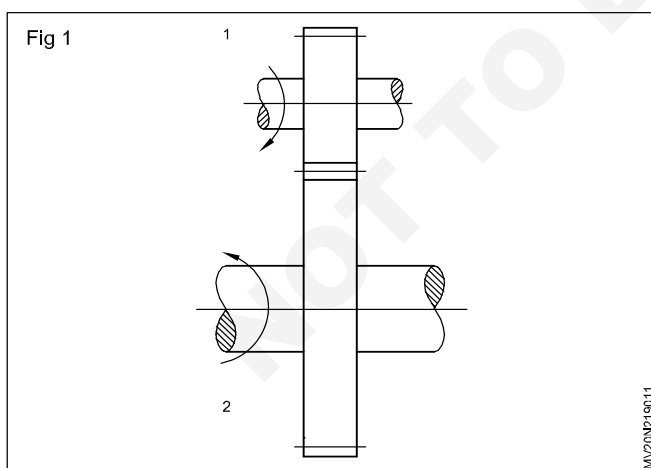
- Road resistance
- Air resistance
- Gradient resistance
- Load on vehicle

By engaging different gears, engine torque is increased while speed is decreased. In the top gear the r.p.m and torque of the engine and gearbox remain the same.

Simple gear train

When there is only one gear on each shaft it is known as Simple gear train. When the distance between turn shaft is small, it is used.

When a small gear (1) (Fig 1) drives the bigger gear (2) the r.p.m. of the bigger gear (2) is reduced in proportion of the gear tooth. For example: Gear (1) is having 10 teeth and gear (2) is having 20 teeth. Assuming gear (1) rotates at 50 r.p.m.



$$\text{Gear ratio (or) speed ratio} = \frac{\text{No. of teeth on driven}}{\text{No. of teeth on driver}}$$

$$\text{Gear ratio} = \frac{T_2}{T_1} = \frac{10}{20} = \frac{1}{2} = 1:2$$

Linear velocity 'V' remains the same for both the gears.

$$\text{So, } T_1 \times N_1 = T_2 \times N_2$$

$$N_2 = \frac{T_1 \times N_1}{T_2} = \frac{10 \times 50}{20} = 25$$

Here the r.p.m. of gear (2) is half of gear (1). So torque will be double.

It means in higher gear the torque is less and in lower gear the torque is more.

Different sets of gears are used in the gearbox to achieve different speeds and torques.

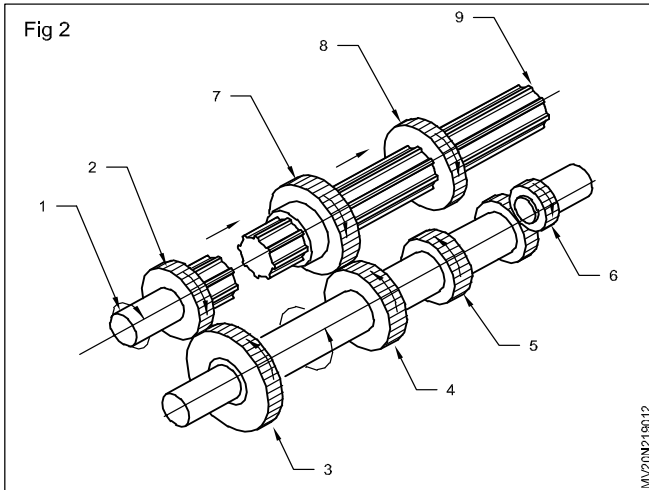
Compound gear train

When there are more than one gear on a shaft it is called as compound gear train. When the distance between the driver and driven has to be bridged over by intermediate gears and at the same time high gear ratio or small gear ratio is required then the advantage of intermediate gears is intensified by providing compound gears on intermediate shaft.

$$\text{Gear ratio} = \frac{\text{Product of the number of teeth on the driven}}{\text{Product of the number of teeth on the driver}}$$

Power train (Fig 2)

The drive shaft (1) along with the gear (2) is always rotating at the engine r.p.m. The shaft (1) drives the countershaft gear (3), (4), (5) & (6) which are fixed on the countershaft. The gears (7) & (8) on the main shaft (9) get power from the countershaft's respective gear, when engaged. To get the desired r.p.m or the torque the respective gear, on the main shaft (7) or (8) is engaged with the countershaft gears (7) and (8) are splined on the mainshaft and when these gears are engaged with the countershaft gears, power is transmitted to the main shaft (9). To get the reverse speed the idler gear (6) is used in between the main shaft and the countershaft gears.



Gear selection

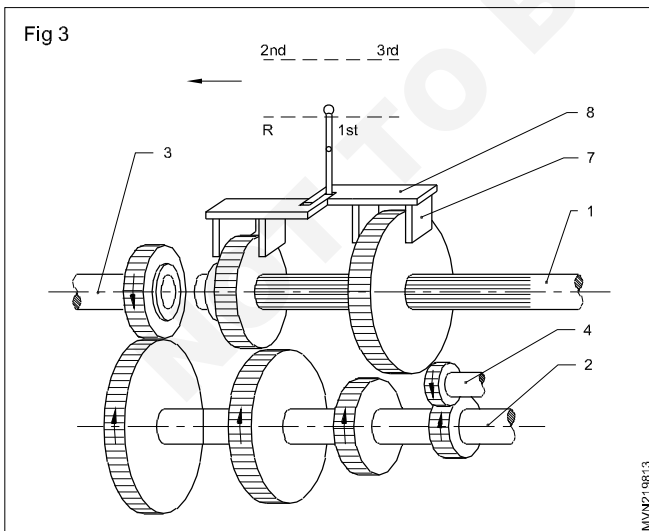
The selection of gear depends upon the speed of the vehicle it is to be driven. For example the speed and appropriate gear selection of a vehicle is given below:

Gear selection	Speed in Km/h
I st gear	15
II nd gear	30
III rd gear	45
IV th gear	65
V th gear on top gear	80

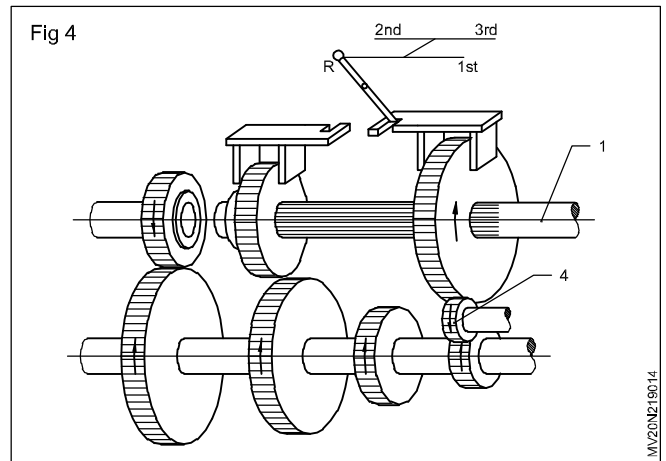
Types of gear boxes

- Sliding mesh gearbox
- Constant mesh gearbox
- Synchromesh gearbox

Sliding mesh gearbox (Figs 3 & 4)



In this gearbox, the gears are mounted directly on the main shaft (1). The gear is slid on the main shaft with the help of the shifter yoke mechanism (7) to engage with the countershaft (2) gear. The gears on the clutch shaft (3) and countershaft (2) are fixed. The idler gear is always in mesh with the countershaft's gear.

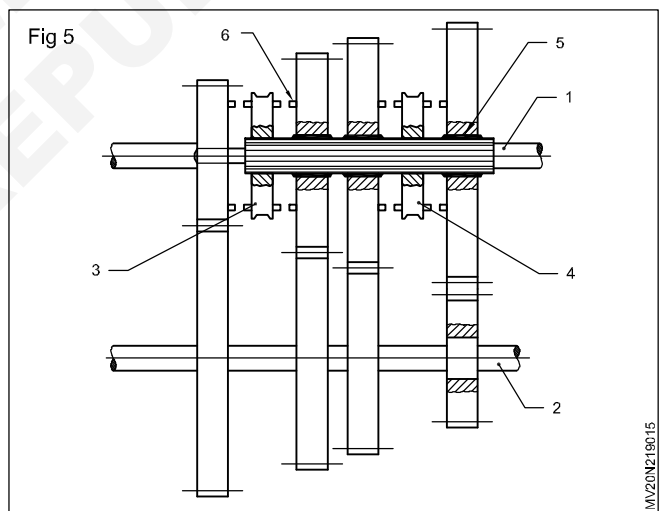


To achieve reverse speed, the mainshafts (1) gear is slid on the main shaft, to engage with the idler gear (4).

To slide the gear on the shaft the shifter forks (7) directly sit on the main shaft's (1) gear. The shifter forks are connected to the gear shift lever through the selector rods (8).

In this type of gearbox, spur gears are always used, because the gear is slid on the shaft to engage with the countershaft gear.

Constant mesh gearbox (Fig 5)



In this gearbox the gears of the mainshaft (1) are always in mesh with the corresponding gears of the countershaft (2). But power is not transmitted unless the dog clutch (3) or (4) engages with the particular gear on the main shaft (1). The main shaft is splined. In between the splined main shaft and gears, bushes (5) are provided.

The fixed dog clutch (6) is splined on the main shaft gear (1). Therefore the gear and the fixed dog clutch both rotate freely without transmitting power. The dog clutch can slide along and revolve with the main shaft. When the sliding dog clutch (3 or 4) is engaged with the respective gear's fixed dog clutch, power is transmitted from the gear to the main shaft through the sliding dog clutch (4) and fixed dog clutch (6).

In this type of gearbox, helical gears are used.

Advantages

The power transmission is smooth when helical gears are engaged because more than one tooth in contact at a time.

Easy to engage

Less wear of gears in comparison to the sliding mesh gearbox because gears are always in mesh and gear shifting is done through the sliding dog clutch.

Gearbox troubles

Gear noise

The following are the causes for noise in the gearbox.

- Wrong adjustment of gear shifting fork.
- Misalignment between gearbox and engine.
- Gearbox not lubricated.
- Excessive backlash between gears/worn out gears.
- Gearbox bearings damaged/worn out pitted
- Gear teeth broken / worn out

Bearings

When a component slides over or rotates around another part, the surfaces that contact each other are called bearing surfaces.

A bearing is a device placed between two bearing surfaces to reduce friction and wear.

Sliding bearings are used at following conditions:

- Low rotating speed
- Very large bearing surfaces
- Low use applications

Sliding bearings composed of a relatively soft bronze alloy, many are made from steel with bearing surface bonded.

Rolling bearings/antifriction bearings such as roller bearing, ball bearings etc., are used in high speed applications, high load with relatively small bearing surfaces, and high use.

In gear box gear rotating on a fixed shaft can have more than one bearing surface, it is supported and held in place by the shaft in a radial direction with the help of the bearings.

Bushes

Bushes are cylindrically shaped and held in place by press fit. Since bushes are typically made of a soft metal, they act like a bearing and support many of the rotating parts. It takes the radial load.

Thrust washers

It is fitted with roller bearings. Thrust bearings/washer's are used to limit the end play and also reduce the friction between two rotating parts. Roller bearings are used in combination with flat thrust washers to control end play of a shaft or the gap between a gear and its drum.

Static

A seal used between two parts that do not move in relationship to each other, such as the pan and oil pump-to-case gaskets.

Dynamic

A seal used between two parts that do move in relationship to each other. This movement is either a rotating or reciprocating (up and down) motion. The seal of a clutch piston is an example of this type of seal.

Positive

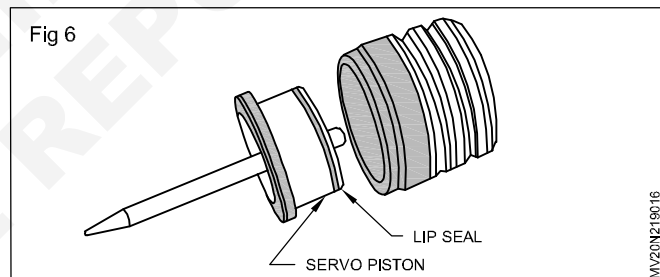
A seal that prevents all fluid leakage between two parts.

Non positive

A seal that allows a controlled amount of fluid leakage. This leakage is typically used to lubricate a moving part.

Three major types of rubber seals are used in manual automatic transmission. They are 'O' ring, Lip seal and the square cut seal. Normally an 'O' ring is installed in a groove cut into the inside diameter of one of the parts to be sealed. 'O' ring is compressed between the inner part and the groove 'O' ring, seal forms a tight seal between the two parts.

Lip seals (Fig 6) are used to seal parts that have axial or rotational movement. Lip seals are used around input and output shafts to keep fluid in the housing and dirt out. Lip seals are also commonly used as shaft seals.



Square cut seals

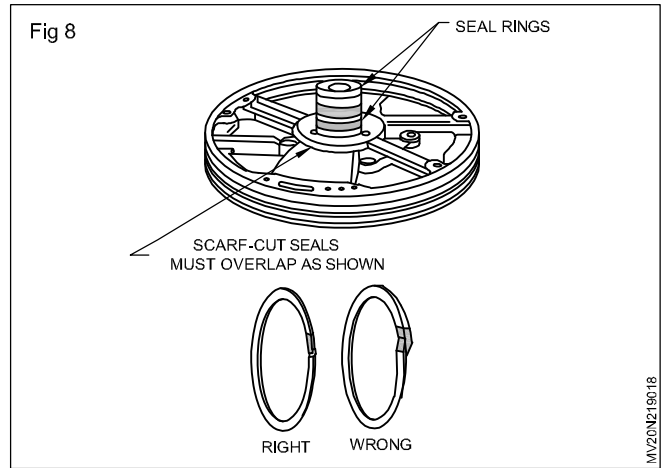
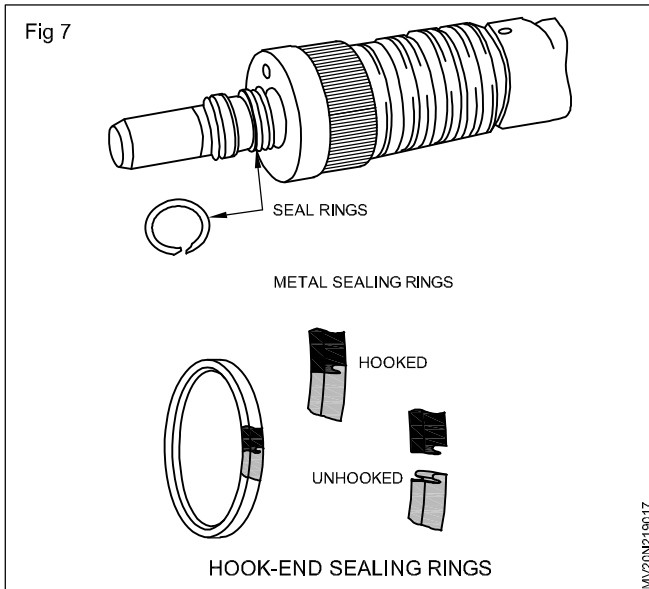
It is similar to an 'O' ring, however, a square-cut seal can withstand more axial movement than an 'O' ring can. Square-cut seals have a rectangular or square cross section. They are designed this way to prevent the seal from rolling in its groove, when there are large amounts of axial movement.

Metal sealing ring (Fig 7)

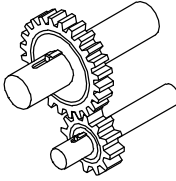
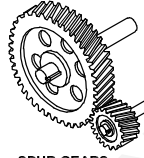
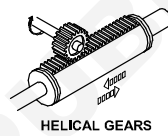
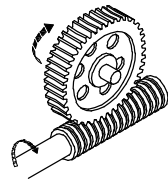
The metal sealing rings are used at the places in which some leakage is acceptable. Metal sealing rings are used in transmission at pressurized. Ring seals are made of cast iron, nylon or teflon.

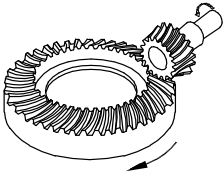
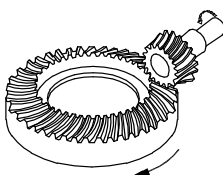
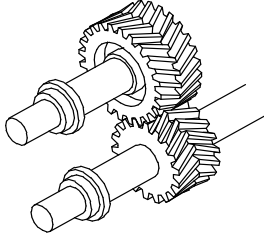
Teflon seals

Some transmission use teflon seals instead of metal seals. Teflon provides for a softer sealing surface, which results in less wear on the surface that it rides on and therefore a longer-lasting seal. Teflon seals are similar in appearance to metal seals except for the hook-end type. The ends of locking end teflon seals are cut at an angle (Fig 8).



TYPES OF GEARS

Spur gears	Helical gears	Rack & pinion	Worm gears
 <p>Teeth are straight and parallel to the gear axis.</p>	 <p>Teeth are at an angle to the gear axis.</p>	 <p>Teeth are parallel to the axis of the gears.</p>	 <p>Teeth are at an angle with the axis and are curved.</p>
Only one tooth in contact at a time	More than one tooth in contact at the same time	Only one tooth in contact.	More than one tooth in contact.
No axial thrust is produced while transmitting torque. Hence it is often used for reverse gear in transmission	Axial thrust is produced while transmitting torque.	No axial thrust is produced while transmitting torque.	Axial thrust is produced while transmitting torque.
It transmits torque for parallel and non-coplanar shaft	It transmits torque for parallel and non-coplanar shaft	It converts rotary motion into linear motion and vice versa.	It transmits torque at right angle for parallel and non-coplanar shaft
Drawback: Clicking noise during teeth contact	Drawback: Due to axial thrust gear will move front and back		

Spiral bevel gears	Spur bevel gears	Herring bone gears
		
Teeth are curved.	Teeth are straight.	Teeth are straight at an angle and opposite.
More than one tooth in contact.	Only one tooth in contact.	More than one tooth in contact.
Produces axial thrust.	Produces axial thrust.	Although teeth are inclined, the shaft does not produce axial thrust. It neutralises the axial thrust.
Used to transmit torque at 90° axis	Used to transmit torque at 90°.	Used to transmit torque for parallel and coplanar axis.

Synchromesh gearbox

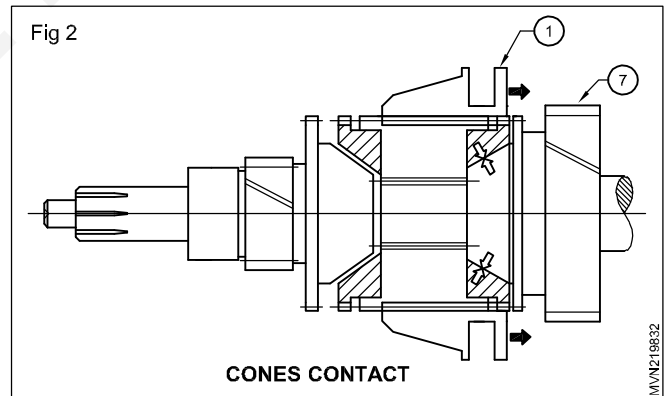
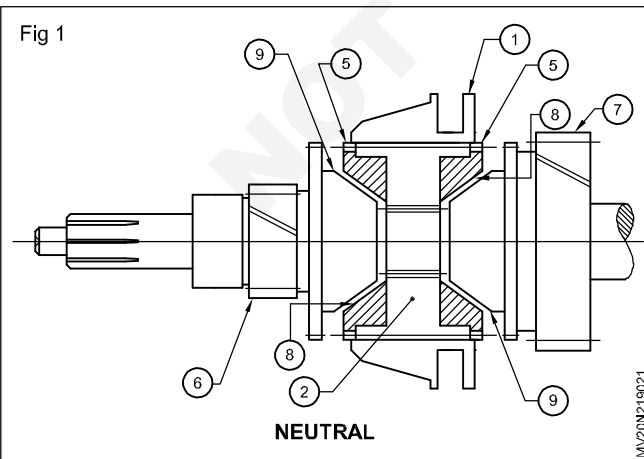
Objectives: At the end of this lesson you shall be able to

- explain the need of synchromesh action in a gearbox
- list out the different types of synchromesh gearboxes
- explain each type of synchromesh gearbox
- explain the function of a synchromesh unit
- explain power flow in different gear positions
- explain the advantages of a synchromesh gearbox over-sliding mesh and constant mesh gearboxes.

Synchromesh are used for easy gear shifting when a vehicle is in motion.

With synchromeshing action, gears can be changed without using double declutching. An unskilled driver can also change gears with less danger of gear clashing as in the case of in-sliding mesh and constant mesh gearboxes. .

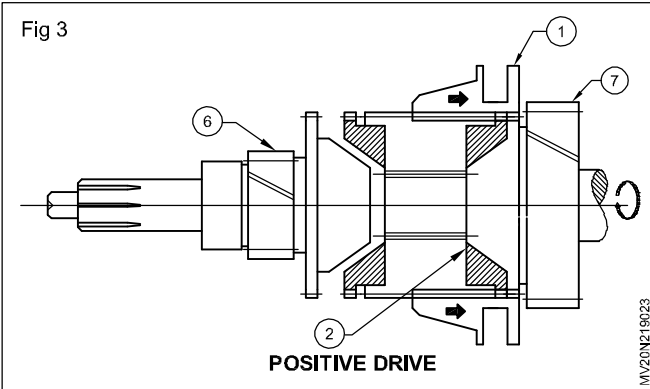
Synchronising action (Figs 1,2 & 3)



A synchroniser unit has a synchroniser sleeve (1), hub (2), a set of blocking rings (5), conical cup (8) provided on the blocking ring. Correspondingly a cone (9) shape is provided on gears (6) and (7) to suit the matching of the cup (8) and cone (9). Gears (6) and (7) rotate in mesh with the countershaft gear whereas the hub (1) rotates at the main shaft's speed.

Whenever any particular gear is to be engaged, the sleeve (1) is pushed towards the gear, and it further pushes up (8). The first cup (8) makes contact with the

cone (9) of the gear (7) and due to friction between the cone and the cup's blocking ring (5) and gear (7) start rotating at the same speed. Further movement of the sleeve (1) engages the dog teeth of the sleeve (1) with the dog teeth of the blocking ring (5) and gear (7). As at this stage the blocking ring and gear are rotating at the same speed. This engagement is carried out smoothly without double declutching and without causing any clashing noise.

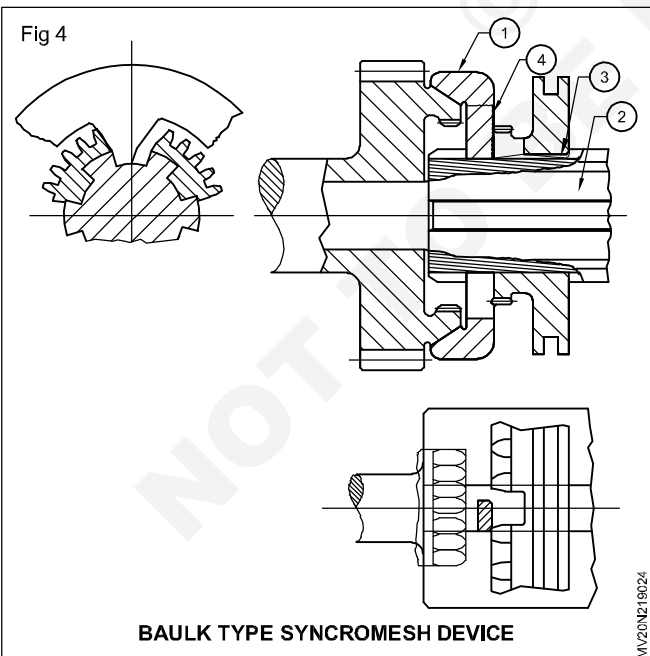


Types of synchromesh gearboxes

The various types of synchromesh gearboxes are given below:

- baulk type
- baulk ring type
- multi and double cone type
- porche type

Baulk type (Fig 4)

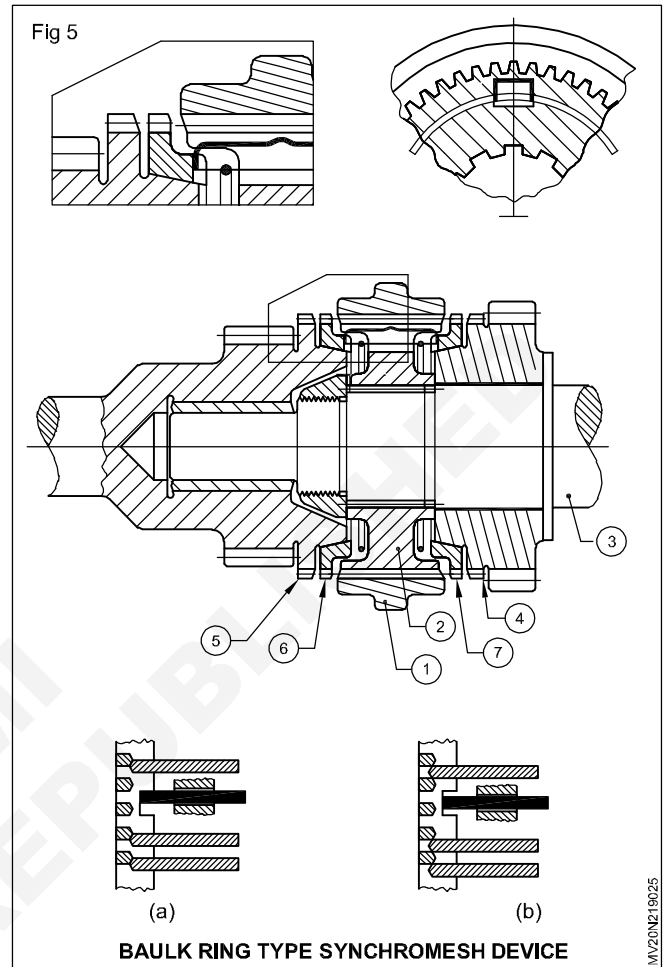


In this type the cone (1) and the main shaft (2) rotate at the same speed.

The cones will be pressed together and the friction between them will tend to bring about synchronising.

It needs minimum pressure to press the cones together. Once the gear is engaged, the springs (3) will press against the fingers (4) and hold the gear in position.

Baulk ring synchromesh (Fig 5)



This type of synchroniser unit is mostly used to engage the IV gear from III and vice versa.

In this dog clutch sleeve (1) is free to slide on the splines on the hub. The hub (2) is fixed to the main shaft; when the clutch sleeve is moved to the right its internal splines engage the dog teeth to the 3rd gear (4), and when it is moved to the left its splines engage with the dog teeth of the 4th gear (5). The synchronising action is provided by the baulk rings (6 & 7) which are having internal cones to engage with the external cones formed on gears.

Multi and double cone synchronisers

This type is mostly used for heavy commercial vehicles.

This type is provided with three slipping surfaces in the cone assembly.

In this type the torque will be three times more than the other types.

Porsche synchroniser

In this type the gear on the end of the clutch shaft drives the lay shaft.

It consists of a three-armed spider.

This synchroniser is used to change the top gear with a positive drive between the top gear and the main shaft.

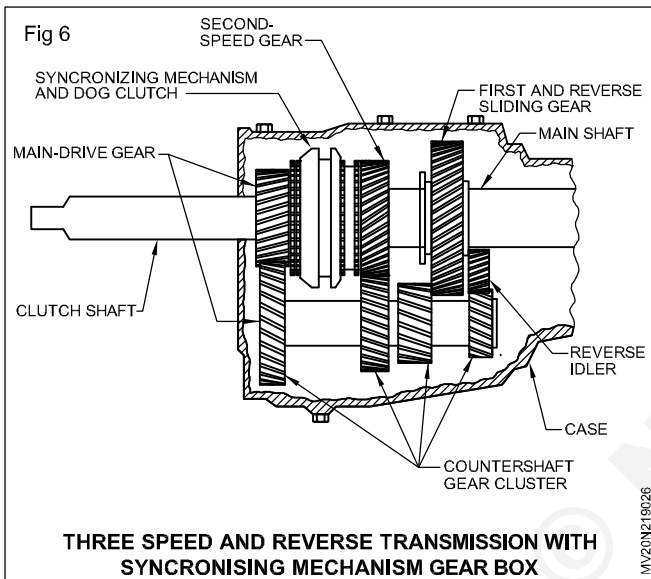
It is designed to obtain uniform pressure between the ring and the sleeve.

The above two synchronisers are not widely used in Indian vehicle. hence figures are not given.

The synchromesh gearbox and power flow in different gears.

Introduction

A 3-speed all helical gear, synchromesh gearbox (transmission) of a passenger car is shown in Fig 6.



It has 3 forward speed and one reverse speed for selection. This is closed as manually operated selective type because the driver can select the required gear ratio by shifting the gear by the operation of the gear shift lever.

Construction

The gearbox shown in Fig 6 here consists of the following main parts.

- Case and extension of housing
- Rotating parts including bearings
- Shift mechanism

Details

The case houses all parts of the gearbox and serves as a container for the gear oil.

The rotating parts consist of the main and lay shafts, its bearings, gears, dog clutches and synchroniser mechanism.

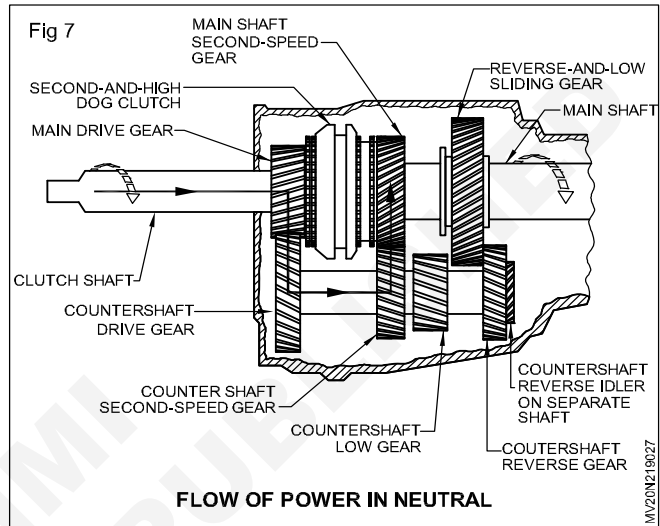
The case cover carries a selector and shifter mechanism and seals the gearbox housing against water and dirt.

Gear ratios	Jeep vehicle
1st gear	2.798:1
2nd gear	1.151:1
Top or 3rd gear	1:1
Reverse gear	3.798:1

Power flow in different gear positions is shown by figures below and also briefly discussed.

Power flow in Neutral

Neutral position (Fig 7)



In the neutral position there is no flow of power from engine-clutch primary shaft transmitted to the gearbox main shaft. This condition helps to start the engine and run it without movement of the vehicle.

Secondly, the main shaft and lay shaft second speed gears are in constant mesh but the second speed and high speed dog clutch is not engaged. Also the main shaft second speed gear is not splined or keyed to the main shaft but it simply rotates on it without transferring any power.

The black line with arrow shows the power flow from the clutch shaft to the countershaft through the main drive gear and countershaft gears which are in constant mesh.

All gears are revolving but no power is being transmitted.

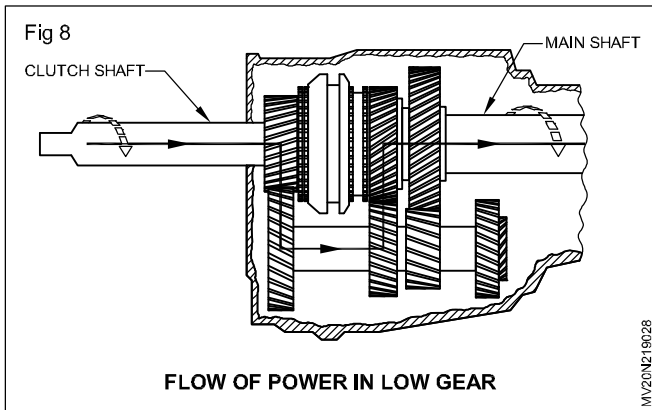
Power flow in first or low gear

First or low gear (Fig 8)

The power flow in first or low gear is shown in the figure.

By shifting the reverse and low sliding gear towards the left and making it mesh with countershaft (Layshaft low gear, First gear) position is obtained. The ratio is 2.798:1. The clutch primary shaft drives the countershaft through the main drive gear and countershaft drive gear.

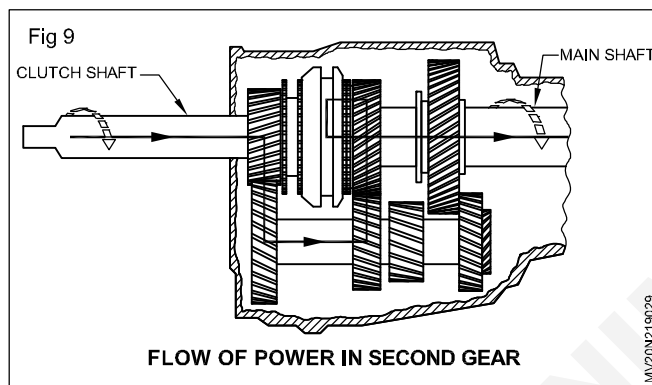
The flow of power (shown in black line arrow) goes from the countershaft to the main shaft, through countershaft low gear to the reverse and slow sliding gear (1 gear) which is splined to the gearbox main shaft and then to the U-joints and to the rear wheels.



Speed of main shaft = $1/2.798$ of clutch shaft speed.

All forward shifting is accomplished by action of the mechanism synchroniser.

Second gear position (Fig 9)

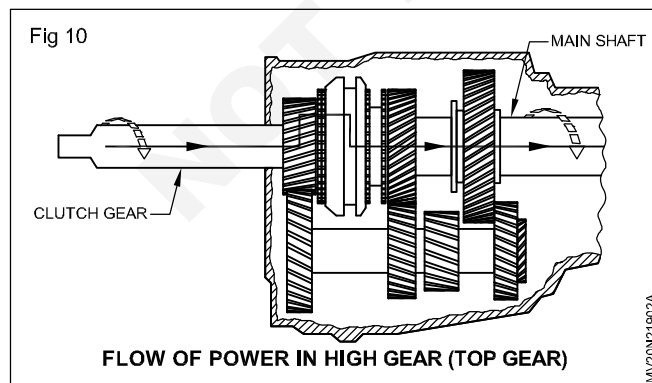


The first engagement is released out by shifting the first and reverse sliding gear out of mesh and bringing the system to neutral position.

The synchroniser sleeve is then moved to the right so that its teeth are meshed with the teeth on the hub of the second gear after synchronisation. The synchroniser hub is internally splined to the main shaft. Hence the power flows through clutch shaft main drive gear to the counter shaft second speed gear which turns the main shaft.

Speed of main shaft = $1/1.151$ of clutch shaft speed.

Top gear or high gear position (Fig 10)



Power flow in the top gear is shown in the figure. The synchroniser sleeve is moved to the left so that its teeth could mesh with the teeth on the hub of the main drive gear after the second speed gear is released out of

engagement. Now a direct drive engagement takes place locking the main shaft to the clutch shaft.

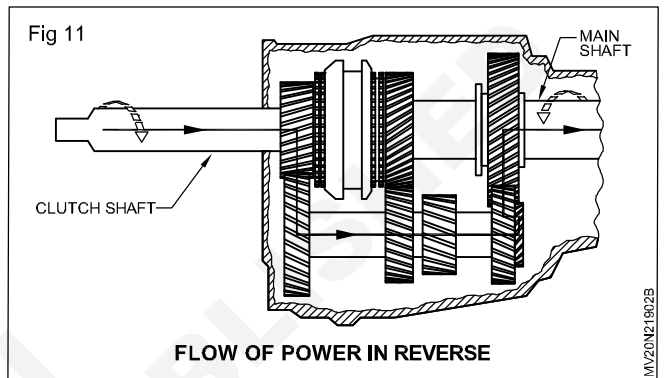
Speed of main shaft = speed of clutch = 1:1 shaft

No power is transmitted through the other revolving gears in the system.

The power flow the line (arrow) shows the direct drive through the synchroniser mechanism to the gearbox main shaft.

Reverse gear position (Fig 11)

In this gear, the synchroniser mechanism stands in neutral position. The clutch shaft and the main shaft are separated from the drive.



By operating the gear shift lever the reverse and low sliding gear is moved to the right and is engaged with the reverse idler gear. This engagement causes the change of direction of rotation of the reverse gear which in turn transfers the drive to the main shaft. Now the main shaft rotates in the reverse direction. The drive is then transmitted to the road wheels at the rear through U-vehicle moves in the reverse direction.

The power flow is from the clutch shaft main gear, countershaft gears, the reverse idler and then to reverse and low sliding gear and then to the main shaft.

Speed of main shaft = $1/3.798$ of clutch shaft.

Advantages of synchromesh gearbox over sliding and constant mesh gearboxes.

It requires less force to change the gears.

In sliding mesh gear boxes, the gear wheels themselves move on the shaft to mesh with each other which is eliminated in the synchromesh gearboxes, thereby increasing the life of the gears.

The constant mesh and sliding mesh gearbox requires double declutching while changing the gears which is not needed in a synchromesh gear boxes.

An unskilled driver can operate the synchromesh gear boxes as compared to constant mesh and sliding mesh gearboxes since double declutching is not required for this.

Synchromesh gearbox troubles

Objective: At the end of this lesson you shall be able to

- list out the various troubles and their causes in a synchromesh gearbox.

Common troubles and remedies in a synchromesh gearbox

Trouble	Causes	Remedies
Hard gear shifting	Synchronising unit damaged or springs improperly installed after service	Replace the unit or re-install springs correctly
Gear locked in one gear	Synchronising unit stuck	Free the sticking units. Replace the damaged parts.
Gear slip	Synchroniser worn out or defective	Repair/replace
Noise from gearbox in neutral position.	Bearings worn out or dry	Lubricate/replace. Fill gear oil to correct level.
Transmission noisy in gear	Insufficient lubricant in the gear box. Gear box misaligned with engine.	Check and realign.
	Clutch friction disc defective. Synchroniser worn out or damaged. Gears worn out	Replace/set right. Replace the worn out or damaged or damaged part
Gear clash during shifting	Synchroniser defective. Clutch free play too much. Gear shifting linkage out of adjustment.	Repair or replace. Adjust clutch pedal free play. Readjust again.

Layout of drive shafts

Objectives: At the end of this lesson you shall be able to

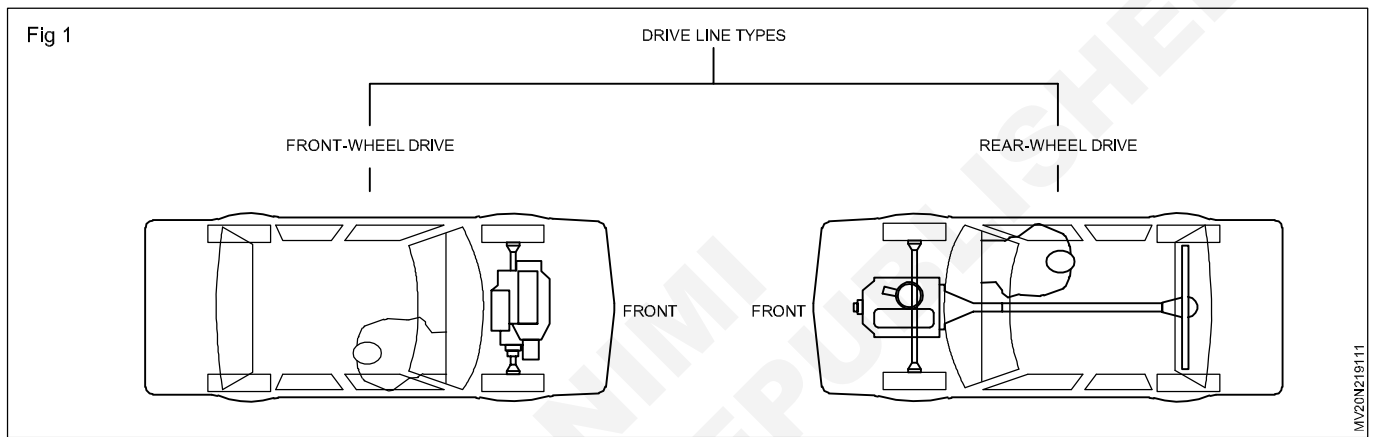
- draw a layout of drive lines
- draw a layout of front wheel drive
- draw a layout of rear wheel drive.

Drive line types

In transmission system there are two types of drive lines are adopted. One is front wheel drive and the other one is rear wheel drive line to transmit the engine torque to the driving wheels as shown in Fig.1.

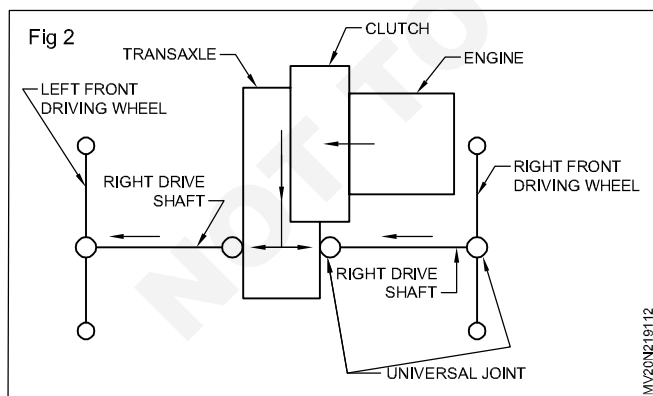
Drive line

The drive line represents the universal joints, drive shaft and other parts transmitting engine torque to the driving wheels or rear driving axle. The purpose of the drive line is to transmit engine torque smoothly to the driven parts in the driving axle.

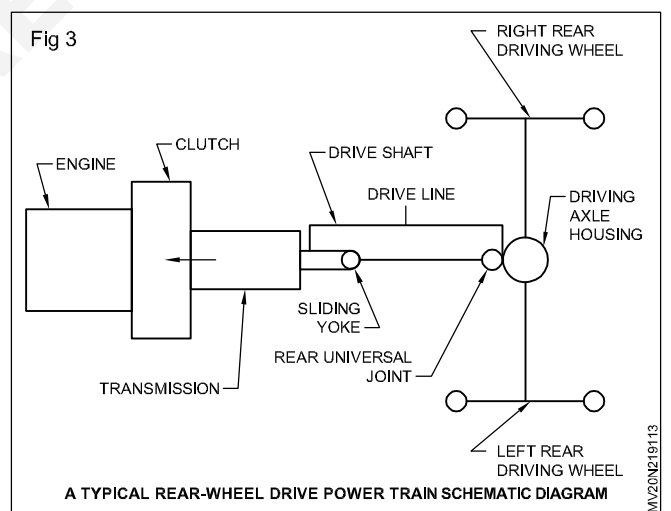


Front-wheel drive line

Front wheel drive has the engine and driveline located between the front driving wheels. A typical front wheel power train is illustrated schematically in Fig 2. A key point to observe with front wheel drive is that the power flow leaves the transaxle (transmission and axle) housing to enter the driveline to rotate the front driving wheels.

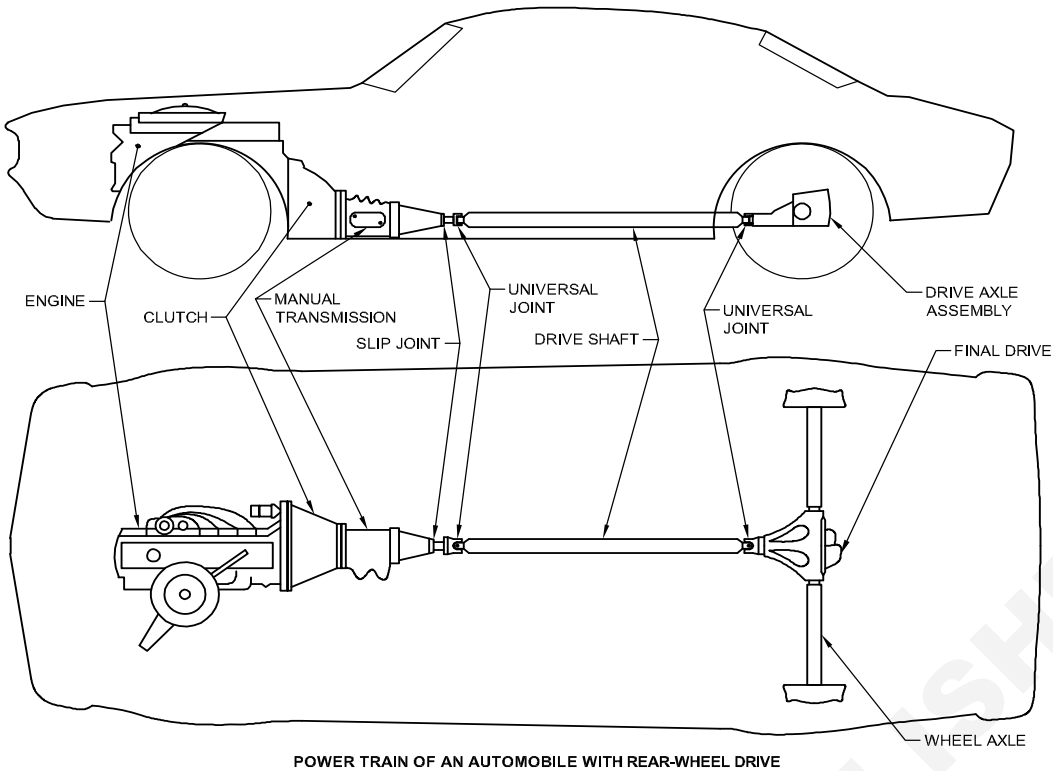


Rear wheel drive line: The purpose of the rear wheel drive line is the same as the front wheel drive line; the difference is location. The rear wheel driveline is located between the transmission and the rear axle housing as illustrated in Fig 3. The power flow will leave the transmission to enter the drive line. The drive line torque will then enter the rear driving axle to rotate the driving wheels.



Power train of an automobile with rear-wheel drive: A manual transmission shown in the above Fig. 4 is a transmission that the driver must shift by hand or manually. It is an assembly of gears and shaft that transmits power from the engine to the final drive or drive axle.

Fig 4



POWER TRAIN OF AN AUTOMOBILE WITH REAR-WHEEL DRIVE

MV20N219114

All wheel drive, 4WD, free wheeling and transfer case

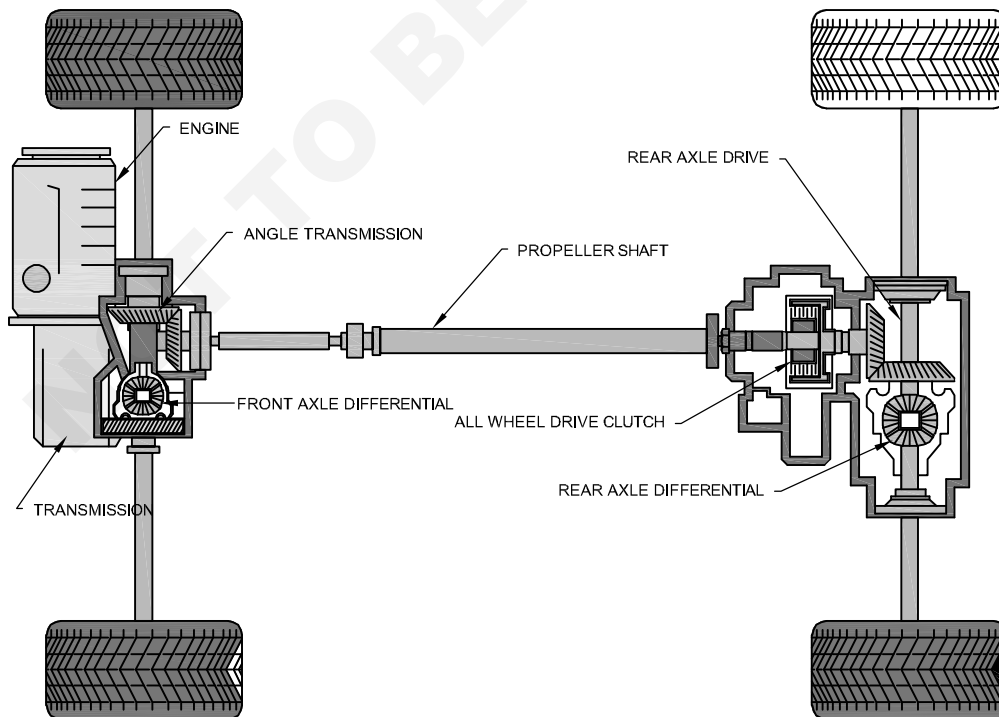
Objective: At the end of this lesson you shall be able to
• differentiate all wheel drive and 4 wheel drive.

All wheel drive (Fig 1)

These system are sometimes called full - time four wheel drive. All - wheel -drive systems are designed to function on all types of surface, both on-and off-road, and most

of them cannot be switched off. All wheel drive is used in special application like race and sports cars. These systems can be used in high gears and high speed applications.

Fig 1



ALL WHEEL DRIVE LAYOUT

MV20N219121

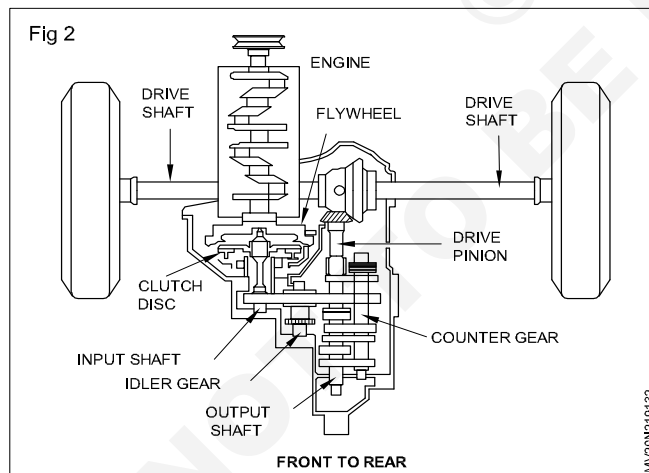
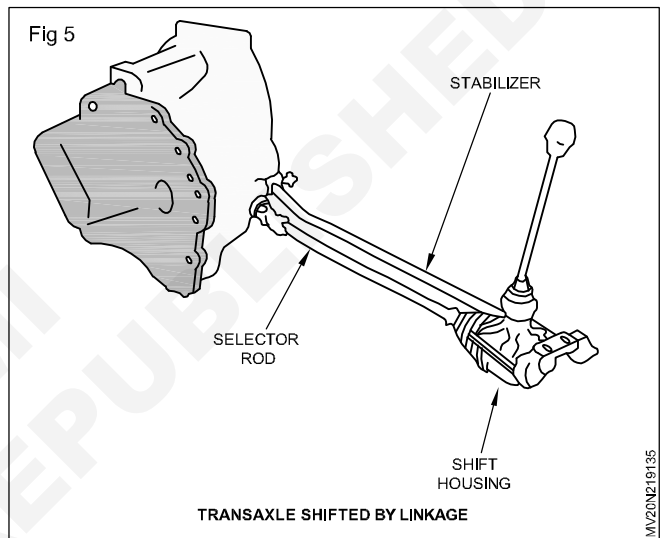
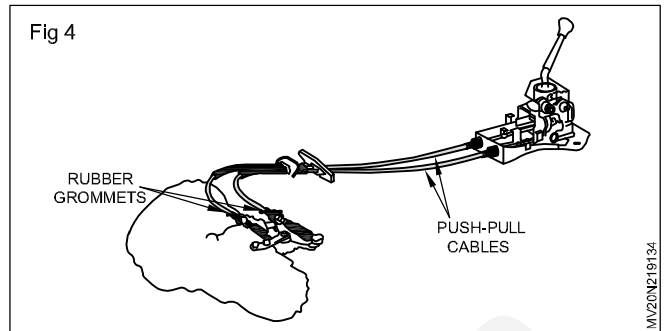
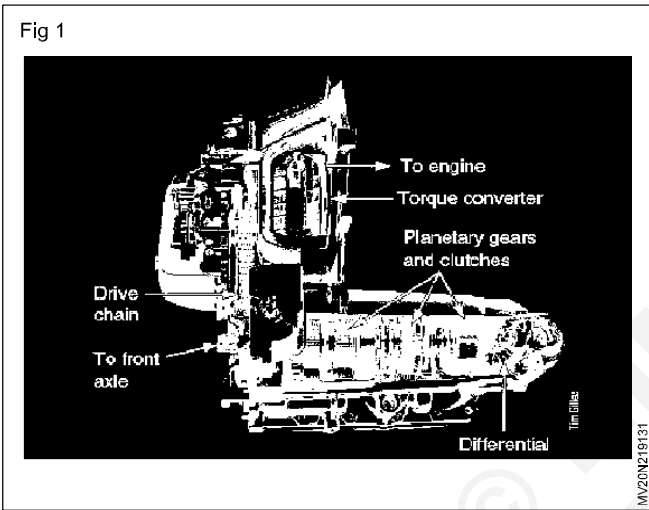
Front - Wheel - Drive (Transaxle and CV joint)

Objectives: At the end of this lesson you shall be able to

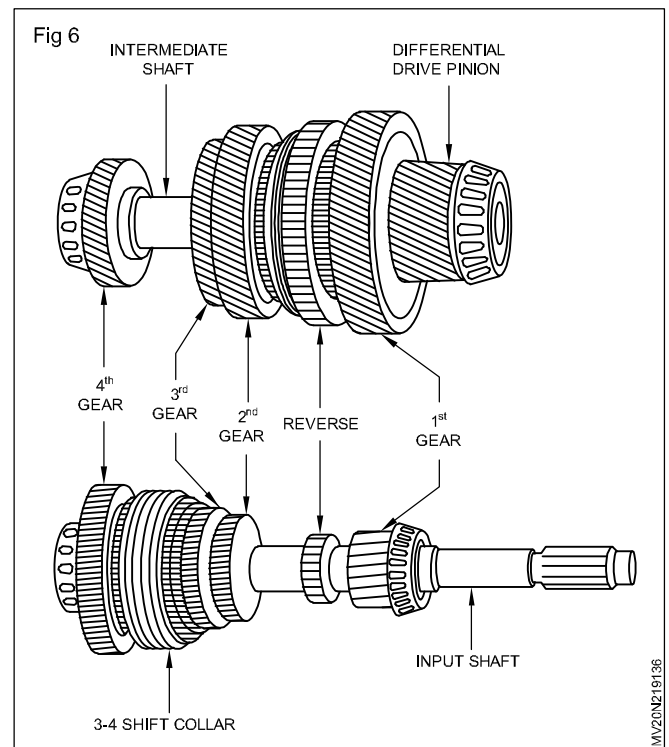
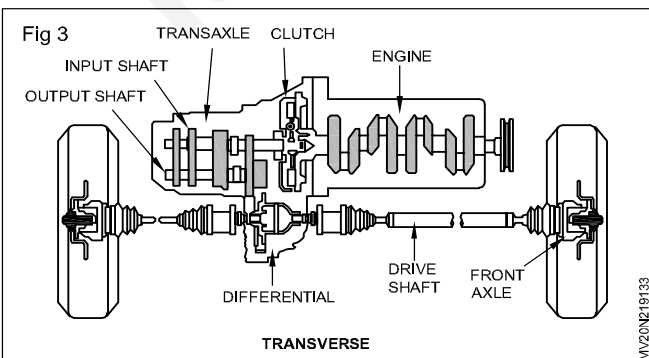
- describe transaxle function
- describe the transaxle powerflow.

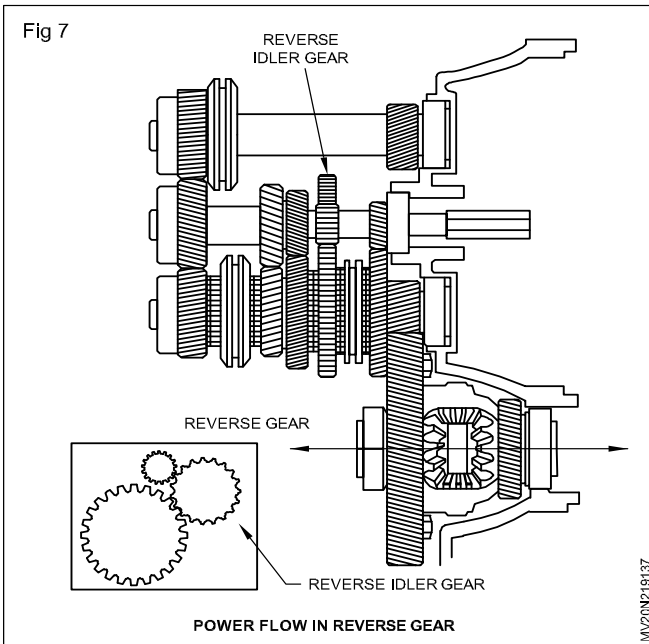
Introduction

FWD car has transaxle either manual or automatic (Fig 1). Most of the transaxle mounted sideways and a few have been mounted longitudinally (Fig 2&3). Manual transaxles have three parallel paths for power flow. Transverse transaxles shifted through two cables or rods. One moves a selector other moves shift fork back and forth Fig (4&5). Transaxle differential allows wheels to turn at different speeds when rounding corners. Differential side gears is transmitted power to front axles through axles shaft.



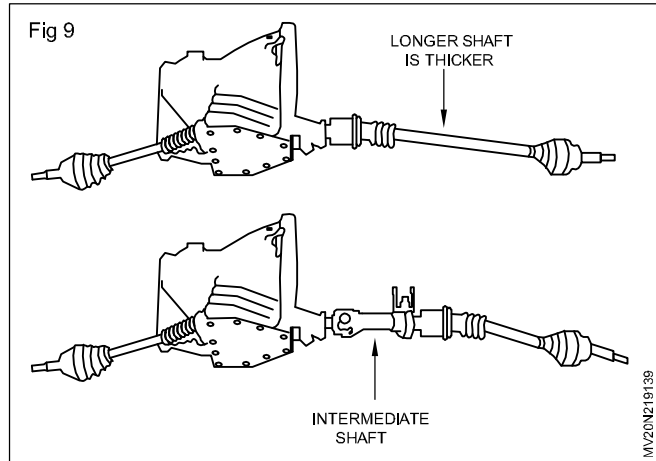
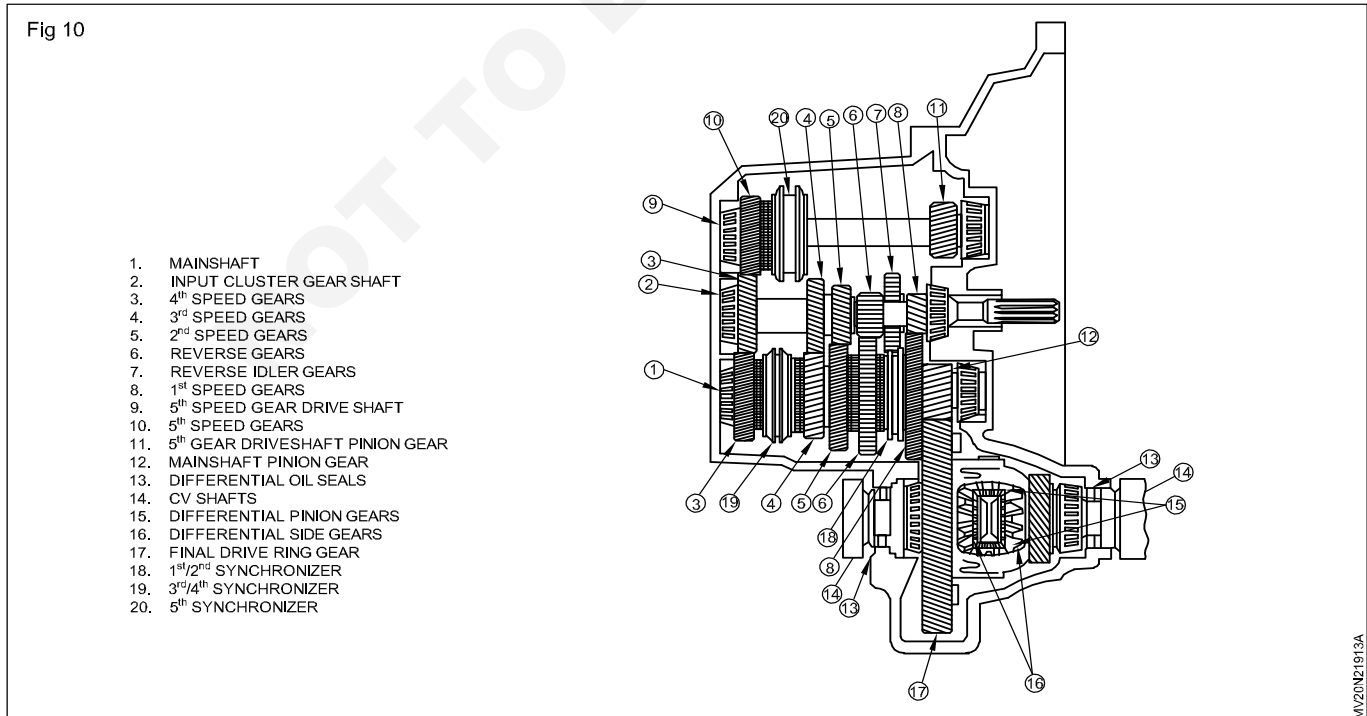
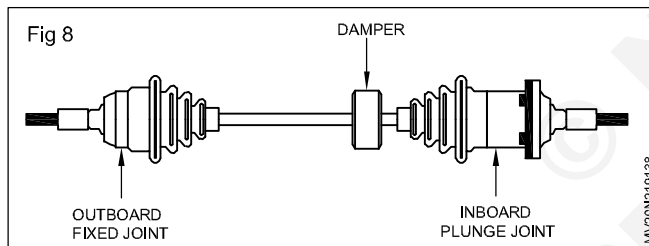
Transaxle power flow (Fig 6 & 7)





- Fixed gears for first, second and reverse on input shaft.
- Fixed gears for third, fourth, fifth on intermediate shaft.
- Engine is mounted sideways.
- Axle run parallel to input shaft

Axle shafts and CV joint boots (Fig 8 & 9)



Front wheel final drive

In front wheel drive vehicles the transaxle is transmit the power from engine to the front wheels through drive shaft. Transmission (Gearbox) and final drive (Differential assembly) are enclosed in one casing is called transaxle.

In front wheel final drive no propeller shaft is required, in which transmission main shaft pinion gear is directly connected to the ring gear of differential assembly.

Note: The engine is fitted at front side of the vehicle.

Drive shafts are connected to the differential assembly through constant velocity joints.

Front wheel differential (Fig 10)

In front wheel drive vehicles differential is attached with transmission. It is used to differ the front wheels speeds left and right side to make a smooth turn while maneuvering during turns. It consists of sun gears and star gears. The friction of differential gears similar to the rear wheel differential. The only difference is the transaxle shafts (drive shafts) having the constant velocity joints at the juncture of wheel hubs.

Transmission/Transaxle designs

The internal components of a transmission or transaxle consist of a parallel set of metal shafts on which meshing gear sets of different ratios are mounted. By moving the shift lever, gear ratios can be selected to generate different amounts of output torque and speed.

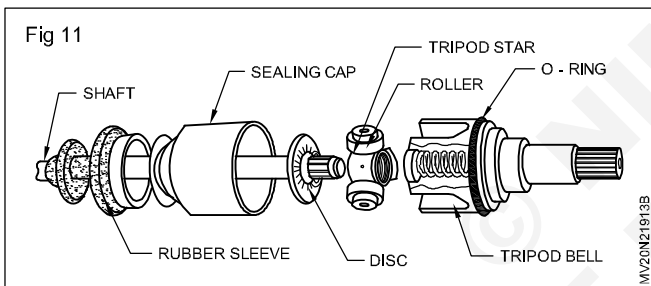
The gears are mounted or fixed to the shafts in a number of ways. They can be internally splined or keyed to a shaft. Gears can also be manufactured as an integral or “clustered” part of the shaft. Gears that must be able to freewheel around the shaft during certain speed ranges are mounted to the shaft using bushings or bearings.

The shafts and gears are contained in a transmission or transaxle case or housing. The components of this housing include the main case body, side or top cover plates, extension housings and bearing retainers. The metal components are bolted together with gaskets providing a leak-proof seal at all joints. The case is filled with transmission fluid to provide constant lubrication and cooling for the spinning gears and shifts.

Types of constant velocity joints

Sliding constant - velocity joints

Tripod joints (Fig 11)

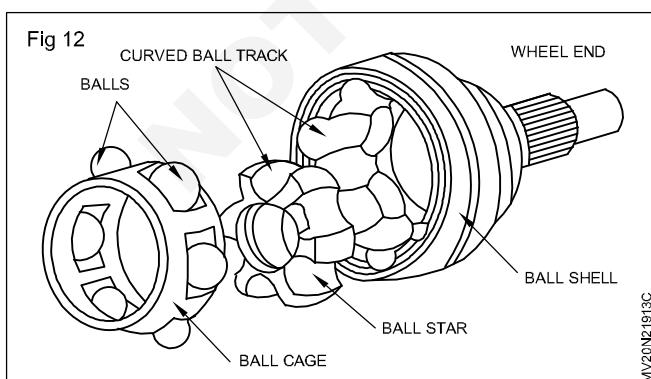


These can be used in the case of independent suspension both on powered front axles (front - wheel drive) and on powered rear axles (rear-wheel drive)

Tripod joints permit diffraction angles upto 26° and axial displacement upto 55 mm.

The tripod star is always towards the final drive end.

Pot joint (Fig 12)



These are ball joints, the balls of which are guided by a cage run on **straight tracks** of the ball and the ball shell.

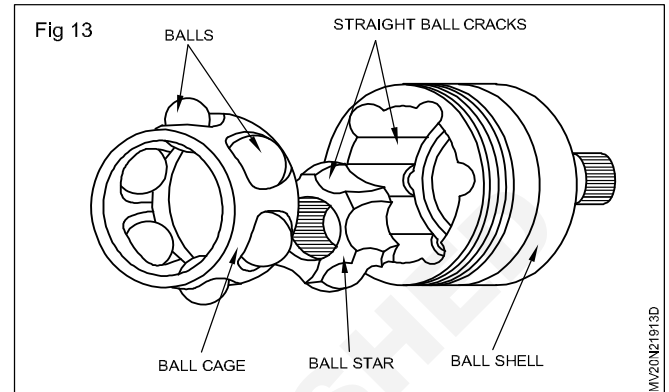
Pot joints permit diffraction angles upto 22° and axial displacement upto 45 mm.

Post joints are situated at the final-drive end.

Fixed constant-velocity joints

Ball joints

These consist of the ball star, ball shell, ball cage and balls (Fig 13)



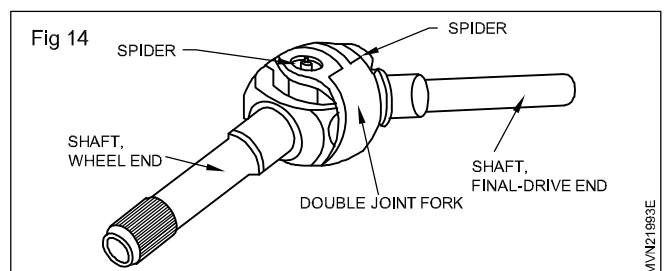
The ball shell and ball star have curved tracks, on which the balls run.

Ball joints permit diffraction angles upto 38° in their normal version and upto 47° in their special version. They do not permit any axial displacement.

Ball joint as fixed constant-velocity joint

Double joints

Two universal joints are combined to form a single joint (Fig 14). In order to ensure fault-free operation, the shaft ends to be connected are centered on the inside of the joint.



They are used in commercial vehicles.

Double joints permit diffraction angles upto 50°. They do not permit any axial displacement.

Flexible discs

Flexible discs are resilient, maintenance-free joints. They permit only small diffraction angles and linear variations. They are installed in the derivation primarily as flexible elements for damping vibrations and noises. Flexible discs are permanently connected with the body or frame.

There are the following different types:

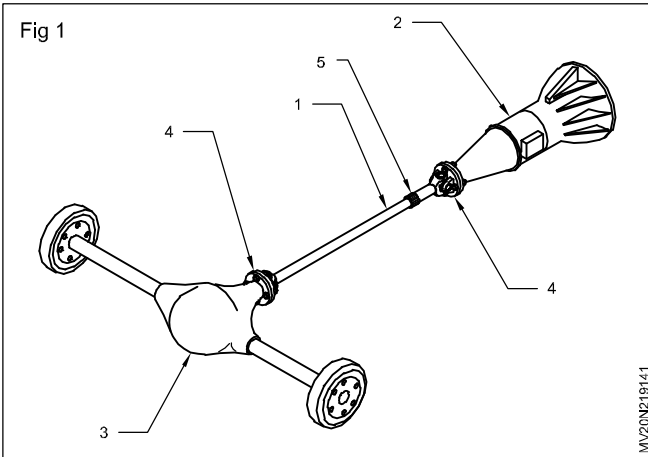
- Hardy discs
- Silentbloc joints

Rear wheel drive - Propeller shaft

Objectives: At the end of this lesson you shall be able to

- state the function of the propeller shaft
- state the need for centre bearing
- state the hotchkiss drive
- state the torque tube drive.

Functions of propeller shaft (Fig 1)



The propeller shaft (1) connects the gearbox (2) and final drive (3). The pinion shaft of the differential is connected to the propeller shaft (1). One universal joint (4) is used in between the propeller shaft and the pinion shaft of the differential. Another universal joint (4) with one slip joint (5) is also used between the propeller shaft (1) and the gearbox (2).

The propeller shaft rotates at high speed and bears a heavy torque. So it is made of strong steel tube. In some vehicles a solid propeller shaft is also used. Vehicles having a larger wheel base use two propeller shafts.

Whenever the distance between gearbox and rear axle is very large (example-passenger buses) more than one propeller shaft is used for torque transmission. Centre bearing is used to connect the two propeller shafts.

Types of drives

Two types of drives are used:

- Hotchkiss drive
- Torque tube drive

Universal and slip joints

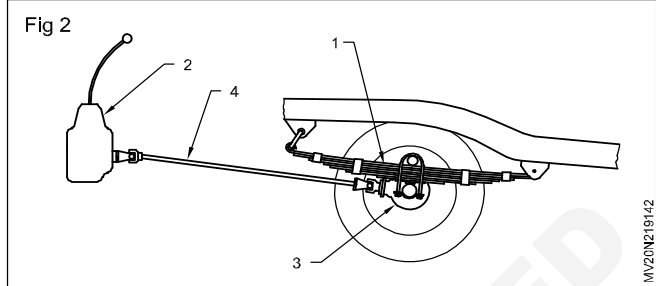
Objectives: At the end of this lesson you shall be able to

- state the need for a universal joint
- state the function of a universal joint
- state the constructional features and function of the different types of universal joints
- state the need for a slip joint.

Need and function of universal joint

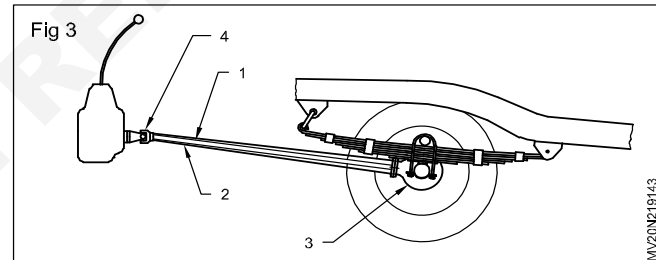
In any vehicle the gearbox and the rear axle are at different levels. A universal joint provides a flexible connection. It allows the propeller shaft to transmit torque from the gearbox to the rear axle. Similarly due to the

Hotchkiss drive (Fig 2)



It has two longitudinal rear leaf springs (1). The front end of the spring (1) is connected to the frame with the pin and the rear end is connected to the frame by a bracket and shackles. The gearbox (2) and the rear axle (3) are connected by an open propeller shaft (4), through the universal joint and the slip joint. Whenever the torque resistance of the rear axle changes i.e while driving fast or applying the brake, the springs get deflected and this helps to damp the shock. The slip joint accommodates variation in length between the gearbox (2) and the rear axle (3).

Torque tube drive (Fig 3)



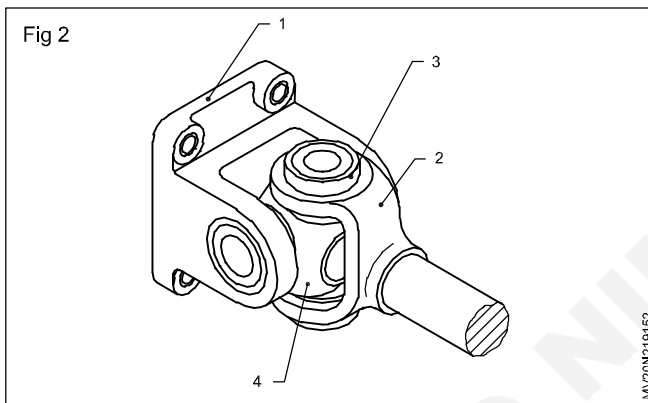
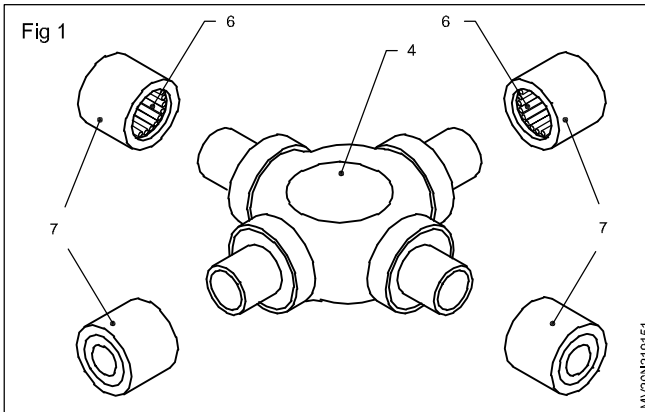
In this type of drive the propeller shaft (1) is enclosed in the tube (2). The tube (2) is fastened to the differential housing (3). The other end of the tube (2) is connected to the gearbox by a flexible joint (4). Only one universal joint is used in this drive. To provide strength, brace rods are connected between the torque tube (2) and the differential housing (3). In this drive or torque bar springs can be used.

ups and downs on a road, the angle between the gearbox and the rear axle changes. The universal joint accommodates this variation in angle and permits smooth transmission of torque from the gearbox to the rear axle.

Types of universal joints

- Cross-type or spider and two yoke type
- Ball and trunnion type

Cross-type universal joint (Figs 1 & 2)

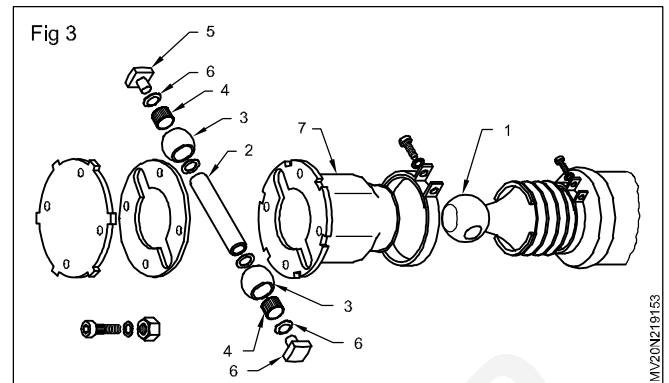


A cross-type universal joint has a spider (4). At the four ends of this, needle roller bearings (6) are fixed with bearing caps (7). Two yokes (1) and (2) at 90° to each other are pivoted to the spider (4).

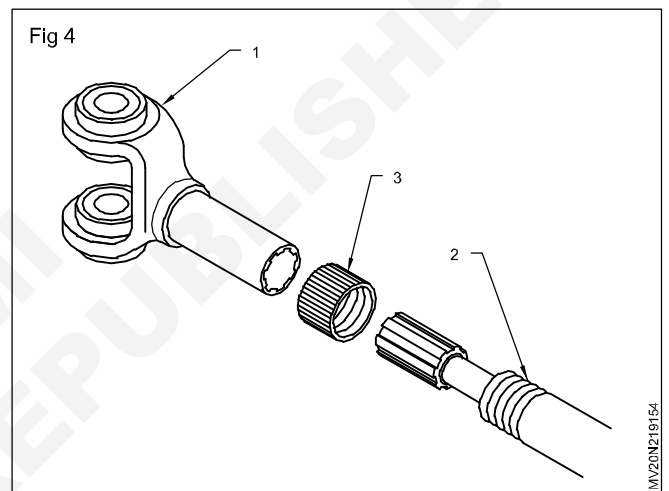
Ball and trunnion type universal joint (Fig 3)

In this type of joint a ball head (1) is fixed at the end of the propeller shaft by a pin (2). At both the ends of the pin two steel balls (3) with roller bearings (4) are fixed. The centering button (5) and a button spring (6) keep the pin (2) in the centre. The propeller shaft and universal

joint assembly is fixed to the companion flange (7). Whenever the angle between the gearbox and the rear axle changes, the ball accommodates this variation by moving in the 'U' channel.



Slip joint (Fig 4)



When the vehicle is moving, the rear suspension spring compresses and expands because of the ups and downs on the road. As a result, the length and the angles between the gearbox and rear axle varies. To accommodate this change in length, slip joints are used.

The joint yoke (1) has internal splines matched with external splines of the propeller shaft (2). Whenever there is any change in length the joint yoke (1) moves on the shaft (2) and adjusts the length.

Rear axle assembly

Objectives: At the end of this lesson you shall be able to

- state the various types of axle housings
- state the various types of rear axles.

Parts of rear axle assembly

The rear axle assembly consists of the following units:

- Axle housing
- Axle shaft
- Hub, brake and wheel
- Differential and CWP

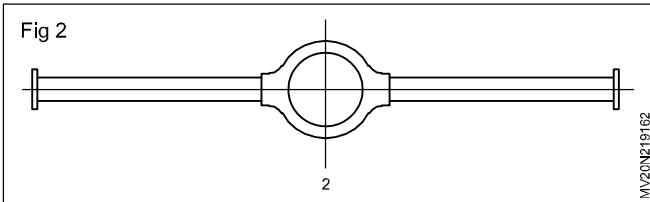
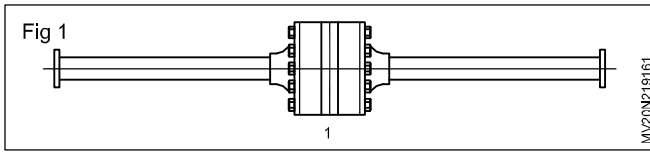
Types of axle housings

- Split type (Fig 1)
- Banjo type (Fig 2)

In the split type housing (1) two halves are bolted to the differential housing.

Banjo type housing (2) is welded and made into a single piece. The differential carrier is bolted to the housing.

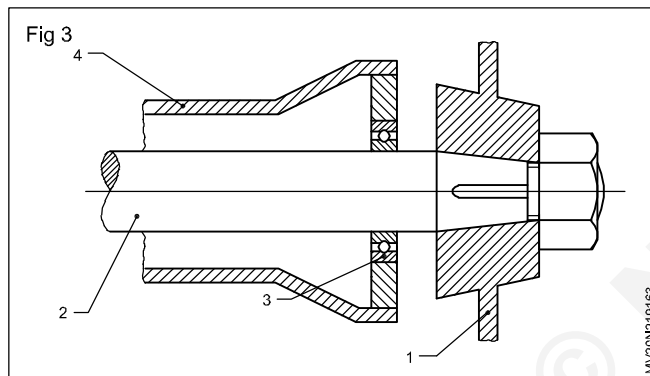
Power is transmitted from the final drive to the wheel hub through the two axle shafts. The axle shaft's inner end has external splines which sit in the sun gear's splines.



Types of rear axles

Three types of rear axles are used depending upon the mounting of the hub.

Semi-floating axle (Fig 3)

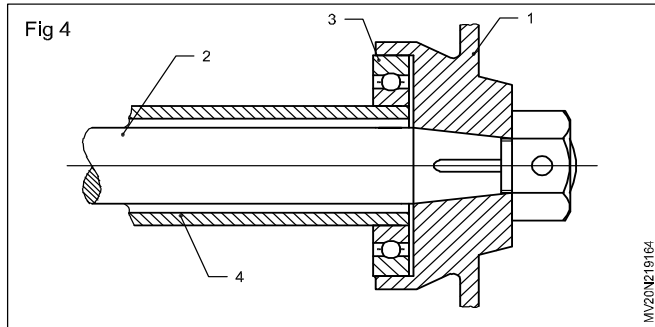


In this type of axle the hub (1) is directly fitted on the axle shaft (2). The axle shaft rests on the bearing (3) in the axle housing (4). In this, the axle shaft takes the vehicle load as well as the driving thrust.

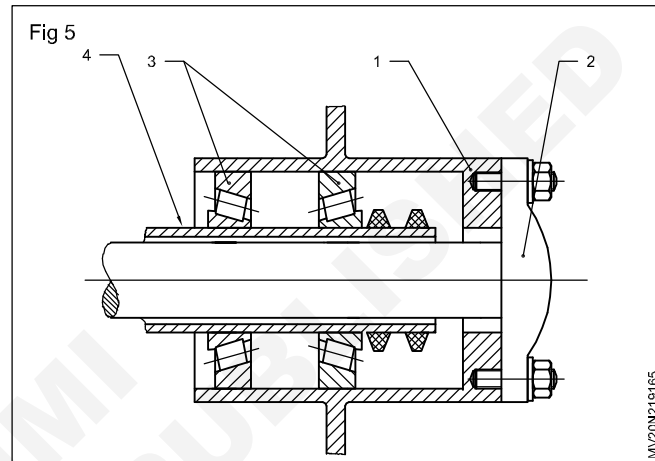
Three quarter floating axle (Fig 4)

In this type of axle, the hub (1) is mounted on the axle housing (4) at one end by the bearing (3). The other end of the hub (1) is connected to the axle shaft (2). As such

the axle shaft takes only a partial load of the vehicle but the full driving thrust.



Fully floating axle (Fig 5)



In this type of axle, the hub (1) is mounted on the axle housing (4) on two taper roller bearings (3). The axle shaft (2) takes only the driving thrust. The vehicle's load is taken by the axle housing (4).

Both semi floating and 3/4 floating axles cost of axle is less but load carrying capacity is less. Axle shaft bend on excess load. Bearing life is poor. Fully floating axle used heavy taper roller bearing and carries high load. Axle shaft gives good life. Cost of full float axle is high.

Final drive

Objectives: At the end of this lesson you shall be able to

- state the function of the differential
- state the internal parts of differential
- state the need for the differential.

Final Drive (Differential) - function

The final drive serves two purposes.

- It transmits power at a right angle.
- It increases the torque by reducing the speed.

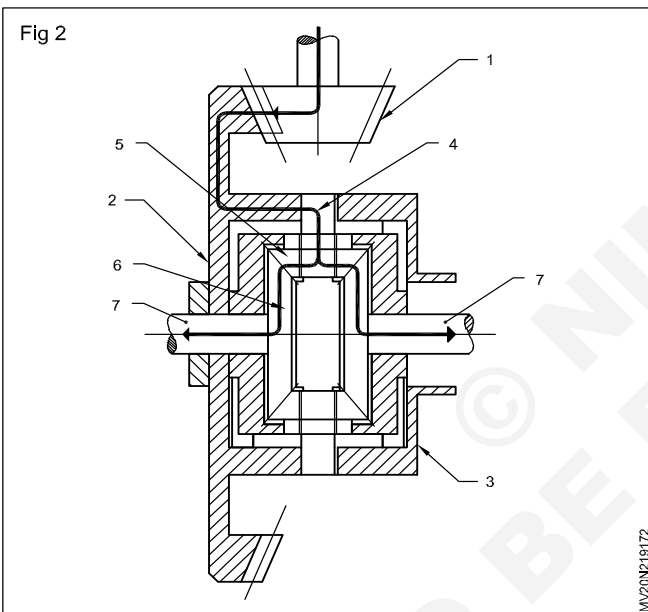
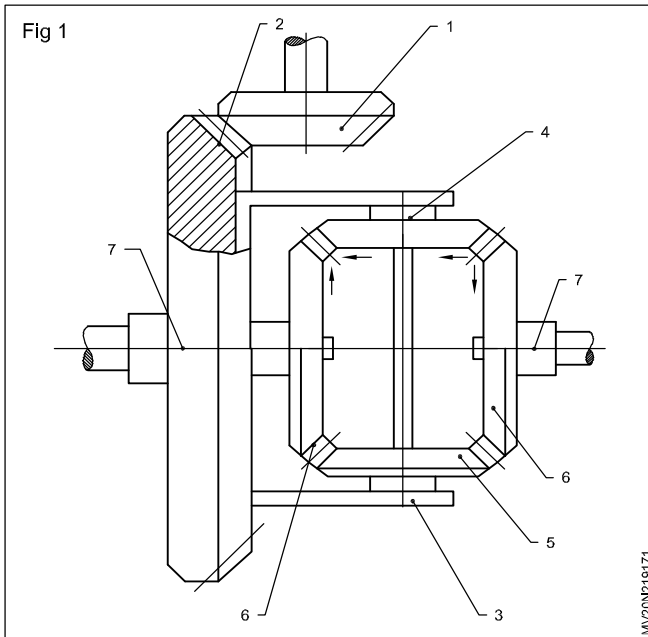
Types of differential

- 1 Conventional
- 2 Power or Non-slip

3 Double reduction type

Internal parts of differential (Figs 1 & 2)

The final drive consists of a pinion (1) crown wheel (2) and a differential cage (3). Inside the cage the spider-cross (4) with planetary gears (5) are assembled. Also two sun gears (6) are assembled on both sides of the planetary gears (5). The sun gears (6) have internal splines in which the axle shaft's (7) spline end sits.

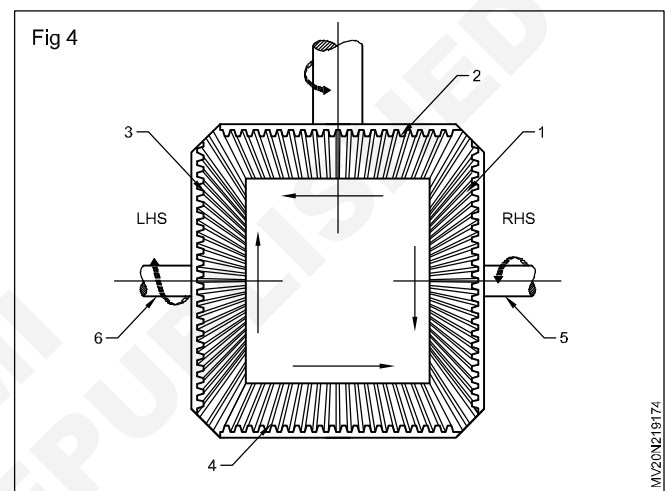
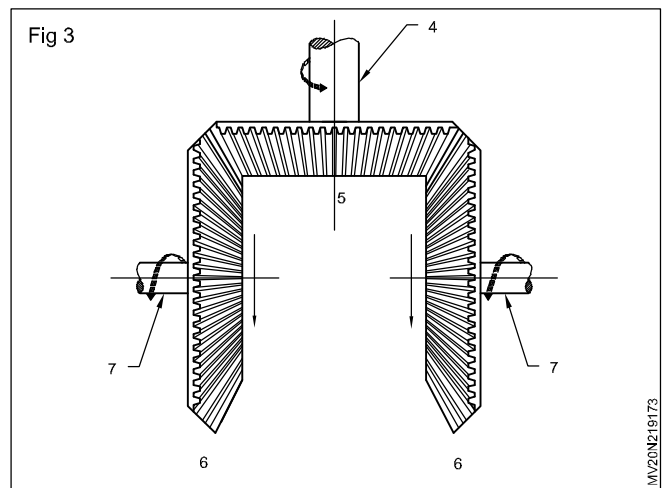


The crown wheel is fixed on the cage (3). The axle shaft's splined end is fixed to the sun gears and the other end is bolted to the wheel hub.

When the vehicle is moving straight, (Fig 3) the power is transmitted from the pinion (1) to the crown wheel (2) and to the cage (3). When the cage (3) is rotating the spider (4) also rotates along with the star gears (5). The sun gears (6) are pushed by the star gears, and power is transmitted to the axle shafts (7). During a straight line run the star gears (5) do not rotate on their axis.

Need for the differential

When the vehicle makes a turn (Fig 4), the inner wheel has more grip on the road than the outer wheel. So the respective inner sun gear (6) offers more resistance. At that time, the star gears (5) rotate on their own axis and move the inner sun gear slowly and allow the outer sun gear to rotate faster. So the outer wheel travels more distance in the same time.



To examine differential action, raise the rear axle assembly till both wheels clearly ground and support them on two jacks. Rotate RHS wheel by 1 turn in forward direction. You will observe LHS wheel runs in opposite direction by 1 turn. While taking a LHS turn the outer wheel has to travel longer distance and turn several turn etc. compared to left wheel. This is how the differential turns is achieved between the inner and outer wheels.

Limited slip differential

A limited slip differential (LSD) is a type of differential that allows its two output shafts to rotate at different speed but limit the maximum difference between the two shaft.

Working of a Limited Slip Differential

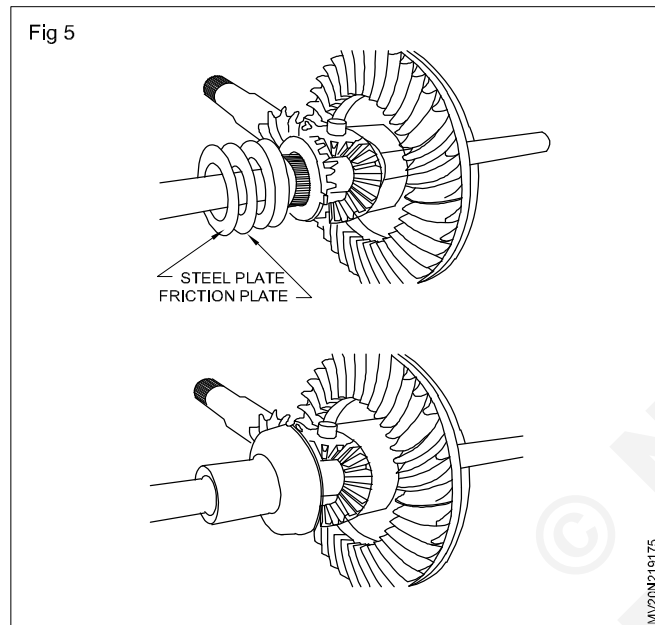
Limited slip differentials (LSD) are used in automobiles to overcome the traction difference problem of drive wheels. A vehicle fitted with a standard differential moves straight, and one drive wheel is on a surface with good traction and the other wheel is on a slippery track. In a standard differential the left and right axle rotations are completely independent. Since one wheel is on a slippery track, the standard differential will make that wheel spin in excessive speed, while the good traction wheel will remain almost dead. This means high power supply to the slippery wheel and low power flow to the good traction wheel. So the vehicle won't be able to move.

One way to overcome this problem is to limit the independency or relative motion between the left and right axles. Limited slip differentials are introduced for this purpose. One of the most commonly used LSD technology is clutch-pack based.

Constructional Features of LSD

The basic components of a standard differential are shown below. It has got pinion gear, ring gear, case, spider gears and side gears.

Apart from its basic components a Limited slip differential has got a series of friction and steel plates packed between the side gear and the casing. Friction discs are having internal teeth and they are locked with the splines of the side gear. So the friction discs and the side gear will always move together. (Fig 5)



Steel plates are having external tabs and are made to fit in the case groove. So they can rotate with the case. If any of the clutch pack assembly is well pressed, the frictional force within them will make it move as a single solid unit. Since steel plates are locked with the case and friction discs with the side gear, in a well pressed clutch pack casing and the clutch pack will move together. Or motion from the casing is directly passed to the corresponding axle.

Four wheel drive

Objectives: At the end of this lesson you shall be able to

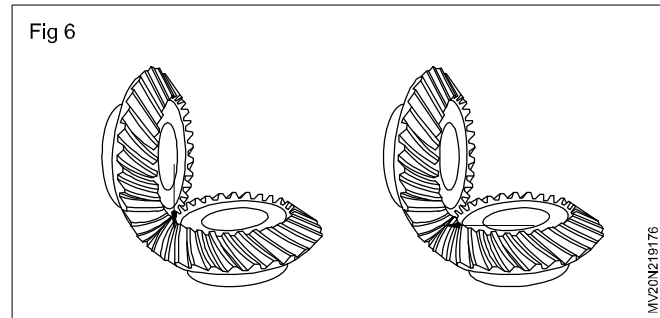
- explain the necessity of a four wheel drive
- explain the purpose of the transfer case
- explain the operations of a four wheel drive
- explain the shifting mechanism in the transfer case.

Necessity of a four wheel drive

In the four wheel drive mechanism, there is provision to supply power to all the four wheels, whenever it is needed. When the vehicle is moving on sand, slushy ground, traction between wheels and road is lost and the drive wheel tends to slip on the ground. In this

condition, the vehicle cannot be pushed. Therefore, power is transmitted to other wheels also through the transfer case.

Separating action of Bevel gears (Fig 6)



Spider and side gear are bevel gears. It has got one specialty. When torque is transmitted through a bevel gear system axial forces are also induced apart from the tangential force. The axial force tries to separate out the gears. Side gear and axle are 2 separate units. The side gear has got a small allowance for axial movement.

So during high torque transmission through spider-side gear arrangement, a high separating thrust force is also transmitted to the clutch pack. This force presses and locks the clutch pack assembly against wall of the casing.

Since one wheel is on a high traction surface, the torque transmitted to it will be higher. So the thrust force developed due to the bevel gear separation action also will be high at that side. Thus clutch pack at high traction wheel side will be pressed firmly and clutch pack will be locked. So power from the differential casing will flow directly to high traction axle via clutch pack assembly.

On the other hand clutch pack on the low traction wheel side is not engaged yet, so power flow will be limited to that side. So the vehicle will be able to overcome the traction difference problem.

However while taking a turn the LSD can act like a normal differential. In this case thrust force developed due to bevel gear separation action won't be that high. So the plates in clutch pack will easily overcome frictional resistance and will be able to slip against each other. Thus the right and left wheel can have different speed just like an open differential.

condition, the vehicle cannot be pushed. Therefore, power is transmitted to other wheels also through the transfer case.

Purpose of transfer case

The transfer case is mounted in the back of the main transmission. It is sometimes called auxiliary gearbox.

The transfer case can transmit engine power either only to the rear wheels of the vehicle or to all the four wheels according to the driving requirements.

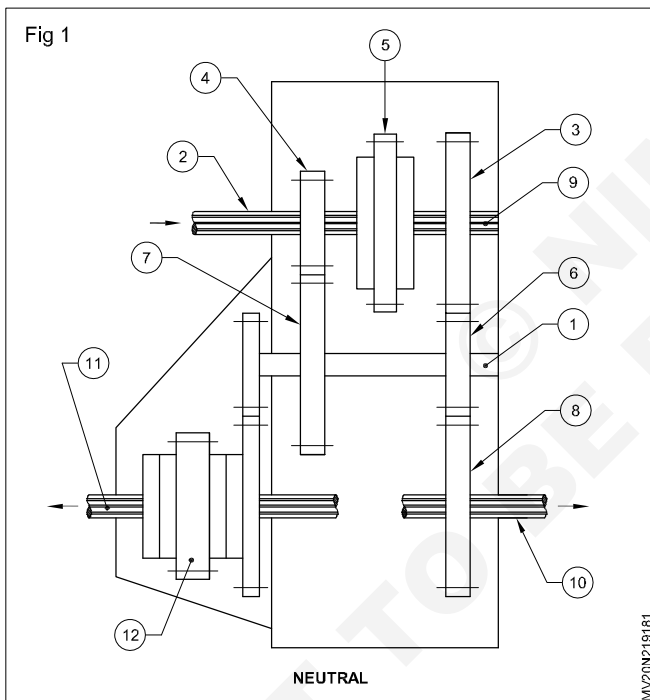
The transfer case can also provide low or high speed transmission.

A low speed transmission drive is mostly used when moving with the heavy load requiring high traction torque.

Operation of transfer case (Four wheel drive)

The transfer case consists of a main shaft (9) on which the low range gear (4) and the high range gear (3) are fixed. These gears rotate freely on bushes. The sliding gear (5) slides on the main shaft. An idler gear shaft (1) is fixed between the main shaft and the rear differential drive shaft (10) and the front differential drive shaft (11). A clutch locking drive gear (12) is fixed on the front differential drive shaft (11).

During neutral position, (Fig 1) the sliding gear (5) and clutch drive gear (12) are not engaged with their respective gears and power is not supplied to the front and rear wheels.

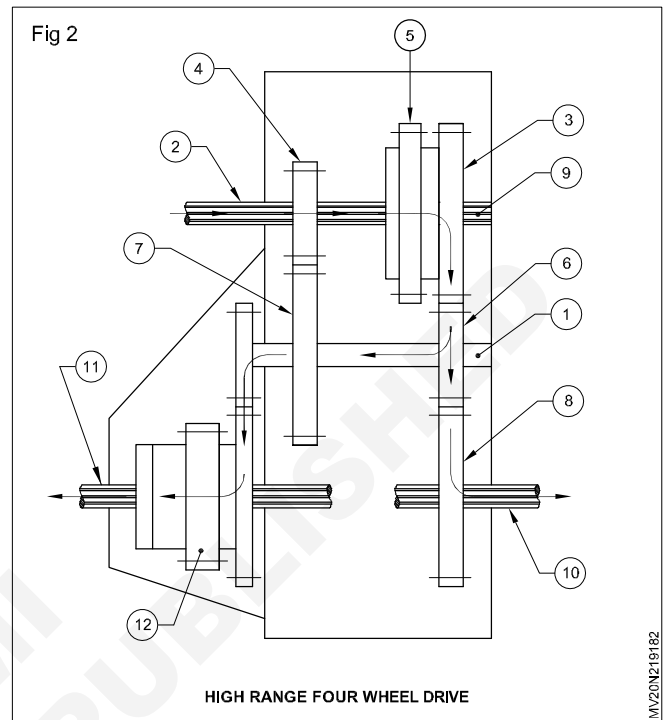


When power is to be supplied to the rear wheels only, the front drive clutch gear is kept in neutral position and the sliding gear (5) on the main shaft is engaged to low or high range gears (4) or (3), depending upon the requirements. In this condition, power flows only to the rear axle.

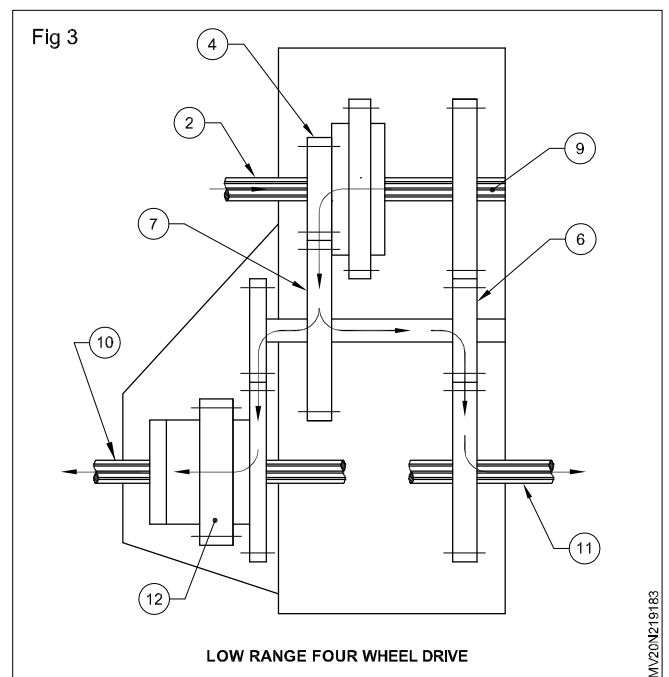
When a vehicle is driven over slushy ground the drive wheels tend to spin without moving the vehicle.

In this position, the clutch drive gear to front wheels is engaged. Now power will be supplied to all the four wheels.

When the lever is shifted to engage a high range four wheel drive position, the drive from the primary gear shaft (2) goes to the main shaft (9). The main shaft's sliding gear (5) engages with the high range gear (3) (Fig 2) and power is transmitted to the front wheel's drive output shaft (11) and the rear wheel's output shaft (10) through the idler gears. (Fig 2)



When the lever is shifted to engage the low range four wheel drive position, the drive from the primary gear shaft (2) goes to the main shaft (9). The main shaft's sliding gear (5) engages with the low range gear (4) (Fig 3) and transmits the drive to the output shafts of the front and rear drive shafts (10 & 11) through the idler gears.



Shifting mechanism in four wheel drive

The transfer case is provided with a shift mechanism to operate the four-wheel drive mechanism.

A gear shifting lever is provided in the driver's cabin and it is connected to a clutch locking drive gear of the first gear through a shifting rod and fork. Similarly another lever is provided to engage the sliding gear (5) with low range or high range gears, and is connected with the sliding gear through the shifting fork and rod.

Differential & transfer case

Vehicles are equipped with at least one differential and some also have a transfer case. Each need to work efficiently in order transfer torque from the transmission to the wheels. A four-wheel drive (4WD) and an all-wheel drive (AWD) vehicle, however, needs a transfer case in addition to differentials on each axle. While both operate similarly, there is a difference between transfer case and differential.

Differential

As part of the front and/or rear axle assembly, the differential is designed to drive wheels while allowing them to rotate at different speeds when turning by providing proportional rpms between the left and right wheels. The power from both the engine and transmission is directed through the differential and out to the wheels.

Transfer case: The transfer case is located between the transmission and front and rear differentials via the driveshafts, creating a two-wheel drive (2WD) or four-wheel drive vehicle. On a four-wheel or all-wheel drive (AWD) vehicle, it directs power to two or four wheels. When the transfer case engages the front shaft, which feeds power to the front wheels, the vehicle then becomes a four-wheel drive. All-wheel drive vehicles receive power through the transfer case at all times. Each vehicle has a different setup. Pick-up trucks have two-wheel and four-wheel drive options, some crossovers have an option of all-wheel or two-wheel drive, while some SUVs have an option of all-wheel drive. Performance vehicles also are available in 2-wheel or all-wheel drives. Four wheel and all-wheel drive options offer better traction and maneuverability for steep roads.

The transfer case with its neutral, high and low ratio selection and choice of two or four wheel drive is generally operated by a floor mounted lever. This lever is normally located near the gear lever. This lever is normally located near the gear lever. It has four positions:

H2-High ratio, two wheel drive

H4-High ratio, four wheel drive

N-Neutral (for power take off use)

L4-Low ratio, four wheel drive.

A shift between H2 and H4 can be made at any speed below 50km per hour, in any gear. Ensure the freewheeling hubs are at LOCK when 4WD is engaged.

To shift between H4 and L4 or L4 and H4 the vehicle should be stationary.

Purpose of a transfer case

Vehicles equipped with a transfer case (4WD & AWD) for better on slippery surfaces, giving them the ability to accelerate more efficiently, when purchasing a vehicle its important to ask yourself if you will be travelling with your vehicle on snowy, wet, sandy or rocky roads. If so considering a vehicle with four-wheel or all-wheel drives may be tight for you. Four wheel drive and all-wheel drive vehicles are ideal for off-roading and the needed traction with adverse weather conditions.

Maintaining the differential & transfer case

Transaxle oils, differential fluid and gear oils should be changed between 30,000 - 60,000 miles by a certified technician. Clean, fresh oil provides better protection of the differential and well-lubricated parts as with any component on the vehicle ensure the best performance. Transfer case fluid should be replaced every 30,000 miles to remove any debris or contaminants and to better lubricate components. This is highly recommended for trucks that tow loads and utilize four wheel drive frequently.

Symptoms of trouble in the differential

- Wiring or whining noises when decelerating.
- A howl or whine during acceleration over high or low speeds.
- Rumbling whining at speeds over 20 miles per hour but changes while turning.
- Frequent clunking sound every few feet or when starting to move.
- Vibration that increases with speed.

Transfer case will need to be inspected unable to or have trouble switching from two wheel drive to four wheel drive or the vehicle shudders when turning.

Neglecting any maintenance service on vehicle is unwise in any situation. Spent differential fluid after time, becomes dirty and contaminated. Continuing to drive with unclean fluid is risky as it may result in undue wear or components leading to permanent damage. Avoiding maintenance on the transfer case may impair the vehicles ability to convert to four wheel drive. Drivers should take extreme caution trouble with the transfer case and avoid rough or slippery terrains.

All wheel drive

An A.W.D vehicle with 4 driven wheels can, with the same drive power and weight distribution, transmit twice as much motive force as a vehicle with 2 wheel drive.

$$\begin{aligned} \text{Ex: Total weight} &= 2800 \text{ kg} \\ \text{Each wheel} - 2800/4 &= 700 \text{ kg} \\ 2 \text{ WD} = 2 \times 700 &= 1400 \text{ kg} \end{aligned}$$

$$4 \text{ WD} = 4 \times 700 = 2800 \text{ kg}$$

All wheel drive vehicles are used to drive the vehicles at rough roads, hills, sandy surface and it can be used for sports. These vehicles are also called as sports utility vehicles (SUV).

All wheel drive has two types:

1 Conventional switchable All wheel drive

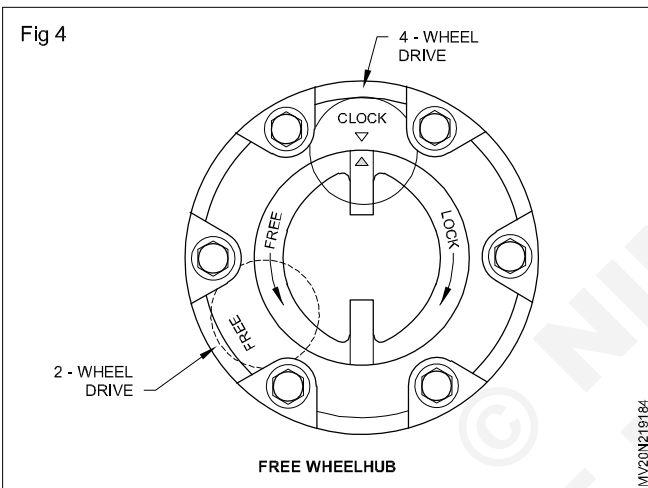
Here the wheels on a powered axle are always drives. While the other axle wheels are engaged whenever necessary. The selector switch or knob is provided inside the driver cabin for this purpose.

2 Permanent All wheel drive

All the four wheels (front & rear) are permanently driven.

Wheels a centre differential for balancing different speeds between the front and rear axle is required.

Free wheeling (Fig 4)



In mechanical or automotive engineering, freewheel or over running clutch is a device in a transmission that disengages the driveshaft from the driven shaft when the driven shaft rotates faster than the driveshaft.

Free-wheeling hubs

Vehicles can be fitted with freewheeling hubs to reduce noise and wear, and improve fuel consumption. However, you must ensure that both hubs are locked in position before selecting 4WD. Free-wheeling hub selectors are located at the centre of the front wheels and have two distinct positions before selecting 4WD. (Commonly marked LOCK and FREE). In the LOCK position, the axle is connected to the wheels by a dog clutch system enabling power to be delivered to the wheels when 4WD is selected. When placed in the FREE position, the dog clutch is disengaged and the wheels rotate independent of the axle. This allows the front drive shaft, differential and axle to remain stationary for highway travel.

When the FREE position, the hub disconnects the wheel from front axle shaft, differential gears and propeller shaft and revolution of front wheel becomes free giving the following benefits:

- 1 Increase in mileage
- 2 Better pick-up
- 3 Steering becomes free
- 4 Less load on engine
- 5 Less wear on front differential
- 6 Less noise from gear train
- 7 Less tyre wear

When in the "LOCK" position, the axle shaft and the vehicle wheel are connected and the vehicle runs like a normal 4 wheel drive.

Construction

The following assemblies are used in vehicles with permanent all-wheel drive.

- Transfer box with centre differential and longitudinal lock.
- Front final drive with differential
- Rear final drive with differential and inter wheel lock

Transfer box

This distributes the torque from the variable speed gear box in the proportion of e.g. 50% to the rear final drive.

Centre differential

This balances different speeds, for example when cornering. Distortions in the drive train are avoided.

If the drive wheels on an axle spin, the centre differential can be locked by means of a longitudinal lock. In this way, more torque is allocated to the wheels on the axle with the better road-surface adhesion.

Front and rear differentials

These balance different wheel speeds and distribute the torque in equal proportions to the drive wheels on one axle.

If a wheel spins, balancing can be looked by an inter wheel lock and more torque is allocated to the wheel with the better road-surface adhesion.

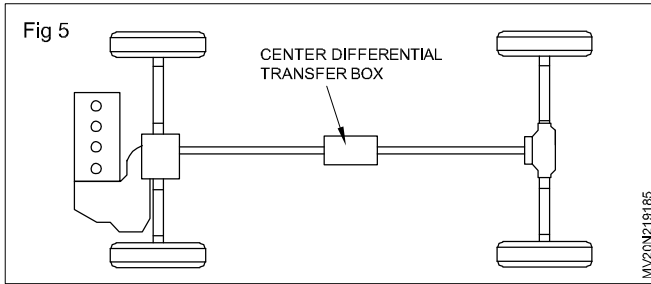
1 longitudinal lock and 2 interwheel locks are required in order to be able to transmit a maximum torque under all driving conditions with an all-wheel-drive vehicle.

Centre differential and transfer box

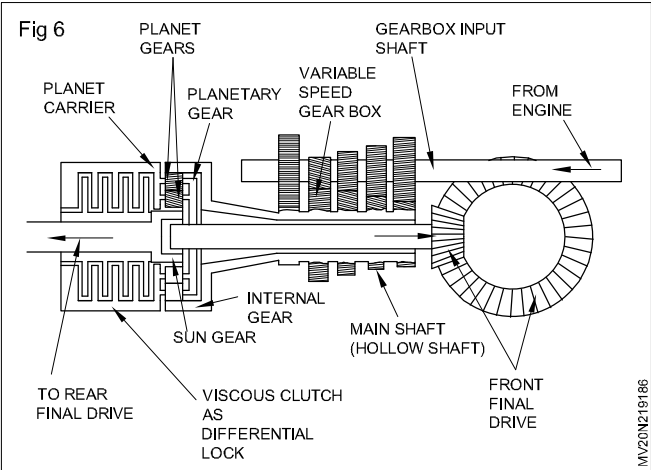
These are usually combined in a single structural unit. The following different types may be used:

- Bevel gear differential
- Planetary gear
- Haldex clutch
- Torsen differential
- Viscous clutch

The possible torque distributions to the front and rear axles are set out in Fig 5.



Planetary gear as centre differential (Fig 6)



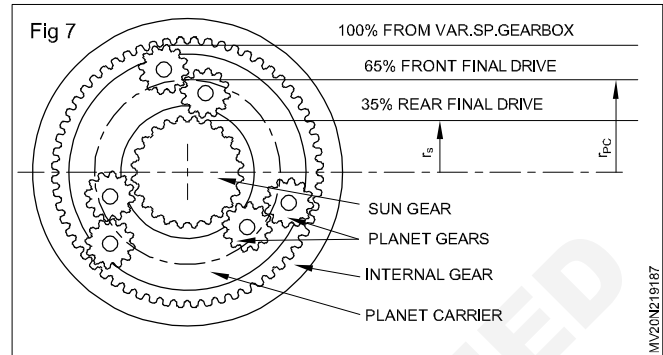
This balances different speeds of the front and rear wheels and distributes the torque with a constant ratio to the final drives on the front and rear axles.

Planetary gear as centre differential

The torque comes from the variable-speed gear box via the hollow shaft (main shaft) to the internal gear of the planetary gear. From there it is distributed by the planet carrier to the front final drive. Torque distribution is effected on account of the different lever arms of the planet carrier and the sun gear. (Fig 7) in an equal proportions (a symmetrical), e.g. 65% to the front and

35% to the rear final drive. In the event of slip at the front or rear wheels, a viscous clutch locks as a function of traction and allocated more torque to the drive side with the better road-surface adhesion.

An A.W.D operation most of the time in two wheel drive mode and power delivered to all four corners only when additional traction control is needed.



Possible torque distribution

Type	Front axle	Rear axle
Bevel gear differential	50%	50%
Planetary gear	e.g. 35%	35%
Viscous clutch	98%	2%
	2%	98%
Torsion differential	22%	78%
	78%	22%
Haldex clutch	100%	0%
	0%	100%

Automatic Transmission

Objectives: At the end of this lesson you shall be able to

- define automatic transmission
- state the controlling variables of the automatic transmission
- identify the major components
- explain the working principle of automatic transmission
- state the electro hydraulic transmission control.

Definition

Automatic transmission of an automobile is defined as to shift the gears automatically depending upon the speed and load of the vehicle.

Controlling parameters of the automatic transmission

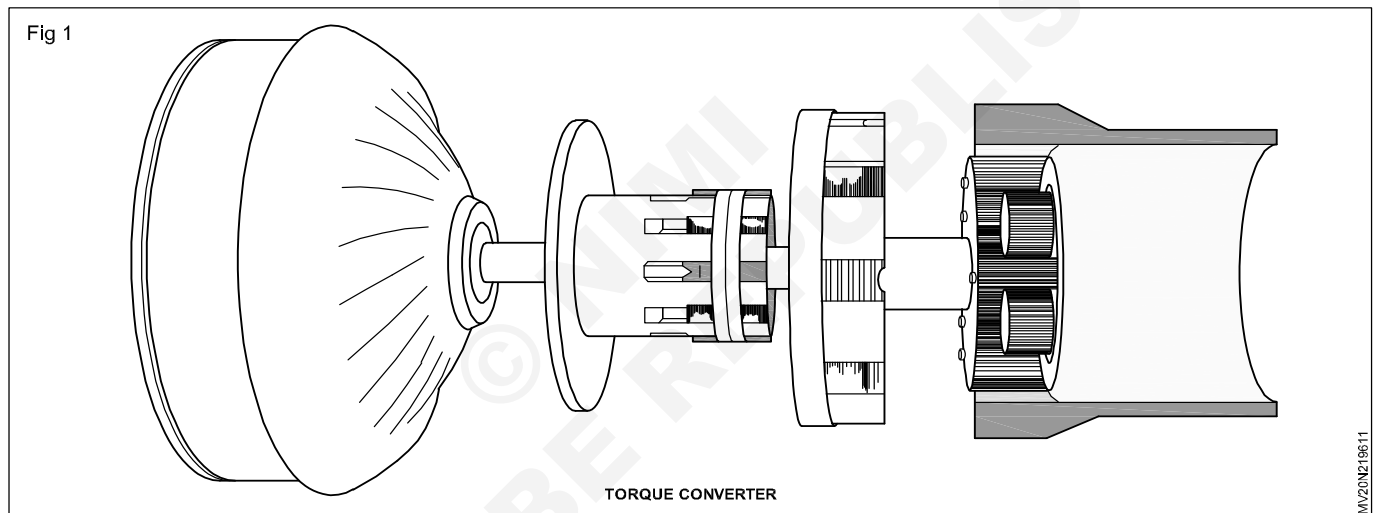
The main controlling variables are

- Selector lever position

- Driving speed
- Engine load (accelerator pedal position)

Major automatic transmission components

- Torque converter (Fig 1)
- Planetary gear unit
- Electro hydraulic control



Advantages of Automatic transmission

- Simple driving control
- Improved acceleration and hill climbing
- Reduced fuel consumption
- Less wear and tear due to planetary gearing
- Less fatigue to operator
- No need clutch pedal and gear lever
- Vehicle smooth running under all conditions due to automatic gear change
- Noiseless gear shifting
- Longer life
- No jerky driving

Torque converter

Torque converter is used to transfer power from the engine to the transmission input shaft. It acts as an

automatic clutch to engage and disengage the engine and the transmission. It allows the engine to run idle when the vehicle is standing still.

The torque converter is mounted on the transmission input shaft and connected with the fly wheel of the engine.

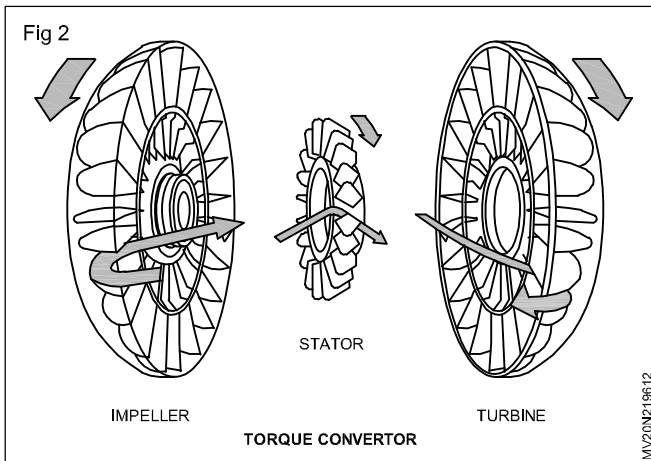
Functions of torque converter

- It convert and transmit the engine torque
- It facilitate smooth, comfortable starting
- It damp the engine torsional vibrations
- The major components of torque converter are
 - Impeller
 - Turbine
 - Stator

The impeller, turbine wheel and stator are designed as curved blade wheels and operate in an enclosed housing which is filled with hydraulic fluid.

The impeller is driven by the engine flywheel. Guide rings are provided on the inner edges of the vanes to provide smooth fluid flow. When the impeller is driven by the engine, the centrifugal force causes the fluid to flow outward towards the turbine.

The input shaft of the transmission is attached with the turbine hub which is splined. The curvature of the vanes in the turbine is opposite to the impeller vanes. This makes the turbine to rotate when the fluid is forced from the impeller vanes. Therefore the turbine is also starts rotating in the direction of engine rotation. (Fig 2)



The stator is located in between the impeller and the turbine. It is mounted on the reaction shaft which is fitted to the transmission case. The vanes of the stator catch the fluid as it leaves the turbine and redirects it back to the impeller. This gives the impeller an added torque.

The over running clutch drive in the stator allows the stator to rotate in one direction. Normally it rotates in the direction of the crank shaft. The over running clutch drive does not allow the stator to rotate in opposite direction.

Working principle

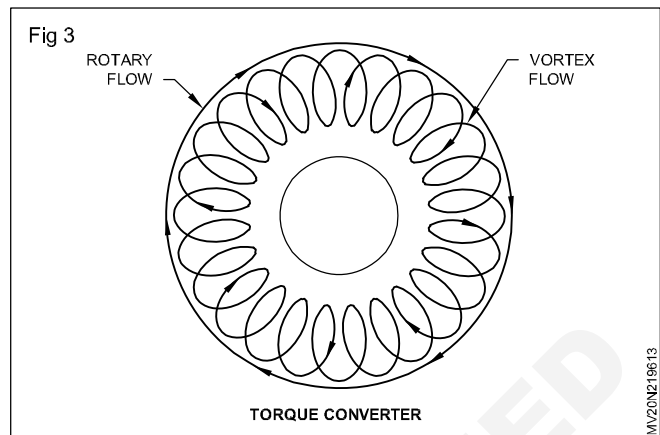
During starting, the impeller rotates at the engine speed, while the turbine wheel and stator are stationary. The fluid flows from the impeller to the turbine wheel, dissipates its energy to the turbine and it deflected in the process.

During idling speeds the speed of the impeller is low and the fluid flow will not be able to rotate the turbine. But when the engine speed increases, the fluid moves fast and rotates the turbine.

There are two types of fluid flow (Fig 3). Vortex flow and radial flow. The flow will be vortex till the speed of the impeller and the turbine is not same. Vortex flow is a spiraling flow. Radial flow is fluid flow which circulates with the converter body rotation. This radial flow usually happens when the speed of the impeller and the turbine will be same.

When the engine is accelerating, the speed difference in the impeller and the turbine will be very high and the flow is called high vortex. During this time, fluid from the impeller directed towards the outer surface of the turbine and from the turbine it strikes the front of the vanes of

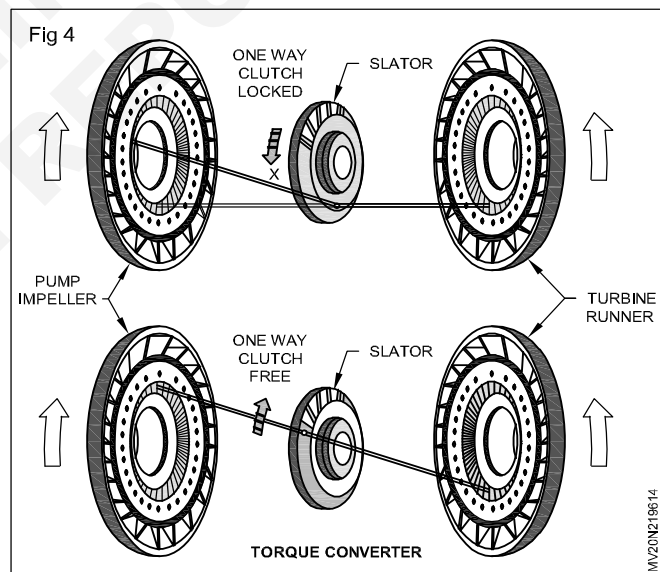
the stator and locks it on the stator reaction shaft, preventing it from rotating in the anti-clockwise direction. The fluid passing through the stator is redirected by the shape of the vanes and strikes on the back of the vanes of the impeller which increase the torque of the impeller.



When the flow is rotary, the fluid from the turbine strikes the stator which allows the stator to rotate in the clockwise direction. This happens normally when the speed of the impeller and the turbine are in the same speed.

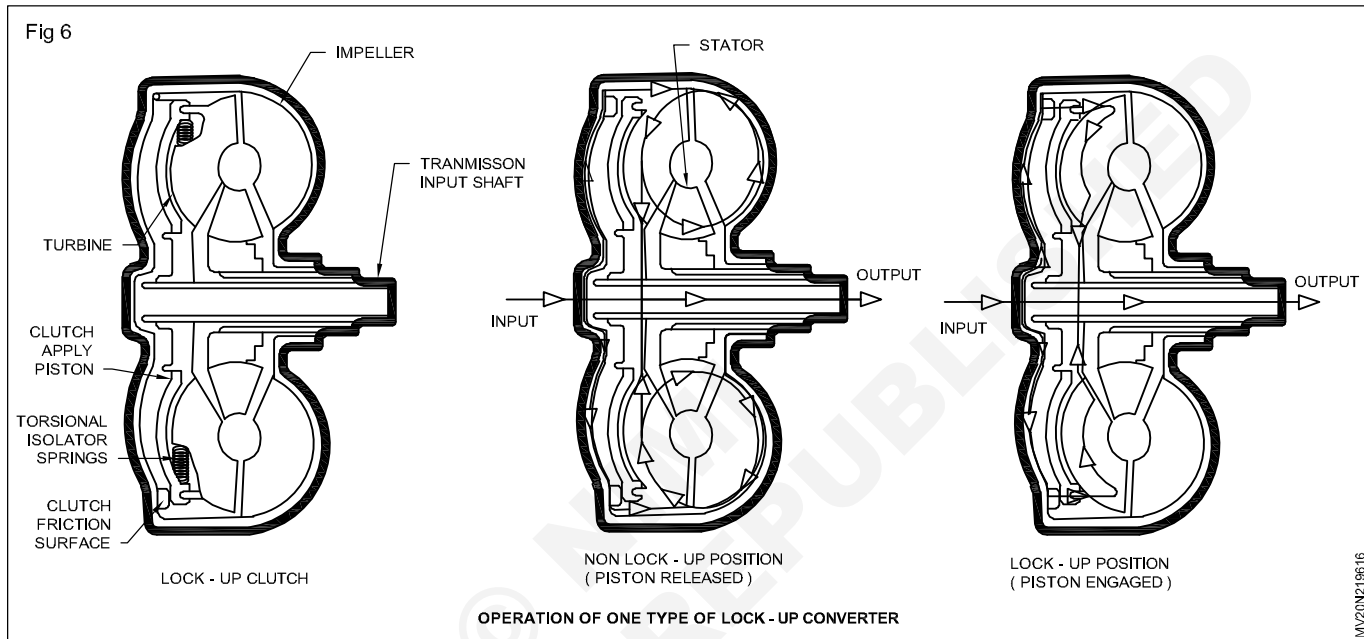
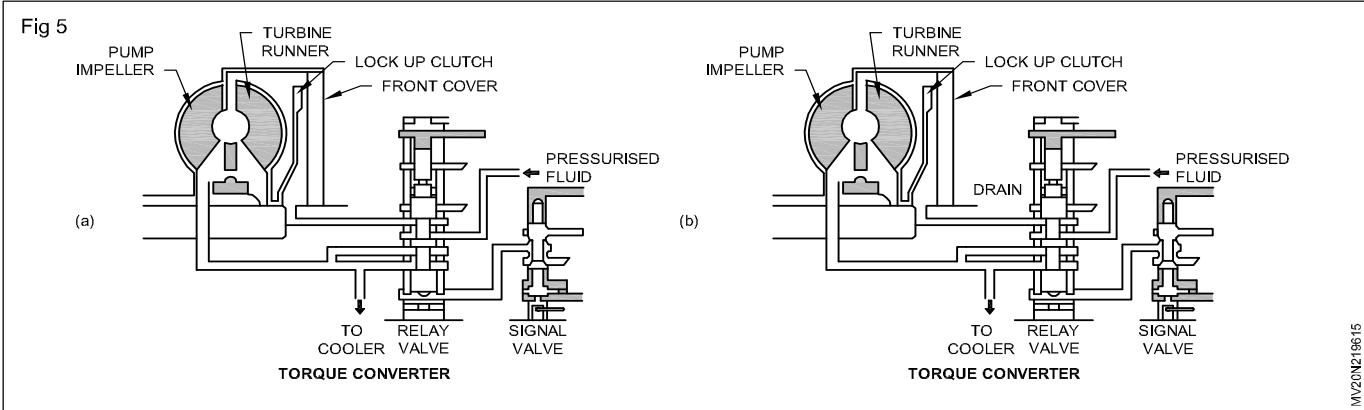
The rotary flow inside the torque converter happens when the vehicle is running in constant speed. This is called the coupling point.

Lock up clutch mechanism (Figs 4, 5 & 6)



When the impeller and turbine are in the same speed, there is no torque multiplication takes place. The ratio is almost 1:1. However, it is not possible to get 100% power transmission in the torque converter, there is some power loss. The lock up clutch mechanically connects the impeller and the turbine when the vehicle speed is 60kmph and above. Thus 100% power transmission is possible.

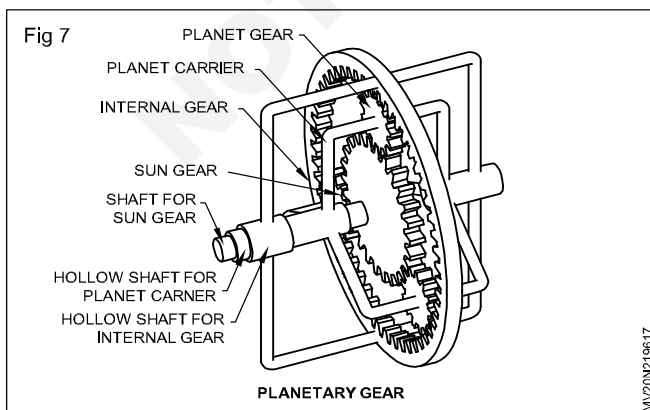
The lock up clutch is fitted on the turbine hub. The lock up clutch is normally in disengaged position. When the clutch is operating, it engages the turbine with the torque converter case. It operates with the fluid. Relay and signal valves are control the hydraulic fluid flow.



When the vehicle is running at low speeds, the pressurized fluid flows in to the front of the lock up clutch and the clutch is disengaged. (Fig.5a)

When the vehicle is running at medium and high speeds, the pressurized fluid flows in the other side of the lock up clutch, creating low pressure in the front side of the lock up clutch. The difference in pressure makes the lock up clutch engaged (Fig.5b). As a result, the turbine and the case rotate together.

Planetary gear (Fig 7)



A simple planetary gear set consists of

- Sun gear

- Planet gears
- Ring gear
- Planet carrier

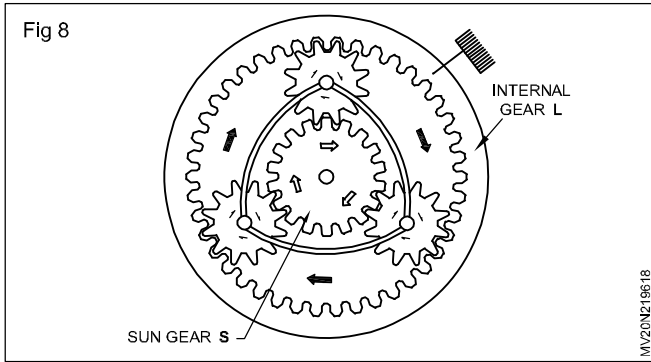
The planet gears are supported with their axis in the planet carrier. The planet gears circulate on the internal teeth of the ring gear and the outer teeth of the sun gear. All gears are constantly meshed. The sun gear, planet carrier and ring gear are driven and braked. Output is effective through the ring gear or the planet carrier. Different gear ratios are achieved by this planetary gear set.

Three different forward gear ratios and one reverse gear ratio are possible in this type. The drive of the planetary gears is set through the multi plate clutch. Different gear ratios and directional change are obtained by braking any one of the component.

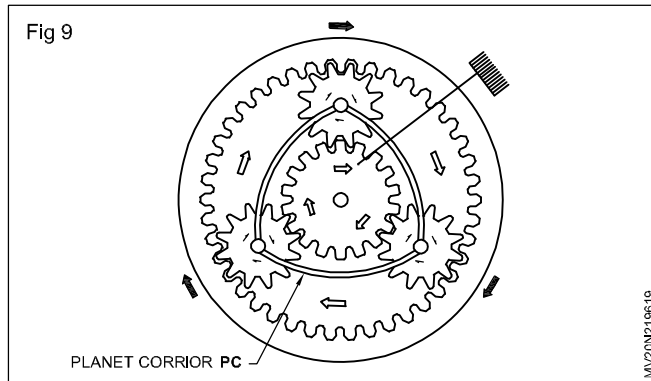
Working principle of planetary gear set

1st gear (Fig 8)

The sun gear is the driving gear and the sun gear blocked. The planet gears circulate on the inner teeth of the ring gear. The power transmitted to the output shaft through the carrier. A larger gearing down takes place.

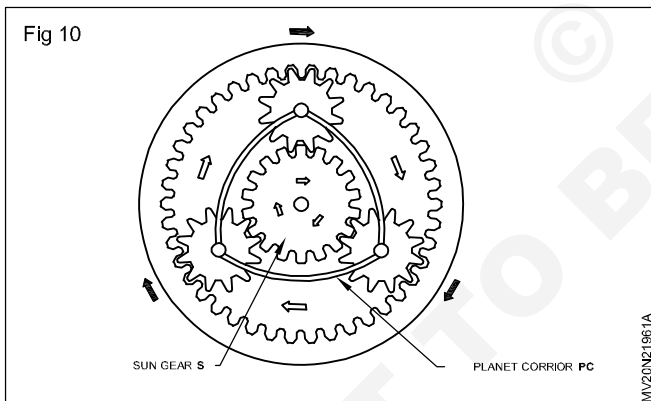


2nd gear (Fig 9)



The ring gear is the driving gear and the sun gear blocked. The planet gears circulate on the outer teeth of the sun gear. Power output from the carrier. The smaller gearing down takes place.

3rd gear (Fig 10)



The planetary gear set is blocked the planet gears stop rotating and act as drivers. The output rotates same as input and power flow takes from planet carrier.

Reverse gear (Fig 11)

The planet carrier is braked. The sun gear is the driving gear and planet gears reverse the direction of rotation of the ring gear. A large gearing down takes place.

Shifting logic

The table 1 shows the shifting logic for a simple planetary gear set with three forward and one reverse speed.

Normally two or three planetary gear sets are used to get sufficient gear ratios.

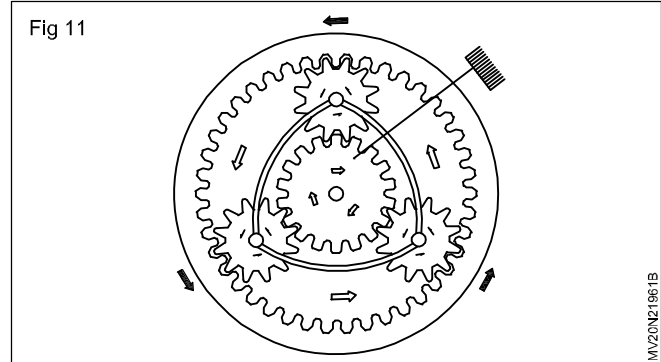


Table 1: Shifting logic, 3 gear planetary gear

Gear	Input	Braked	Output
1st gear	S	I	PC
2nd gear	I	S	PC
3rd gear	S+1	--	PC
Rear	S	PC	I

S-Sung gear, I-Internal gear PC-Planet Carrier

Electro hydraulic transmission control

The electro hydraulic transmission control involves sensors, solenoid and hydraulic valves. The sensors recording specific operating status. The solenoid valves operate hydraulic valves which control the hydraulic pressure to the respective shift elements. The gear shifting is effected by driving and braking of different shift elements.

The electronic gear box control unit (EGS) processes the input signals from the sensors and other ECUs.

Vehicle side signals

Select lever contains

- P - Park
- R - Reverse
- N - Neutral
- D - Drive (all forward gears)
- Gear box side signals
- Gear box input speed
- Driving speed
- Transmission fluid temperature
- Engine side signals
- Acceleration pedal position
- Engine load
- Engine speed
- Coolant temperature

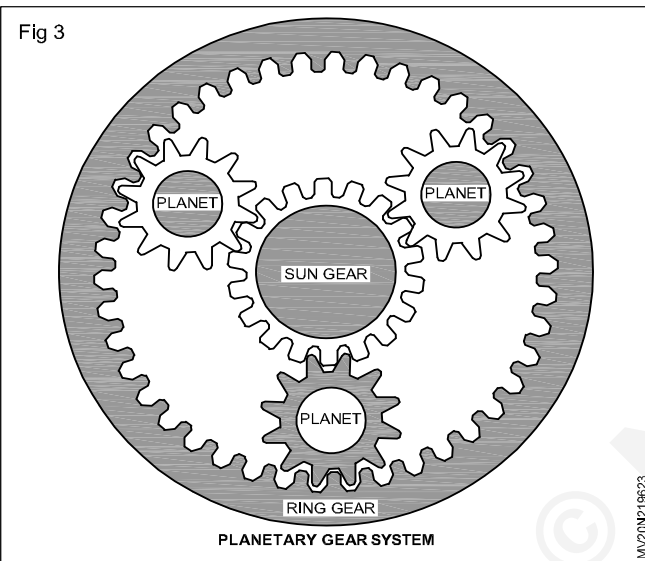
The gear shift sequences are selected using stored program in the EGS. The gear shift process and the

leaving the turbine is moving at about the same speed as the impeller. The fluid leaving the turbine is moving at about the same speed as the impeller. The fluid could pass directly into the impeller without stator action. The fluid is striking the back sides of the stator vanes. To allow the stator vanes to move out of the way, the stator mounts on a one way clutch.

Torque convertor clutch TCC

A lockup torque convertor eliminates the 10% slip that takes place between the impeller and turbine at the coupling stage. The engagement of a clutch between the impeller and the turbine assembly greatly improves fuel economy and reduces operational heat and engine speed.

Planetary gears (Figs 3)



Epicyclic gearing or planetary gearing is a gear system consisting of one or more outer gears, or planet gears, revolving about a central, or sun gear. Typically, the planet gears are mounted on a movable arm or carrier which itself may rotate relative to the sun gear. Epicyclic gearing systems also incorporate the use of an outer ring gear or annulus, which meshes with the planet gears. Planetary gears are typically classified as simple and compound planetary gears. Simple planetary gears have one sun, one ring, one carrier, and one planet set. Compound planetary gears involve one or more of the following three types of structures: meshed planet (there are at least two more planets in mesh with each other in each planet train), stepped - planet (there exists a shaft connection between two planets in each planet train), and multistage structures (the system contains two or more planet sets).

Compared to simple planetary gears, compound planetary gears have the advantages of larger reduction ratio, higher torque-to-weight ratio, and more flexible configurations.

Epicyclic gearing is also available which consists of a sun, a carrier, and two planets which mesh with each other. One planet meshes with the sun gear, while the second planet meshes with the ring gear. For this case,

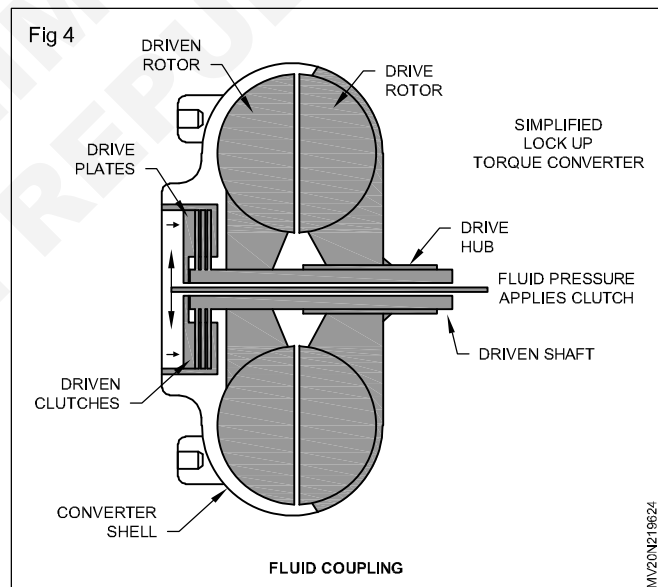
when the carrier is fixed, the ring gear rotates in the same direction as the sun gear, thus providing a reversal in direction compared to standard epicyclic gearing.

Torque convertor

If you have read about manual transmissions, you know that an engine connected to a transmission by way of a clutch. Without this connection, a car would not be able to come to a complete stop without killing the engine. But cars with an automatic transmission have no clutch that disconnects the transmission from the engine. Instead, they use an amazing device called a torque converter. It may not look like much, but there are some very interesting things going on inside.

In a torque converter there are at least three rotating elements: the impeller, which is mechanically driven by the prime mover; the turbine, which drives the load; and the stator, which is interposed between the impeller and turbine so that it can alter oil flow returning from the turbine to the impeller. The classic torque converter design dictates that the stator be prevented from rotating under any condition, hence the term stator. In practice, however, the stator is mounted on an overrunning clutch, which prevents the stator from counter-rotating with respect to the prime mover but allows forward rotation.

Fluid fly wheel/coupling (Fig 4)

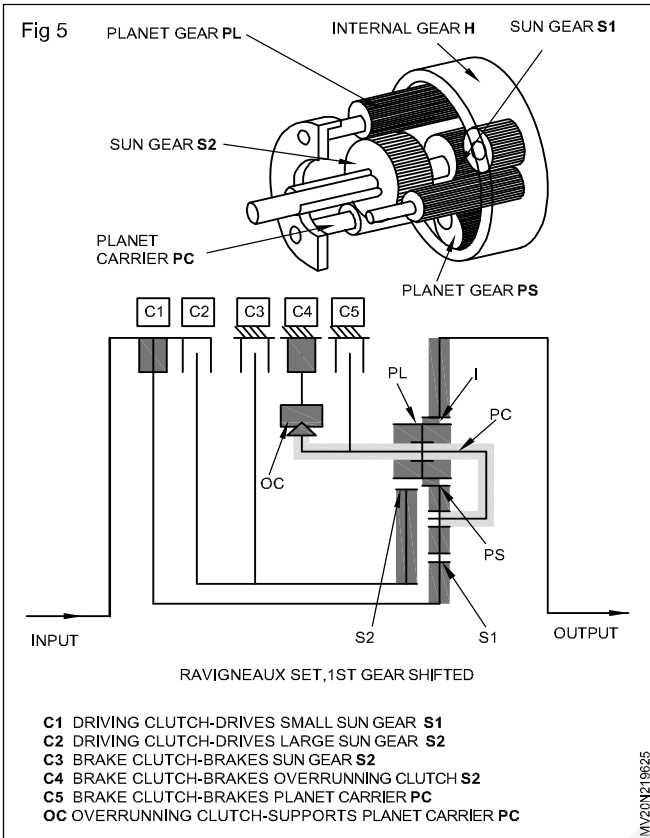


A fluid coupling is a two element drive that is incapable of multiplying torque, while a torque converter has at least one extra element-the stator-which alters the drive's characteristics during periods of high slippage, producing an increase in output torque.

Planetary compound gear set

One simple planetary-gear set cannot be used for automatic gearboxes because in practice it does not deliver sufficiently useable gear ratios and two output are shifted in succession.

Ravigneaux set (Fig 5)



This consists of:

- a common internal gear
- a common planet carrier
- two different-sized sun gears and
- short and long planet gears.

The different gear-ratio stages are achieved as in the simple planetary-gear set by driving and braking specific parts or by blocking the entire planetary-gear set.

Electronic control transmission

Output can be effected either via the internal gear or via the planet carrier.

The ravigneaux set shown in Fig 5 facilities 3 forward gears and 1 reverse gear.

- C1** Driving clutch - drives small sun gear **S1**
- C2** Driving clutch - drives large sun gear **S2**
- C3** Brake clutch - brakes sun gear **S2**
- C4** Brake clutch - brakes overrunning clutch **OC**
- C5** Brake clutch - brakes planet carrier **PC**
- OC** Overrunning clutch - supports planet carrier **PC**

Example of 1st gear

C1 and C4 are shifted. C4 holds the planet carrier in one direction of rotation overrunning clutch.

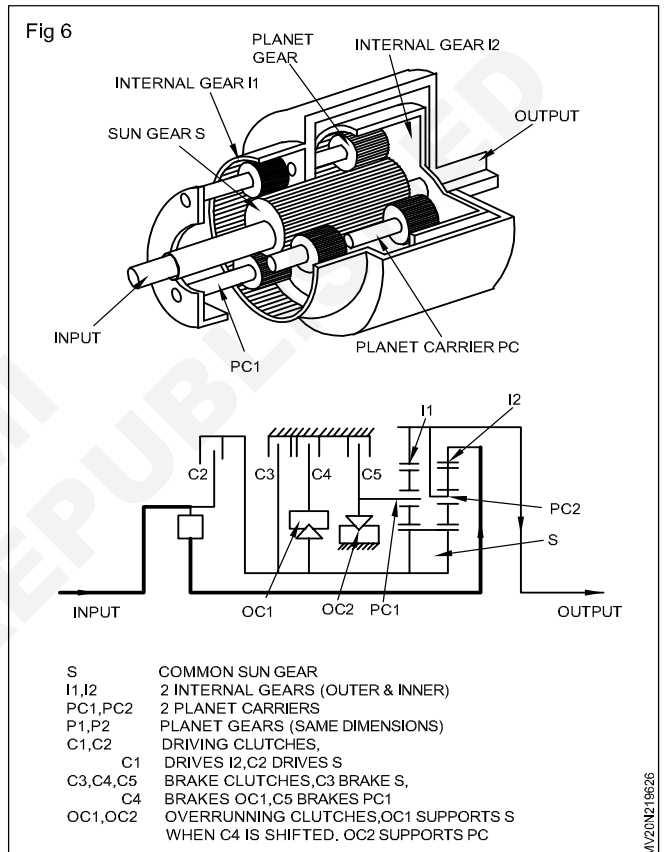
Power-flow progression:

Input → C1 → S1 → PS → PL → 1 → Output

Table 1: Shifting logic, Ravigneaux set

Gear	C1	C2	C3	C4	C5	OC
1st gear	•			•		•
2nd gear	•		•			
3rd gear	•	•				
R gear		•			•	

Simpson set (Fig 6) this consists of



- S** Common sun gear
- 11,12** 2 internal gears (outer & inner internal gears)
- PC1, PC2** 2 planet carriers
- P1, P2** Planet gears (same dimensions)
- C1, C2** Driving clutches
- C3, C4, C5** Brake clutches, **C3** brakes S, **C4** brakes OC1, **C5** brakes PC1.
- OC1, OC2** Overrunning clutches, OC1 supports S when **C4** is shifted OC2 supports PC

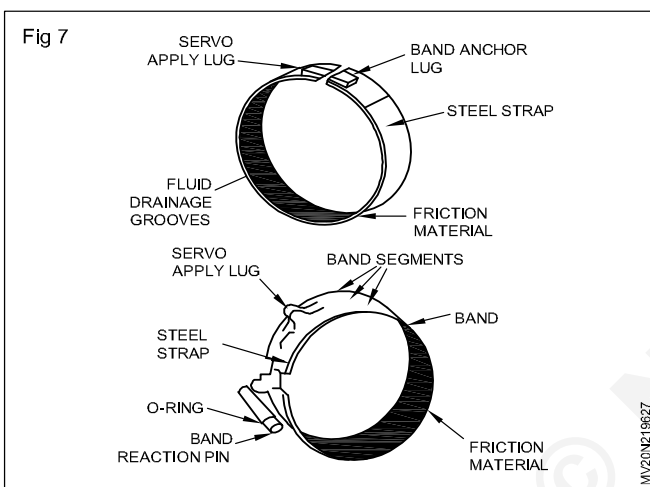
Output is effected via the outer internal gear (I1).

The Simpson set is used for example in 4-speed automatic gearboxes in conjunction with a simple planetary-gear set.

Gear	C1	C2	C3	C4	C5	OC1	OC2
1st gear	•						•
2nd gear	•		•	•			•
3rd gear	•	•		•			
R gear		•			•		

• By adherence for selection-lever position D
In selection-lever position 2 C3 is shifted S is torsionally resilient

Transmission brake band (Fig 7)



A band is a braking assembly positioned around a stationary or rotating drum or carrier. The band brings a drum to a stop by wrapping itself around the drum and holding it. The band is hydraulically applied by a servo assembly. The purpose of a band is to hold a member of the planetary gear member stationary.

When a band closes around a rotating drum, a wedging action takes place to stop the drum from rotating. The wedging action is known as self-energizing action. A typical band designed to be larger in diameter than the drum it surrounds. This design promotes self-disengagement of the band from the drum. A friction material is bonded to the inside diameter of the band.

The lining material of a band is a semi metallic compound, paper-based lining.

Band lugs are either spot welded or cast as a part of the band assembly. The purpose of the lugs is to connect the band with the servo through the actuating (apply) linkage and the band anchor (reaction) at the opposite end. The band's steel strap is designed with slots or holes to release fluid trapped between the drum and the applying band.

The bands used in automatic transmissions are rigid, flexible, single wrap, or double wrap types. Steel single wrap bands are used to hold gear train components

driven by high-output engines. Self-energizing action is low because of the rigidity of the band's design. Thinner steel bands are not able to provide a high degree of holding power, but because of the flexibility of design, self-energizing action is stronger and provides more apply force.

The double wrap band is a circular external contracting band normally designed with two or three segments. As the band closes, the segments align themselves around the drum and provide a cushion. The steel body of the double wrap band may be thin or thick steel strapping material. Modern automatic transmissions use thin single or double wrap bands for increased efficiency. Double wrap bands made with heavy thick steel strapping are required for high output engines.

Electro hydraulic transmission control

Electro hydraulic transmission control involves sensors recording specific operating states. These states are processed by the electronic gearbox control unit. Solenoid valves are electrically activated, depending on the driving situation. These valves actuate hydraulic valves, which control the hydraulic pressure to the respective shift elements. The gear change in the automatic gear box is effected by driving and braking of different shift elements. (Fig 8)

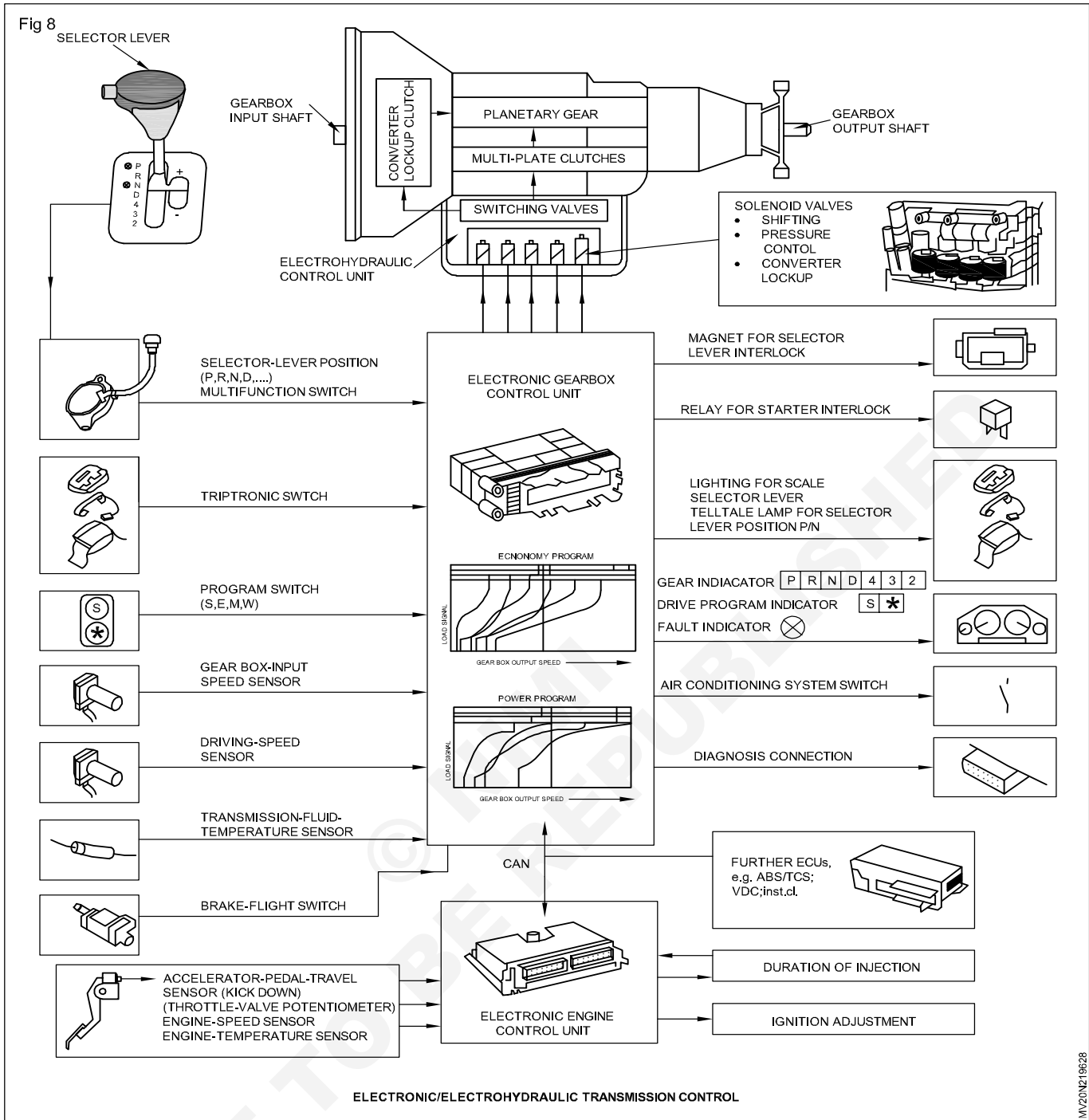
Features:

- High gearshift comfort.
- Short shifting times.
- Common utilisation of sensors.
- Optimisation of exhaust emissions and consumption.
- Shift-curve selection possible, e.g. Economic, Sport, Winter, Manual (Tiptronic, Steptronic).
- Shift-program matching to driver type possible (**ATS** - adaptive transmission control or **DSP** - dynamic shift-program selection).
- Simple realisation of various safety functions, e.g. selector-lever interlock.

Design of control system

The control system consists of

- Sensors, e.g. selector lever with multifunction switch, accelerator-pedal-travel sensor (load signal) speed sensor (these sensors from the main controlled variables)
- Electronic gearbox control unit, which among other things communicates via the CAN bus with other ECUs, e.g. engine control unit.
- Electro hydraulic control unit with solenoid valves and hydraulic switching and control valves.
- Shift elements e.g. multi-plate clutches, band brakes, overrunning clutches.



Basic operating principle

Electronic gearbox control unit (EGS). This processes the input signals of the different sensors and switches as well as single from other ECUs via the CAN bus.

Vehicle-side signals:

• **Selectors lever**

- P - Park
- R - Reverse
- N - Neutral
- D - Drive (all forward gears)
- 1st gear to 4th gear
- 1st to 3rd gear

2 - 1/2 gear

• Triptonic function = manual shifting

• **Program selector switch**

Spott - S

Economic - E

Winter - W

starting eg. in 2nd gear

• Brake - light switch

• Signals from other vehicle systems, e.g. ABS/TCS, ESP, vehicle-speed controller

Gearbox-side signals:

- Gearbox input speed
- Gearbox output speed / driving speed
- Transmission-fluid temperature

Engine-side signals:

- Accelerator-pedal position with kickdown (throttle-valve position)
- Engine load (injection time)
- Engine speed
- Coolant temperature

The gearshift sequences are selected using stored program maps in the electronic gearbox control unit in accordance with the vehicle's current operating state. The relevant gearshift process and the control of the converter lockup clutch are effected by electric activation of solenoid valves in the **electro hydraulic control unit**.

Additional functions of electronic gearbox control unit EGS

Activation of display in instrument cluster. Gear, program and fault indicators.

Engine intervention

In order to improve shift quality and extend the service life of the shift elements (multi-plate clutches), the engine torque is reduced running the gear shift processes by brief ignition retardation in spark- ignition engines. In diesel engines, the injected fuel quantity is reduced briefly.

Downshift protection

Selector-lever downshifts are only executed if these do not result in excessively high engine speeds.

Selector-lever interlock-shift-lock

Only after the ignition is switched on can the selector lever be moved with the brake applied from the **P** or **N** position to a new position so that vehicle cannot move off unintentionally. An actuator solenoid is activated by the electronic gearbox control unit for this purpose.

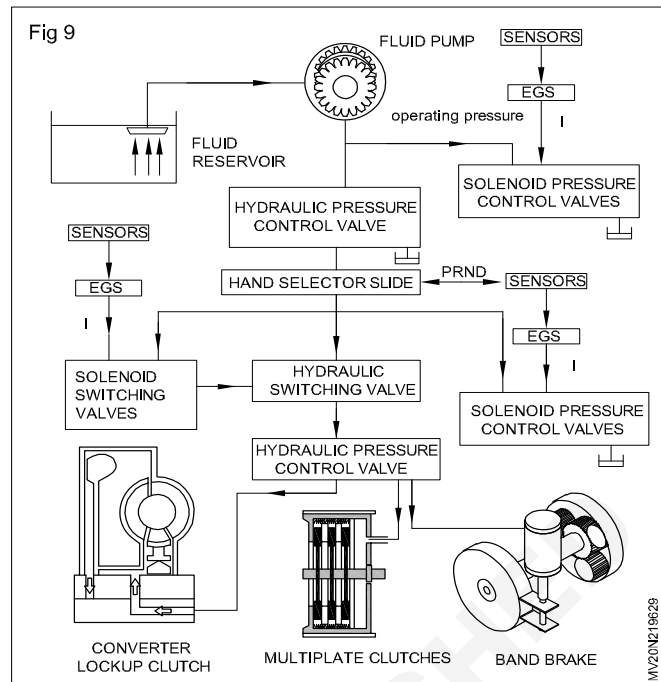
R / P interlock. At speeds generally in excess of 10 km/h, the selector lever cannot be moved from **R** to **P**. This prevents mechanical gearbox damage.

Starter interlock. In order to start the engine, the selector lever must be in the **P** or **N** position and the brake pedal must be actuated. Otherwise the start-locking relay is not actuated by the electronic gearbox control unit.

Electro hydraulic system (Fig 9)

The electro hydraulic system consists of:

- Fluid pump for pressure generation.
- Pressure-control valve for operating pressure control.
- Control valves for shift pressure control.
- Hand selector slid for distributing fluid flow to the respective valves.



- Switching valves for controlling multi-plate clutches, band brakes and converter lockup clutch.

Shift elements

These connect or brake corresponding components of the planetary-gear set.

There are the following different types:

- Drive clutches (multi-plate clutches)
- Brake clutches or band brakes
- Overrunning clutches

Drive clutch

Clutch closed

The operating pressure is directed by the switching valve and acts on the plunger. The plunger actuates the disc spring, which compresses the plate pack. The frictional / adherent connection is established.

Clutch released

There is no acting operating pressure; the plunger is pressed back by the disc spring. The power flow is interrupted.

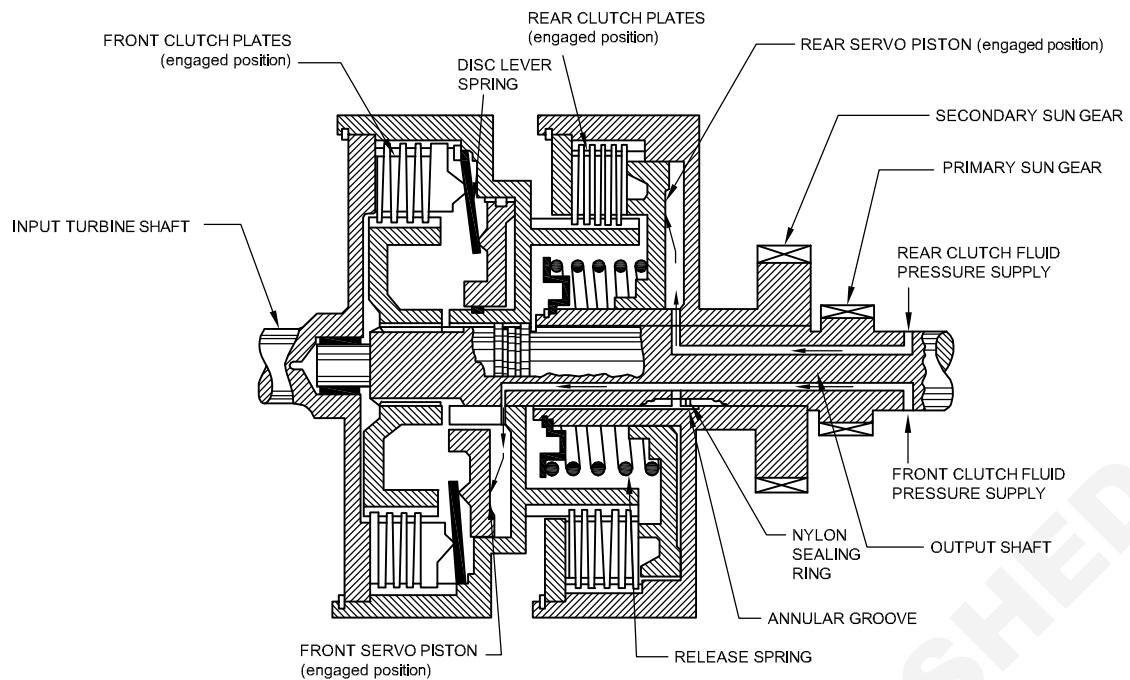
By means of appropriate control of the shift pressure, the clutch can be both fully closed and operated with slip. This enables the shift quality to be improved.

The shift pressure is replaced by the operating pressure at the end of the shift process.

Front clutch (FC) Servo (Fig 10)

When pressurized, fluid is supplied to the front clutch piston chamber. The piston will move over to the right and through the leverage of the disc spring will clamp the plates together with considerable thrust. The primary sun gear will now be locked to the input turbine shaft and permit torque to be transmitted from the input turbine shaft to the central output shaft and primary sun gear.

Fig 10



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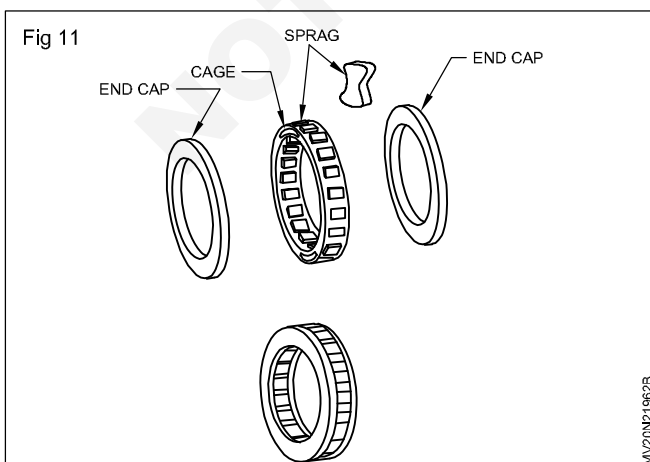
Rear clutch (RC) Servo

When pressurized, fluid is released from the front clutch piston chamber and transferred to the rear clutch piston chamber. The servo piston will be forced directly against the end plate of the rear clutch multiplate pack. This compresses the release spring and sandwiches the drive and driven plates together so that the secondary sun gear will now be locked to the input turbine shaft. Torque can now be transmitted from the input turbine shaft to the secondary sun gear.

The working principles of one-way clutch

One-way sprague clutch resembles a roller bearing but instead of cylindrical rollers, non-revolving shaped sprag are used. When the unit rotates in one direction the rollers slip or free-wheel, when a torque is applied in the opposite direction, the rollers tilt slightly, producing a wedging action and binding because of friction. The sprage are spring-loaded so that they lock with very little backlash.

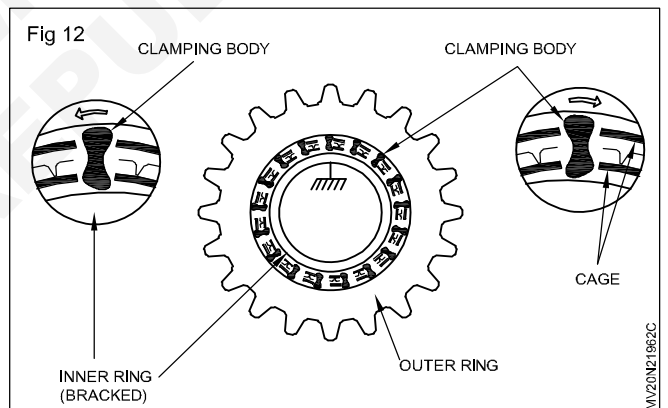
The components of one way clutch (Fig 11)



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A one-way clutch consists of outer race, inner race, cage, sprage and so on.

Overrunning clutch (Fig 12)



MV20N21962C

Its function is to connect with each other specific parts of the planetary-gear set.

The clamping-body overrunning, clutch shown in Fig 12 consists of an outer ring, an inner ring and the clamping bodies supported in a cage.

When the outer ring rotates in a clockwise direction while the inner ring is braked, the clamping bodies assume an upright position and establish the torque proof connection.

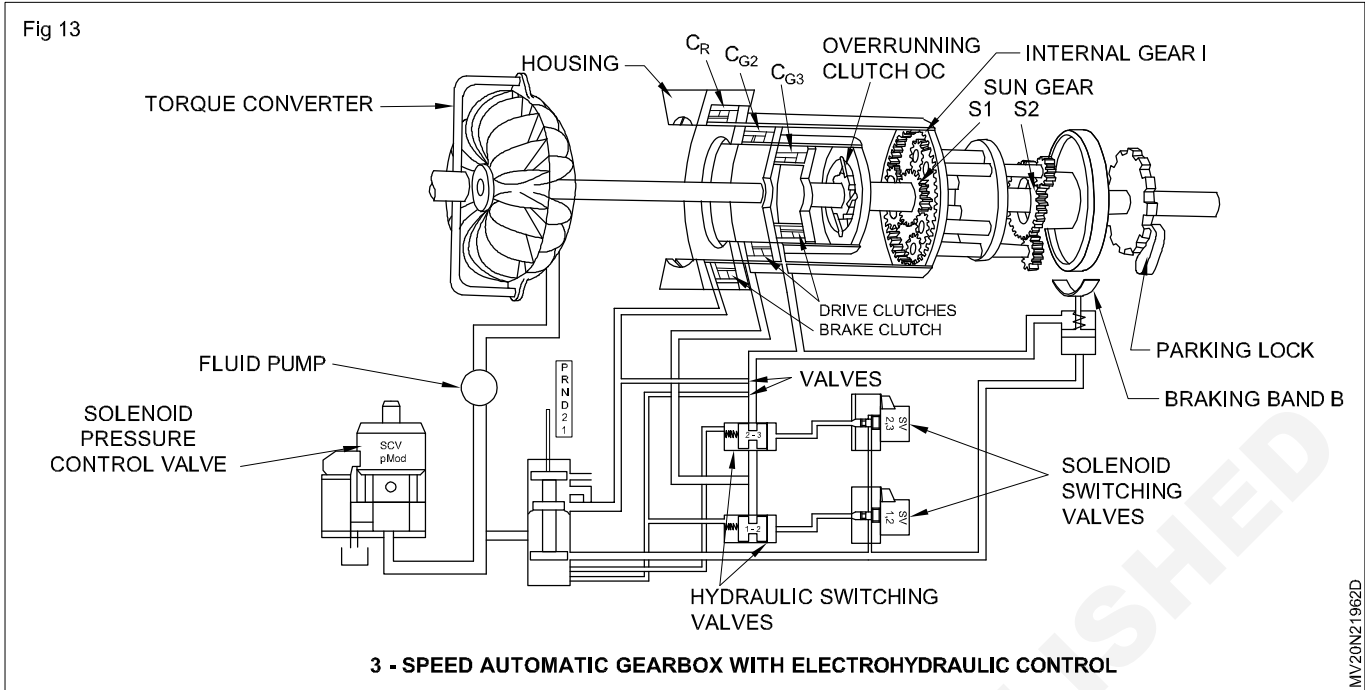
The connection is released when the outer ring rotates in an anticlockwise direction.

Band brake

This consists of a steel band, friction lining, plunger rod, plunger, housing, spring, and adjuster.

Operating principle. When the operating pressure acts on the plunger surface from the right, the plunger rod tightens the brake band and brakes the brake drum.

3-speed automatic gearbox with Ravigneaux set (Fig 13)



The shifting logic (Table 1) shows which shift elements (clutches, band brake, overrunning clutch) are shifted in the different gears and which parts of the planetary-gear set are driven or braked by them.

Gear	Input	Fixed	Output	B	C _{G2}	C _{G3}	OC	C _R
1	S1	S2	PC	•			•	
2	1	S2	PC	•	•			
3	S1+1	-	PC		•	•		
R	S1	1	PC			•		•

Influence of different operating parameters on shift program and shift-point control

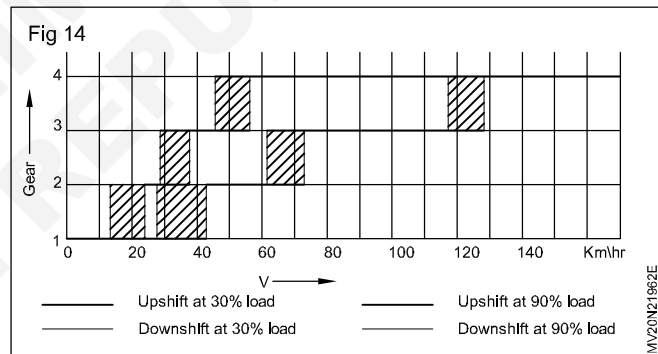
The basic shift program with upshift and down shift points is dependent on the main controlled variables of selector-lever position, accelerator-pedal position driving speed.

The shift program/shift curve selection can be adapted to different operating parameters, eg. transmission-fluid temperature, coolant temperature, program-selector-switch position, kickdown, driving style, uphill/downhill gradient, trailer operation, vehicle-speed-controller operation, road-surface condition.

Load signal and driving speed

These two main controlled variables essentially determine the shifting points. The further, for example, the accelerator pedal is pressed takes place. Downshifts generally take place at lower driving speeds than upshifts.

In this way, a constant shifting back and forth (gear hunting) between two gears is avoided. (Fig 14)



Program selector switch

(Economy, sport, winter, manual). In the sport program as opposed to the Economy program upshifts are carried out only at higher driving speeds. In this way, the vehicles has a better acceleration response, but this is accompanied by an increase in fuel consumption. In the winter program the vehicle is started in a higher gear, e.g 2nd gear, in order to reduce the drive the drive torque and thus prevent the wheels from spinning. In the manual program the driver can shift up (**M+**) and down (**M-**) by means of a special selector-lever gutter by touching the selector lever. There is no automatic shifting.

Kickdown (forced downshift)

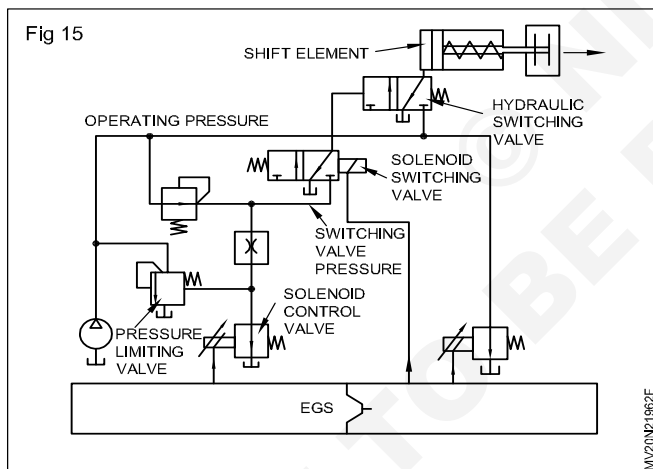
When the accelerator pedal is fully depressed, either a kickdown switch is actuated or the signal is determined by the accelerator-pedal-travel sensor. Where possible, a down-shift by one or two gears takes place. The shifted gears are then driven flat out upto the maximum engine revs in each case in order to improve the vehicle's acceleration response.

Transmission-fluid temperature When a specific critical fluid temperature is reached, shifting is only performed at higher engine speeds. This increases the amount of repumped fluid.

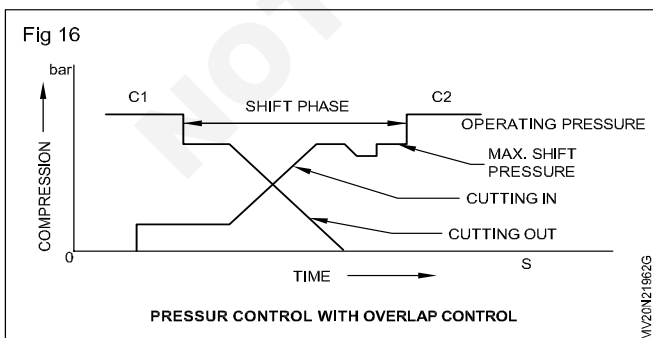
Hydraulic diagram for shift-pressure control-shift-quality control

In the interests of avoiding gearshift jolts, the multi-plate clutches and the converter lockup clutch are activated by means of solenoid control valves with a load-sensitive, metered shift pressure.

In Fig 15 shift-pressure controls is shown schematically in a simplified electro hydraulic circuit diagram. At the shifting point the 3/2 way solenoid switching valve is electrically actuated by the electronic gear box control unit (EGS). The hydraulic 3/2-way switching valve is then pressurised with switching-valve pressure and switches. It actuates a working cylinder, which actuates, for example, the multi-plate clutches. In order that the working cylinder is not pressurised immediately with full operating pressure, a solenoid control valve actuated by the EGS reduces the shift pressure during the shift phase. The extent of the operating pressure is then set as a function of load to the highest currently required pressure. A solenoid control valve with an upstream pressure-limiting valve is actuated by the EGS for this purpose.



Overlap control (Fig 16)



Here the pressure is reduced in the shifted clutch C1 and at the same time increased in the clutch to be shifted C2. Shifting can be performed with slip without interrupting the power flow.

Operating parameters for controlling converter lockup clutch.

This is activated by a valve as a function of gearbox output speed (driving speed), engine speed, gearbox input speed, brake-light switch and engine temperature.

Converter lockup clutch is usually opened order...

- to achieve a high starting torque in low gears.
- to avoid vibrations in the drivetrain when the engine is cold at low vehicle speeds.
- when operating the brake pedal to prevent the engine from stalling during braking.

It is possible to operate converter lockup clutches with slip control with the aid of electro hydraulic transmission control. In this way, vibrations in the drive train are avoided, while converter efficiency is improved.

Special functions

Interlock (keylock)

Here the ignition key can only be removed from the ignition lock when the selector lever is in the **P** position. This is effected, for example, mechanically via a cable. This prevents the vehicle from moving/rolling after the ignition key has been removed.

Adaptive transmission control (ATS)

This makes use of different criteria to select automatically a suitable shift program, e.g optimised consumption or sporty, from a range of several programs.

Circuit-diagram example of electronic automatic-gear box control (Fig 17)

The circuit diagram shows a simplified example of electronic 4-speed automatic-gearbox control without a CAN bus with two solenoid switching valves, converter-lockup control and pressure control for the operating pressure.

Power supply

The ECU is supplied via pin 18 by terminal 30 with continuous positive and via pin 17 by terminal 15 (+) with power. Pins 22 and 35 are connected to terminal 31 (earth/ground).

Starting process

The vehicle can only be started with the selector lever in the **P** or **N** position. The start-locking relay is actuated via terminals J and K. At the same time the brake-light switch **S4** must be actuated by the foot brake. The ECU is actuated with positive via pin 11 in the process. This prevents the vehicle from being started unintentionally.

Selector-lever position (Table 2)

The selector-lever position switch **S1** is connected via pins 9,10,27,& 28 to the EUC. Depending on its respective position, positive is connected via terminals A,B,C and E to the respective pin. The logic is specified in the circuit diagram.

Fig 17 30

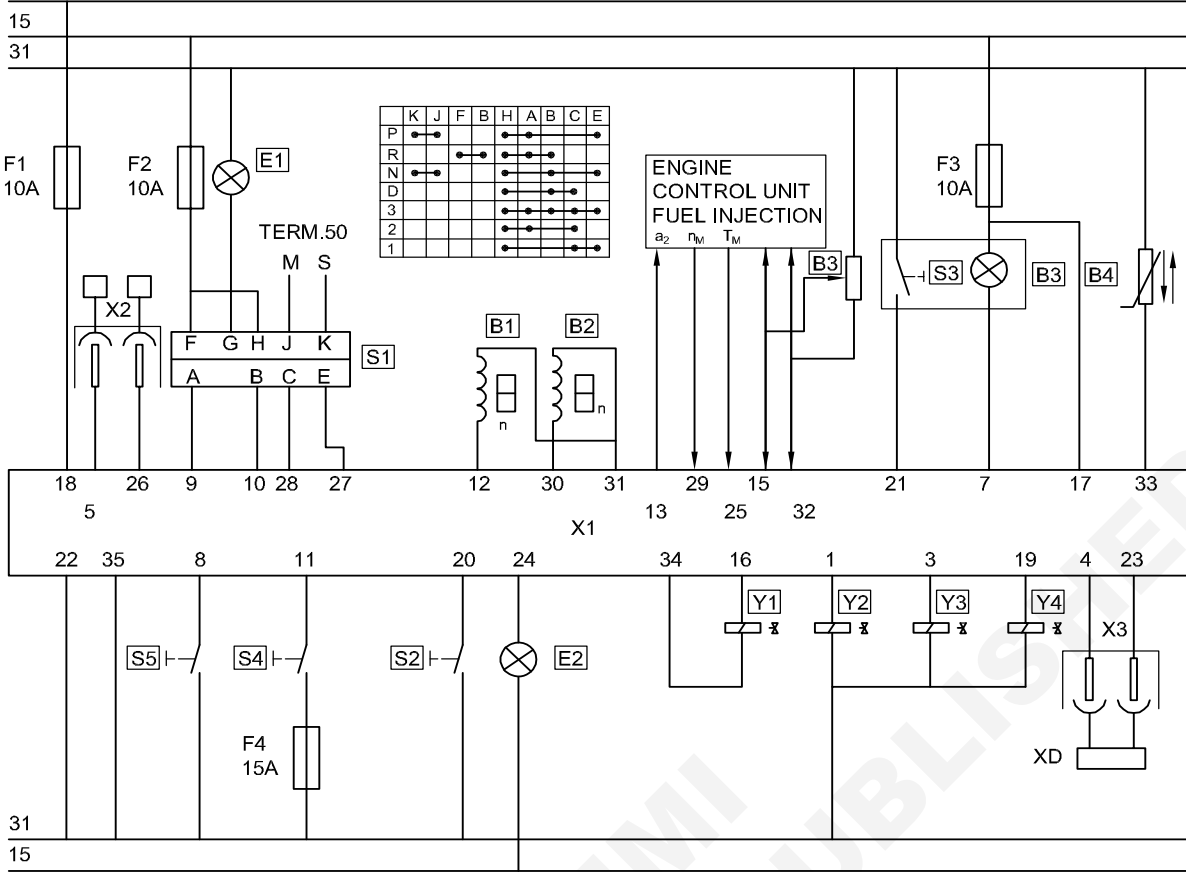


Table 2: Pin activation with positive

Pin	P	R	N	D	3	2	1
9	⊕	⊕			⊕	⊕	
10		⊕	⊕	⊕	⊕		
27	⊕		⊕		⊕		⊕
28				⊕	⊕	⊕	⊕

Hydraulic System

A hydraulic system uses a liquid to perform work. In an automatic transmission, this liquid is automatic transmission fluid (ATF).

The transmission’s pump is the source of all fluid flow in the hydraulic system. It provides a constant supply of fluid under pressure to operate, lubricate, and cool the transmission. **Pressure regulating valves** change the fluid’s pressure to control the shift quality of a transmission and the shift points of the transmission equipped with a governor. **Flow-directing valves** direct the pressurized fluid to the appropriate apply device to cause a change in gear ratios. The hydraulic system also keeps the T/C filled with fluid.

The reservoir for ATF is the transmission’s oil pan. Fluid is drawn from the pan and returned to it. The pressure source is the oil pump. The valve body contains control valve to regulate or restrict the pressure and flow of fluid

within the transmission. The output devices for the hydraulic system are the servos or clutches operated by hydraulic pressure.

Hydraulic Principle

An automatic transmission uses ATF fluid pressure to control the action of the planetary rear sets. This fluid pressure is regulated and directed to change gears automatically through the use of various pressure and control valves.

Fluids work well in increasing force because they are perfect conductors of pressure. Fluids cannot be compressed. Therefore, when a piston in a cylinder moves and displace fluid, that fluid is distributed equally within the circuit.

Functions of ATF

The ATF circulating through the transmission and torque converter and over the parts of the transmission cools the transmission. The heated fluid moves to a transmission fluid cooler, where the heat is removed. As the fluid lubricates and cools the transmission, it also cleans the parts. The dirt is carried by the fluid to a filter, where the dirt is removed.

Another vital job of ATF shifting gears. ATF moves under pressure throughout the transmission and causes various valves to move. The pressure of the ATF changes with changes in engine speed and load.

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ATF is also used to operate the various apply devices (clutches and bands) in the transmission. At the appropriate time, a switching valve opens and sends pressurized fluid to the apply device that engages or disengages a gear. The valve and hydraulic circuits are contained in the valve body.

Reservoir

A fluid reservoir stores fluid for the system. In an automatic transmission, the reservoir is the pan, located the bottom of the transmission case. A transmission dipstick placed within a filler tube is used to check the level of the fluid and to add ATF to the transmission.

Venting

The reservoirs have an air vent that allows atmospheric pressure to force the fluid into the pump when the pump creates a low pressure at its inlet port. The pans of many automatic transmissions vent through the handle of the dipstick; or a vent in the transmission case. Transmission must also be vented to allow for the exhaust of built-up air pressure that results from heat and moving components inside the transmission.

Transmission Coolers

The removal of heat from ATF is extremely important to the durability of the transmission. Excessive heat causes the fluid to break down. Once broken down, ATF no longer lubricate well and has poor resistance to oxidation. Oxidized ATF may damage transmission seals. When a transmission is operated for some time with overheated ATF, varnish is formed inside the transmission. Varnish buildup on valves can cause them to stick or move slowly. The result is poor shifting and glazed or burned friction surfaces. Continued operation can lead to the need for a complete rebuilding of the transmission.

It is important to note that ATF is designed to operate at 175°F (80°C). At this temperature, the fluid should remain effective for 100,000 miles (160,000 km). However, when the operating temperature increases, the useful life of the fluid quickly decreases. A 20°F increase in operating temperature will decrease the life of ATF by one-half !

Transmission housing are fitted with ATF cooler lines that direct the hot fluid from the torque converter to the transmission cooler, normally located in the vehicle's radiator. The heat of the fluid is reduced by the cooler and the cool ATF returns to the transmission. In some transmissions, the cooled fluid flows directly to the transmission's bushings, bearings, and gears. Then, the fluid is circulated through the rest of the transmission. The cooled fluid in other transmission is returned to the oil pan, where it is drawn into the pump and circulate throughout the transmission. Some vehicles, such as those designed for heavy duty use, are equipped with an auxiliary fluid cooler, in addition to the one in the radiator. This cooler removes additional amounts of heat from the fluid before it is sent back to the transmission.

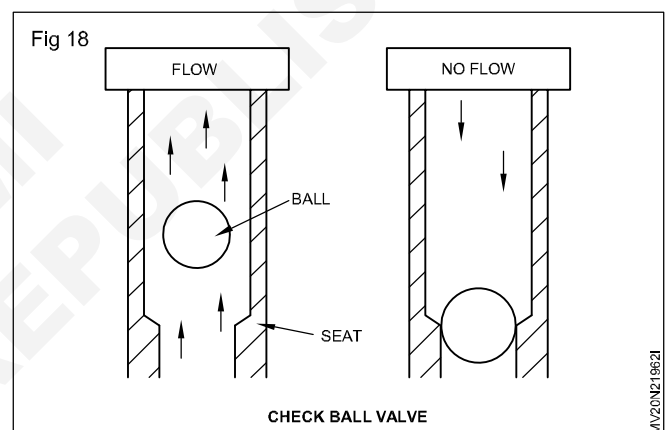
Valve Body

For efficient transmission operation, the bands and multiple-disc packs must be released and applied at the

proper time. The **valve body** assembly is responsible for the control and distribution of pressurized fluid throughout the transmission. This assembly is made of two or three main parts: a valve body, separator plate, and transfer plate. These parts are bolted as a single unit to the transmission housing. The valve body is machined from aluminium or iron and has many precisely machined bores and fluid passages. Various valves are fitted into the bores, and the passages direct to various valves and other parts of the transmission. The separator and transfer plates are designed to seal off some of these passages and to allow fluid to flow through specific passages.

The purpose of a valve body is to sense and respond to engine and vehicle load as well as to meet the needs to the driver. Valve bodies are normally fitted with three different types of valves: spool valves, check ball valves, and poppet valves. The purpose of these valves is to start, to stop, or to use movable parts to regulate and direct the flow of fluid throughout the transmission.

Check Ball Valve (Fig 18)



The check ball valve is a ball that operates on a seat located on the valve body. The check ball operates by having a fluid pressure or manually operated linkage force it against the ball seat to block fluid flow. Pressure on the opposite side unseats the check ball. Check balls and poppet valves can be normally open, which allows free flow of fluid pressure, or normally closed, which blocks fluid pressure flow. At times, the check ball has two seats to check and direct fluid flow from two directions, being seated and unseated by pressures from either source.

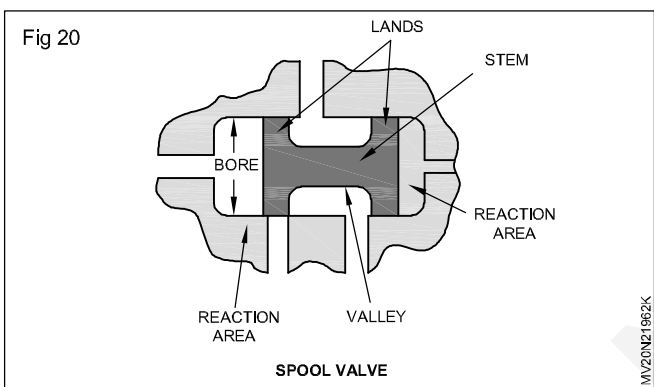
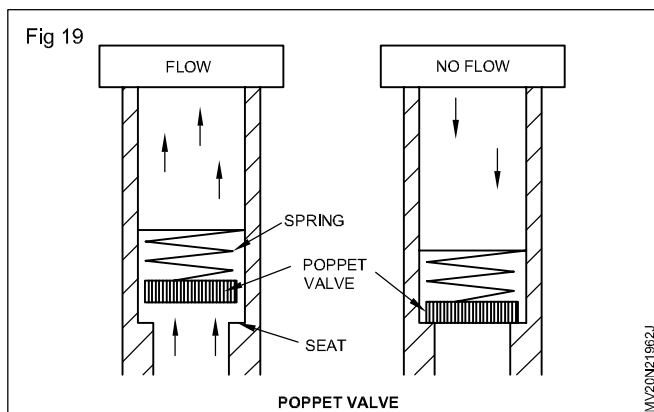
Poppet valve (Fig 19)

A poppet valve can be a ball or a flat disc. In either case, the poppet valve blocks fluid flow. Often the poppet valve has a stem to guide the valve's operation. The stem normally fits into a hole acting as a guide to the valve's opening and closing. Poppet valves tend to pop open and closed, hence their name. Normally poppet valves are held closed by a spring.

Spool Valve (Fig 20)

The most commonly used valve in a valve body is the spool valve. A spool valve looks similar to a sewing thread

spool. The large circular parts of the valve are called the lands. There is a minimum of two lands per valve. Each land of the assembly is connected by a stem. The space between the lands and stem is called the valve. Valleys form a fluid pressure chamber between the spools and valve body bore.



The fluid reaction area, also known as the face, is the space at the outside of the lands at the end of the valve. Forces acting against the reaction area that cause the valve to move include spring tension, fluid pressure, or mechanical linkage.

Oil Pump: The source of fluid flow through the transmission is the oil pump. Three types of oil pumps are commonly used in automatic transmission: gear type, rotor type, and vane type. Oil pumps are driven by the pump drive hub of the T/C or oil pump shaft converter cover or transaxles. Therefore whenever the T/C cover is rotating, the oil pump is driven. The oil pump creates fluid flow throughout the transmission.

Pressure Regulator Valve: Transmission pumps are creating exceeding fluid pressure that may cause damage the system therefore, transmission is equipped with a pressure regulator valve, which is normally located in the valve body. Pressure regulating valves are typically spool valves that toggle back and forth in their bores to open and close an exhaust passage. By opening the exhaust passage, the valve decreases the pressure of the fluid. As soon as the pressure decreases to a predetermined amount, the spool valve

Governor Assembly: The governor assembly is driven by the transmission's output shaft, senses road speed,

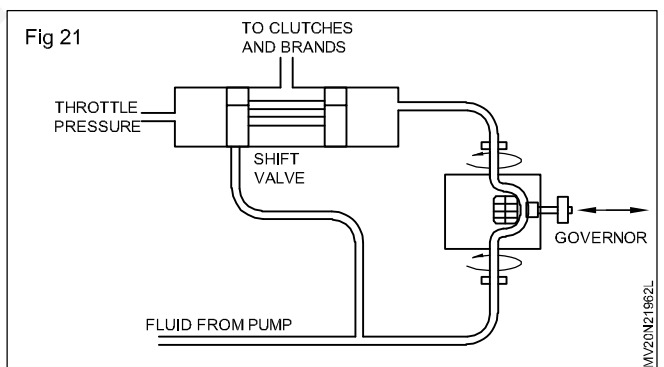
and sends, a fluid pressure signal to the valve body to either upshift or downshift. When vehicle speed is increased, the pressure developed by the governor is directed to the shift valve. As the speed increases, the spring tension and throttle pressure on the shift valve are overcome and the valve moves. This action causes an upshift. Likewise, a decrease in speed results in a decrease in pressure and a downshift.

Pressure Boosts

When the engine is operating under heavy load condition, fluid pressure must be increased to increase the holding capacity of a hydraulic member. Increasing the fluid pressure holds the band clutch control units tighter to reduce the chance of slipping while under heavy load. This is accomplished by sending pressurized fluid to one side of the pressure regulator's spool valve. This pressure works against the spool valve's normal movement to open the exhaust port and allows pressure to build to a higher point than normal.

Engine load can be monitored electronically by various electronic sensors (primarily the TP and MAP sensors) that send information to an electronic control unit, which in turn controls the pressure at the valve body. Load can also be monitored by throttle pressure. Throttle pedal movement moves a **throttle valve** in the valve body via a throttle cable. When the throttle plate is opened, the throttle valve opens and applies pressure to the pressure regulator. This delays the opening of the pressure regulator valve, which allows for an increase in pressure. When the driver lets off the throttle pedal, the pressure regulator valve is free to move and normal pressure is maintained.

Automatic transmissions: Valves and modulators (Fig 21)



To shift properly, the automatic transmission has to know how hard the engine is working. There are two different ways that this is done. Some cars have a simple cable linkage connected to a throttle valve in the transmission. The further the pedal is pressed, the more pressure is put on the throttle valve. Other cars use a vacuum modulator to apply pressure to the throttle valve. The modulator senses the manifold pressure, which increases when the engine is under a greater load.

The manual valve is what the shift lever hooks up to. Depending on which gear is selected, the manual valve

feeds hydraulic circuits that inhibit certain gears. For instance, if the shift lever is in third gear, it feeds a circuit that prevents overdrive from engaging.

Modulator pressure valve

The hydraulic modulator allows an electric current to control hydraulic force. When power is applied the solenoid, magnetic force open and closes the valves in the modulator, controlling the flow of fluid.

Shift valves

Shift valves supply hydraulic pressure to the clutches and bands to engage each gear. The valve body of the transmission contains several shift valves. The shift valve determines when to shift from one gear to the next. For instance, the 1 to 2 shift valve determines when to shift from first to second gear. The shift valve is pressurized with fluid from the governor on one side and the throttle valve on the other. They are supplied with fluid by the pump and they route that fluid to two circuits to control which gear the car runs in.

The shift valve will delay a shift if the car is accelerating quickly. If the car accelerates gently, the shift will occur at a lower speed.

MAP Sensor

Engine load can be monitored electronically through the use of various electronic sensors that send information to an electronic control unit, which in turn controls the pressure at the valve body. The most commonly used sensor is the MAP sensor. The MAP sensor senses air pressure in the intake manifold. The control unit uses this information as an indication of engine load. A pressure sensitive ceramic or silicon element and electronic circuit in the sensor generates a voltage signal that changes in direct proportion to pressure. A MAP sensor measures manifold air pressure against a precalibrated absolute pressure: therefore, the readings from these sensors are not adversely affected by changes in operating altitudes or barometric pressure.

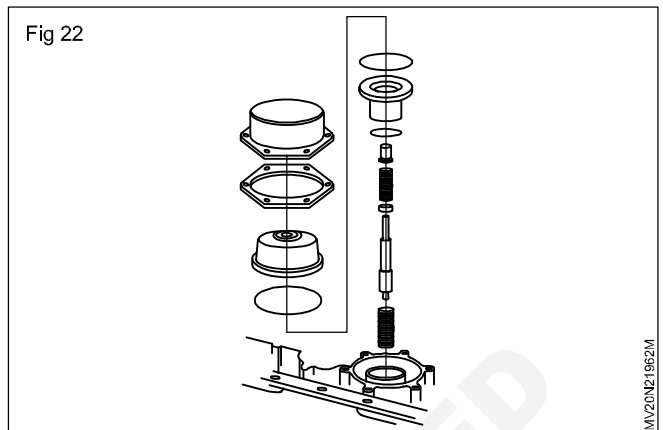
Kickdown Valve

The valve body is also fitted with a **kickdown** circuit, which provides a downshift when the driver requires additional power. When the throttle pedal is quickly opened wide, throttle pressure rapidly increases and directs a large amount of pressure onto the kickdown valve. This moves the kickdown valve, which opens a port and allows mainline pressure to flow against the shift valve. The spring tension on the shift valve, the kickdown pressure, and throttle pressure will push on the end of the shift valve, causing it to move to the downshift position and forcing quick downshift.

Shift Quality (Fig 22)

All transmissions are designed to change gears at the correct time according to engine and vehicle speed, load, and driver intent. However, transmissions are also designed to provide for positive change of gear ratios without jarring the driver or passengers. If a band or clutch is applied too quickly, a harsh shift will occur. Shift feel is

controlled by the pressure at which each hydraulic member is applied or released, the rate at which each is pressurized or exhausted, and the relative timing of the apply and release of the members.



To improve shift feel during gear changes, a band is often released while a multiple-disc pack is being applied. The timing of these two actions must be just right or both components will be released or applied at the same time, which would cause engine flare-up or clutch and band slippage. Several other methods are used to smooth gear changes and improve shift feel.

Multiple friction disc packs sometimes contain a wavy spring - steel separator plate that helps smooth the application of the clutch. Shift feel can also be smoothed out by using a restricting orifice or an accumulator piston in the band or clutch apply circuit to restrict fluid flow and slow the pressure increase at the piston by limiting the quantity of fluid that can pass in a given time. An accumulator piston by diverting a pressure buildup at the apply piston by diverting a portion of the pressure to a second spring-loaded piston in the same hydraulic circuit. This delays and smooths the application of a clutch or band.

Manufacturers have also applied electronics to get the desired shift feel. One of the most common techniques is the pulsing (turning on and off) of the shift solenoids, which prevents the immediate engagement of a gear by allowing some slippage.

Shift Timing

Shift timing is determined by throttle pressure and governor pressure acting on opposite ends of the shift valve. When a vehicle is accelerating from a stop, throttle pressure is high and governor pressure is low. As vehicle speed increases, the throttle pressure decreases and the governor pressure increases. When governor pressure overcomes throttle pressure and the spring tension at the shift valve, the shift valve moves to direct pressure to the appropriate apply device and the transmission upshifts.

Gear Range:	Neutral and park
Gear Selector	Position: N and P
Throttle Position:	0 to 10 psi (0 to 70 kPa) (approximately closed)

Pump pressure leaves the transmission pump and is directed to the pressure regulator valve and manual valve. At the pressure regulator valve, pump pressure is regulated to become line pressure. Line pressure enters the pressure regulator valve and leaves as converter pressure, flowing to the switch valve. The switch valve allows line pressure to enter the torque converter. Converter pressure circulates from the switch valve to fill the torque converter from the switch valve to fill the torque converter and returns to the switch valve to become cooling and lubrication pressure.

From the pressure regulator valve, line pressure flows to the manual valve. Line pressure seats check ball 9 and flowing around check ball 8 to stop at the land of the closed throttle valve. Throttle pressure is low because the throttle valve is not open. Line pressure flows to the accumulator to cushion the engagement of the planetary controls when the gear selector is moved to D or R ranges. The accumulator is basically a hydraulic shock absorber designed to absorb the shock of engaging planetary controls.

In neutral, line pressure is maintained by the pressure regulator valve and flows to the manual and throttle valves.

Gear Ranges: D first gear

Selector position: D

Torque Converter Mode: Unlocked

Planetary Controls Engaged: Rear check overclutch

Approximate Speed: 8 mph (13 km/h)

Throttle position: Half throttle

In pressure between the manual valve and pressure regulator valve is considered to be line pressure. The line pressure circulates to the switch valve. Since the switch valve is held in the torque converter unlocked position, line pressure flows no further.

Line pressure

Beginning at the first manual valve outlet 1, line pressure seats check ball and flows past check ball to enter the throttle valve and establish throttle pressure. Line pressure also flows to the pressure regulator valve to regulate pressure. Line pressure moves the accumulator piston against coil spring tension, cushioning the engagement of the rear clutch. At outlet part 2 of the manual valve, line pressure fills the worm track, which engages the rear clutch and flows to the governor assembly. When the rear clutch is engaged and the governor assembly is filled with line pressure, the forward circuit is ready to drive the vehicle forward.

Torque converter controls and pressure

The torque converter lockup clutch assembly is controlled by the PCM. When the PCM receives signals from the different sensors confirming the requirements for lockup have been met, clutch engagement begins. These sensors, include an engine coolant sensor, vehicle speed sensor, engine vacuum sensor and the throttle position sensor.

When the clutch is disengaged, a check ball is held off its seat by the fluid pressure. The unseated check ball prevents line pressure from building until it is high tension of the spring inside the switch valve. The converter clutch is never engaged in reverse gear and its action during reverse is similar to other times when it is not engaged.

Drive range : Reverse gear

Gear selector position: R

Torque converter mode: Unlocked

Planetary controls engaged: Low and reverse rear band; from clutch.

Approximate vehicle speed: 5 mph (8 km/h)

Throttle position: Part throttle

Line pressure from the outlet of the manual valve outlet that was not used before circulated through a bypass around the manual valve. Line pressure circulates to the low and reverse servo and front clutch. During the process of engaging the low and reverse servo and from clutch, the numbers 4 and 3 check balls are seated by the pressure.

Line pressure

Line pressure from between the pressure regulator and manual valve circulates around the pressure regulator valve. After flowing through a restriction to the seat number 8 check ball, the pressure enters the throttle valve, which produces line-to-throttle pressure. With the throttle valve open, throttle pressure charges the kickdown valve and strokes the throttle plug to its extreme left position at the pressure regulator valve. Line pressure from the manual valve does not flow to the pressure regulator valve to oppose spring tension. The pressure regulator valve coil spring pushed the pressure regulator valve over to close the exhaust port. Line pressure build to approximately 200 to 300 psi (1,380 to 2,070 kpa)

Throttle pressure

Throttle pressure circulates to the shift valve area to keep both the 1-2 and 2-3 shift valves downshifted. Throttle pressure also keeps the shuttle valve throttle plug tight seat in the valve body.

Converter pressure

In reverse, the transaxle needs the torque multiplication of vortex flow to start the vehicle moving from a stop. Therefore, the switch valve maintains the position and holds the torque converter piston in the unlocked position.

Lockup clutch engagement

The lockup relay is energized when the PCM grounds the circuit. The lockup relay sends 12 volts to energize the lockup solenoid. When the lockup solenoid is energized, it seats the check ball, which stops the exhaust of line pressure. Line pressure builds up on the reaction area of the switch valve and moves the valve against spring tension to begin lockup engagement.

Drive range: D third gear

Gear selector position: D

Torque controls engaged: Rear clutch; front clutch

Approximate vehicle speed: 40 mph

Throttle position: Half throttle

In drive range third gear lockup, the tranaxle operators in the same makker as third gear unlock.

The coolant sensor reports to the computer that the engine has reached a temperature of at least 150°F (66°C). The vehicle's speed is monitores by a VSS. When the vehicle has a speed of more than 40 mph (65 km/h), it is at the desired engagement speed. Before engagement of initiated, the vaccum transducer must report to the PCM that engine vaccum is between 4 and 22 in. Hg (102 to 560 mm Hg). Based on these inputs, the PCM energies the clutch relay and lockup solenoid to move the solenoid check ball into its seat. The check ball steps the exhausting of line pressure. The increasing line pressure forces the switch valve to move against spring tension. Line pressure from the switch valve is directed to the pump drive hub and stator support to fill the torque converter with fluid. Fluid in the torpue converter during lockup operation resides there to become the cooling and lubricating pressure. Line pressure flows from the impeller and turbine to fill the space behind the torque converter clutch piston and force engagement.

Throttle pressure

As line pressure passes through the valley of the throttle valve, it becomes throttle pressure. Throttle pressure circulates around the kickdown valve, a very quick downshift response to full-throttle operation is provided. Throttle pressure is directed to the pressure regulator throttle plug spring. The result is that the pressure regulator valve chooses the exhaust port, which results in a line pressure increase. Throttle pressure moves to act on the spring end of the 1-2 shift valve. The throttle

pressure and coil spring tension work together to hold the shift valve and governor plug in the downshift position against governor pressure. Throttle pressure passes check ball 5, which is acting on the spring end of the 2-3 shift valve. From the 2-3 shift valve, throttle pressure flows to hold the shuttle valve throttle plug against its stop in the valve body.

Governor pressure

Governor pressure developed from line pressure leaves the governor assembly terminating at the shuttle valve spool land. Government pressure also acts on the 2-3 and 1-2 shift valve governor plugs. Because the vehicle is traveling at 8 mph (13 km/h), governor pressure is not strong enough to overcome throttle pressure and spring tension at the opposite end of the shift valves. Therefore, the transmission stays downshifted in drive range first gear.

Converter pressure

From the pressure regulator valve, converter pressure is directed to the converter pressure control valve. From the converter pressure control valve, converter pressure flows through the switch valve valley and enters the torque converter turbine shaft to keep the lockup piston disengaged. Converter pressure entering between the impeller and turbine fills the torque converter. Converter pressure flows back to the switch valve and enters the cooler to become cooler pressure. When cooler pressure returns to the transmission, it cools and lubricates transmission parts.

Drive rage: D second gear

Gear selector position: D

Torque congerter mode: Unlock

Plantary controls engages: Reart clutch, front kickdow band.

Continuously variable transmission

Objectives: At the end of this lesson you shall be able to

- state the function of CVT
 - state the merits of CVT
 - types of CVT
 - state parts and their function of CVT
 - list out the application.
-

Function of CVT

A continuously variable transmission or CVT, is a type of automatic transmission that provides more useable power, better fuel economy and a smoother driving experience than a traditional automatic transmission.

Conventional automatic transmissions use a set of gears that provides a given number of ratios (or speeds). The transmission shifts gears to provide the most appropriate ratio for a given situation: Lowest gears for starting out, middle gears for acceleration and passing, and higher gears for fuel efficient cruising.

The CVT replaces the gears with two variable - diameter pulleys, each shaped like a pair of opposing cones, with a metal belt or chain running between them. One pulley is connected to the engine (input shaft), the other to the drive wheels (output shaft). The halves of each pulley are moveable; as the pulley, effectively making the pulley's diameter larger.

Changing the diameter of the pulleys varies the transmission's ratio (the number of times the output shaft spins for each revolution of the engine), in the same way that a 10-speed bike routes the chain over larger or

smaller gears to change the ratio. Making the input pulley smaller and the output pulley larger gives a low ratio (a large number of engine revolutions producing a small number of output revolutions) for better low - speed acceleration. As the car accelerates, the pulleys vary their diameter to lower the engine speed as car speed rises. This is the same thing a conventional transmission does, but instead of changing the ratio in stages by shifting gears, the CVT continuously varies the ratio - hence its name.

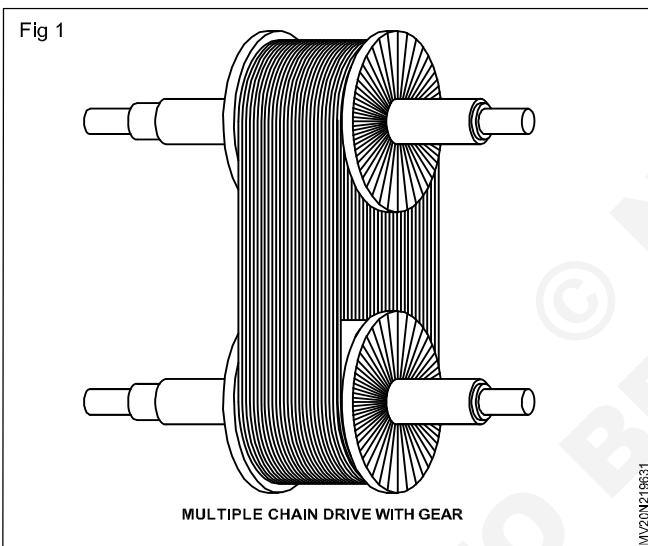
Merits of CVT

A continuously variable transmission has fewer moving parts, which can reduce friction and heat. We know very well that friction and heat leads to heavy wear and tear on out transmission. Reduced exposure to friction and heat can help a transmission last longer.

And of course fewer parts means a reduction in weight. So that CVT is typically lighter than a traditional automatic transmission. It will have benefit on both performance and fuel consumption.

Various types of CVT

- 1 Multiple chain with gear drive (Fig 1)



- 2 Toothed belt drive (Fig 2)
- 3 Steel belt drive step pulley (Fig 3)
- 4 Conical pulley drive (Fig 4)
- 5 Chain with auto slack adjusting gear drive

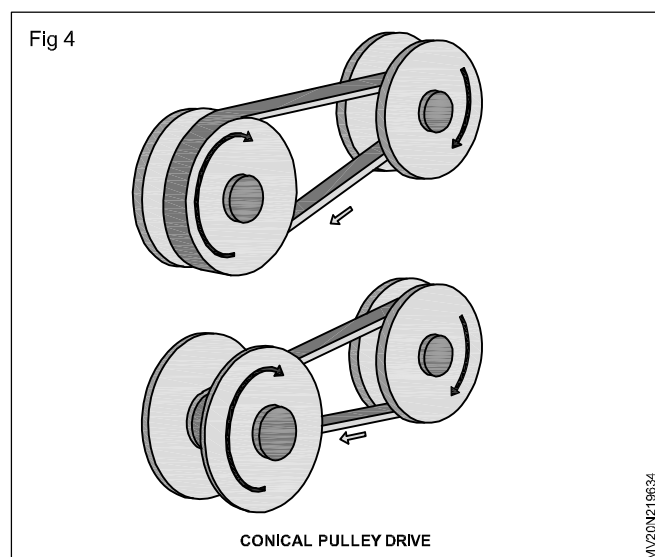
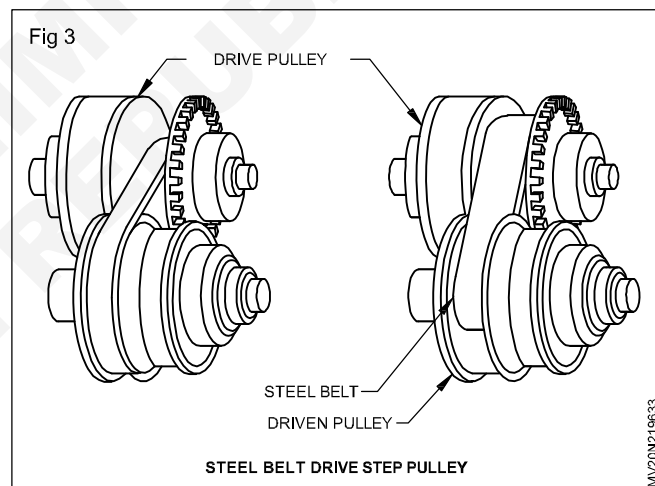
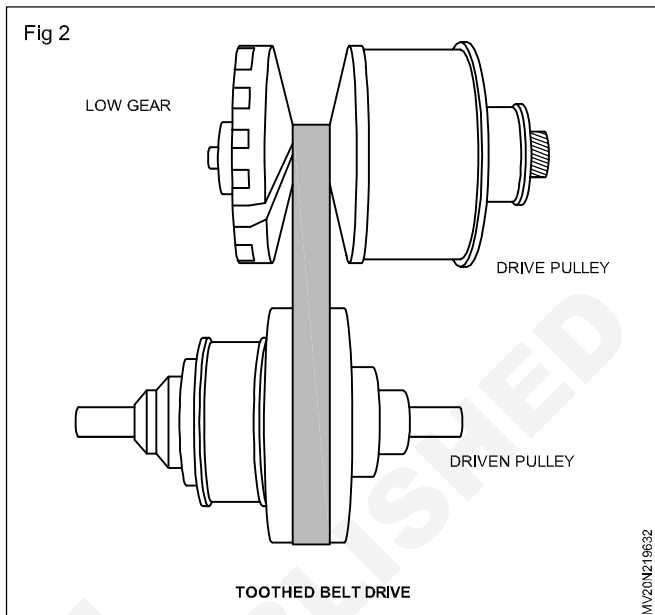
Various parts in CVT

- 1 Driver pulley
- 2 Driven pulley
- 3 Belt
- 4 Slack adjuster Or A set of conical pulley with belt

When the power drawn from the driver pulley from the minimum dia side of a cone will supply more torque, where as power drawn from the maximum dia of a cone it will have a more speed.

Application

- 1 Modern motor cycle
- 2 Modern scooterette
- 3 Modern cars
- 4 Modern medium commercial and sport utility vehicles.



Steering system

Objectives: At the end of this lesson you shall be able to

- state the functions of the steering system
- state the ackerman geometry of steering mechanism
- describe steering linkages
- state the 4 wheel steering system
- state the collapsible steering column.

Function

The main function of the steering system is to convert the rotary motion of the steering wheel into angular motion of the front wheels to negotiate a turn.

The other functions of steering system are as follows.

- To turn the vehicle whenever required.
- To provide stability to the vehicle on road.
- To provide true rolling motion of the wheels at all times.
- To provide self-centering action after negotiating a turn.
- To minimize tyre wear.
- To multiply the driver's effort to turn the vehicle for easy operation.
- To prevent road shocks reaching the driver.

Steering mechanisms

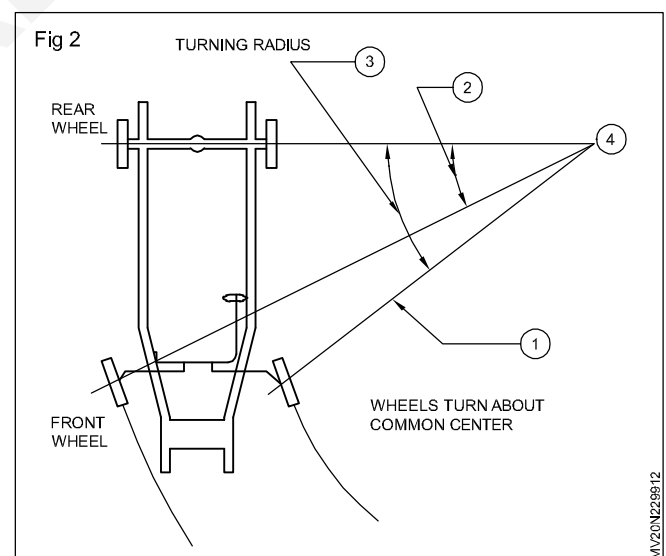
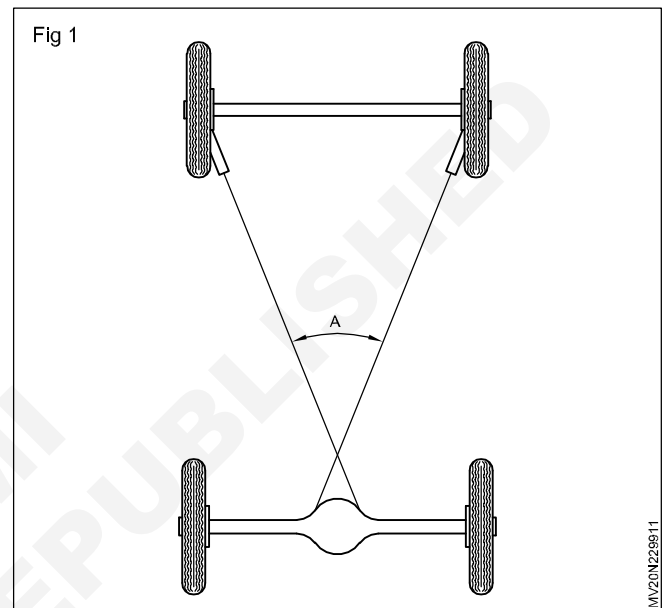
Two types of steering mechanism are used.

- Ackerman steering mechanism.
- Davis steering mechanism.

Only Ackerman steering mechanism is used in vehicles nowadays because of its simplicity and less wear of the parts.

Ackerman steering mechanism

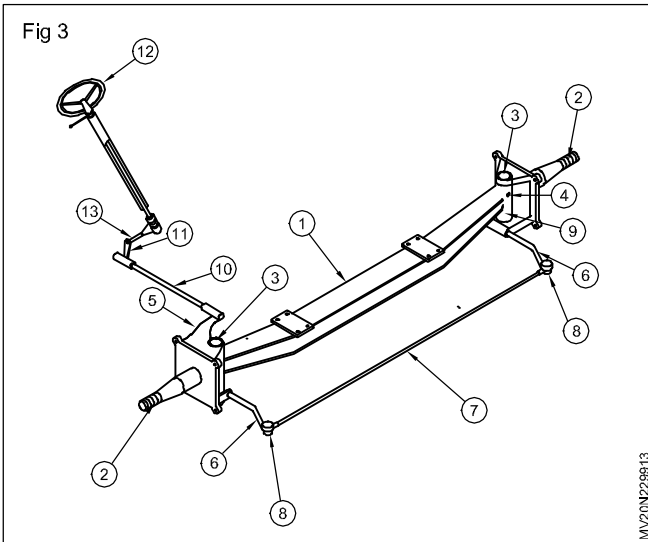
To avoid skidding of tyres when the vehicle is negotiating a turn (Fig 2), it is necessary that all the wheels turn on an arc which has a common centre (4). The inner wheel turns at a larger angle (3) than that of (2) of the outer wheel. When the front wheels are in the straight ahead position and lines are drawn through the kingpin's centre and the steering arm's end, they will meet at a point at the centre of the rear axle just ahead of the differential. The included angle is called Ackerman angle (A) (Fig 1). The Ackerman steering results in different angles, through which the front wheels turn. This is achieved by setting the steering arms not exactly at right angle with the spindle body. Steering arms are slanted slightly towards the centre of the vehicle to get the Ackerman angle.



Principles of steering

The steering system along with the suspension system, allow the driver to safely and easily control the vehicle's direction while driving/

Steering linkages (Fig 3)

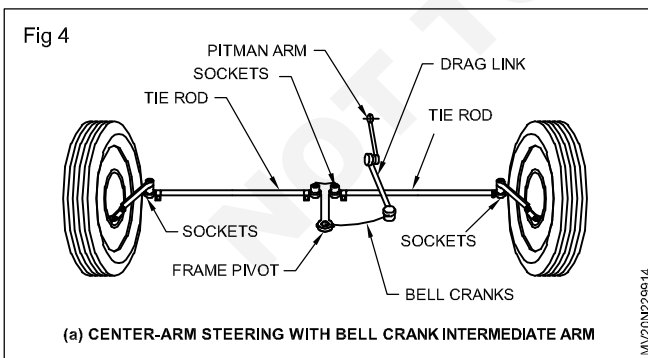


When the steering wheel (12) is turned its motion is carried to the steering box through the steering cross-shaft (13). In the steering box this motion is converted into angular motion of the drop arm (11) which is connected to the drag link rod (10). The drag link rod's (10) other end is connected to the steering lever arm (5). The steering lever arm (5) is connected to the stub axle spindle (2). At the lower end of the stub axle, the spindle steering arm (6) is fitted. Both the steering arms (6) are connected by a track rod (7). When the steering wheel is rotated the drop arm (11) moves towards or away from the front wheel depending upon the direction of turn (right or left).

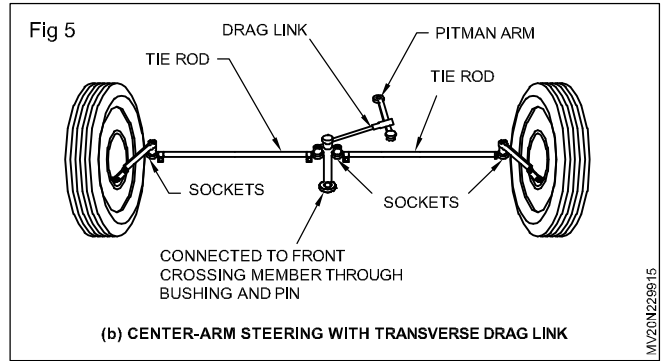
For example if the vehicle is to be turned to the right side the steering wheel is rotated clockwise. The drop arm (11) is pushed towards the front wheel, which forces the stub axle (2) spindle to turn right through the drag link rod (10) and the steering lever arm (5). The reverse will happen when the vehicle is turned left.

Different types of steering linkages (Figs 4-9)

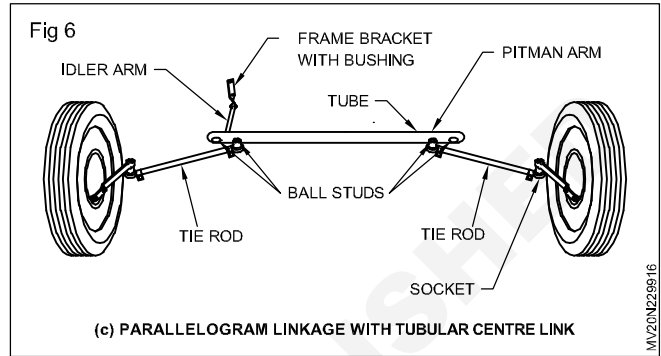
Following types of steering linkages are used.



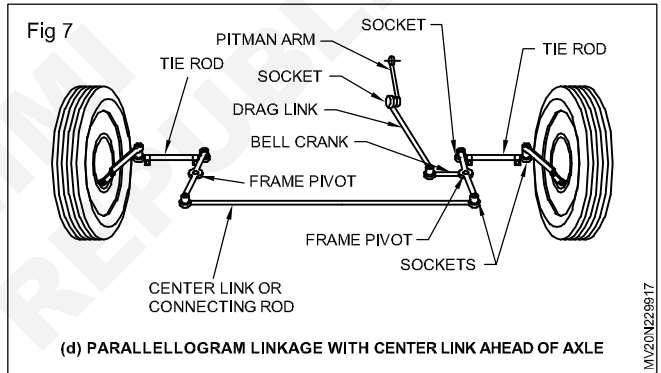
(a) CENTER-ARM STEERING WITH BELL CRANK INTERMEDIATE ARM



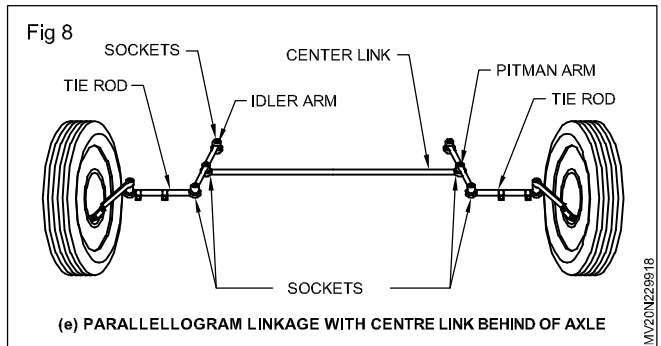
(b) CENTER-ARM STEERING WITH TRANSVERSE DRAG LINK



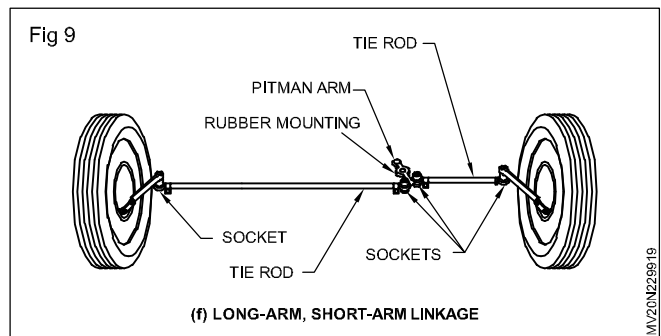
(c) PARALLELOGRAM LINKAGE WITH TUBULAR CENTRE LINK



(d) PARALLELOGRAM LINKAGE WITH CENTER LINK AHEAD OF AXLE



(e) PARALLELOGRAM LINKAGE WITH CENTRE LINK BEHIND OF AXLE



(f) LONG-ARM, SHORT-ARM LINKAGE

Four wheel steering system

This paper deals with the details of four wheel steering (4WS) system. With the help of this system all the four wheels can be turned to any direction using the steering. Thus the vehicle can be controlled more effectively especially during cornering and parking. Also the speed of the vehicle can be increased or decreased.

There are three types of production of four wheel steering systems:

- 1 Mechanical 4WS
- 2 Hydraulic 4WS
- 3 Electro / hydraulic 4WS

The mechanical 4WS uses two separate steering gears to control the front and rear wheels. The hydraulic 4WS uses a two way hydraulic cylinder to turn both the wheels in the same direction. It is not possible to turn them in the opposite direction. The electro/hydraulic 4WS combine computer electronic controls with hydraulics to make the system sensitive to both steering angle and road speeds.

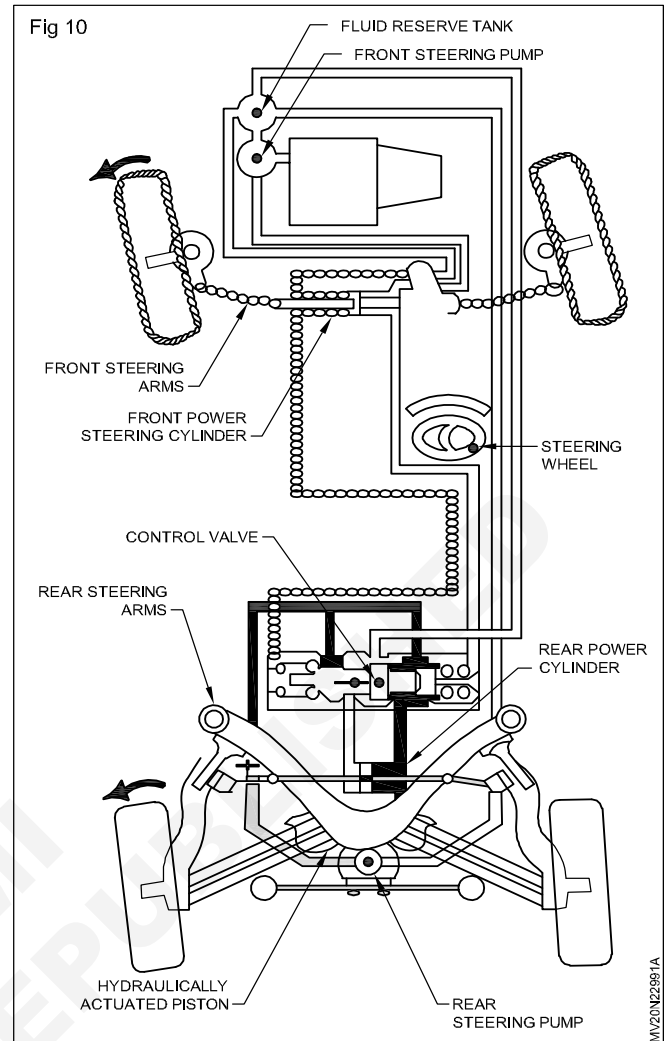
This system finds application in off-highway vehicles such as forklifts, agricultural and construction equipment and mining machinery. It is also useful in passenger cars, mainly SUVs. Four-wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. It should not be confused with four wheel drive in which all four wheels of a vehicle are powered. It improves handling and help the vehicle make tighter turns.

Production - built cars tend to understeer or, in few instances, oversteer. If a car could automatically compensate for an understeer/oversteer problem, the driver would enjoy nearly neutral steering under varying conditions. 4WS is a serious effort on the part of automotive design engineers to provide near neutral steering. The front wheels do most of the steering. Rear wheel turning is generally limited to 50-60 degrees during an opposite direction turn. During a same direction turn, rear wheel steering is limited to about 10-15 degrees.

When both the front and rear wheels steer toward the same direction, they are said to be in-phase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase, counter-phase or opposite - phase and it produces a sharp, tighter turn.

Need of four wheel steering system (Fig 10)

In India, road trains used for passenger transportation in city bus service, use 4 wheel steering to enable the extra long vehicles to pass through the present turnings on the road.



Besides multi axle vehicles fitted with twin front axle where both the front axles are simultaneously steered.

For parking vehicles in congested parking area, 4 wheel steering in cars are very helpful.

To understand the advantages of four wheel steering, it is wise to review the dynamics of typical steering maneuvers with a conventional front steered vehicle. The tires are subject to the forces of grip, momentum, and steering input when making a movement other than straight - ahead driving. These forces compete with each other during steering maneuvers. With a front-steered vehicle, the rear end is always trying to catch up to the directional changes of the front wheels. This causes the vehicle to sway. As a normal part of operating a vehicle, the driver learns to adjust to these forces without thinking about them.

When turning, the driver is putting into motion a complex series of forces. Each of these must be balanced against the others. The tires are subjected to road grip and slip angle. Grip holds the cars wheels to the road, and momentum moves the car straight ahead. Steering input causes the front wheels to turn. The car momentarily resists the turning motion, causing a tire slip angle to form. Once the vehicle begins to respond to the steering input. Cornering forces are generated. The vehicle sway as the rear wheels attempt to keep up with the cornering forces already generated by the front tires.

This is referred to as rear - end lag, because there is a time delay between steering input and vehicle reaction. When the front wheels are turned back to a straight - ahead position, the vehicle must again try to adjust by reversing the same forces developed by the turn. As the steering is turned, the vehicle body sways as the rear wheels again try to keep up with the cornering forces generated by the front wheels.

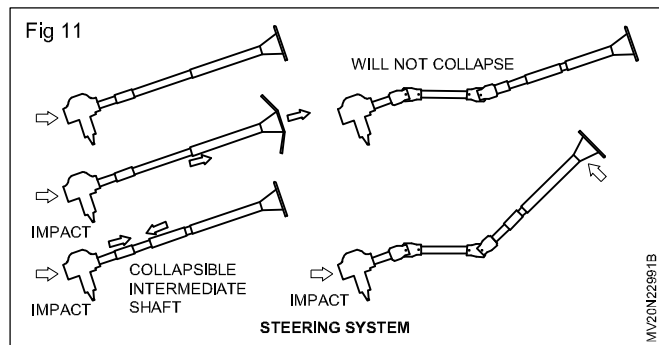
The idea behind four - wheel steering is that a vehicle requires less driver input for any steering maneuver if all four wheels are steering the vehicle. As with two wheel steer vehicles, tire grip holds the four wheels on the road. However, when the driver turns the wheel slightly, all four wheels react to the steering input, causing slip angles to form at all four wheels. The entire vehicle moves in one direction rather than the rear half attempting to catch up to the front. There is also less sway when the wheels are turned back to a straight - ahead position. The vehicle responds more quickly to steering input because rear wheel lag is eliminated.

Collapsible steering column (Fig 11)

A typical car from 50 years ago not only had a massive steering wheel with a metal horn rim, but it connected to a steering column that was one piece. So in frontal collision the driver was getting injured by the steering wheel hit in the stomach.

With collapsible steering system is made of several joints and intermediate pieces. During impact the intermediate

pieces, act like fuse, which collapses saving the life of driver.



General arrangement of steering system

The arrangement of steering linkage depends upon the type of front suspension and also with the location of the steering gear in relation to the front wheels.

Steering columns

The steering column is always at an inclination to vertical for comfort in driving. In fact, the driver comfort and the location of the steering gear bore on the chassis frame. Due to this two factors, the inclination of column is about 20° in commercial vehicles and 50° in motor cars and upto 70° in sports car. The steering wheel is connected to the steering linkages to turn the front wheels with great effort.

Steering gear box

Objectives: At the end of this lesson you shall be able to

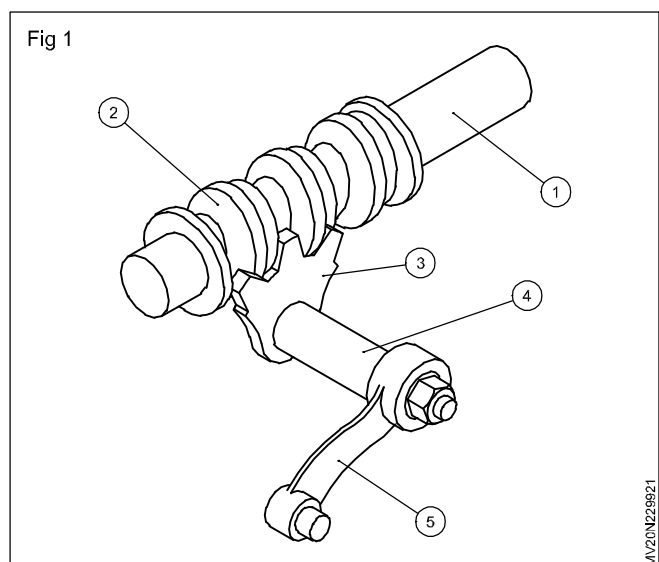
- state the various types of steering gear boxes
- state the maintenance of the various steering gear box.

The following types of steering boxes are used.

- Worm and sector
- Worm and wheel
- Worm and nut
- Worm and roller
- Worm and recirculating ball and nut
- Rack and pinion

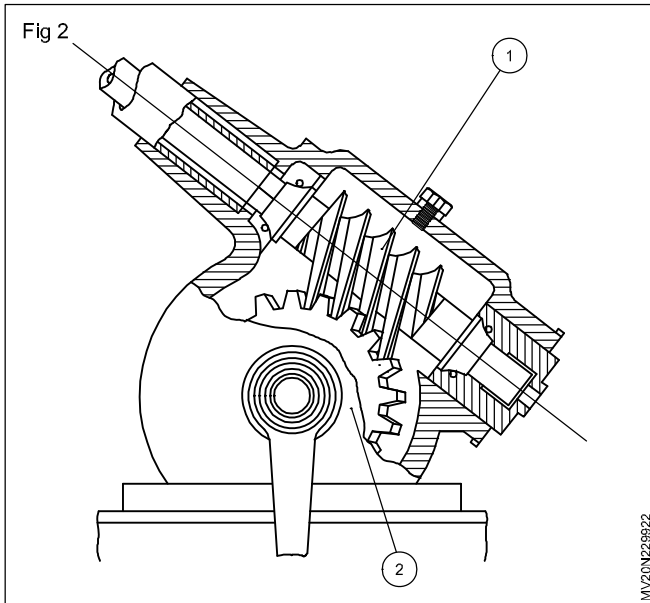
Worm and sector type (Fig 1)

The steering gearbox consists of the steering shaft (1) fitted with a worm (2) at one end. The worm (2) is in mesh with the sector (3). When the steering wheel is rotated, its motion is transmitted to the sector (3), through the worm (2). The sector (3) rotates at a certain angle. The sector shaft (3) in turn rotates a cross-shaft (4) which is connected to the drop arm (5). This angular movement is transmitted to the front wheels through the linkages to turn the vehicle.

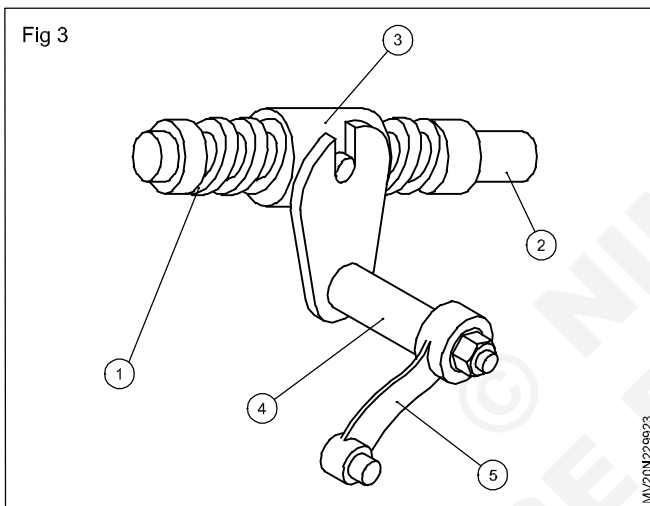


Worm and wheel type (Fig 2)

In this type a complete gear (2) is used instead of a sector. The worm (1) and gear (2) can be rotated to a new position as the sector portion wears out faster on use.



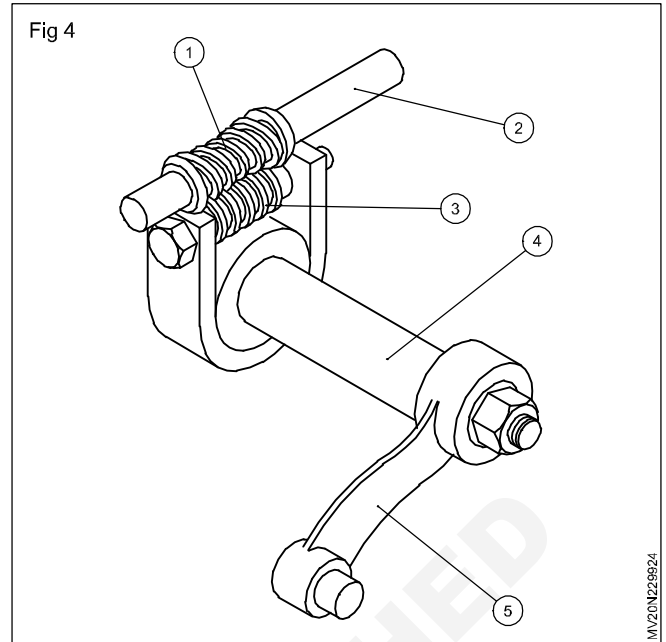
Worm and nut type (Fig 3)



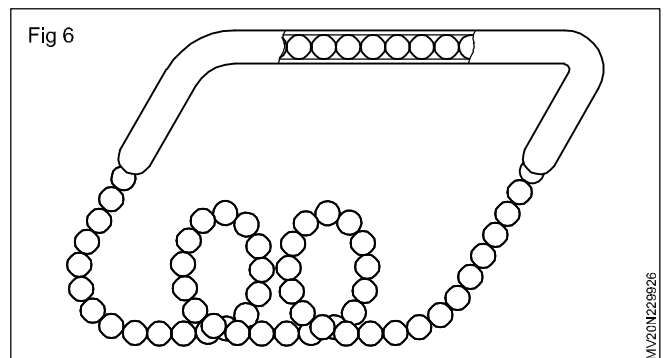
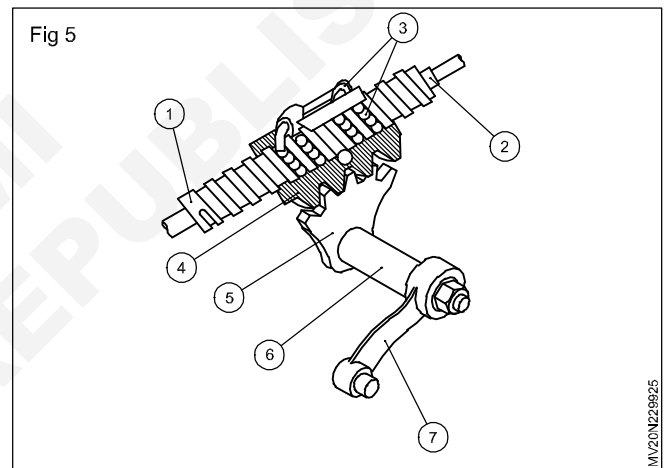
In this type the worm (1) is an integral part of the steering column (2). When the steering column (2) rotates the worm (1) also rotates. The worm (1) is in mesh with the nut (3). When the worm rotates the nut (3) moves up and down on column (2). This enables the cross-shaft (4) to rotate in an arc. This in turn rotates the drop arm (5) in an arc. This movement is transmitted to the front wheels to turn the vehicle.

Worm and roller type (Fig 4)

The worm (1) is at the end of the steering column (2). The diameter of the worm (1) is more at its ends. Its diameter is gradually reduced at the centre. This enables the roller (3) to keep the contact with the worm (1) at all the positions. It also provides a variable ratio to permit faster and efficient steering. The roller (3) is mounted on the cross-shaft (4). The cross-shaft (4) is fitted to the drop arm (5). When the steering wheel is rotated, the column (2) also rotates along with the worm (1), which allows the roller (3) to rotate in an arc. This makes the cross-shaft (4) and drop arm (5) to move in an arc, which in turn moves the front wheels to the left or right through the linkages.



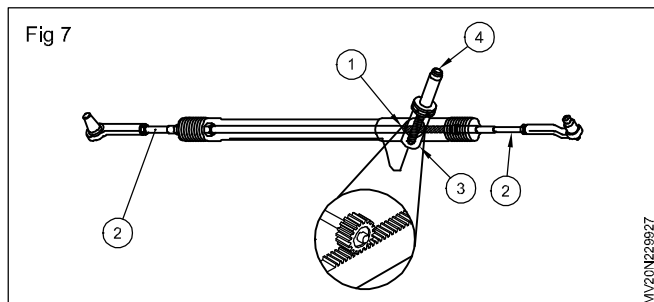
Worm and recirculating ball and nut type (Fig 5 & 6)



The worm (1) is at the end of the steering column (2). A ball nut (4) is fixed on the worm (1). Several balls (3) circulate in between the ball nut (4) and the worm (1). This reduces friction between the worm (1) and nut (4). A sector (5) is in mesh with the ball nut (4). When the steering wheel is rotated the steering column (2) also rotates and the ball nut (4) moves downward or upward on the worm (1). This makes the sector (5), cross-shaft (6) and drop arm (7) to move in an arc. This movement is transmitted to the front wheels to turn the vehicle.

Arrangement of balls is shown in Fig 6. During overall always count the number of balls and ensure that the correct quantity is inserted. Lesser quantity of ball will affect the response from steering.

Rack and pinion type (Fig 7)



In this type a rack (1) is either connected or made part of a divided track-rod (2). The pinion (3) is attached to the steering column (4). The pinion (3) always remains in mesh with the rack (1). When the steering wheel is rotated the pinion (3) also rotates and the rack (1) moves left or right, causing the wheels to turn.

Helix gear

Helical gears are one type of cylindrical gears with slanted tooth face compared to spur gears, they have the larger contact area and excel in quietness and less vibration and able to transmit large force a pair of helical gears has the same helix angle but the helix hand is opposite.

Maintenance of steering components

Fill oil upto the recommended level with the prescribed grade of lubricant. Remove the oil at prescribed intervals. Steering becomes hard in the absence of lubrication. After same run, the mating parts wear out, increasing the play this leads to steering noise & vibration.

The drop arm nut is to be tightened to a prescribed torque.

Drop arm and rocker shaft is to be fixed only at a prescribed position. It can be assembled only in one way. Otherwise make punch marks in both rocker shaft and drop arm at the time of removal.

'O' rings, seals, used in steering box are to be renewed during over haul or renewed in case of oil leaks.

Universal joints (single or double) are provided at the end of steering column, to provide

- i Comfortable steering angle as per design
- ii Absorb road shocks, which is not transmitted to drivers hand.

Backlash between mating gears are specified based on design. Rocker shaft end plays are specified by the supplier and the same is to be adjusted. Bearing preload is to be done during assembly of steering.

Helix's new steering box uses state of art CAD/CAM technology to ensure the quickest and smoothest steering on the market.

Power steering

Objectives: At the end of this lesson you shall be able to

- state the need of power steering
- state the benefits of power steering
- state the types of power steering
- state the features of power steering
- state the construction of fully integral power steering
- state the operation of power steering
- state the shock absorption by power steering
- explain flow control valve of power steering
- briefly explain on pressure relief valve.

Need for power steering

The need to achieve the greatest possible road safety under

- Increasing traffic density
- High axle loads
- Poor road conditions

Led to the development of power steering.

Benefits of power steering

- Effortless steering - reducing drivers fatigue
- Quick response - power assistance is immediate
- Positive road feel to the driver
- Absorbs road shocks
- Greater safety (in case of front tyre burst)
- Steering can be operated manually, in case of loss of power assistance
- Absolute control during driving
- Greater maneuverability

Types of power steering

There are three types of power steering system used in automobiles

- 1 Integral power steering
- 2 Linkage power steering
- 3 Electronic power steering

Fully integral power steering gear (Fig 1)

Salient features of power steering gear

Rotary valve

This device provides responsive steering control

Unloading valves

Furnish power steering pump protection and reduce pressure to unload steering linkage at the ends of steering gear travel.

Recirculating balls

Combines high mechanical efficiency with smooth operation.

Torsion bar

Provides positive valve centering with ultimate feel of the road.

Balanced area cylinder

Back pressures cannot affect steering stability.

Manual steering capability

Provides for steering control in the event of hydraulic failure

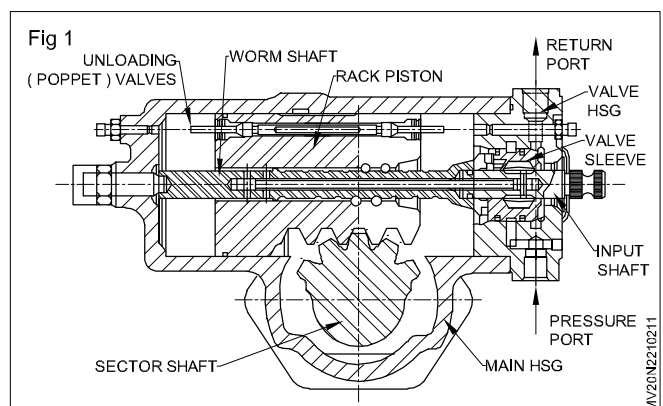
Construction

The fully integral power steering gear consists of

- A manual steering mechanism (Re circulating ball & nut type)
- Hydraulic power cylinder and piston
- A rotary control valve.

In a single compact package.

Normal operation (Fig 1)



When the driver turns the steering wheel, he activates the steering gear input shaft. A torsion bar pinned at its one end to the input shaft and the other end to the worm

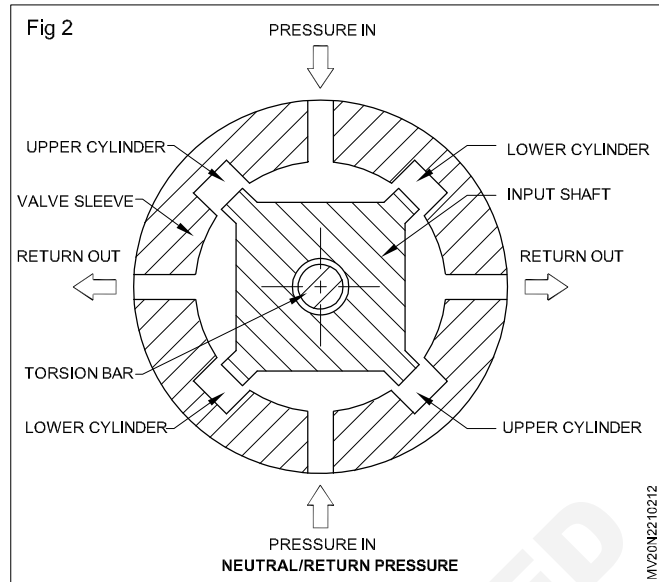
shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to this rotational force the worm shaft acting through the re-circulation ball mechanism, tries to move the rack piston axially through the gear housing cylinder bore.

Hydraulic power assistance

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is connected by linkage to the steered wheels. Because of this resistance, the torsion bar is twisted by the input shaft, thereby actuating the control valve. Pressurised fluid directed by the control valve assists in moving the rack piston axially through the cylinder bore. The rack piston then turns the sector shaft to steer the vehicle to the desired direction.

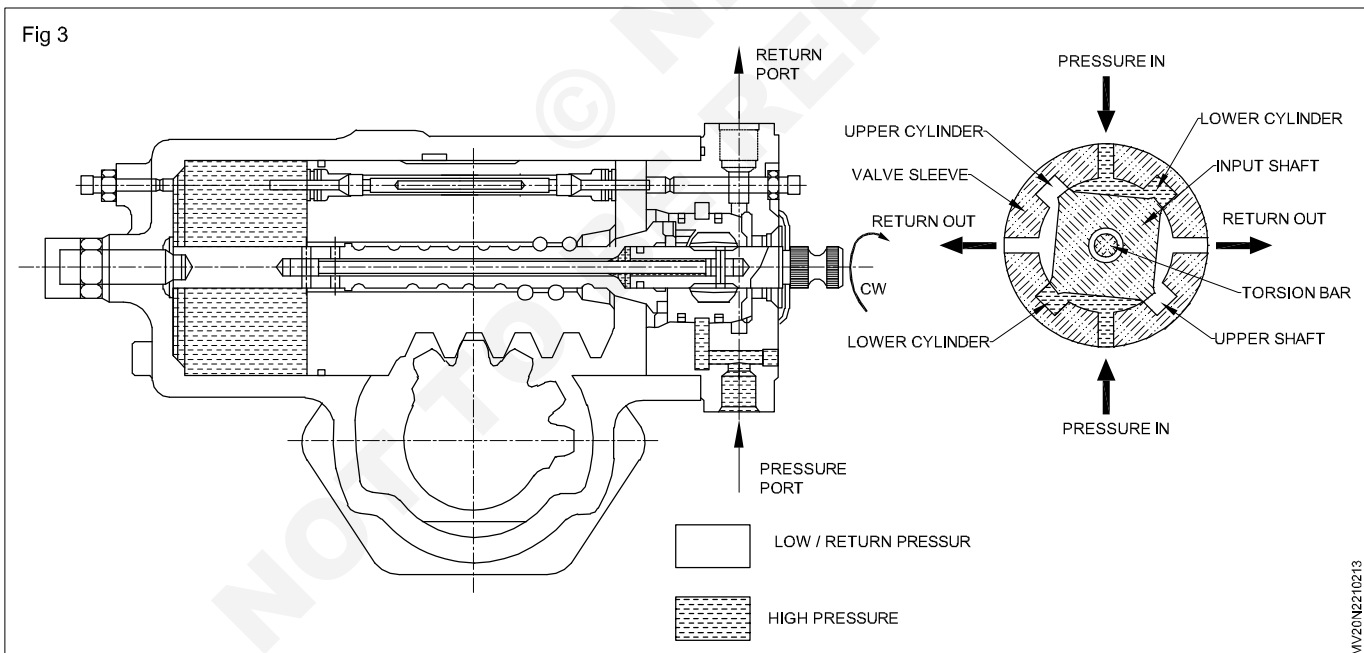
Neutral condition (Fig 2)

The rotary control valve mechanism, which is the heart of power steering system comprises of input shaft, worm shaft, torsion bar and valve sleeve. When all these components assembled together this becomes "valve assembly". The input shaft has four lands and the valve sleeve has four pockets assembled in neutral condition. The valve sleeve has keyed connection with the worm shaft. The diagonally opposite pockets connect the oil to the lower or upper cylinder. Always the valve will be in neutral condition. In this condition the oil flows to both sides of the cylinder and return back to the reservoir.



Right turn (Fig 3)

When the driver rotates the input shaft to the right through the steering wheel. Because of the road resistance the torsion bar gets twisted and the input shaft alone will twist to the right and disturbs the valve neutral position, thereby causing all the oil to flow to the lower cylinder and pushes the rack piston towards top. Once the driver stops rotating the steering wheel the torsion bar will gain its original position, as the worm shaft rotates and bring back the valve sleeve to the neutral position.



Left turn (Fig 4)

When the driver rotates the input shaft to the left through the steering wheel. Because of the road resistance the torsion bar gets twisted and the input shaft alone will rotate to the left and disturbs the valve neutral position, thereby causing all the oil to flow to the upper cylinder and pushes the rack piston towards bottom. Once the driver stops rotating the steering wheel the torsion bar

gain its original position, as the worm shaft rotates and bring back the valve sleeve to the neutral position.

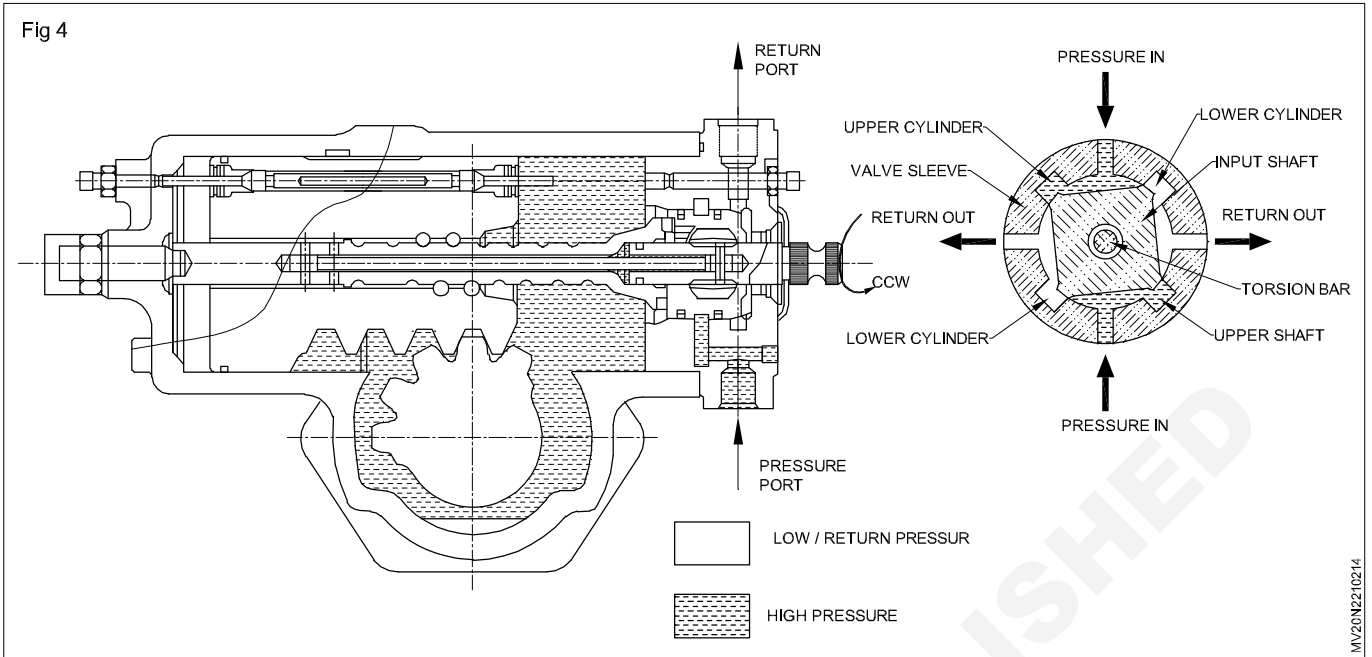
Shock absorption

Valve in shock absorption (Fig 4)

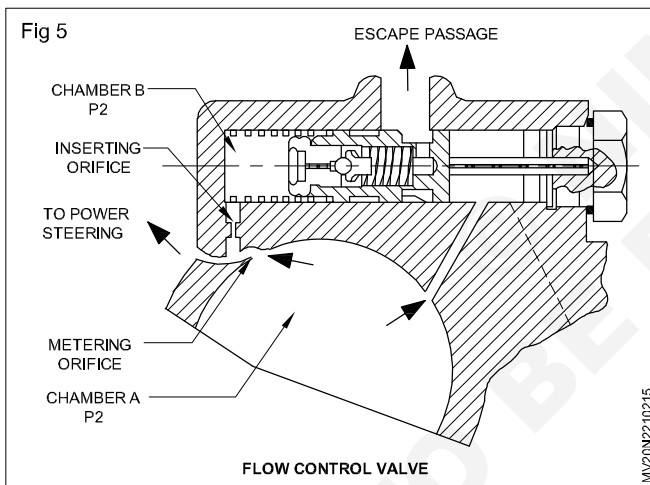
In general during the turns the driver disturbs the valve neutral position, causing the oil to flow to the respective cylinder. During shock absorption the road shocks force

the worm shaft to rotate causing the valve sleeve to move from neutral condition, thereby causing the neutral condition disturbed and the oil flow on the opposite side

resisting the Rack piston's movement, thus the oil absorbs all the road shocks and prevent shocks getting transmitted to the driver.



Flow control valve (Fig 5)



Function

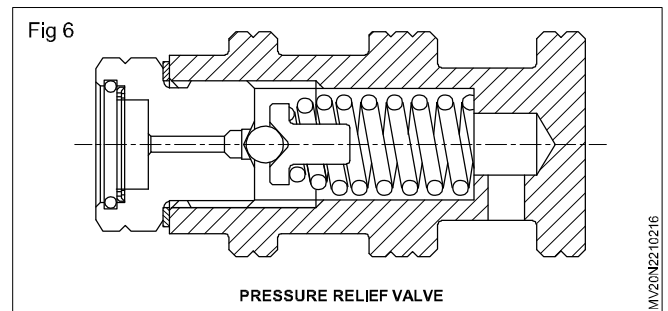
The flow control valve controls the rate of flow within the power steering circuit. This is because, since the discharge rate per oil pump revolution (characteristic discharge rate) is constant, the discharge rate per unit time increases and decreases in proportion to the engine speed. To maintain uniform performance, the power steering requires a flow rate that remains within certain fixed range. The flow rate required by power steering is determined by the speed at which steering wheel is tuned, but must be such that power steering can respond at higher speeds. Consequently when the oil pump discharge rate exceeds a certain value in respect to the engine speed increase, the excess flow escapes to the interior of the pump or the reservoir so that the hydraulic fluid is always supplied to the system at the required rate.

Operation

The hydraulic fluid discharged by the oil pump enters the pressure chamber, from it passes through the metering orifice to power steering chamber. When the pump discharge rate is lower than the adjustment flow rate, the fluid pressure differential between the chambers, movement of the flow control valve is prevented by the pressure of the spring and all of the fluid from the oil pump supplied to the power steering gear box.

The oil pump speed increases together with the engine speed, which increases the hydraulic fluid rate. When the discharge rate exceeds the adjustment flow rate (spring force) the spring is deformed from its original position and the flow control valve will move in and the excess oil will bypass to the suction line.

Pressure relief valve (Fig 6)



Function

The pressure relief valve controls the maximum pressure in the power steering circuit. That is the load on the oil pump is directly proportional to the steering wheel resistance. When steering wheel resistance is high, the hydraulic pressure required for power steering is also

high and vice versa. Whenever the road wheels contact an obstacle or wheel stopper, which requires additional force to steer the wheel, the pressure will increase infinitely. Therefore a mechanism is required to prevent excessive force being applied and to protect the steering mechanism.

Operation

The pressure relief valve is built into the flow control valve. When the steering wheel is not being operated and during normal steering wheel operation the operating pressure will never raise above the adjustment pressure. Therefore the relief valve and the steel ball are seated by the force of the spring to close the passage.

The steering wheel is turned fully, therefore the power steering valve remains closed. In this state the hydraulic fluid from the oil pump is under pressure and the pressure exceeds the force of the spring, the relief valve and steel ball are lifted from its seat causing the oil to bypass to the suction side of the pump.

Trouble shooting

Noise in steering - Presence of air in the fluid will make it noisy and spongy (not responding) low fluid level also lead to noisy operation and unresponsive steering.

The remedy is to fill fluid upto the level and bleed the system to remove air.

Electronic power steering

Objectives: At the end of this lesson you shall be able to
 • state the working principle of electronic power steering.

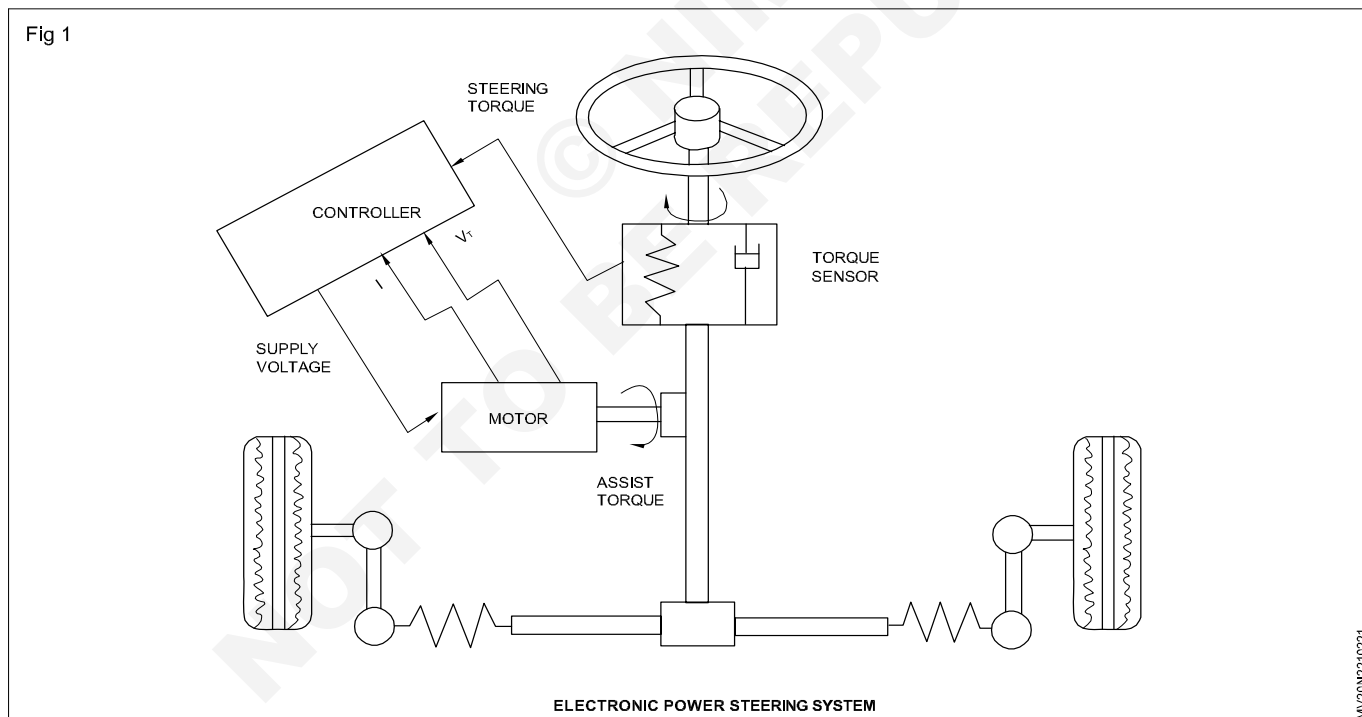
Electronic power steering (Fig 1)

There is a provision to protect the electric motor from being overloaded and also from the voltages surges from a faulty alternator or charging problem.

The electronic steering control unit is capable of self-diagnosing faults by monitoring the system's inputs and outputs and the driving current of the electric motor. In

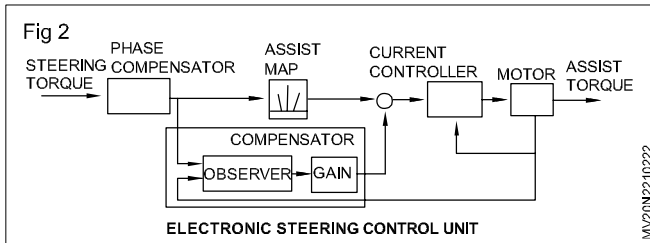
case of a problem, the control unit turns off the entire system by actuating a fail-safe relay in the power unit, the system reverts back to manual steering and warning light on the dashboard alerts the driver.

An electronic power steering has the following advantages over the hydraulic power steering, due to which it is being increasingly used in modern cars:



- 1 No problem of leakage of fluid.
- 2 Energy being consumed only while steering.
- 3 Steering assistance available even when the engine is not running.
- 4 While steering manually lesser force is required compared to a hydraulic system since there is no fluid to forced through valves.

In an electronic power steering system (Fig 2), steering sensor consisting of in fact two sensors, viz, a 'torque sensor' that converts the steering torque input and its direction into voltage signals, and a 'rotation sensor' that converts the rotation speed and direction into voltage signals, is located on the input shaft of the steering-gear box.



Inputs from the steering sensor and the vehicle speed sensor are fed to a microprocessor control unit where these are compared with a preprogrammed force assist map. The control unit then sends out the appropriate command signal to the current controller which supplies the appropriate current to the electric motor. The motor pushes the rack to the right or left depending on in which direction the current flows. Increasing the current to the motor increases the amount of power assist.

Wheel alignment (Wheel geometry)

Objectives: At the end of this lesson you shall be able to

- state the purpose of wheel alignment
- state the camber and castor angle
- state the purpose of kingpin inclination and included angle
- state the purpose of the toe-in/toe-out
- state the steering ratio
- state the combined angles and scrub radius
- state the thrust angle.

Purpose of wheel alignment

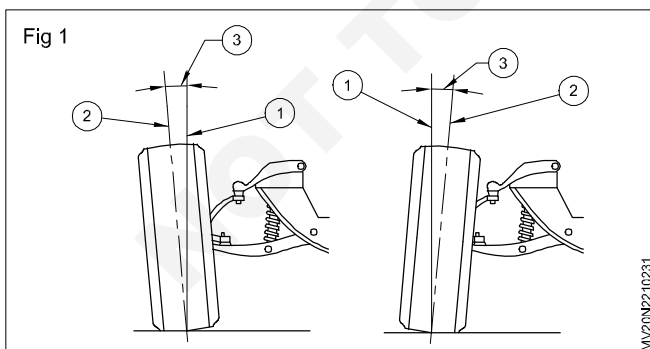
Wheel alignment is positioning of the front wheel and steering mechanism to

- minimize tyre wear
- reduce the driver's effort to turn the vehicle
- achieve self-centering after turning
- achieve directional stability of the vehicle while running straight ahead.

Front wheel alignment depends upon the following.

- Camber
- Castor
- Kingpin inclination
- Toe-in and Toe-out

Camber (Fig 1)



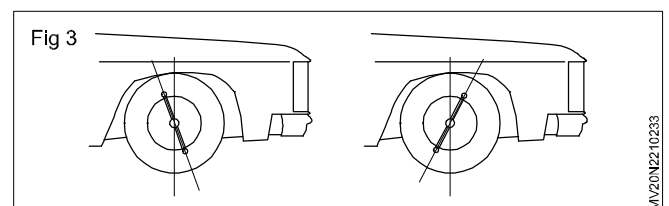
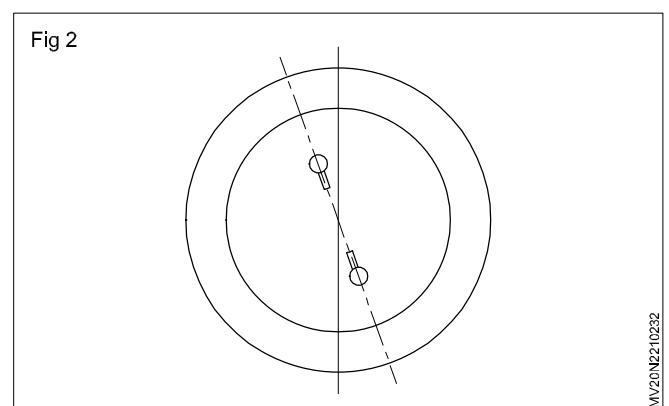
The angle between the vertical line (1) from the central point of the tyre and the central line (2) of the tyre is known as camber angle (3). When the wheels are tilted outward at the top it is called positive camber, and if tilted inward at the top, it is called negative camber. Equal camber angle is provided on both the front wheels. With the positive camber wheels become vertical under load

the tyre will have full contact with the road. If the positive camber is excessive then the tyre's outer edge will wear out faster. If the negative camber is excessive the tyre's inner edge will wear out faster. Unequal camber on both the front wheels will result in wheel shimmying at low speed (abnormal vibration).

Factors affecting camber

- Hub bearing play
- Kingpin bush wear
- Kingpin end play
- Front axle bend/twist

Castor angle (Figs 2 & 3)



The castor angle is the angle formed by the forward or backward tilt of the steering axis from vertical, when viewed from the side of the wheel. A backward tilt is

known as positive castor and a forward tilt is known as negative castor. If castor is not equal on both the sides it will cause the vehicle to pull to the side of the wheel having lesser castor angle.

Purpose of castor

- To maintain directional stability and control.
- To increase steering stability.
- To reduce the driver's effort to turn the vehicle.

Maintenance of steering components

Fill oil upto the recommended level with the prescribed grade of lubricant. Remove the oil at prescribed intervals. Steering becomes hard in the absence of lubrication. After same run, the mating parts wear out, increasing the play this leads to steering noise & vibration.

The drop arm nut is to be tightened to a prescribed torque.

Drop arm and rocker shaft is to be fixed only at a prescribed position. Many manufactures, make it 'idiot proofing'. so that it can be assembled only in one way. Otherwise make punch marks in both rocker shaft and drop arm at the time of removal.

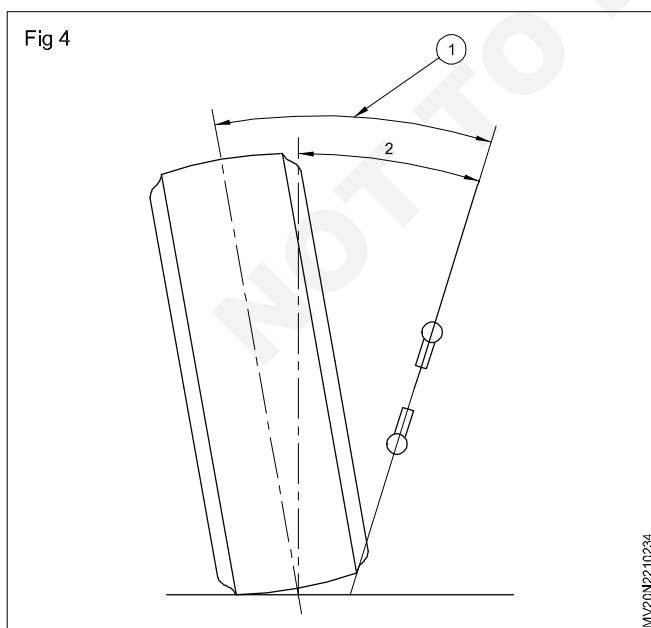
Orings, seals, used in steering box are to be renewed during over haul or renewed incase of oil leaks.

Universal joints (single or double) are provided at the end of steering column, to provide

- comfortable steering angle as per design
- absorb road shocks, which is not transmitted to drivers hand.

Backlash between mating gears are specified based on design. Cross shaft end plays are specified by the supplier and the same is to be adjusted. Bearing preload is to be done during assembly of steering.

Kingpin inclination (Fig 4)



King pins are mounted in such a way that they tilt inward. The angle between the centre line of the kingpin and the vertical line is called kingpin inclination (2) (Fig 4).

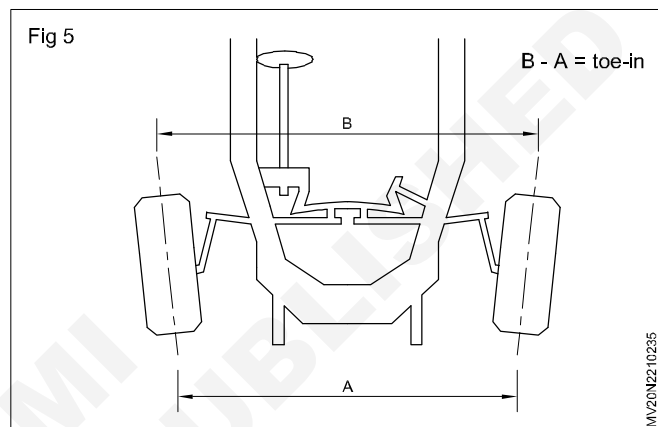
Purpose of kingpin inclination

- It provides directional stability along with the castor angle.
- It helps in self-centering of wheels after negotiating a turn.

Included angle

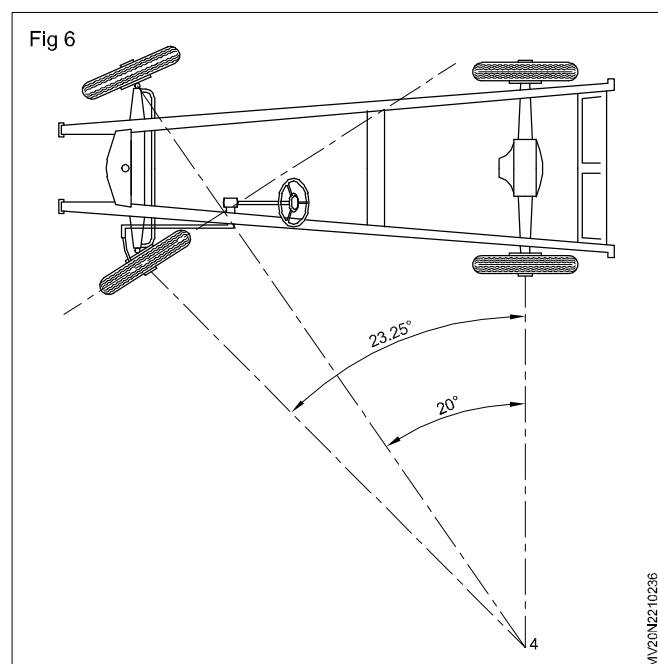
It is the angle (1) in the vertical plane between the kingpin axis and the wheel centre line.

Toe-in and toe-out (Fig 5)



When viewed from the top, if the front wheels are inclined inward at the front it is called toe-in. When vehicle runs wheels tend to shift outward. An initial toe-in keeps the wheels straight ahead. If wheels are inclined outward at front it is called toe-out. Incorrect toe-in causes abnormal tyre wear, tyre slip and poor steering stability. The toe-in varies for different makes of vehicles. A few vehicles do not have any toe-in.

Toe-out on turns (Fig 6)



It is the difference between the two angles formed by the two front wheels on turn. The inner wheel follows the radius of a smaller circle than the outer wheel. Therefore the inner wheel must toe-out more to prevent tyre side slip and excessive wear. This is achieved by arranging linkages in such a way that the inner wheel toes-out more than the outer wheel on turns.

Steering ratio

It refers to the number of turns on the steering wheel required to produce one turn of the steering - gear cross shaft. It is done by the pitman arm. This steering ratio ranges from 11:1 to 24:1 in passenger cars having no power steering. A variable reduction ratio on steering gears is obtained by varying the pitch of the worm or cam. It is higher for the straight-ahead range and lower for the outer ranges.

The steering gear ratio is defined as the ratio between the number of degrees of rotation of the steering wheel and number of degrees through which the cross shaft is free to rotate at the same time. Higher steering gear ratio gives slow steering and fast steering is obtained by lower steering gear ratio. Vehicles connected with power steering have average steering gear ratios of 20 percent less than vehicles with manual steering.

Overall steering ratio

As the steering linkage gives a mechanical advantage or leverage, the front wheels will turn through a smaller angle than the cross or sector shaft. The number of degrees through which the steering wheel is turned is divided into the number of degrees that the front wheels turn. It is known as overall steering ratio. The ratio varies from 15 to 20 percent higher than the steering - gear ratio in both manual and power steering.

In other words, the ratio of the output force to the input force applied is known as steering ratio. A small applied force produces a much greater force at the other end of the device. Actual steering ratio varies mainly dependent on the type of vehicle and the type of operation. Many cars with manual steering use steering ratios as high as 28:1 with minimized steering effort.

Some lightweight sports cars use the steering ratios as low as 10:1. High steering ratios are called slow steering because the steering wheel has to be turned many degrees to obtain a small steering effect. Low steering ratios is called fast or quick steering because steering wheel has to be turned to obtain a large steering effect.

Steering ratio is determined by two factors:

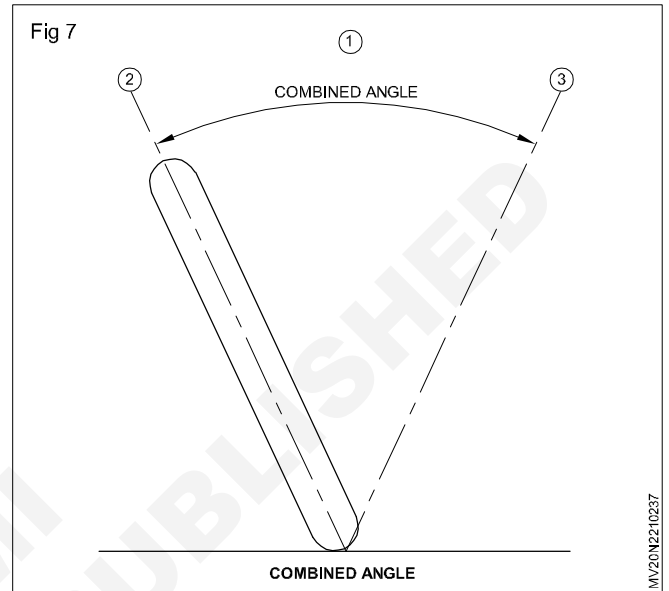
- 1 Steering - linkage ratio, and
- 2 Gear ratio in the steering gear

The steering linkage ratio is determined by the relative length of the pitman arm and the steering arm. If the effective lengths of the pitman arm and the steering arm are equal, the linkage has a ratio of 1:1. If the pitman arm is shorter than the steering arm, the linkage ratio will be less than 1:1. For example, the pitman arm is

about twice as long as the steering arm. This means that for every degree the pitman arm swings, the wheels will pivot about 2 degrees. Therefore, the steering-linkage ratio is about 1:2.

In the case of a rack-and pinion steering system, the steering ratio is determined largely by the diameter of the pinion gear. This steering ratio ranges from 14:1 to 24:1 in passenger cars without power steering.

Combined angle and scrub radius (Fig 7)



Combined angle or included angle (1) is the angle between the vertical plane of the wheel centre line (2) and the king pin centre line (3) called steering axis.

Combined angle is the sum of camber and king pin inclination called steering axis inclination. In a rear - wheel drive vehicle, the suspension cross member is pushed by the tractive force of the vehicle and the body is made to move forward during drive. The road resistance acts on the wheel at the contact point on the road. The distance acts on the wheel at the contact point on the road. The distance between the two points is known as scrub radius. When the tyre centre line lies outside the steering axis, this radius will be positive as shown in Fig 7.

It will be negative when the tyre centre line lies inside the steering axis. It is always referred in mm. This radius is mainly dependent upon the steering axis inclination, the wheel offset and suspension height. In the case of front wheel drive vehicle, the tractive force is acted on the front wheels at the contact point on the road. It is reversed in the case of rear-wheel drive.

Effect of combined angle

The effect of combined angle variation on the scrub radius. If the scrub radius is not equal to zero, a torque acted on the wheel turns away from the straight ahead position.

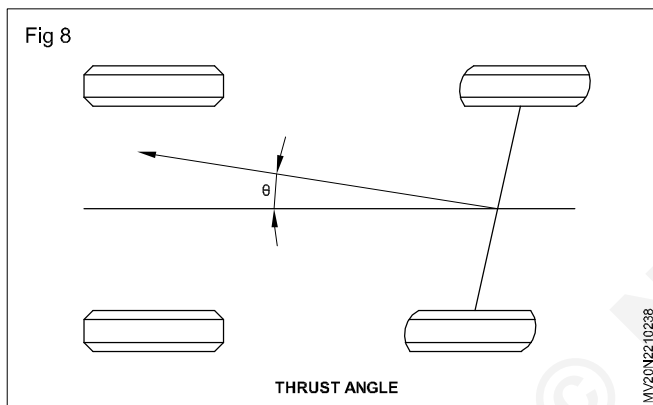
Effect of scrub radius

- i When the scrub radius is negative, the wheel is caused to toe-in

- ii When the scrub radius is positive, the wheel is caused to toe-out
- iii When the scrub radius becomes zero, the wheel is kept in straight position without any toe-in or toe-out. This position is known as centre point steering. In case the centre point steering is implemented, any small change in the combined angle will cause the point of intersection alternately above and below the ground. Thus, toe-in or toe-out is caused. A large scrub radius will cause greater torque required to turn the wheel. This means, higher loads on the steering linkage and suspension components act. It results in greater wear of steering linkage and unequal braking on the front wheels.

The scrub radius is the parameter to provide necessary road feel to the driver. The recommended value of combined angle is from 9-10° and the scrub radius should be up to about 12mm.

Thrust angle (Fig 8)



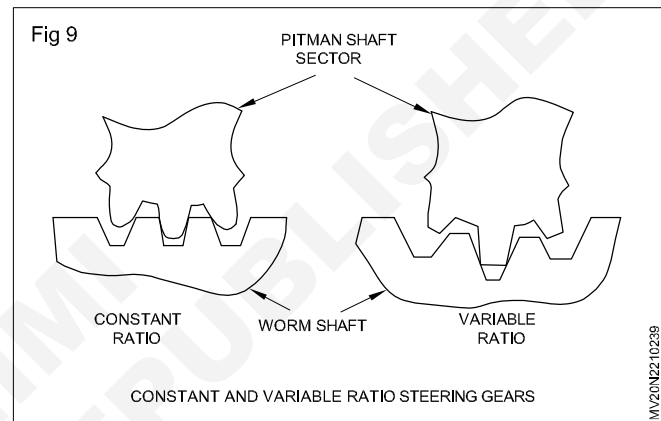
Thrust angle is the direction that the rear wheels are pointing in relation Fig 8 to the centerline of the vehicle. The vehicle will "dog track" (goes slightly outwards) down the road if the thrust angle is not zero and the steering wheel will not be centered.

Turning Radius

It is the radius of circle on which the out side wheel moves when the front wheels are turned to their extreme outer position. The radius is 5 to 7.5 meters for buses and trucks. The turning radius is usually proportional to the wheel base of the car, because the maximum rotation of the steering knucle is seldom more than 35 degrees.

Variable steering ration

The number of input turns per output turn of the steering gearbox is called the gearbox ratio. steering gears can have a constant or a variable ratio. The sector teeth in a constant ratio unit are identical in size and shape, while the sector of a variable ratio unit has larger center teeth Fig 9. This makes the steering faster in turns than in a straight direction. Variable ratio is normally used only in power-steering units.



Suspension system

Objectives: At the end of this lesson you shall be able to

- state the function of the suspension system
- describe unsprung of and sprung weight
- list out the different types of suspension forces.

While moving on the road the wheels are thrown up and down due to the unevenness of the road. This results in strain on the components of the vehicle and the passengers. To prevent damage to the working parts and also to provide riding comfort, suspension is used in the vehicles.

Functions of the suspension system

- It maintains the body level.
- It prevents road shocks reaching the frame and other units and provides riding comfort to passengers.
- It gives cushioning effects.
- It transfers the driving torque to wheels of the dead axle.
- It transfers the braking torque to the chassis.

Unsprung weight and sprung weight

Unsprung weight is largely a function of the design of a vehicle's suspension and the materials used in the construction of suspension components. Beam axle suspension, in which wheels on opposite sides are connected as a rigid unit, generally have greater unsprung weight than independent suspensions systems, in which the wheels are suspended and allowed to move separately. Heavy components such as the differential can be made part of the sprung weight by connecting them directly to the body (as in a de Dion tube rear suspension). Light-weight materials, such as aluminium, plastic, carbon fiber, and / or hollow components can provide further weight reductions at the expense of greater cost and/or fragility.

In a ground vehicle with a suspension, the unsprung weight (or the unsprung mass) is the mass of the suspension, wheels or tracks (as applicable) and other components directly connected to them rather than supported by the suspension. (The mass of the body and other components supported by the suspension is the sprung weight includes the mass of components such as the wheel axles, wheel bearings, wheel hubs, tires and a portion of the weight of drive shafts, springs, shock absorbers, and suspension links. Even if the vehicle's brakes are mounted outboard (i.e., with the wheel), their weight is still considered part of the unsprung weight.

Scooter-type motorcycles use an integrated engine-gear-box-final drive system that pivots as part of the rear suspension and hence is partly unsprung. This

arrangement is linked to the use of quite small wheels, further affecting the reputation for road - holding.

Driving uneven surface

If a vehicle is driven over a hump at high speed, the body initially remains balanced due to the large mass. The wheel, with its small mass in relation to the body, is accelerated upwards very rapidly, and in doing so it compresses the spring. Only the force corresponding to this spring travel is acting on the body.

On the other side of the hump, the wheel is accelerated downwards by the preloaded spring. Only the load relief of the spring corresponding to the bump acts on the body.

If the force the wheel is greater than the initial tension of the spring, the wheel loses adhesion on the road surface for a short time, as the initial spring tension is insufficient to move the wheel downwards quickly enough.

To achieve good driving safety and the best possible comfort, the unsprung mass should be as small as possible.

Body vibration frequencies

These can be determined by the vibration at the front or rear of the vehicle. A complete vibration consists of the spring compression and rebound process. The number of vibrations per minute then gives the body-vibration frequency. Vibration dampers do not control the vibration frequency, the amplitude of oscillation is downrated by the greater resistance. In contrast, the mass plays a large part. The heavier the vehicle or the larger the payload, the lower the vibration frequencies become.

Frequency: This is the number of vibrations per second. Since a body does not vibrate very quickly, the number of vibrations is also given per minute (vibration frequency, body-vibration frequency).

A large mass and soft springs result in a low frequency (vibration frequency) and a large spring level.

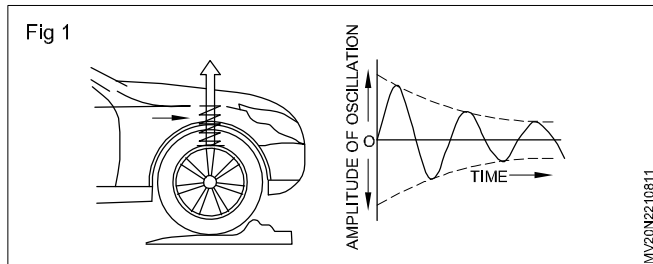
Damping vibration

If the wheel of a motor vehicle travels over an obstacle, both the body and the wheel start to vibrate. The upwards movement of the wheel causes the helical spring to be compressed, the spring force accelerates the body upwards. The spring force generated when the spring expands slows the body down again, the upper reversing point is reached. The body is accelerated downwards by the weight, beyond the rest position. The spring is

compressed (tightened), the resulting spring force slows the movement of the body to the lower reversing point.

The travel from the upper to the lower reversing point of a vibration is known as the amplitude of oscillation.

This motion sequence is repeated until the kinetic energy is converted into heat by spring and air friction. (Fig 1)



Location of suspension system

The suspension system is provided in between the axles and chassis frame. There are two type of axles generally used in motor vehicles. They are:

1 **Solid Axle:** A solid axle (also called live axle or beam axle) houses the vehicle differential inside the axle itself connected to the wheels by rigid half shaft.

The entire axle moves as one, so if a left wheel drops into a pot hold, right wheel moves upto response.

2 **Dead Axle:** The axle shaft does not transmit power to the wheels and if it is provided for supporting the wheels and the suspension parts then it is called as dead axle.

Leaf springs: Leaf springs were the first type of suspension spring used on automobiles, today they are generally found on light-duty & heavy trucks, vans, and some passenger cars. There are three basic types of leaf springs: multiple leaf, monoleaf and fiber composite.

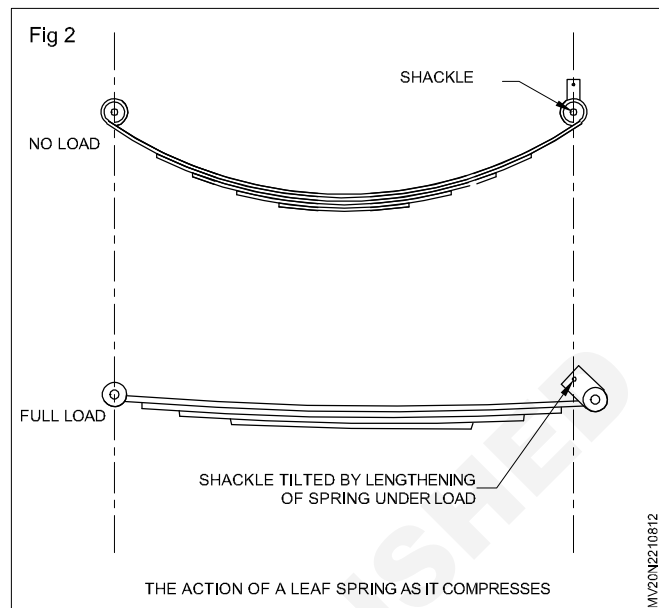
Multiple-Leaf springs: Multiple-leaf springs consist of a series of flat steel leaves that are bundled together and held with clips or by a bolt placed slightly ahead of the center of the bundle. One leaf called the main leaf, runs the entire length of the spring. The next leaf is a little shorter and attached of the main leaf. The next leaf is shorter yet and attaches to the second leaf, and so on. This system allows almost any number of leaves to be used to supported the vehicle's weight. (Fig 2)

Multiple-leaf springs have a curve in them. This curve, if doubled, forms an ellipse. Thus, leaf springs are sometimes called semielliptical or quarter elliptical. The semi or quarter refers to how much of the ellipse the spring actually describes. The vast majority of leaf springs are semielliptical.

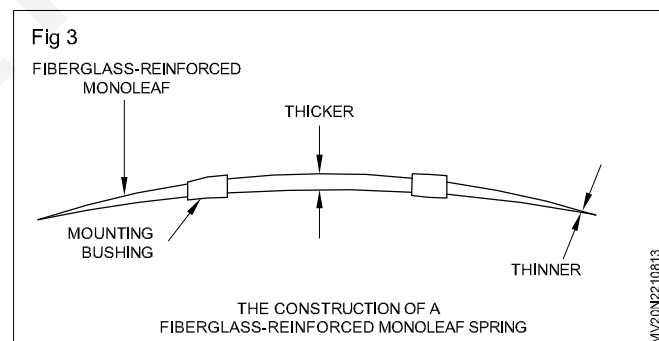
Leaf springs are typically mounted at right angles to the axle.

Monoleaf springs: Monoleaf or single-leaf springs are usually the tempered plate type with a heavy or thick center section tapering off or both ends. This provides a

variable spring rate for a smooth ride and good load-carrying ability. In addition, single-leaf springs do not have the noise and static friction characteristic of multiple-leaf springs.



Fiber composite springs: While most leaf springs are still made of steel, fiber composite types are increasing in popularity (Fig 3). Some automotive people call them plastic springs in spite of the fact that the springs contain no plastic at all. They are made of fiberglass, laminated and bonded together by tough polyester resins. The long strands of fiberglass are saturated with resin and bundled together by wrapping (a process called filament winding) or squeezed together under pressure (compression molding).



Fiber composite leaf springs are incredibly lightweight and possess some unique ride control characteristics. Conventional monoleaf steel springs are heavy weights, tipping the scale at any where

Coil spring: These are mainly used as compression springs in passenger care. Generally open coil helical springs are used in vehicles.

Advantages: Low weight, low space requirements,

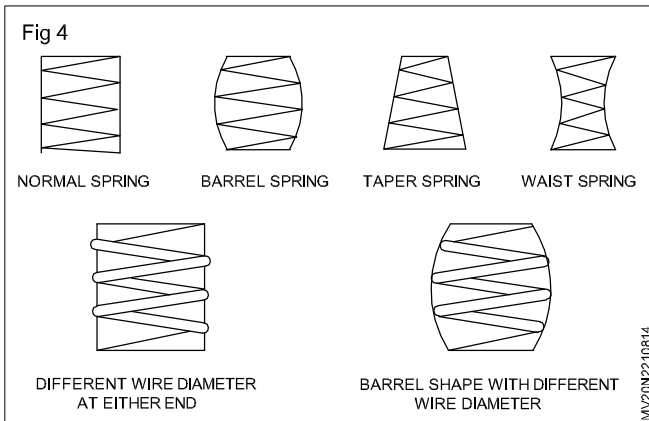
Disadvantages: Almost no damping, no transmission of wheel forces (longitudinal and transverse forces).

Helical springs usually have a linear spring characteristic. Soft helical springs differ from hard helical springs in that they have a:

- Smaller wire diameter
- Larger spring internal diameter
- More loosely wound coil

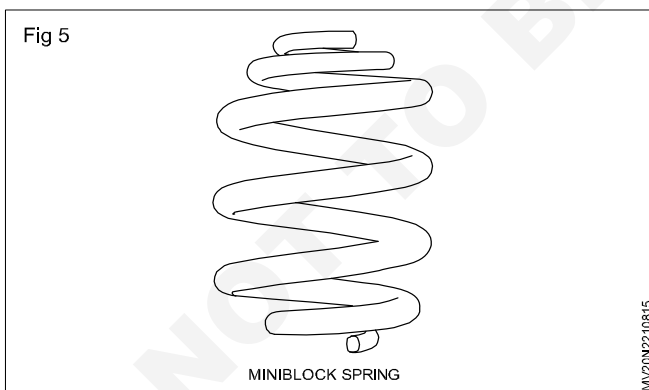
Helical springs with a progressive characteristic must be fitted to allow a greater payload and adequate comfort when the vehicle is unladen. This can be achieved with the following:

- Different sizes of the internal diameter, e.g. taper shape, barrel shape, waist shape
- Different wire diameters. (Fig 4)



Types of helical springs

The barrel-shaped miniblock spring has the advantage over the cylindrical helical spring that the spring coils cannot touch when the spring is compressed while the vehicle is in motion because each coil lies inside the larger ones forming a spiral (Fig 5). This means that the spring can be shorter without sacrificing a long spring range for a high load-carrying capacity. The miniblock spring incorporates all the options for a progressive spring.

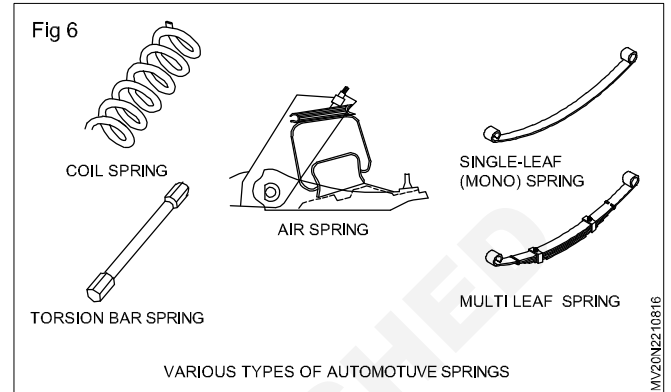


Helical springs cannot transfer wheel guidance forces.

They are therefore only used in axle designs in which the motive, braking and lateral forces are transferred by other elements (control arm, trailing arm McPherson-suspension strut). Vibration dampers are nowadays only rarely used inside the helical spring (Fig 5) because fitting and removal are very time consuming.

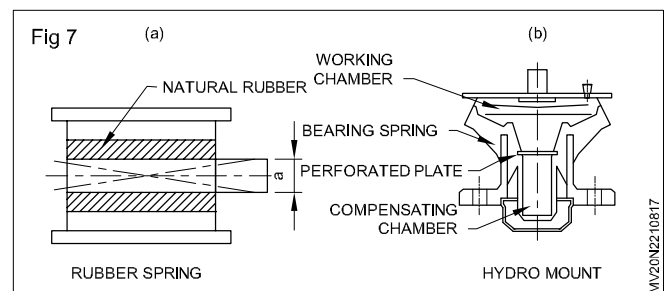
Rubber spring

Natural and synthetic rubber are very elastic and have high internal damping characteristics. Hence it is used with vehicle springs. The high internal damping and elasticity of the rubber is used to intercept high-frequency vibrations, e.g. the control arm, are mounted in rubber cushions. This also improves the transverse suspension. (Fig 6)



Rubber spring & Hydro mount

Hydraulically damped elastomer mountings (hydro mount, Fig 7) are used instead of simple rubber springs to prevent vibrations of various frequencies from being transferred from the engine to the body. These consist of an elastic bearing spring made from natural rubber, which forms the mechanical connection between the engine and the body, and a hydraulic section, which consists of a working chamber and a compensating chamber and which is filled with hydraulic fluid. A perforated plate between the two chambers impedes the flow of fluid into the compensating chamber and damps any vibrations that have been transferred here.

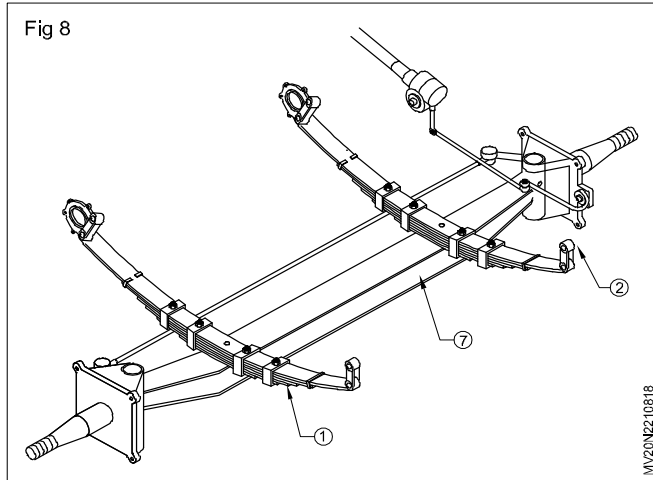


Different types of suspensions system

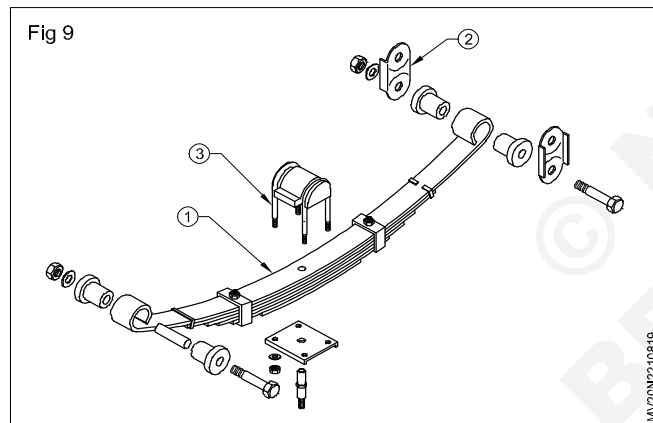
The following types of suspensions are used in automotive vehicles.

- Conventional suspension system (fixed axle suspension)
- Independent suspension system
- Air suspension system
- Rubber spring suspension system

Conventional suspension system (leaf spring) (Fig 8)



In this system, a set of leaf springs (1) is used which connect the frame and axle (7). One end of the spring is fixed to the frame (8) and the other end is anchored by the shackle (2). The spring is mounted on the axle by 'U' bolts (3) (Figs 9 & 10). When the vehicle moves on bumps or ditch etc. the spring (1) elongates and the shackle (2) moves backward to accommodate the change in the spring length.



The following types of leaf springs are used.

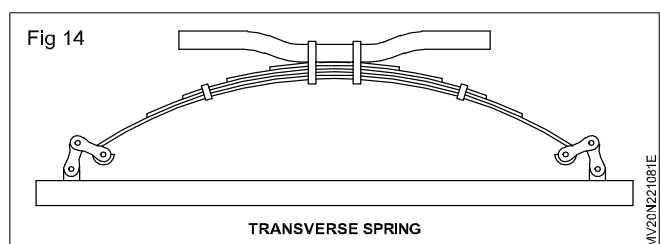
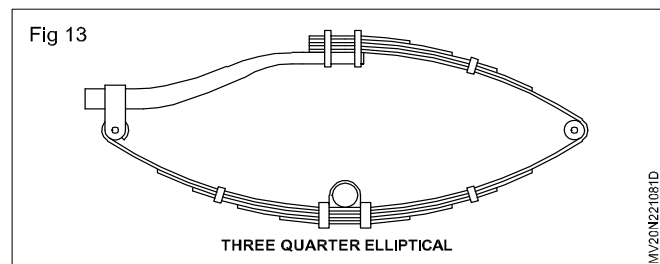
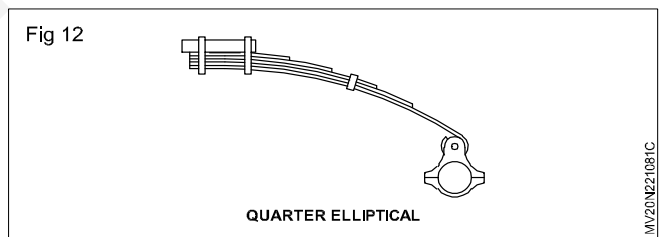
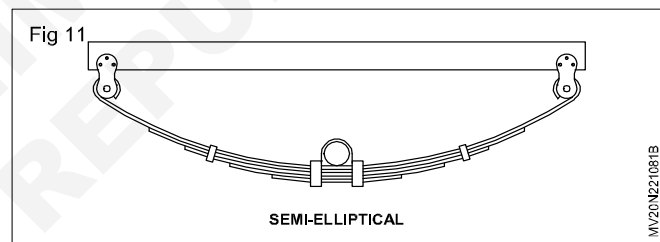
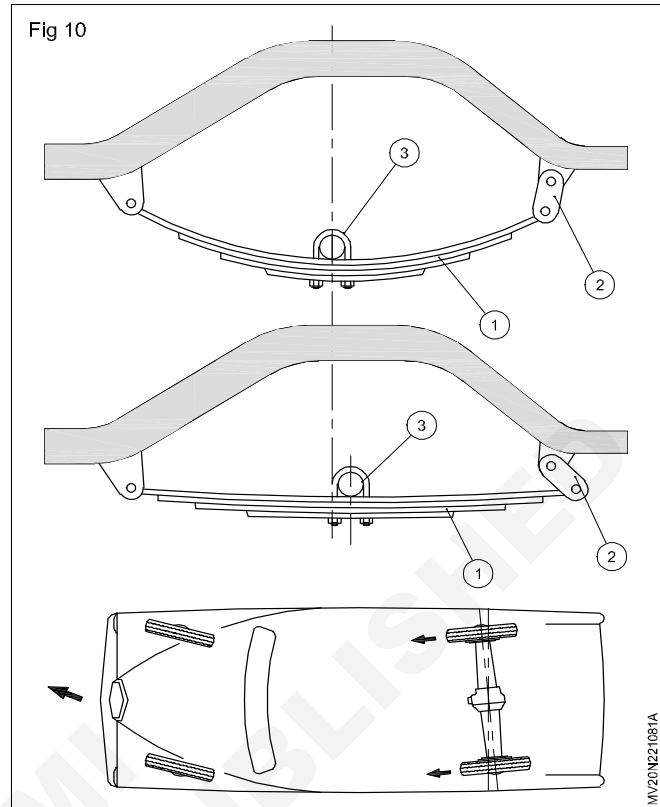
- Semi-elliptical spring (Fig 11)
- Quarter elliptical spring (Fig 12)
- Three quarter elliptical spring (Fig 13)
- Transverse spring (Fig 14)
- Full elliptical spring (Fig 15)

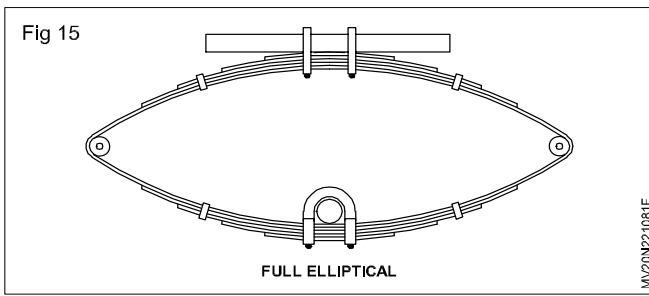
In some vehicles a helper spring is used to relieve heavy load from the main spring assembly. The helper spring (4) is mounted on the top of the main spring assembly and its ends are kept loose. When the main spring deflects upward under heavy load, these loose ends rest against the brackets (5). A rubber buffer (6) is mounted on the frame so in the event of a heavy jerk spring does not hit the chassis frame. (Fig 16)

Non reactive suspension arrangement on multi-axle vehicles (Fig 17)

The suspension allows the load on the spring of one axle to be shared by the spring of the other, when an

uneven road surface is encountered and result in minimal vertical movement of the frame.





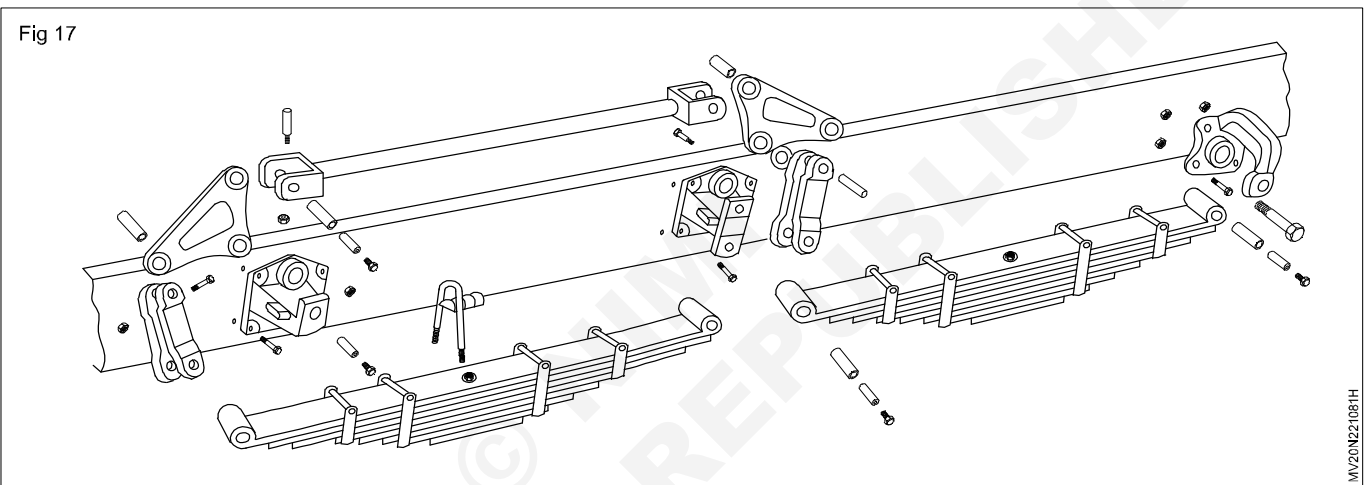
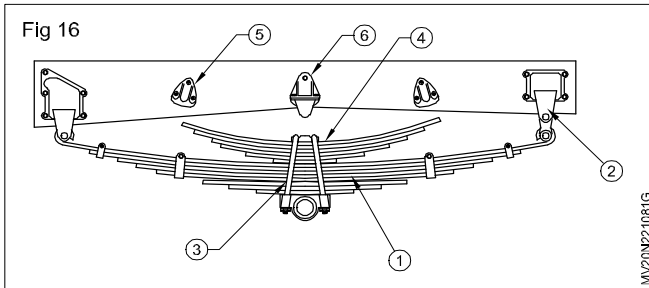
The braking efficiency in both the rear wheels are good, because of good road grip, due to balancing action of bell crank levers and connecting tie rod (3)

Weweller suspension

These suspension is mostly used for front springs in commercial passenger vehicle for better riding comfort and spring life.

The main purpose of rubber spring attachment is to prevent metal to metal contact between spring and chassis, by making use of rubber as a shock absorbing medium. Another advantage is prevention of rattles.

Rubbers in which the ends of springs are enclosed are fitted in the spring supports, attached to the chassis frame.

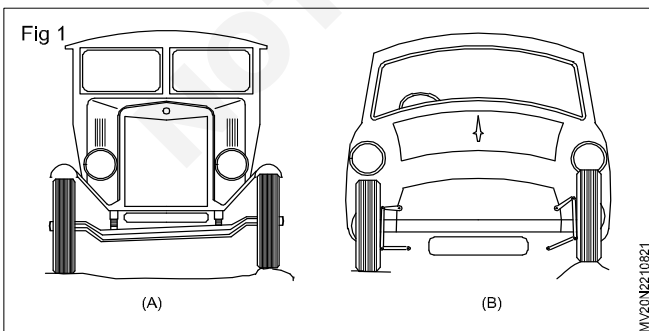


Independent suspension system

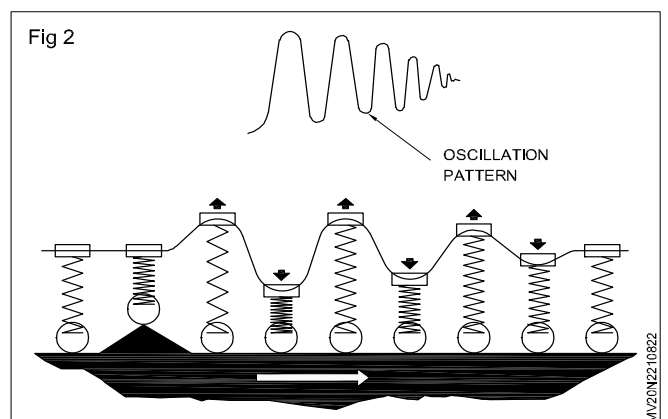
Objectives: At the end of this lesson you shall be able to

- state the constructional features of the coil spring suspension
- state the constructional features of the torsion bar suspension system
- state the constructional features of the strut suspension system
- state the adaptive air suspension operation
- state the electronic air suspension system.

Independent suspension system (Figs 1 & 2)

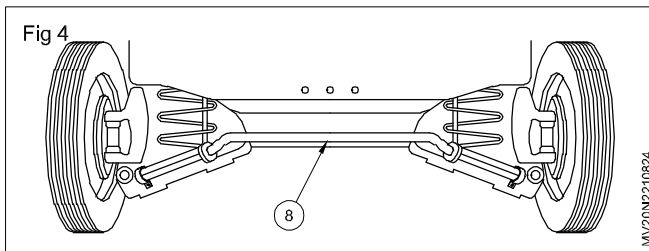
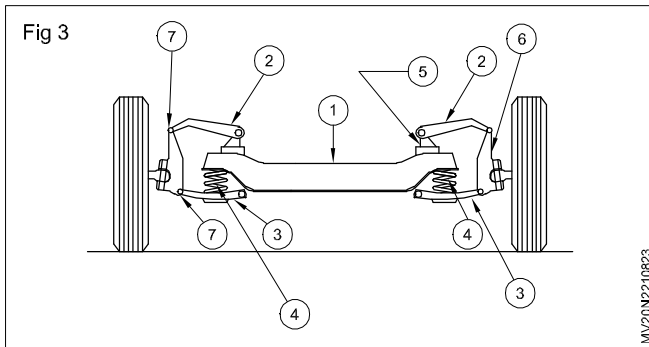


In this type, the up or down movement of one wheel does not affect the other wheel (B). Each wheel moves independently on pot holes and bumps unlike in rigid suspension (A). The following types of independent suspension systems are used.



- Coil spring suspension
- Torsion bar suspension
- Strut type suspension

Coil spring suspension (Figs 3 & 4)



A leaf spring does not deflect quickly due to stiffness under light load. A coil spring responds quickly to road shocks. It can store more energy than a leaf spring and it is light in weight.

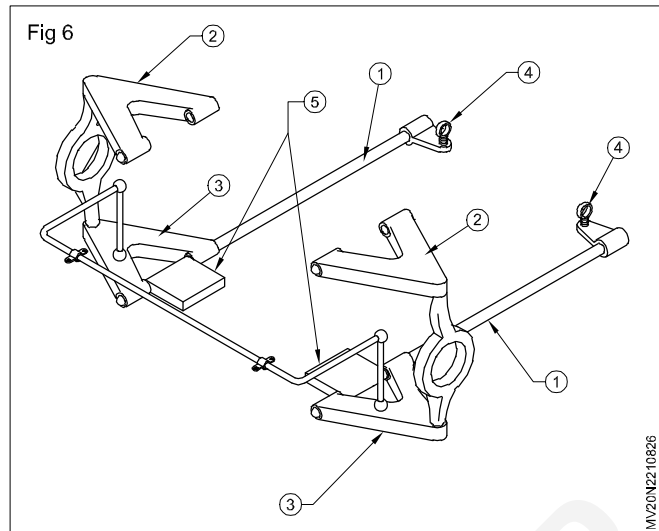
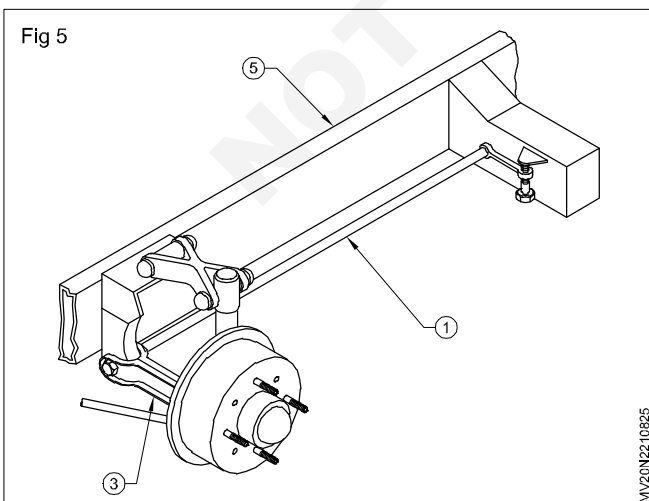
In the coil spring suspension, each wheel is independently supported by a coil spring. Shocks are sustained by each spring.

Construction

A coil spring suspension system comprises a frame (1), an upper control arm (2), a lower control arm (3), a coil spring (4) and a shock absorber (5). The coil spring (4) is seated on rubber pads between the lower control arm (3) and the upper control arm (2) and the frame. A steering knuckle (6) is pivoted at each end of the upper and lower control arms through ball joints. (7) This allows for angular movement of linkages. This suspension is called wish-bone suspension.

A stabilizer bar (8) is used on the radius rods to guide the cushioning motion of the springs.

Torsion bar suspension (Figs 5 & 6)

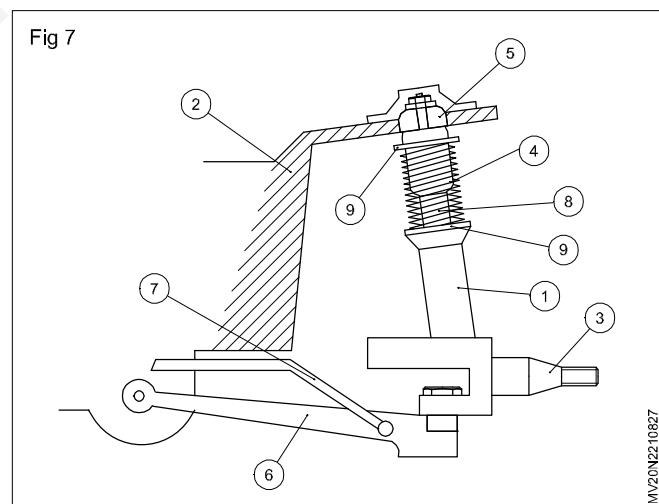


In this suspension, a torsion bar (1) is used as a spring between the upper (2) and lower (3) control arms. The torsion bar stores energy like a coil spring by twisting when the vehicle goes over a pot hole. When the wheel comes on plain surface the torsion bar untwists and comes to its normal position.

A torsion bar (1) is fixed on each side of the frame (5). One end of this is connected to the wheel hub spindle and the other end is connected to the frame cross-member. As the wheel moves on a pothole the lower wish-bone (3) tries to rotate the torsion bar (1). The torsion bar (1) twists and tries to keep the lower control arm (3) in a straight position.

In this system an eye bolt adjuster (4) is provided to adjust the height of the lower control arm (3). This system is used in Ambassador cars.

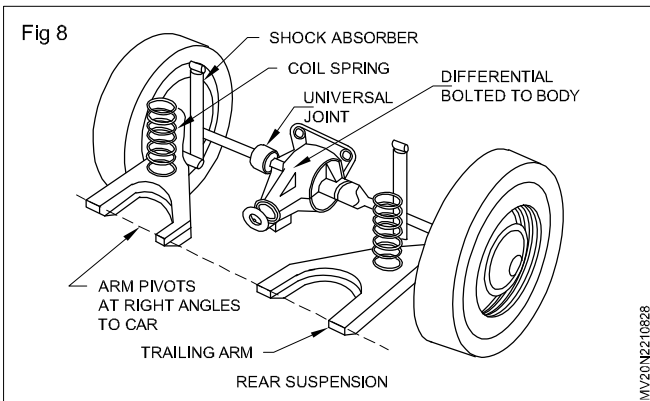
Strut type suspension (Fig 7)



In this type a strut (1) is mounted between the frame (2) and the stub axle (3). A shock absorber (8) is fixed inside the strut (1). A coil spring (4) is mounted on two collars (9). A rubber pad (5) is used between the upper end of the strut (1) and the frame (2). A transverse link (7) is attached to the frame (2) and stub axle (3) by a ball joint or rubber pad. It controls the wheel path. A stabilizer bar (6) connects the two lower transverse members.

This suspension system is known as MCPHERSON strut type suspension. It is simple in construction and light in weight. It allows more deflection of the front wheel without any effect on the steering.

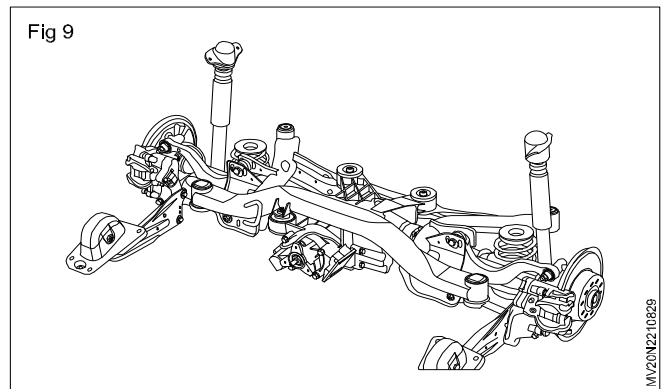
Rear independent suspension (Fig 8)



Independent coil-spring rear suspensions can have several control arm arrangements. For example, A-shaped control arms are sometimes employed. When the wide bottom of a control arm is toward the front of the car and the point turns in to meet the upright, they are called trailing arms. When the entire A-shaped control arms are mounted at an angle, they are known as semi trailing control arms or multilink suspensions. Coil springs are used between the control arm and the vehicle body. The control arms pivot on a cross member and are attached at the other end to a spindle. A shock absorber is attached to the spindle or control arm.

Some vehicles use a rear-suspension system that used a lower control arm and open driving axles. A cross member supports the control arms, while the tops of the shock absorbers are mounted to the body. The springs are set in seats at the bottom and tops of the cross member.

Multilink rear suspension (Fig 9)



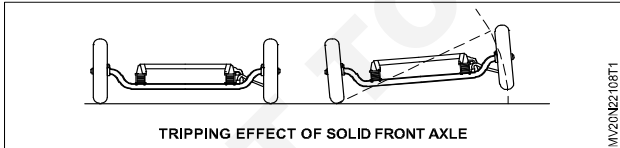
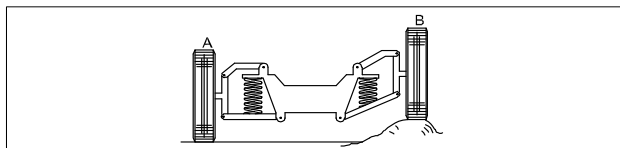
A multilink rear suspension uses several control arms to guide the wheel. Different models feature different types of multilink rear suspensions that satisfy the varying demands of vehicle dynamics, ride comfort, and space requirements. These include the double-wishbone rear suspension, trailing-link double-wishbone rear suspension, and trapezoidal-link rear suspension.

In the double-wishbone suspension, the wheel is guided by two triangulated lateral control arms (the wishbones) and a tie rod. The suspension strut is attached to the lower wishbone to provide vertical support.

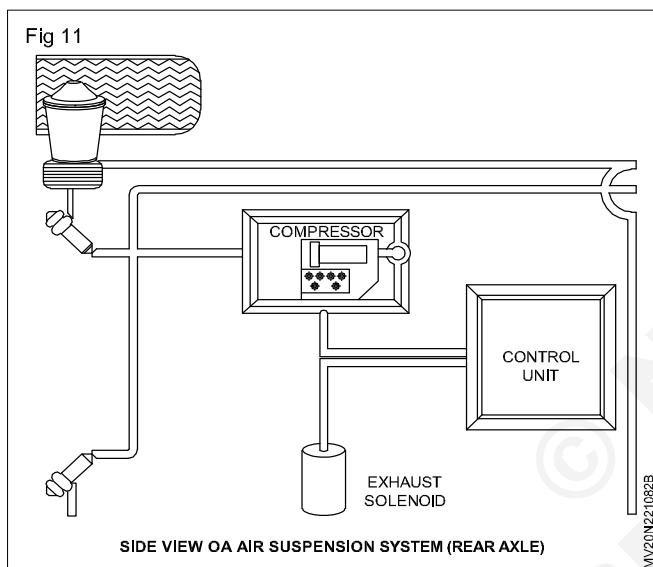
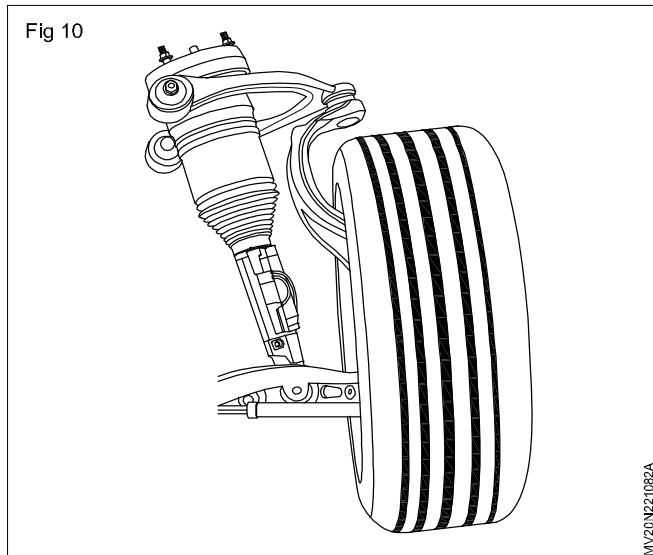
The trailing-link double-wishbone suspension has a trailing link that also carries the wheel and upper and lower wish bones. The spring is located on the trailing link ahead of the center of the wheel; the shock absorber is behind it.

The trapezoidal-link rear suspension permits excellent performance, handling, and comfort. The rear wheel is fixed by an upper lateral control arm and a trapezoidal lower link with a tie rod behind it. For reduced weight, the trapezoidal link and upper control are hollow aluminium castings.

Comparison between rigid and independent suspension

Rigid axle suspension system	Independent suspension system
	
<ol style="list-style-type: none"> 1 This is a simple arrangement. 2 In this system leaf springs are used. The wheels swivel on each end by a pivot arrangement between the axle and the wheel spindle. 3 The up and down movement of either of the front wheels causes a vertical tipping effect on the other wheel as these wheels rotate on a common axle. 4 Shocks are transmitted from one wheel to the other wheel. 5 This system does not allow more deflection of the front wheels and have some effect on steering. 6 In this system the spring weight is more. 7 Vibration damping is less effective. 8 Because of its simplicity, it requires less maintenance, and, therefore, the maintenance cost is less. 	<ol style="list-style-type: none"> 1 This is complicated as compared to the rigid axle suspension. 2 In this system a coil spring is used on each side. 3 In the independent suspension system each front wheel is free to move up and down with minimum effect on the other wheel. 4 Shocks are not transmitted from one wheel to another. 5 This system allows more deflection of the front wheels without any effect on the steering. 6 Spring weight is less. 7 Vibration damping is more effective. 8 Because of its complexity, it requires more maintenance, thereby, the maintenance cost is more.

Adaptive air suspension operation (Fig 10 & 11)



Additionally, the air suspension allows the speed-dependent lowering of the body-this change in ride height means a low center of gravity and significantly increased directional stability as a result. The vehicle's handling characteristics are improved at the same time. Some European vehicles have air suspension struts at all four wheels.

The information obtained from sensors on the axles and acceleration sensors on the body is evaluated in the adaptive air suspensions central control unit. This computer can control the adjustment of the individual shock absorbers in milliseconds, depending on driving situation.

Provided no higher damping forces are required - for instance when driving straight ahead on good roads - the damper setting remain comfortably soft.

Specific adjustments to the damping force at individual wheels eliminates body movement, which could affect occupant comfort.

The height sensor uses the induction principle to constantly monitor the distance between the vehicle's axle and its chassis.

When the ignition is switched on, when the vehicle's door is opened before ignition, the control system is activated. The height sensor uses the induction principle to constantly monitor the distance between the vehicle's axle and its chassis.

When the vehicle is being loaded, unloaded, or lowered due to driver command or vehicle speed, the electronic readings from the height sensor monitor the change. This is picked up by the electronic control unit and compared to the stored reference values.

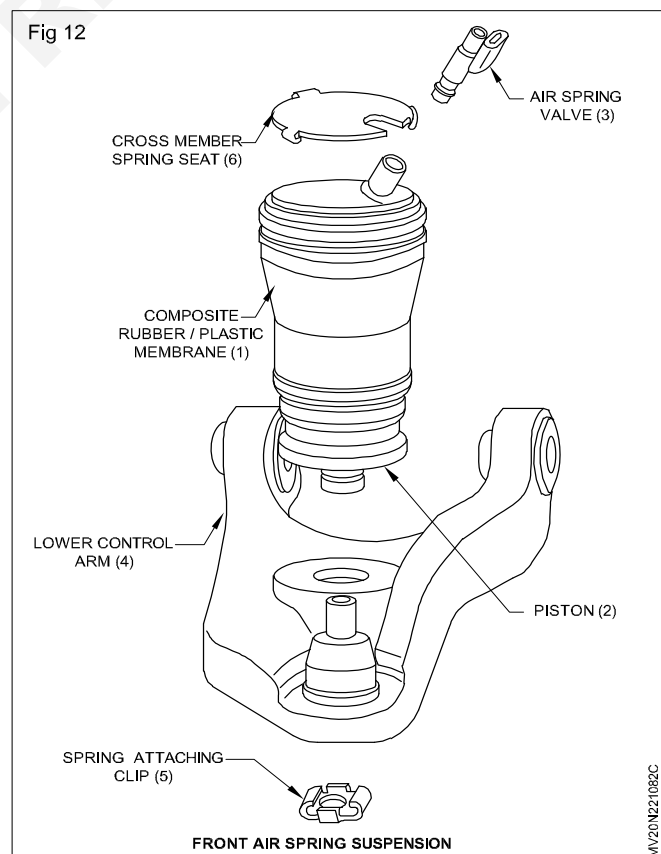
The ECU either activates the electric motor of the compressor, or the exhaust solenoid valve. This also requires the solenoid valve block to be actuated, in order to maintain the required level. The corner solenoid valves are subject to stringent leakage requirements to maintain the vehicle's height even without system operation.

When the vehicle is being loaded, the compressor delivers air into the four air suspension bellows, until the normal level has once again been reached. For additional air delivery or rapid response, the reservoir solenoid valve is opened and air flows directly from the reservoir.

When the vehicle is being unloaded, the solenoid valve block is activated. This results in airflow from the air suspension bellows being removed via the air dryer solenoid valve in the compressor, then via the relay valve. The air is then exhausted into the atmosphere.

Any dynamic air spring movement while the vehicle is in motion is ignored and does not cause the control system to respond.

Aaptive air suspension system (Fig 12)



In an air suspension system, the air springs replace the coil springs in a conventional suspension system. These air springs have a composite rubber and plastic membrane (1) that is clamped to a piston (2) located in the lower end of the spring. An end cap is clamped to the top of the membrane and air spring valve (3) is positioned in the end cap. The air springs are inflated or deflated to provide a constant vehicle trim height. Front air springs are mounted between the control arms (4) and the cross member (Fig.13). The lower end of these air springs is retained in the control arm with a clip (5) and the upper end is positioned in a cross member spring seat (6).

The rear air springs are the same as the front air springs except for their mounting. The lower ends of the rear springs are bolted to the rear suspension arms and the upper ends of these springs are attached to the frame.

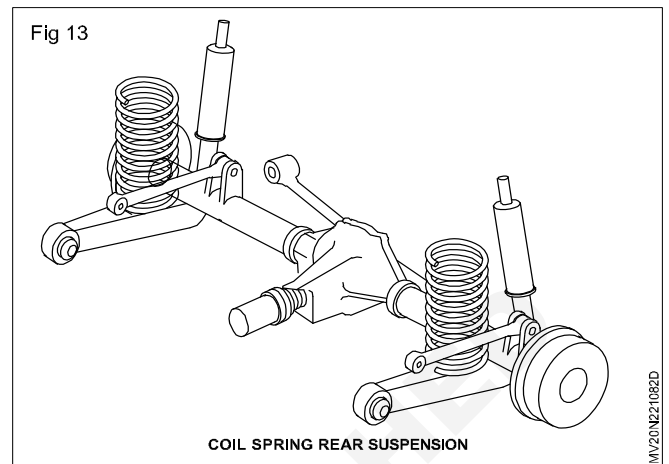
An air spring valve (3) is mounted in the top of each air spring. These valves are an electric solenoid - type valve that is normally closed. When the valve wiring is energized, plunger movement opens the air passage to the air spring. Under this condition, air may enter or be exhausted from the air spring. Two O-ring seals are located on the end of the valves to seal them into the air spring cap. The valves are installed in the air spring cap with a two stage rotating action similar to a radiator pressure cap.

Never rotate an air spring solenoid valve to the release slot in the cap fitting until all the air is released from the spring. If one of these solenoid valves are loosened with air pressure in the spring, the air pressure drives the solenoid out the spring with extreme force. This action may result in personal injury.

Coil spring rear suspension

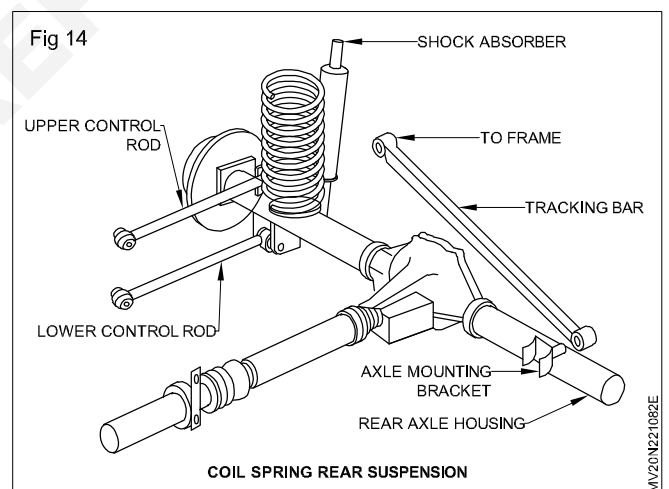
Some rear - wheel drive vehicles have a coil spring rear suspension. Upper and lower suspension arms with insulating bushings are connected between the differential housing and the frame (Fig 14). The upper arms control lateral movement and the lower trailing control arms absorb differential torque. In some rear suspension systems, the upper arms are replaced with strut rods. The front of the upper and lower arms contain

large rubber bushings. When strut rods are used in place of the upper arms, both ends of these rods contain large rubber bushings to prevent noise and vibration transfer from the suspension to the chassis. The coil springs are usually mounted between the lower suspension arms and the frame, while the shock



absorbers are mounted between the back of the suspension arms and the frame.

Some rear suspension systems have a tracking bar connected from one side of the differential housing to the chassis to prevent lateral chassis movement (Fig.16). Large rubber insulating bushing are positioned in each end of the tracking bar. A tracking bar may be referred to as a panhard or Watts rod.



Air suspension

Objectives: At the end of this lesson you shall be able to

- state air suspension
- state the major parts of air suspension
- explain the function of the air supply system
- explain the construction of air bag
- describe the construction of height control valve (HCV)
- describe the functions of air suspension.

Air suspension

An air suspension supports the vehicle on the axles with an arrangement of air bags instead of some type of steel spring, leaf or coil, or some type of torsion spring

arrangement. The air bags are sometimes referred to as air springs or bellows. Suspensions that have steel or torsion springs that are supplemented by the use of air bags are not considered air suspensions. There are

combination systems that have both air and steel springs. Usually the air suspension components are used on the rear of the vehicle. Depending on the situation, this type of air suspension will probably have to be dealt with for leveling purposes.

Normally, the air suspension is just one part of the air system on the vehicle. Most vehicles with an air suspension also have air brakes along with other equipment that may be operated with air.

Major components of air suspension

An air suspension has three basic components

- i Air supply system
- ii Air bag (bellows)
- iii Height control valve (HCV)

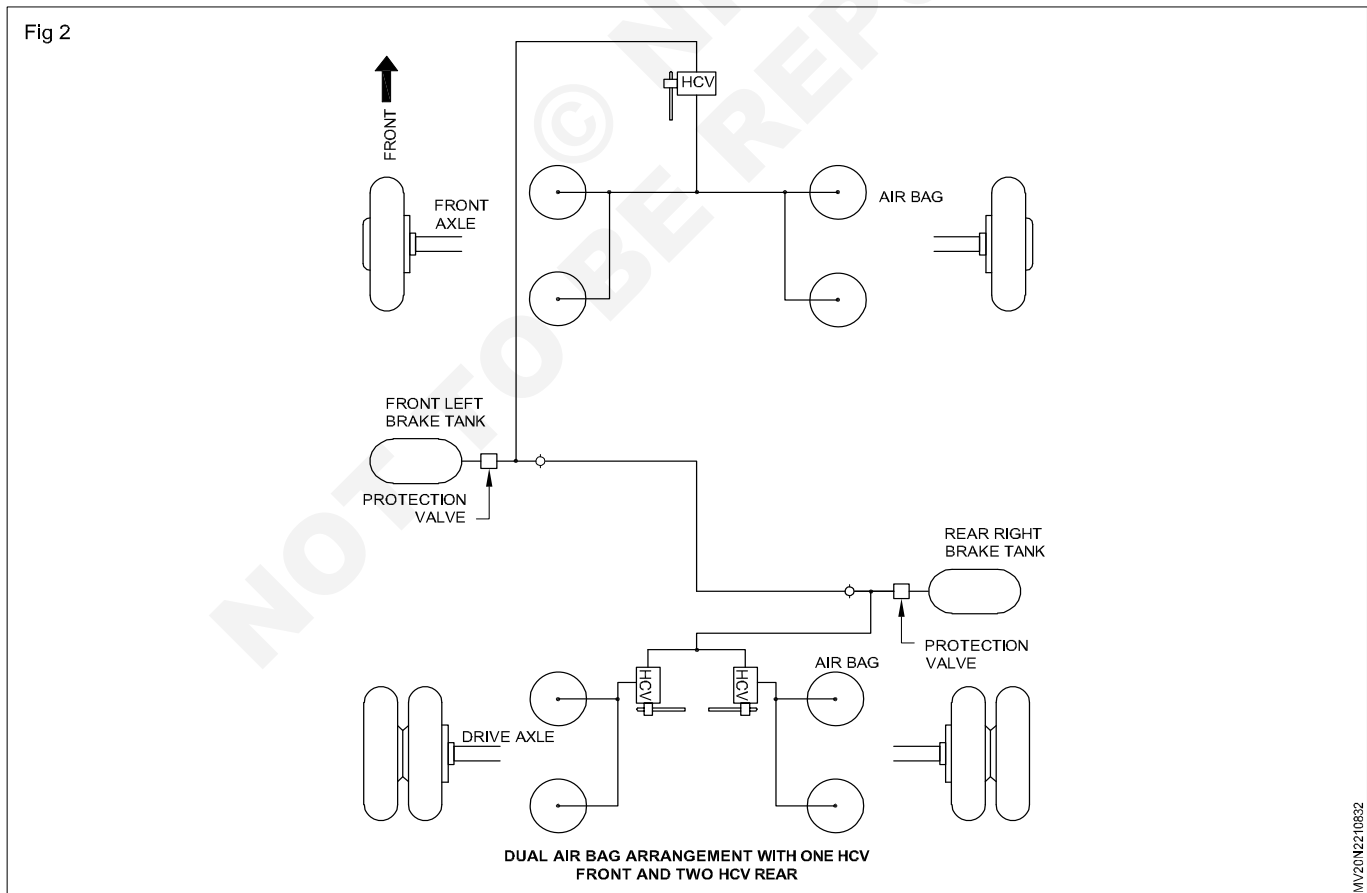
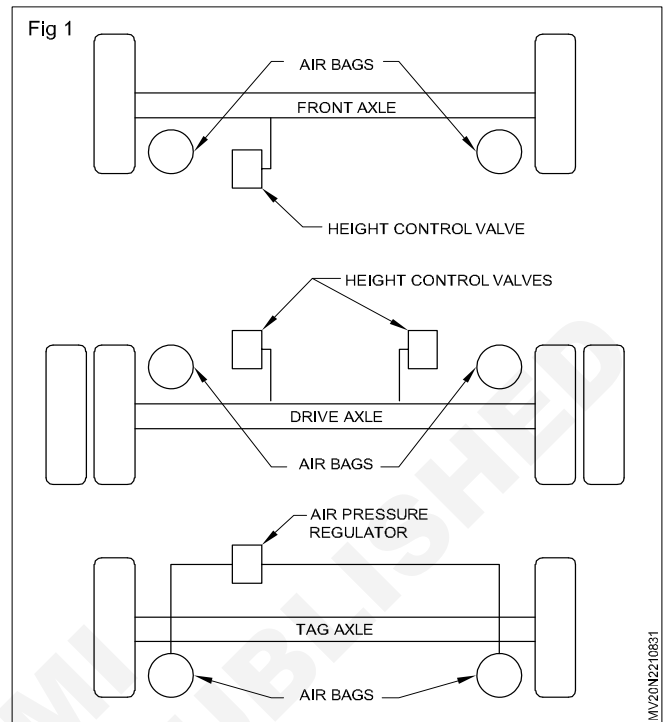
Air supply system

The air supply: The air supply is engine air compressor, the air tanks, air valves and air lines. The engine air compressor supplies air for every piece of air equipment on the vehicle. The maximum pressure supplied by the compressor varies. For many years, the air supply was maintained around 120 to 125 psi but on some newer, larger vehicles this has been increased to 135 psi.

Air bags (bellows) (Figs 1 & 2) : Air bags are simply a rubber bladder that holds air. Air bags are also referred to as air springs or bellows. The air bags are located

between the frame of the vehicle and the vehicle axles. Air bags are rated for weight and pressure capacities.

Single air bag arrangement with one HCV front and two HCV rear with tag axle



Air bags placement and arrangements vary amongst chassis manufacturers. At the very least, there will be one air bag for each side of each axle in the vehicle.

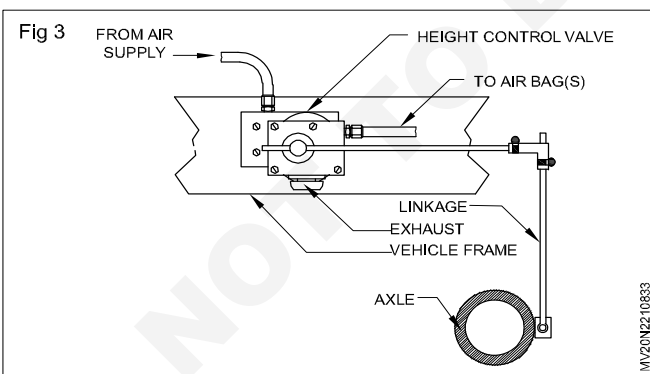
There can be two air bags for each side of the axles. Some manufacturers use two air bags for each side for the drive axle and some use two air bags for each side

of the drive and front axles. Space between air bags for side to side placement also varies. Some place the air bags outboard as far as they can and some have the bags closer together. When two bags per side are used, one will be in front of the axle and the other behind the axle. Again, spacing can vary.

Most air bags will have some device such as a cone that keeps that air bag from being crushed or damaged when fully deflated. Inflating air bags is limited to the available air pressure to the suspension system. How much lift the air bags will have varies with vehicles and air bags, but the average lift the air bags will supply, when maximum available system air pressure is used, is between 5 1/2 and 6 1/2 inches from a totally deflated state.

Construction of height control valves: The height control valves (HCV from now on) (Fig 3) are kind of the brains of the system. They dictate how much air is in the air bags. This dictates the height the vehicle sits at, thus Height Control Valve. Most HCVs are mechanical valves but electronic height control mechanisms are available. The HCV is mounted to the frame of the vehicle. An L shaped linkage attaches the HCV to the axle. As the axle moves up and down in relationship to the frame, the linkage moves the valve or electronic mechanism. With mechanical valves, there is an air line from the air supply to the HCV. There is an air line from the HCV to the air bag or bags that it controls. The HCV also has an exhaust port. When the connecting linkage moves up, the HCV connects the air supply to the air bag(s) to the exhaust port, deflating the bag(s). This controls the height of the vehicle. If the Height Control is electronic, as the control linkage moves up or down, an electronic sensor sends information to an electronic control. These controls will open or close air solenoid valves as needed to inflate or deflate the bags.

Typical height control valve mounting and connection to axle



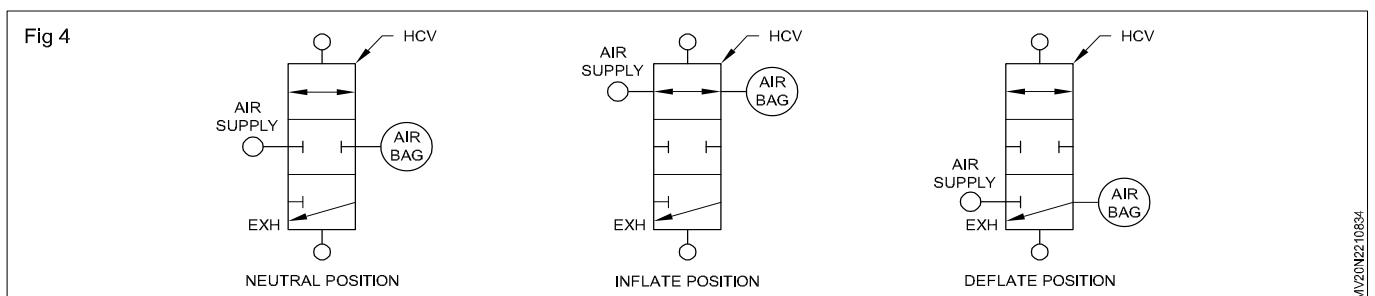
There are two basic styles of mechanical HCVs, the instant response valve (IR valve) and the delay valve. These names are accurate descriptions of how the valves react. The IR valve will start to inflate or deflate the air bags as soon as the valve activating lever moves. The delay valve has a slight delay when the activating lever moves before inflating or deflating the air bags.

The number and arrangement of HCVs used on a suspension varies a little. There are normally three HCVs used on a suspension. Either there is one for the front axle and two for the rear, (most common arrangement) or some use two on the front axle and one on the rear. A few chassis have been done with one HCV for each side of the front and rear axles, a total of four, but this would not be very common. Vehicle with a tag axle use regulated air or tie the tag air bags to the driver air bags to control the tag air bags. Although it may be done, no one using HCVs to control the tag axle air bags.

The following diagrams show the basic mounting of a HCV and several air bag and HCV arrangements.

Functions of air suspensions : The vehicle is supported on the frame with an arrangement of air bags. The vehicle air system, engine air compressor, tanks, lines, etc. supplies air to the height control valves (HCV) mounted to the frame of the vehicle. The height control valves are connected to the air bags with an air line. The linkage which connects the HCVs to the axles rotates the HCV valving as it moves up and down. When weight is added to the vehicle or transferred through the suspension of the vehicle, the air in the air bag(s) is compressed, the frame moves closer to the axle. This forces the HCV linkage up. As the linkage moves up, the valving of the HCV connects the air supply to the air bag(s). The added pressure and volume inflates the air bag(s), causing the frame to move away from the axle. As the frame moves back to the proper ride height, the HCV linkage moves to the neutral position. This moves the valving away from the air supply and locks the air in the air bag to maintain the proper ride height. As weight is removed from the vehicle or the suspension shifts weight away, the existing pressure in the air bag(s) can push the frame away from the axle. The HCV linkage is pulled down. This connects the air bag(s) to the HCV exhaust port. As air is exhausted from the air bag(s), the frame lowers back down towards the axle. As the linkage moves up to the neutral position, the exhaust port is closed and the air is again locked in the air bag(s), maintaining proper ride height.

These three drawings (Fig 4) show as schematic example of the height control valve in the neutral position, inflate position and deflate or exhaust position.



Shock absorbers

Objectives: At the end of this lesson you shall be able to

- state the function of the shock absorber
- state the different types of shock absorbers
- state the construction of a shock absorber
- explain the functioning of a shock absorber
- state the effect of weak suspension system
- state gas pressurized shock absorber
- state load adjustable shock absorber
- state electronic adjustable shock absorber
- automatic load adjustable shock absorber.

Function and location of shock absorber

When the vehicle is running on a rough road, or a stone gets below the wheels or the wheel falls into a pit, heavy shocks are experienced. A bouncing wheel makes it difficult to control the vehicle and it is to avoid such bouncing of the wheels, a suspension system is provided in the vehicles. Vibration of higher amplitude and lower frequency are absorbed by suspension spring. Vibration of low amplitude and high frequency are absorbed by the shock absorber. The shock absorber is connected between the chassis cross-member and the spring axle or suspension control arm. It is also called as Dampers.

Different types of shock absorbers

Shock absorbers are mainly classified into two types.

Mechanical type

This is called a dry or friction type. It absorbs shocks with the help of friction discs and spring.

Hydraulic type

These shock absorbers absorb shock by the resistance of a fluid. There are three types.

- Vane type
- Piston type
- Telescopic type

Nowadays the telescopic shock absorber is most popular and is in use because of easy replacement and handling.

Construction of a shock absorber

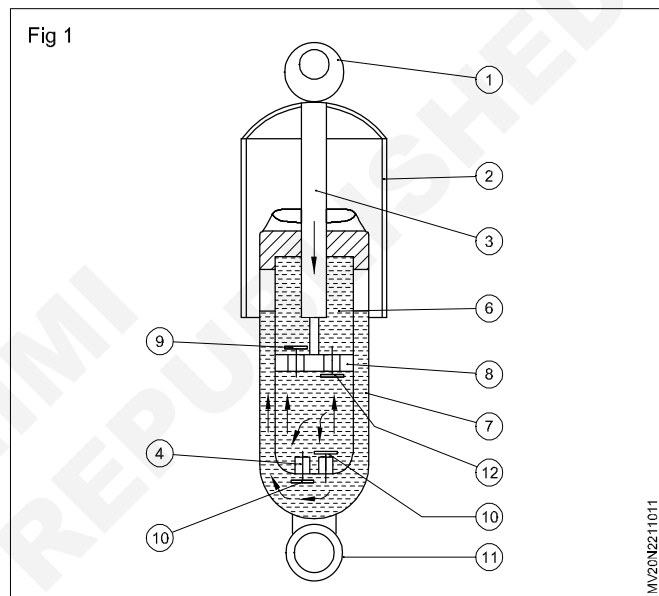
Mechanical shock absorber

It consists of two discs with a small clutch, spring and centre bolt. One disc is fixed to the chassis and the other to the axle. A friction disc works between these two discs.

All discs are assembled with the spring and centre bolt.

When the axle is lifted up the friction produced in between the discs due to the spring pressure, absorbs the vibration.

Telescopic shock absorber (Fig 1)



It is widely used in a vehicles nowadays.

Construction

The telescopic shock absorber is made of two thin steel tubes, the inner forms the cylinder (6) and the outer (7) forms the reservoir. It is called telescopic because the tubes are concentric. The outer tube (7) is connected to the axle or suspension member by an eye (11). A block (4) is welded in the bottom of the inner tube. The block (4) has two non-return valves (10). One valve allows oil from the reservoir (7) to the lower cylinder (6) and the other from the lower cylinder (6) to the reservoir (7). At the upper end of the shock absorber a dust excluder (2) is provided. The piston (8) has a rebound valve (12) and pump valve (9). The piston rod's (3) upper end is welded to an eye (1). This eye (1) is attached to the frame. The cylinder (6) is fully filled with hydraulic fluid and the reservoir is partly filled.

During the rebound/functioning of shock absorber stroke the eye (1) moves away from each other. The piston (8) moves upward. The rebound valve (12) opens and the fluid passes to lower the portion of the cylinder from the upper portion. Since the upper portion does not have

enough fluid to fill the lower portion completely, a vacuum is created in the lower portion. Now the extra fluid flows into the lower portion from the reservoir (7) through the foot valve (10). This passage of fluid provides necessary damping during rebounding.

This way, the shock absorber controls the quick bouncing of the wheels on the road. This provides stability to the vehicle. It also controls the slow balancing of the body to provide comfort to the passenger and avoid damage of other parts.

Factors affecting suspension

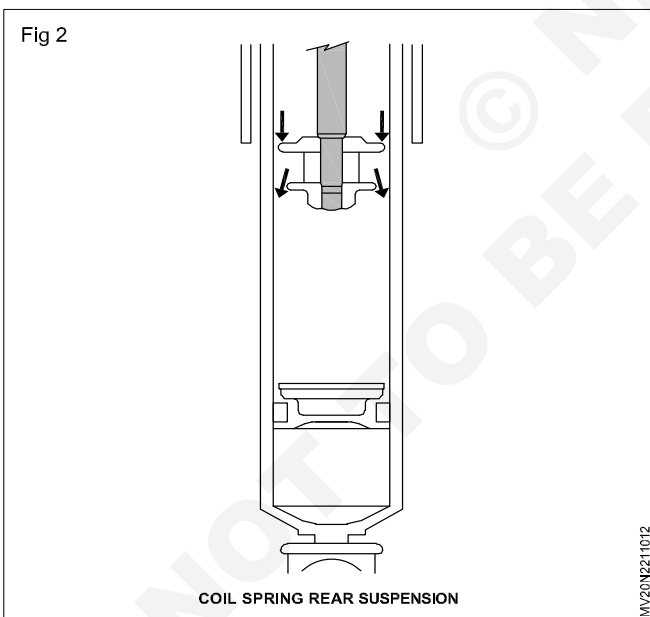
The following factors affect suspension in any vehicle.

- Irregularities of road surface
- Bumps and holes
- Heavy load or unequal weight distribution
- Tyre traction and pressure
- Side forces while negotiating corners.

Effects of weak suspension

- Directional instability of the vehicle
- Excessive/abnormal tyre wear
- Damaging of chassis frame and other parts
- More shocks and uncomfortable riding

Gas pressurized shock absorbers (Fig 2)



Shock absorber 'dissolve' can be reduced by pressurizing the fluid with nitrogen.

In a hydraulic shock absorber, the oil heats up as the energy of motion of the suspension is dampened. The rapid piston movement as the vehicle moves over the road causes the hydraulic fluid to aerate. This reduces the dampening effect, and the shock absorbers performance very quickly deteriorates. This condition is called shock absorber dissolve. It can be reduced substantially by pressurizing the fluid with gas, usually nitrogen.

In this mono-tube design, fluid fills the chambers above and below the piston. As the piston moves in the cylinder, valves control the movement of oil from one chamber to the other.

Pressure on the oil is provided by nitrogen gas at the base of the cylinder, acting on a free floating separation piston which separates the gas from the oil.

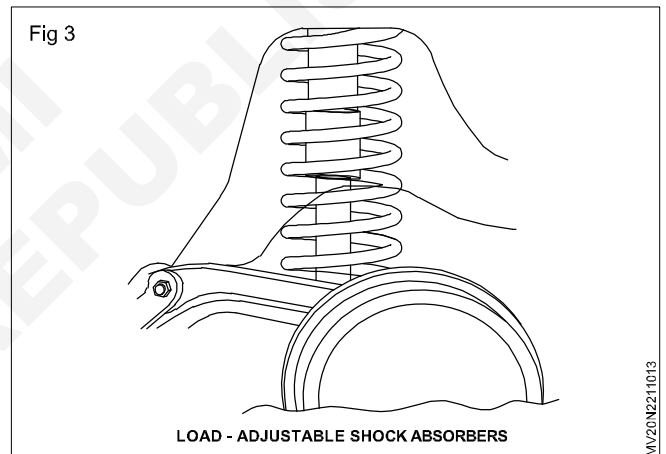
Pressure on the oil is provided by nitrogen gas at the base of the cylinder, acting on a free floating separation piston which separates the gas from the oil.

On bump, the piston moves downwards, and the penetration of the piston rod displaces a quantity of oil equal to its volume. The separation piston is displaced accordingly, and gas pressure increases.

On rebound, the piston and rod move upwards, and gas pressure reduces as the separation piston follows the movement.

Pressure on the oil is maintained, even when the piston and rod are at the top of their stroke.

Load-adjustable shock absorbers (Fig 3)



The rubber air cylinder in the load-adjustable shock absorber can be pressurized to assist suspension springs that are under load. Changing the pressure in the cylinder can alter ride height, and the stiffness of the suspension.

When vehicles carry heavy loads, their suspension is compressed, causing the rear of the vehicle to be lower than normal.

As a result, steering becomes lighter, the alignment of the headlights becomes too high, and the compression length of travel of the suspension over bumps is reduced, causing discomfort to passengers.

To reduce these effects, a manually adjustable air spring can be incorporated into each rear shock absorber. The air spring consists of a flexible rubber cylinder which seals the outside of the upper and lower halves of the shock absorber.

The shock absorber is a standard hydraulic type, providing normal dampening action, but when a heavy load is placed on the rear of the vehicle, the rubber air cylinder can be pressurized to assist the suspension springs.

By changing the air pressure in the cylinder, the ride height can be adjusted, as well as the stiffness of the suspension.

Compressed air in the pneumatic cylinder can absorb smaller road shocks, and provide better ride characteristics than just stiff springs alone.

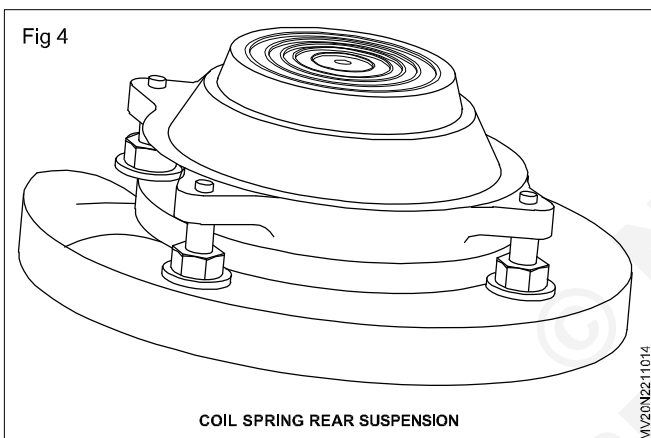
The rubber air cylinder is connected to a filling valve by a flexible plastic hose. Air from a tire pump or a hand unit forces more air into the rubber cylinder, allowing the suspension to support more weight.

The maximum air pressure setting must not be exceeded as this can damage the shock absorber and its mounting points on the vehicle frame.

When the load is removed, the extra air is released through a filling valve, which allows the suspension to return to its original settings.

A minimum air pressure must be maintained in the cylinder to prevent tearing of the rubber as it collapses internally with shock absorber action.

Electronic adjustable - shock absorbers (Fig 4)



The electronic adjustable - shock absorber has a rotary solenoid that can alter dampening rate by changing the number of restrictions the oil must pass through, and varying the force needed to open the valves.

Adjustable shock absorbers provide a means of changing their rate of dampening of the spring oscillations, to suit road conditions. Electronic controls let the changes occur either automatically, or as the driver prefers.

Each shock absorber has a rotary solenoid that can alter the dampening rate by changing the number of restrictions the oil must pass through.

In this position, all orifices are open. Oil can flow more easily through the passageways in the piston. Only a small dampening effect is applied to the oil.

This provides a dampening force that emphasizes ride comfort when traveling at low speeds.

Closing some orifices makes it harder for fluid to flow through the piston. This increases the dampening effect of the shock absorber, providing a firmer ride, more suitable for higher speeds, and faster cornering.

The solenoid is operated by an electrical signal from the electronic control unit or ECU.

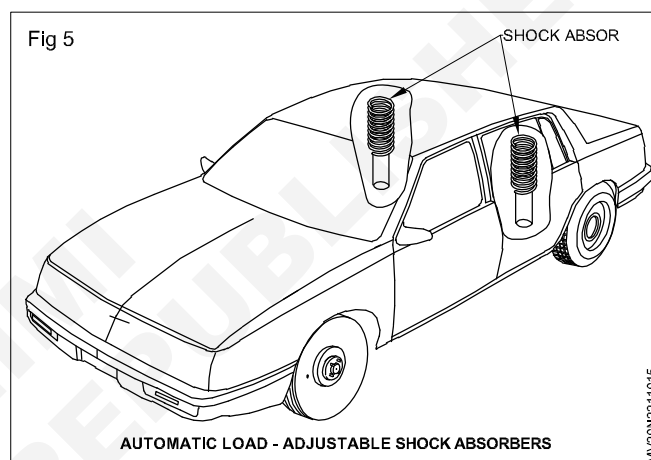
The ECU allows different modes of operation, according to a selector switch on the dash-board. In the Auto position, the dampening effect at the front wheels is increased at road speeds above 80 kilometers per hour.

This improves vehicle stability at high speeds. The rear shock absorbers stay at their normal setting.

The manual position has two setting - normal or sport. In normal setting, all shock absorbers remain at a rate suited to ride comfort. There is no change to the settings at high speeds.

The sport setting increases the dampening rate of all the shock absorbers. This is more suited to brisk driving, with heavy acceleration and cornering.

Automatic load - adjustable shock absorbers (Fig 5)



Automatic load-adjustable shock absorbers maintain vehicle ride at a pre-set level, according to the load placed over the rear axle.

The section examines automatic load -adjustable shock absorbers. They are also called self-leveling.

When vehicles carry heavy loads, their suspension is compressed, causing the rear of the vehicle to be lower than normal.

As a result, steering becomes lighter, the alignment of the headlights becomes too high, and the compression length of travel of the suspension over bumps is reduced, causing discomfort to passengers.

A lower vehicle handles better on smooth roads, but on a rough road, reduced suspension travel can let harsh road shocks be transmitted to the passenger compartment, and cause discomfort.

An automatic load adjustable suspension system controls the vehicle ride height automatically, according to the load placed over the rear axle.

It consists of air-adjustable shock absorbers fitted to the rear suspension, an electrically driven compressor and air-dryer assembly, and an electronic control unit, and associated wiring and tubing.

The ECU is mounted to the cross-member over the rear axle and a moveable link connects it to a rear suspension member.

As the vehicle is loaded, the normal suspension springs are compressed, which lowers the height of the vehicle.

When the ignition is switched on, the ECU senses the lowered ride height and switches on the air compressor. Air is directed to the shock absorbers, causing the airbag around them to expand and raise the suspension to the normal trim height.

If the load is removed, the suspension springs expand, raising the height of the vehicle.

The ECU senses the raised ride height, and air is exhausted from the shock absorbers, causing the airbag to deflate, and lower the suspension to the normal trim height.

During normal suspension operation, continual adjustment of vehicle ride height is prevented by a time delay, in the ECU.

This allows the trim height to be adjusted only when the ECU reads an out-of-trim signal for 5 to 15 seconds. The compressor run-time or exhaust-time is limited to 2 minutes. This prevents it continuing to operate, if the system develops an air leak, or if an exhaust vent remains open.

Hydraulic shock absorbers	The dampening action of a hydraulic shock absorber comes from transferring oil, under pressure, through valves that restrict the oil flow. Resistance to motion is low when the piston moves slowly, and high when its velocity is high.
Gas pressurized shock absorber	Shock absorber 'dissolve' can be reduced by pressuring the fluid with nitrogen.
Load - adjustable shock absorbers	The rubber air cylinder in the load - adjustable shock absorber can be pressurized to assist suspension springs that are under load. Changing the pressure in the cylinder can alter ride height, and the stiffness of the suspension.
Manual adjustable rate in shock absorbers	In a manual adjustable -rate shock absorber, the position of the valves the piston can be changed to vary the number of restrictions the oil has to pass through and to vary the force needed to open the valves.
Electronic adjustable - rate shock absorbers	The electronic adjustable - rate shock absorber has a rotary solenoid that can alter dampening rate by changing the number of restrictions the oil must pass through, and varying the force needed to open the valves.
Automatic load - adjustable shock absorbers	Automatic load - adjustable shock absorbers maintain vehicle ride at a pre-set level, according to the load placed over the rear axle.

NOT TO BE REPRODUCED

Tyres

Objectives: At the end of this lesson you shall be able to

- state the functions of tyre
- state the types of tyres
- state the construction of tyres
- state the tyre specification
- state the tyre inflation
- state the run flat tyres
- state the need of tyre valves
- state the tyre ratings
- tyre pressure monitoring system
- state tyre traction rating
- state the tyre temperature rating
- state the concept of compact spare tyres.

Function of tyres

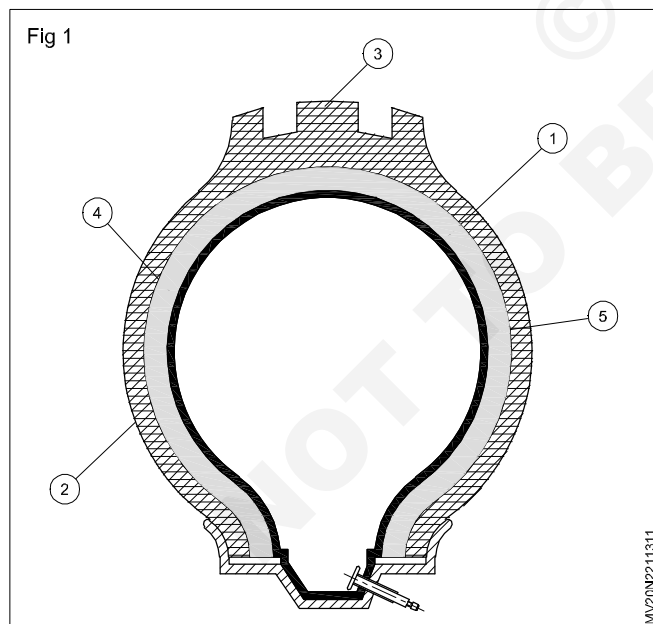
Tyres should be able to:

- absorb shock
- grip the road surface in both wet and dry condition
- withstand vehicle load.

Types of tyres

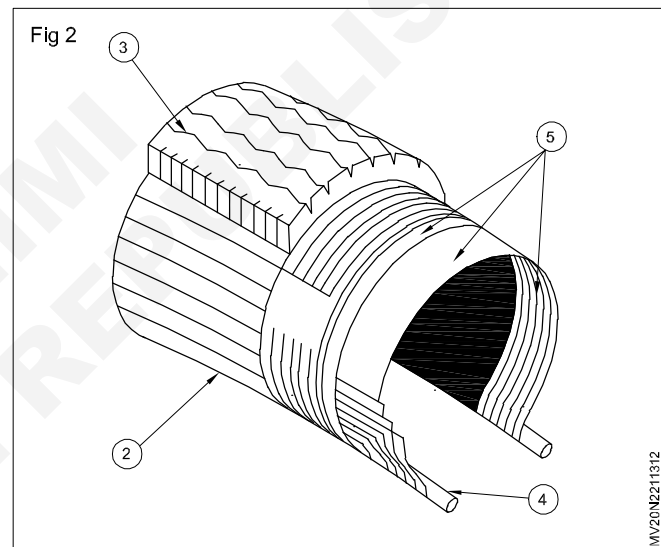
- Tube tyre
- Tubeless tyre

Tube tyre (Figs 1 & 2)

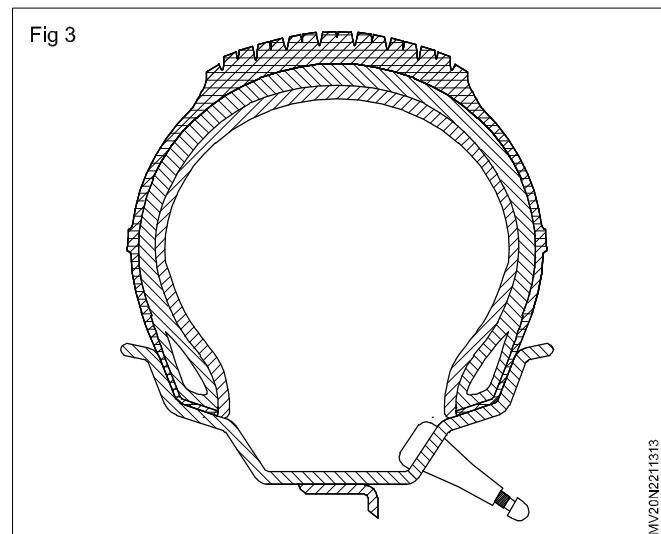


It is the most commonly used tyre. A tube (1) is used inside the tyre (2). The tube is inflated with air at a pressure recommended by the manufacturer. It provides cushioning. The outer portion of the tyre which keeps contact on the road is made of synthetic rubber. This portion is called tread (3). Steel beads (4) are provided at the inner edge. A number of plies (5) of rayon cord are

provided to give strength to the tyre. The beads (4) and plies (5) provide strength to the tyre.



Tubeless tyre (Fig 3)

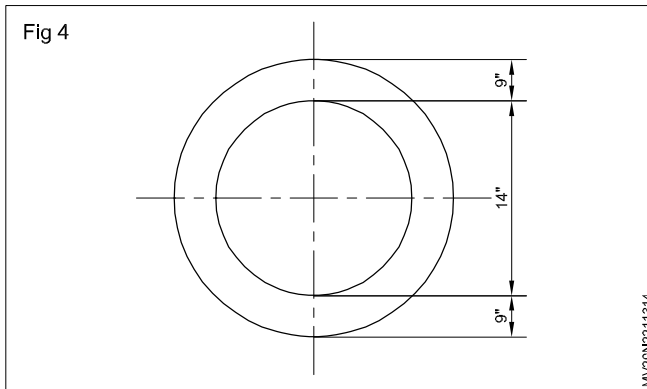


Its construction is similar to that of the tube tyre except that it does not have a tube and air is directly inflated in the tyre. The tubeless tyre can retain air for a longer period than the tube type tyre after puncture. This tyre need not be removed from the wheel to set right a puncture.

Material of tyre

- Rubber - for tread
- Nylon/rayon - for cord
- High tensile steel wire - for bead.

Tyre specification (Fig 4)



Tyre is specified in terms of the shoulder width, bead circle diameter and ply rating (PR).

Eg. 9"x14" - 14 PR

Here the shoulder width is 9". The bead circle diameter is 14" and the No. of plies (Ply rating PR) is 14.

Structure of tyre

Tyre outer diameter (Fig 5)

It is the outer most diameter of the tyre (1)

Tyre width

The width of the tyre corresponds to the distance between the most protruding portions on both sides.

Overall tyre width

Rectilinear distance between both side, including all patterns and characters on tyre sidewalls.

Tyre height

Half of height obtained by subtracting the rim diameter from the tyre outer diameter.

Thread width

The width of the tyre tread surface. This corresponds as a rule to the distance between the most protruding portions on both sides.

Thread radius

This also referred to as the crown R. The radius of curvature is expressed in millimeters.

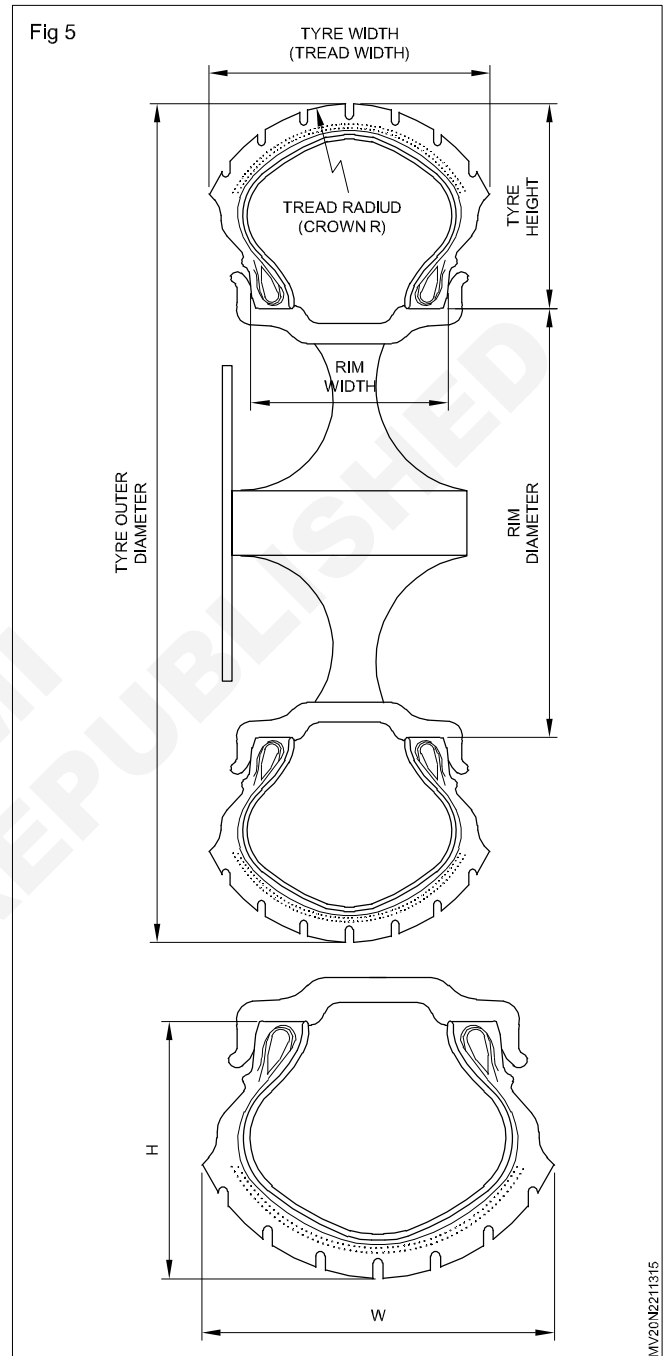
RIM width

Rim width suitable for effective tyre performance

Bead circle diameter

The inside diameter of the tyre rim diameter is called as bead circle diameter of tyre.

Aspect ratio (Fig 5)



The aspect ratio, is, as shown in the drawing, percentage ratio of tyre height to tyre width.

$$\text{Aspect Ratio (\%age)} = H/W \times 100$$

H: Tyre height (mm)

W: Tyre width (mm)

1-Tyre outer diameter

2- Tyre height

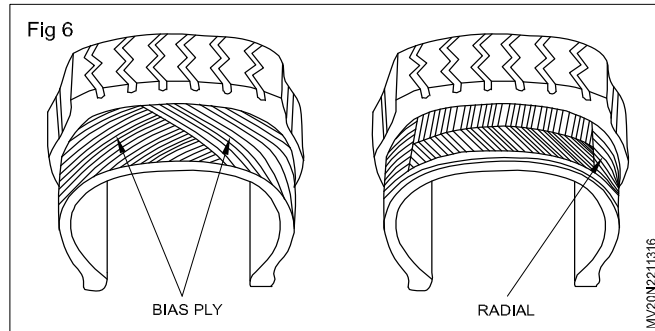
3-Tyre width / Thread width

4-Thread radius

5-Rim width

6-Rim diameter (or) bead circle diameter.

Construction of a tyre (Fig 6)



It is divided into two types.

- Radial ply
- Cross-ply

Radial ply

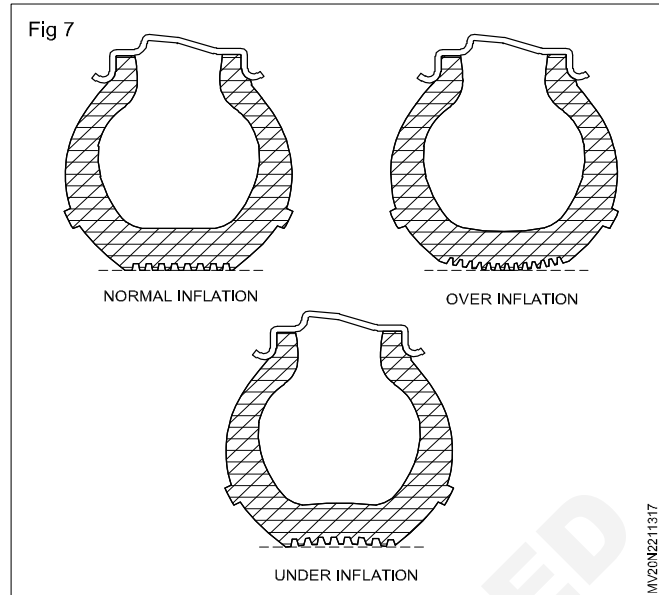
In this type plies are provided radially from bead to bead.

Cross-ply

In this type alternate plies are provided in opposite diagonal directions.

Tyre inflation (Fig 7)

All vehicle manufacturers specify pressure at which air should be inflated in the tyre. It depends upon the tyre size and load of vehicle etc. A tyre should be normal inflated at the specified pressure to have complete contact on road(1). If the tyre is over-inflated, it will have contact with the road only at the centre and the tyre will



wear out faster at the centre (2). If it is under-inflated it will have contact with the road only at the edges which will wear out faster (3).

Tyre storage

- Tyres should be stored on a clean surface free from oil, grease, diesel or other liquid.
- Tyres should be kept vertically on the surface. So that they rest on their treads.
- Tyres should be stored away from electric appliances, gas heaters etc.
- Tyres should be protected from strong sunlight.

Size indication

METRIC INDICATION

	110	/	70	R	17	54	V
	a		b	c	d	e	f
a: Tyre width(110mm)	b:Aspect Ratio (70%)			c: Radial structure			
d: Rim Diameter (17inch)	e: Max. Load (212 kg at 290 kpa)			f:speed limit (240 km/h)			
	130	/	90	-	18	69	H
	a		b	c	d	e	f
a: Tyre width(130mm)	b:Aspect Ratio (90%)			c: Radial structure			
d: Rim Diameter (18inch)	e: Max. Load (325 kg at 280 kpa)			f:speed limit (210 km/h)			

INCH INDICATION

	4.00	H	-	18	4PR
	a	b		c	d
a: Tyre width(4 inch)	b:Speed limit (210 km/h)			c: Rim diameter (18 inch)	
d: Tyre strength (4 ply rating)					

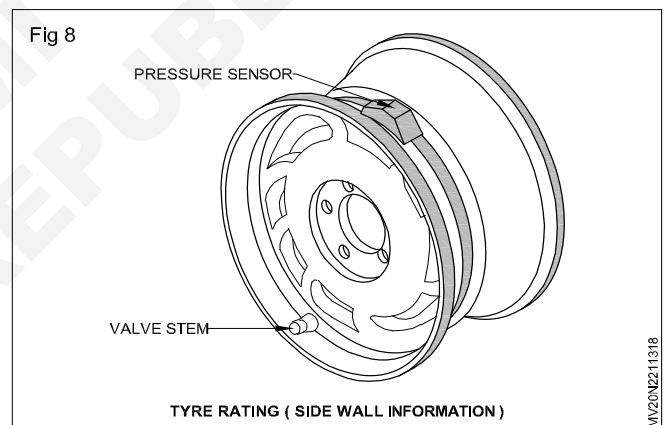
Load index

Maximum air pressure for each speed code. (P:225 kpa, S:250 kpa. H:280 kpa, V:290 kpa)

Load Index (kg)	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)
30	106	40	140	50	190	60	250	70	335
31	109	41	145	51	195	61	257	71	345
32	112	42	150	52	200	62	265	72	355
33	115	43	155	53	206	63	272	73	365
34	118	44	160	54	212	64	280	74	375
35	121	45	165	55	218	65	290	75	387
36	125	46	170	56	224	66	300	76	400
37	128	47	175	57	230	67	307	77	412
38	132	48	180	58	236	68	315	78	425
39	136	49	185	59	243	69	325	79	437

Speed index

Speed symbol	Max. speed (km/h)
J	100
N	140
P	150
S	180
H	210
V	240
ZR	Over 240



Tyre pressure monitoring systems

Tire pressure monitoring systems are mandatory on all new vehicles produced in the United States starting in the 2004 model year. Some tire pressure monitoring systems have a pressure sensor strapped to the drop center in each rim (Fig.8). Other systems have a pressure sensor threaded onto the end of the valve stem. The pressure sensors send radio frequency (RF) signals to the module in the tire pressure monitoring system. These RF signals change if the tire is deflated a specific amount. When the module senses a tire with low air pressure the module illuminates a warning light in the instrument panel.

Other tire pressure monitoring systems use the wheel speed sensor signals in the ABS to monitor tire inflation pressure. When a tire is deflated to some extent, the tire diameter is smaller and wheel speed increases. Therefore, the wheel speed sensor signals may be used to indicate low tire pressure.

Warning: Pressure sensor inside tyre avoid contacting sensor with tire changing equipment tools or tire bead.

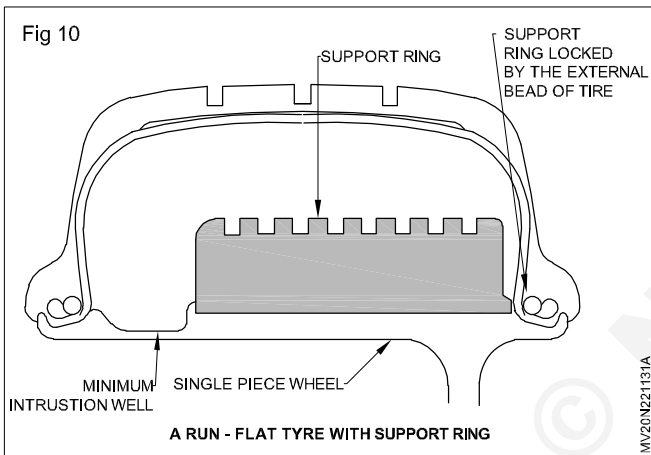
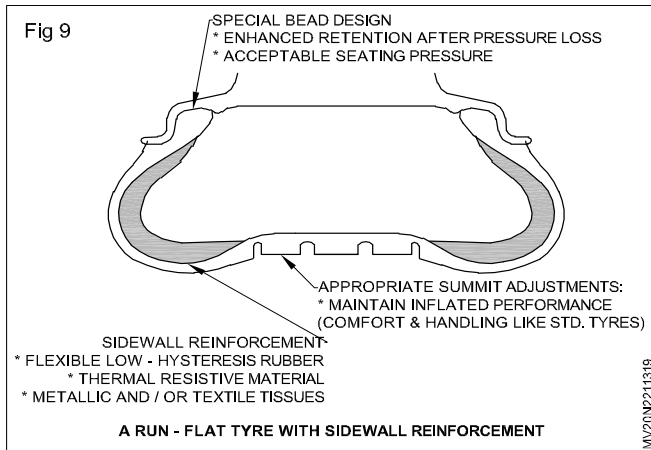
Location	Color code
Right front	Blue
Left front	Green
Right rear	Orange
Left rear	Yellow

Service note: Pressure sensor must be mounted directly across from valve stem.

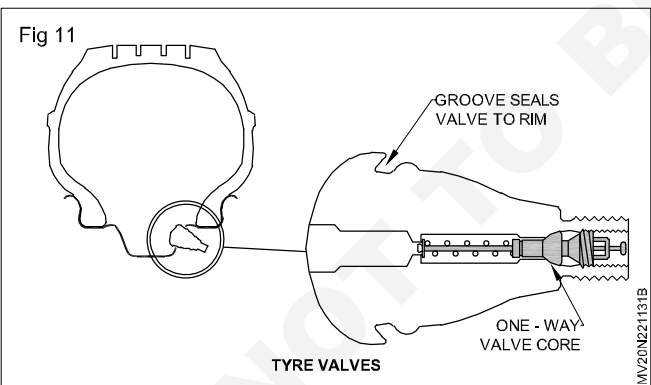
Run flat tyres (Fig 9 &10)

Some luxury and sport type vehicles are equipped with run-flat tires. Run-flat tires eliminate the need for a spare tire and a jack on these cars. This provides a weight and space savings. Run-flat tires must minimize the difference between run-flat tires and conventional tires and provide sufficient zero-pressure durability so the vehicle can be driven a reasonable distance to a repair facility.

Some run-flat tires have stiffer sidewalls that partially support the vehicle weight without air pressure in the tire. Other run-flat tires have flexible rubber support ring mounted on a special rim to support the vehicle weight if deflation occurs.



Tyre valves (Fig 11)

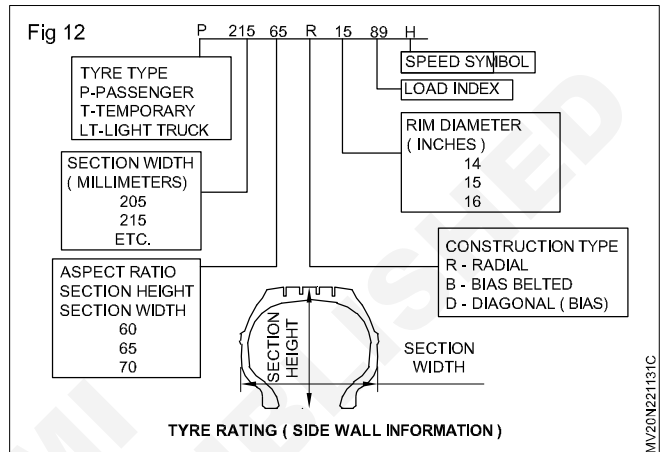


The tire valve allows air to flow into the tire and it is also used to release air from the tire. The core in the center of the valve is spring loaded and allows air to flow inward while the tire is inflated. Once the tire is inflated, the valve core seats and prevents airflow out of the tire. The small pin on the outer end of the valve core may be pushed to unseat the valve core and release air from the tire. An air tight cap on the outer end of the valve keeps dirt out of the valve and provides an extra seal against air leakage. A deep groove is cut around the inner end of the tire valve. When the valve assembly is pulled into

the wheel opening, this groove seals the valve in the opening.

Tyre ratings

A great deal of important information is molded into the sidewall of the average passenger car or light truck tire. The tire rating is part of the information located on the sidewall. The tire rating is a group of letters and numbers that identify the tire type, section width, aspect ratio, construction type, rim diameter, load capacity, and speed symbol. When a tire has a P215/65R15 89H rating on the side wall, the P indicates a passenger car tire (Fig 12).



The number 215 is the size of the tire in millimeters measured from sidewall to sidewall with the tire mounted on the recommended rim width.

The number 65 indicates the aspect ratio, which is the ratio of the height to the width. With a 65 aspect ratio, the tire's height is 65 percent of its width. The letter R indicates a radial-ply tire design. A belted bias-ply tire design is indicated by the letters A B. The letter D indicates a diagonal bias ply - tire.

The number 15 is the rim diameter in inches. The load index is represented by the number 89. This load rating indicates the tire has a load capacity of 1,279 pounds. Various numbers represent different maximum loads. Some tire manufacturers use the letters B,C, or D to indicate the load rating. The letter B indicates the lowest load rating and the letter C represents a higher load rating. A tire with a D load rating is designed for light - duty trucks. This tire will safely carry a load of 2,623 pounds when inflated to the specified pressure.

Traction rating

Traction ratings indicate the braking capabilities of the tire to the consumer. To determine the traction rating, ten skid tests are completed on wetted asphalt and concrete surfaces. Test conditions are carefully controlled to maintain uniformity. The results of the ten skid tests are averaged and the traction rating is designated A, B or C with an A rating having the best traction.

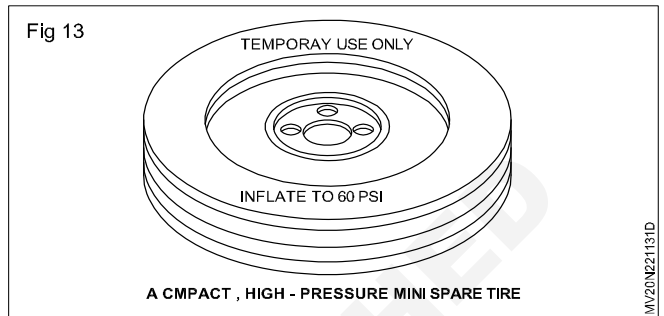
Temperature rating

Temperature resistance ratings indicate the tire's ability to withstand heat generated during tire operation. The National Highway Traffic Safety Administration (NHTSA) has established controlled procedures on a laboratory test wheel for temperature resistance testing of tires. The tire's temperature rating indicates how long the tire can last on the test wheel. Temperature ratings are A, B, or C. An A rating has the best temperature resistance. Tires must have a minimum letter C temperature rating to meet NHTSA standards in the United States.

Compact spare tyres

Since cars have been downsized in recent years, space and weight have become major concerns for vehicle manufacturers. For this reason, many car manufacturers have marketed cars with compact spare tires to provide a weight and space savings. The high - pressure mini spare tire is the most common type of compact spare (Fig13). This compact spare rim is usually 4 inches wide, but it is 1 inch larger in diameter compared to the other rims on the vehicle. The compact spare rim should not

be used with standard tires, snow tires, wheel covers, or trim rings. Any of these uses may result in damage to these items or other parts of the vehicle. The compact spare should be used only on vehicles that offered it as original equipment. Inflation pressure in the compact spare should be maintained at 60psi (425 kpa). The compact spare tire is designed for very temporary use until the conventional tire can be repaired or replaced. Limit driving speed to 50mph (80 kph) when the high - pressure mini spare is installed on a vehicle.



Tube

Objectives: At the end of this lesson you shall be able to

- state tuff up tube
- state the structure of tuff up tube
- state hole plugging mechanism
- state nitrogen filling in tyre
- state tyre thread patterns.

Tuff up tube

The two chamber tube has two separate chambers that are independent from each other. One is the air and other is the liquid chamber. The newly developed anti-puncture sealant gel is sealed in the chamber located on the tyre tread side during the manufacturing process. As the sealant chamber is always pressed against the tyre by the pressure from the air chamber, when there occurs a hole the sealant gel enters in the hole and closes it.

Structure of tuff up tube

This shows how the two chamber tube closes the hole. Usually in an event of a puncture, a hole is pierced through the sealant gel chamber to the air chamber. When a hole occurs, the gel is forced into the hole, and the fibrous material contained in the gel is squeezed out. At that time, the fine ceramic particles fill the openings of the fiber, and the vacant spaces are filled with the gel. As there is a pressure inside of the inner tube, minimal quantity seeps into the air chamber but without causing any harm as it is a water based gel.

Hole plugging mechanism

This shows a picture of the cross - section of the hole closed by the newly developed anti-puncture sealant gel, taken after the sealant gel oozes out, dries and seals the puncture.

Tuff up tube can be repaired like an ordinary tube

Though it is an innovative technology, tuff up tube is easy to repair and with some simple precautions, it can be repaired at any repair shop or by road side mechanic.

Nitrogen filling in tyres

- 1 Car tyres are normally inflated with compressed air
- 2 Air is approximately 80% nitrogen, 20% oxygen
- 3 Nitrogen is comparatively inert, oxygen is a reactive gas.
- 4 The nitrogen used for inflation in tyre depots is normally generated by a separation process from compressed air. It still contains about 5% oxygen.
- 5 Nitrogen used at race tracks and in industry may be 99%+ pure and contained in high pressure cylinders at 2000+psi
- 6 Both sources of nitrogen will be treated to reduce the amount of water vapour.

Now a days nitrogen is used in all tyres in place of air. It is used because it doesn't expand and compress like normal air in altitude and temperature changes. That is why it is used in aviation applications.

Nitrogen is chemically a non-flammable, non-toxic inert gas. An inert gas does not react with any other gas at any temperature. This basic nature of nitrogen helps in keeping minimum moisture in the tyres.

Pros

Nitrogen reduces the running temperature of the tyre, which is advantageous when the car or bike is operating at its maximum load and speed capacity.

Nitrogen in tyres improves the ride quality. That gas is very slightly lighter than air, benefits the tires in terms of un-sprung weight.

It is assumed that nitrogen increases tyre life. It reduces the operating temperature during times of load and speed and thus, enhances the life of a tyre.

It is believed that nitrogen keeps tyre pressures more constant. The gas is assumed to provide more stable pressure range in connection to the tyre temperature. However, again, the factor is applicable in times of heavy load/high-speed conditions.

Tyres are susceptible to loss of pressure as a result of being porous in nature. Due to its chemical structure, nitrogen leak out slowly as compared to compressed air. Therefore, it slows the rate of pressure loss.

Oxygen reacts with the tyre and rim materials causing oxidation or the rust formation in the metal parts. Nitrogen, being an inert gas, does not react with the tyre and rim materials.

Cons:

Inflating tires with nitrogen is quite costly.

Filling tyres with nitrogen requires more maintenance as compared to compressed gas.

The availability factor is the biggest disadvantage of inflating tyres with nitrogen, as the gas is not readily available. It is usually found only with specialist tyre dealers.

Generally it's not that much advantages in case of commuter bikes. More over 78% air is itself nitrogen. It is advantages only in case of formula cars, high speed racing cars & motorcycles & high load carriage vehicle.

Tyre tread patterns

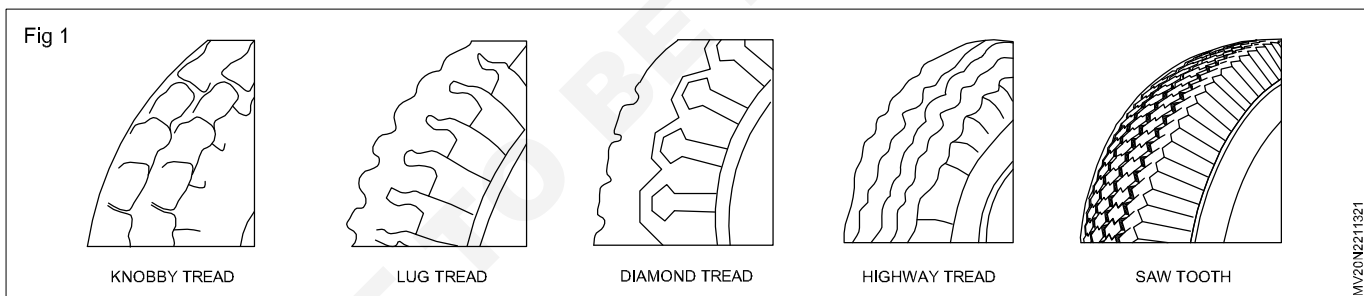
- Function
- Improve grip
- Arrest skidding
- Keeps tyre cool
- Provide longer life
- Can be retreaded

Indicators are provided to show the limits upto which it can be used before renewing or ready for retreading different commercial names are given by manufactures.

Types of tyre tread (samples)

- Knobby tread
- Lug tread
- Diamond tread
- Highway tread
- Saw tooth trade

Sketches given below (Fig1)



Monitoring systems

Tyre pressure monitoring systems are designed both to recognise the air loss in the tyre and also to warn the driver.

The following types of tyre pressure monitoring systems are used in motor vehicles:

- Indirect measuring systems
- Direct measuring system

Indirect measuring systems

When pressure is lost, the tyre's rolling circumference, which increases the engine speed in relation to the other tyres, is reduced. The engine speeds are determined

via the ABS or ESP sensors. However, the driver is not warned until there is a difference in air pressure of more than 30% between the tyres.

Direct measuring system

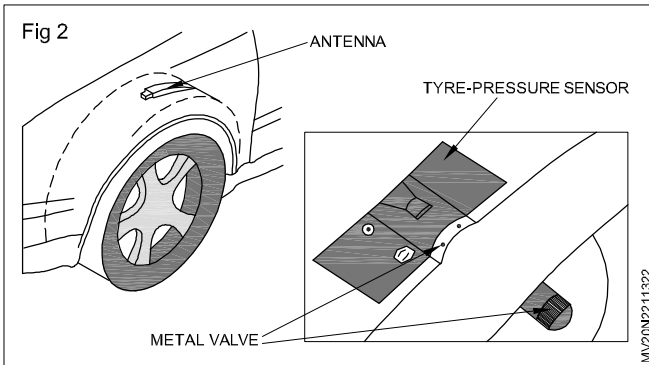
The pressure is measured directly by sensors in the tyre. The following functions are fulfilled:

- Continued monitoring of tyre pressure whilst driving and when the vehicle is stationary.
- The driver is given early warning in the event of a pressure loss, reduced pressure and flat tyre.
- Automatic individual wheel recognition and wheel positioning.

- Diagnostic procedure for systems and components in the workshop.

The system is composed of:

- 1 tyre-pressure sensor per wheel (Fig 2)



- Antennae for tyre pressure monitoring
- Instrument panel with display
- ECU for tyre-pressure monitoring
- Function-selector switches

Tyre-pressure sensor and antenna

Tyre-pressure sensor: This sensor is bolted to the metal valve and can be reused when changing the tyres or wheel rims. In addition, a temperature sensor, transmitting antenna, measuring and control electronics as well as a battery with a service life of approximately 7 years are integrated. Since the filling pressures are altered by temperature influences the pressures and temperatures recorded in the ECU to a standard temperature of 20°C.

To avoid damaging the sensor irreparably when changing a tyre, the tyre must be pressed down on the side opposite the valve.

ECU: The ECU obtains the following information from the transmitting antenna:

- Individual identification number (ID code), used for individual wheel recognition.
- Current inflation pressure and current temperature.
- Condition of the lithium battery.

The ECU evaluates the signals transmitted by the antenna for the tyre pressure monitoring and imparts the information for the driver on the display screen, according to the importance of this information. If wheels are changed on the vehicle, for example, from the axle to the rear axle and vice versa, the ECU must be recoded with the new pressures.

Individual wheel recognition: The sensors belonging to the vehicle are recognised by the ECU and stored. The sensors are recognised when the vehicle is being driven, to avoid interference from the sensors on cars parked nearby.

Nitrogen Air	Atmospheric Air
1 It is 99% purity nitrogen gas	It is the mixture of 78% Nitrogen plus other constituents
2 It does not react or oxidised with rubber of tyre hence tyre life increases.	It reacts with rubber and gets oxidised life of tyre decreases
3 Tyre runs cooler	Tyres becomes hot

Tyre rotation

Objectives: At the end of this lesson you shall be able to

- state tyre rotation
- state the tyre wear pattern.

Tyre rotation

Uneven tyre wear on all the wheels will cause instability of the vehicle. Front tyres wear out faster than the rear tyres, as the front wheels steer the vehicle at turns. In order to have uniform wear on all the wheels, it is necessary that the wheel position is changed after completing a specified travel.

Changing the position of wheels in a set pattern is called tyre rotation. All manufacturers recommend a set pattern of tyre rotation after covering certain kilometres. A simple pattern of tyre rotation is shown in the Fig 1. In this, at the time of tyre rotation the spare wheel (5) is fitted to the rear right. The rear right (1) to front left. The front left (2) is fitted to rear left. The rear left (3) to the front right and the front right (4) is kept as the spare wheel.

Tyre wear

Tyre wear depends upon its position (front or rear), load, road condition, inflation and mechanical faults of the car.

The different types of tyre wear are as follows.

Rapid wear at shoulders (Fig 2)

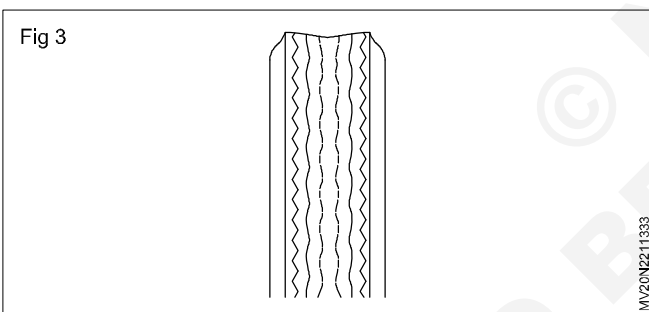
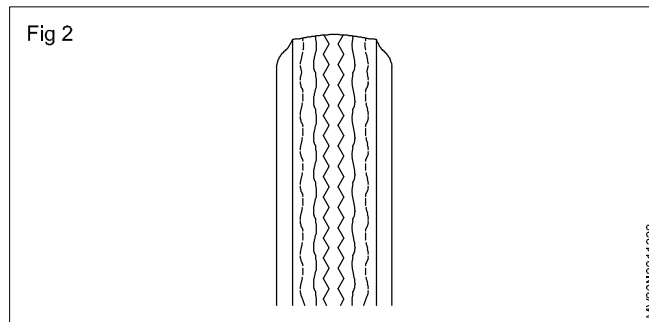
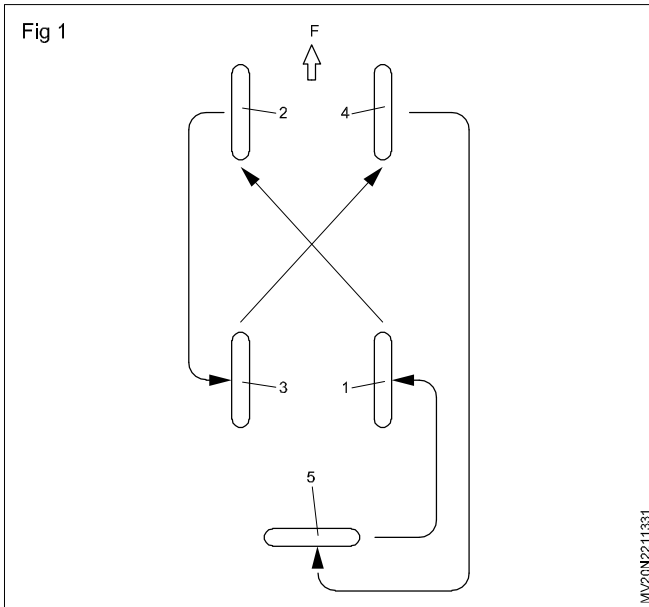
Tyre wears out faster at the shoulder. Under-inflation is the main cause for this.

Rapid wear at centre (Fig 3)

Over-inflation is the main cause for this.

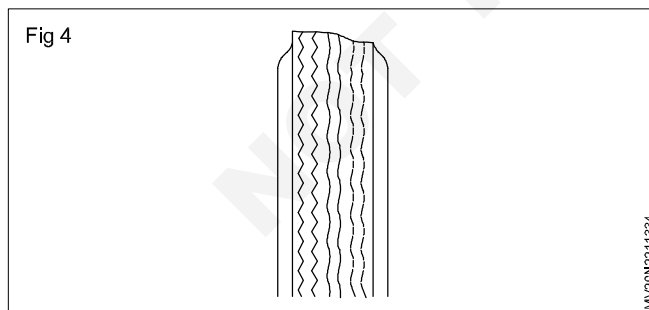
Cracked treads

The main causes for this are under-inflation or excessive speed.



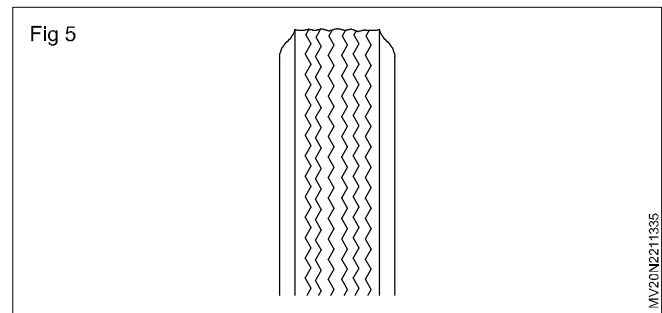
Wear on one side (Fig 4)

The main cause for this is improper camber.



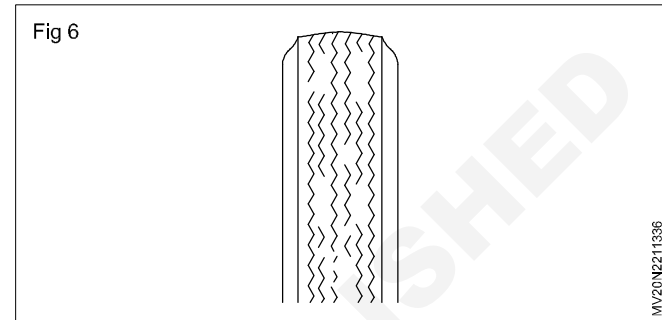
Feather edge (Fig 5)

The main cause for this is incorrect toe-in.



Bald spots wear (Fig 6)

The main cause for this is improper dynamic and static balancing of wheels.



Fierce braking driving habits also may lead such to such patchy wear.

Tyre properties

A tyre must have the following desired properties

- 1 **Non-skidding:** The tyre should not skid or slip on the road surface. It show grip.
- 2 **Uniform wear:** The tyre must get wear uniformly over its outer circumference.
- 3 **Load carrying:** The tyre should be able to carry the vehicle load, and stresses during each revolution.
- 4 **Cushioning:** The tyre should be able to absorb vibrations set-up by the thus providing cushioning effect.
- 5 **Power consumption:** While rolling on the road, the tyre should consume power developed by the engine.
- 6 **Noise:** The tyre should create minimum noise while running on the road.
- 7 **Balancing:** The tyre should be balanced dynamically as well statically.

Tube

A tube - tyre enclose a tube inside it. The tube is held between the rim and the tyre. Air is forced under pressure inside the tube, through a non - return valve, which projects outside through a hole in the rim. Tubes are made of rubber by moulding to conform the shape tyre. Special tyres of tubes are available which minimize the danger of punctures or blowouts. These tubes are self sealing constructions.

Tubes are manufactured with the same care and attention as tyres. Raw material are analysed and tested before use. In the manufacture of tubes but rubber is used of because of its superior qualities. Front warm - up mills the tube stock goes to machine from which it comes out on to a conveyor as an endless sleeve. This is then marked with the proper size, cut to length and stored in specially designed skids.

The ends of the tubes are then joined together on automatic splicing machines and are then fitted with the valves specified for each size. Each tube is then put around a forming ring and inflated to mould shape and is then cured in a steam heated mould. The mould opens automatically at the end of curing period and the cure tube is taken out. Each tube is thoroughly inspected for defects, then polished, packed and made ready for shipping out.

Tyre pressure
Conversion table for PSI and kg/cm²

PSI	Kg/cm ²
23	1.6
26	1.8
29	2.00
32	2.2
35	2.4
38	2.6
41	2.8
44	3.00
46	3.2
50.3	3.5
54.62	3.8
57.5	4.00
60.00	4.15
71.87	5.00
86.25	6.00
100.625	7.00
115.00	8.00
129.375	9.00
143.75	10.00

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Wheels

Objectives: At the end of this lesson you shall be able to

- state the function of wheels
- list out the various types of wheels
- state wheels construction
- explain static and dynamic wheel balance and effect of unbalance.

Wheels

Wheels are connected to the front and rear axles. As power is supplied to either front or rear axle, axle shafts turn the wheels and the vehicle moves.

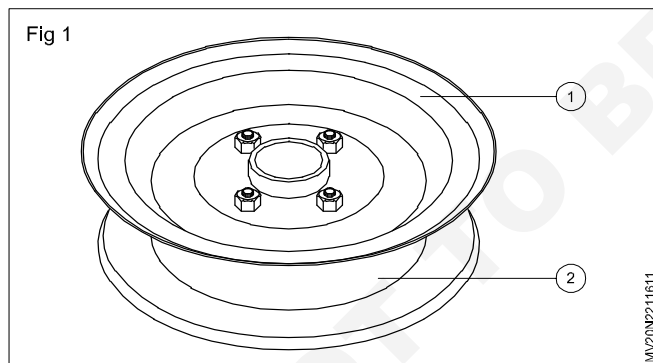
The wheel assembly consists of a hub, rim, tyre and tube. To perform its function the wheel should be:

- able to withstand the driving and braking torque, and support the weight of the vehicle
- able to absorb road shocks
- statically and dynamically balanced
- able to grip the road surface.

Types of wheels

- Disc wheel
- Wire wheel
- Split wheel
- Heavy vehicle wheel

Disc wheel (Fig 1)



In this type, a steel rim (1) is welded on to a steel disc (2). The tube and tyre are fitted on to the rim (2). The disc is provided with holes to mount it on the hub.

Wire wheel (Fig 2)

In this type the hub and rim are connected by a number of wire spokes. Alternate spokes are screwed to slope forward and backward towards the rim to absorb the braking and driving torque respectively. (Eg. Bicycle/Motor cycle wheels)

Split wheel (Figs 3 & 4)

In this type two separate discs are clamped together and a flange of discs provide seating surface for the tyre and tube. This types of wheels are used in car and scooter.

Fig 2

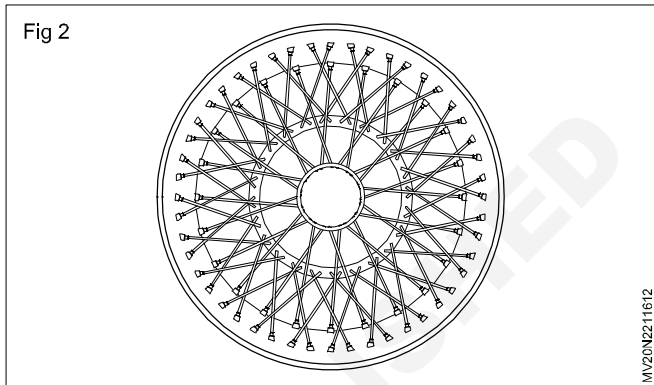


Fig 3

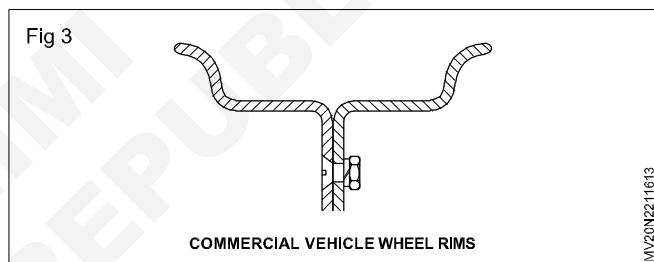
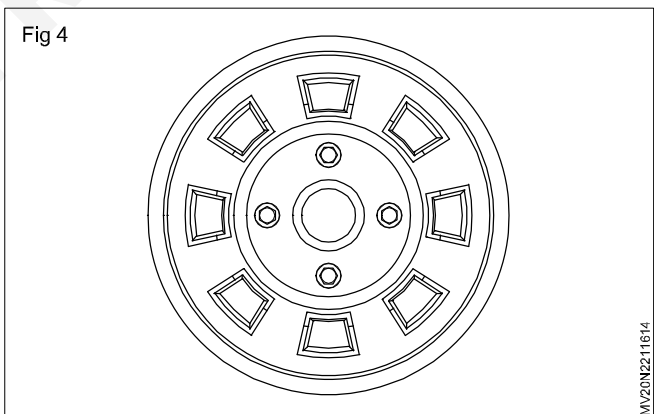


Fig 4



Heavy vehicles wheels

These wheels are similar to disc wheels except that a thicker plate is used for the disc.

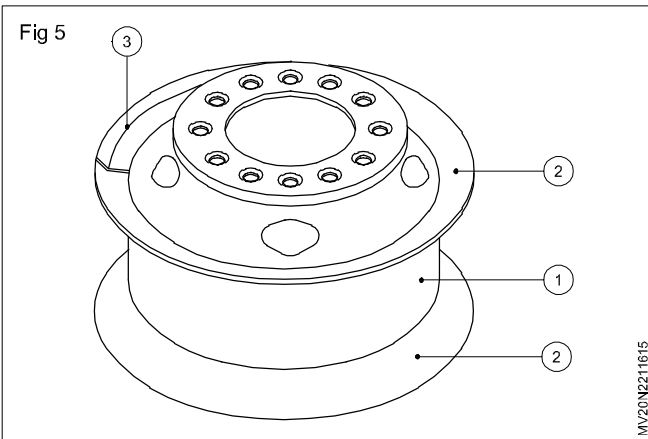
Rims

The rim provides seating surface for the tyre and tube.

Two types of rims are used.

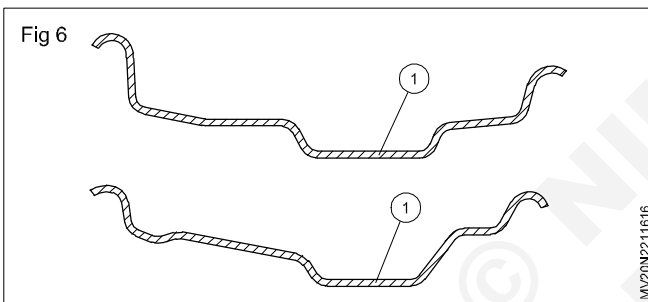
- Flat base rim
- Drop centre rim.

Flat type rim (Fig 5)



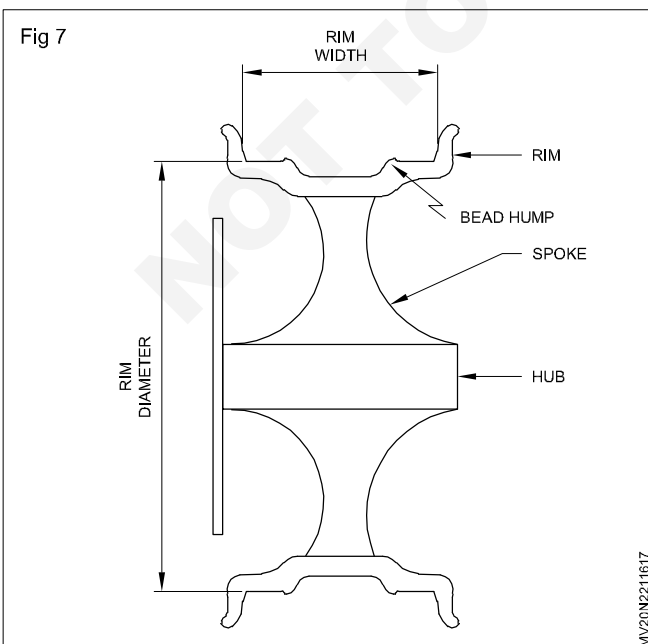
In this type the rim's centre position (1) is kept flat. One edge of the rim has a projection (2), and the other end is removable to install into or remove the tyre and tube from the rim. One plain ring and one split lock ring (3) are provided on the removable end of the rim to lock the tube and tyre in position. This arrangement enables the removal of the tyre without stretching the bead.

Drop centre rim (Fig 6)



In this type a small diameter well (1) is provided at the centre of the rim. It enables removal or installation of the tyre by stretching beads and throwing them in or out of well.

Wheel construction (Fig 7)



Function of each part

Wheels must have the strength to endure shocks and repulsion forces from the road surface as well as braking and driving forces. At the same time they must have the rigidity to maintain stability and maneuverability. Lastly, they must be light in order to reduce unsprung weight.

Wheel can be divided into three parts with the following functions.

Hub

This is the part linked with the frame. It has bearings in the center. The bearings link the rotating wheel to the non-rotating frame. High linkage rigidity and dimensional precision are required for the non-rotating part, while smooth rotation and no play are required for the rotating part. This part supports the spokes and is required to have the appropriate supporting function. It is also designed to facilitate the rotating parts of the brake, the drive system and speedometer.

Spokes

The spokes support the rim while fulfilling the following conditions:

Assure accurate roundness of the rim and ensure its center aligns with the center of the axle shaft (Vertical vibration).

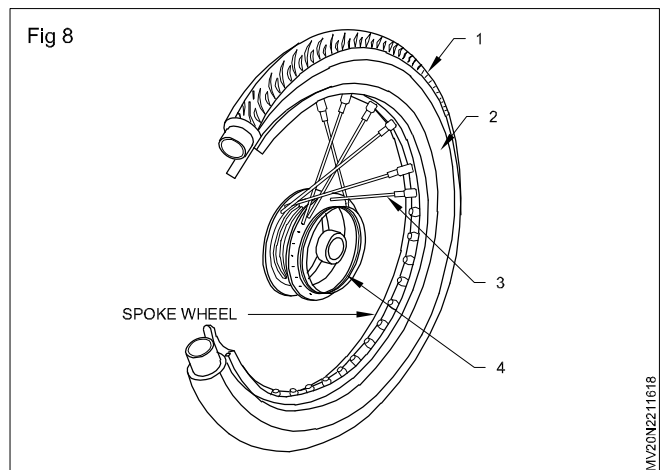
Ensure high degree of flatness with no distortion, and the surface is perpendicular to the axle shaft (horizontal vibration)

RIM

The rim holds the tyre in the correct position. In the case of tubeless tyres, internal pressure is maintained by close adhesion between the bead surface of the tyre and the flange surface of the rim. The rim width indicates the internal width of the flange and is given in inches. The rim diameter is the diameter at the bottom of the rim and is also given in inches. A rim on which tubeless tyre can be fitted is stamped, "Tubeless Tyre Applicable".

Wheel construction

Wire spoke wheels (Fig 8)



Thin steel spokes connect the rim and the hub. This type of wheel is light and inexpensive

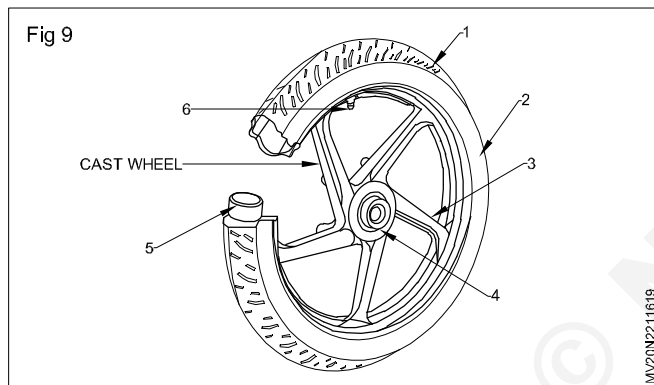
Main parts of spokes wheel are

- 1 Tyre
- 2 Rim
- 3 Spokes
- 4 Hub
- 5 Tube
- 6 Valve

Cast wheel

This wheel is cast from aluminum alloy as a single component. The design became possible following technological development of new materials and manufacturing methods. This type of wheel has high precision, lightweight, high rigidity and high flexibility of design.

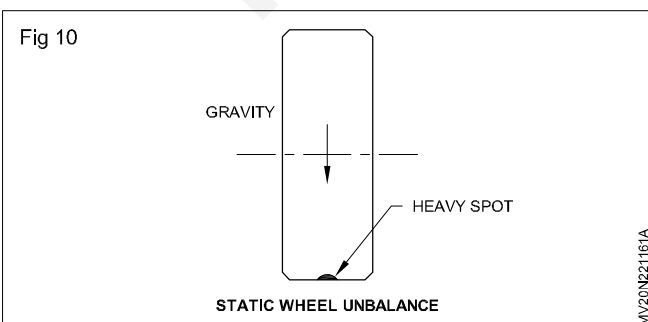
Major parts of cast wheel are (Fig 9)



- 1 Tyre
- 2 Rim
- 3 Spokes
- 4 Hub
- 5 Tube

Some vehicles are equipped with cast aluminum alloy wheel rims or cast magnesium alloy wheel rims. Sometimes these wheels are referred to as "mag" wheels. These wheels are lighter and generally more accurately designed compared to pressed steel wheel rims.

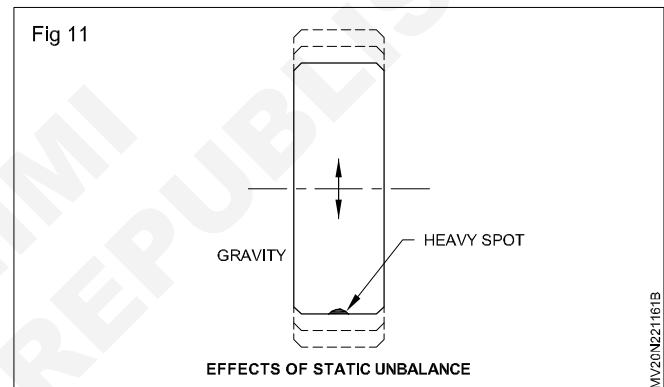
Static wheel balance (Fig 10)



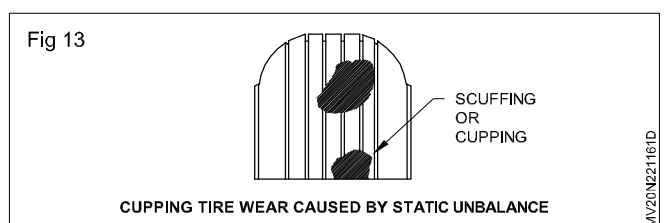
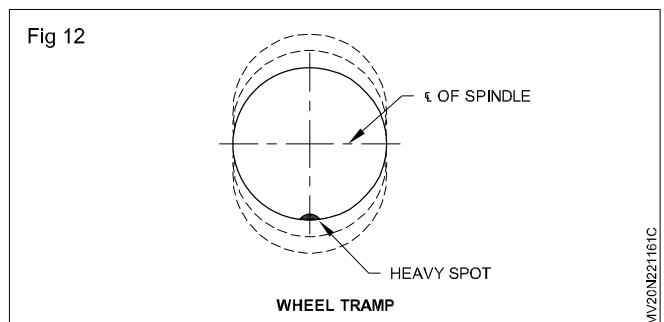
When a wheel and tire has proper static balance, it has the weight equally distributed around its axis of rotation and gravity will not force it to rotate from its rest position. If a vehicle is raised off the floor and a wheel is rotated in 120 degree intervals, a statically balanced wheel will remain stationary at each interval. When wheel and tire are statically unbalanced, the tire has a heavy portion at one location. The force of gravity acting on this heavy portion will cause the wheel to rotate when the heavy portion is located near the top of the tire.

Results of static unbalance

Centrifugal force may be defined as the force that tends to move a rotating mass away from its axis of rotation. As we have explained previously, a tire and wheel are subjected to very strong acceleration and deceleration forces when a vehicle is in motion. The heavy portion of a statically unbalanced wheel is influenced by centrifugal force. This influence attempts to move the heavy spot on a tangent line away from the wheel axis. This action tends to lift the wheel assembly off the road surface. (Fig 11)



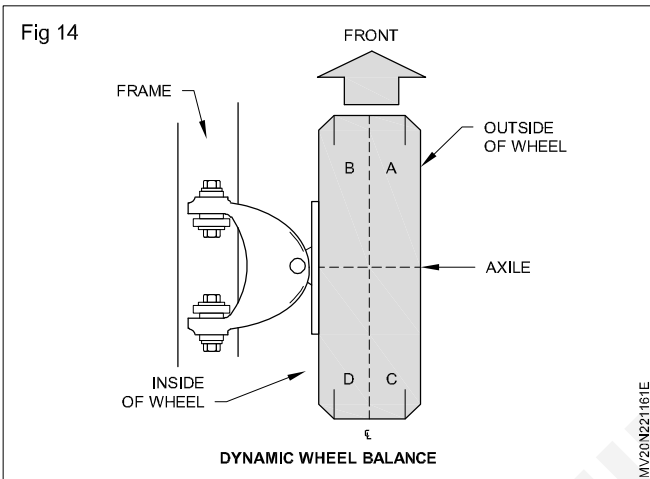
The wheel lifting action caused by static unbalance may be referred to as wheel tramp (Fig 12). This wheel tramp action allows the tire to slip momentarily when it is lifted vertically. When the wheel and tire move downward as the heavy spot decelerates, the tire strikes the road surface with a pounding action. This repeated slipping and pounding action causes severe tire scuffing and cupping. (Fig 13)



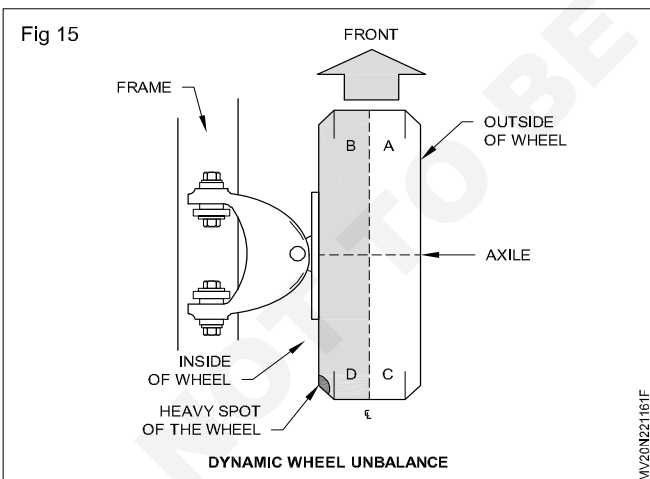
The vertical wheel motion from static unbalance is transferred to the suspension system and is then absorbed by the chassis and body. This action causes rapid wear on suspension and steering components. The wheel tramp action resulting from static unbalance is also transmitted to the passenger compartment which causes passenger discomfort and driver fatigue.

Dynamic wheel balance theory

When a wheel and tire assembly has correct dynamic balance, the weight of the assembly is distributed equally on both sides of the wheel center viewed from the front. Dynamic wheel balance may be explained by dividing the tire into four sections (Fig 14)



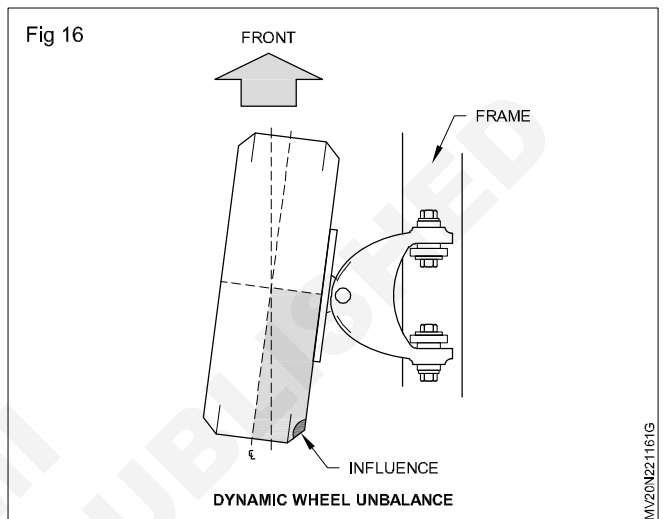
In Fig 14, if sections A and C have the same weight and sections B and D also have the same weight, the tire has proper dynamic balance. If a tire has dynamic unbalance, section D may have a heavy spot and thus sections B and D have different weights. (Fig 15)



From our discussion of dynamic balance, we can understand that a tire and wheel assembly may be in static balance but have dynamic unbalance. Therefore, wheels must be in balance statically and dynamically.

Results of dynamic wheel unbalance

When a dynamically unbalanced wheel is rotating, centrifugal force moves the heavy spot toward the tire center line. The center line of the heavy spot are is at a 90 degree angle to the spindle. This action turns the true center line of the left front wheel inward when the heavy spot is at the rear of the wheel (Fig 16)



When the wheel rotates until the heavy spot is at the front of the wheel, the heavy spot movement turns the left front wheel outward.

From the these explanations we can understand that dynamic wheel unbalance causes wheel shimmy. This action causes steering wheel oscillations at medium and high speeds with resultant driver fatigue and passenger discomfort. Wheel shimmy and steering wheel oscillations also cause unstable directional control of the vehicle. Wheel shimmy is the rapid, repeated lateral wheel movement.

Brake system

Objectives: At the end of this lesson you shall be able to

- state the principle of brake
- state the various types of brake systems
- draw a layout of the mechanical brake system
- state the function and operation of mechanical brakes.

Principle

- To stop the vehicle.
- To slow down the vehicle.
- To park the vehicle.

Types

According to application

- Foot brakes
- Hand brakes

According to operation

- Drum type
- Disc type
- Mechanical brake
- Hydraulic brake
- Air brake
- Air-assisted brake
- Vacuum-assisted brake

Foot brake

The brake which is applied by foot is called the foot brake.

Hand brake

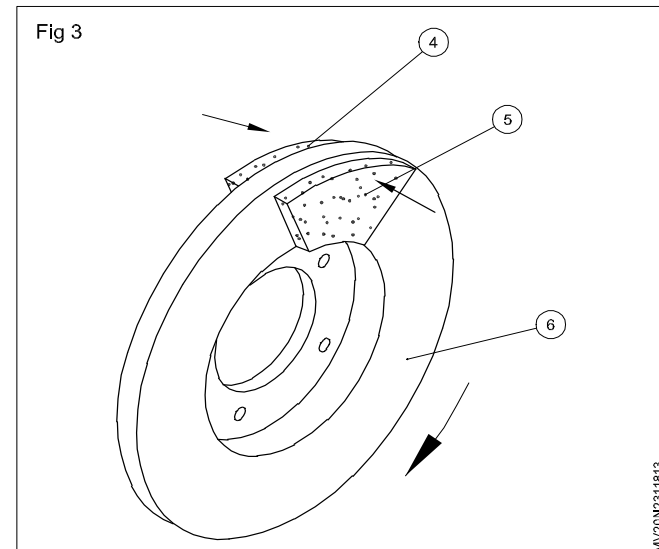
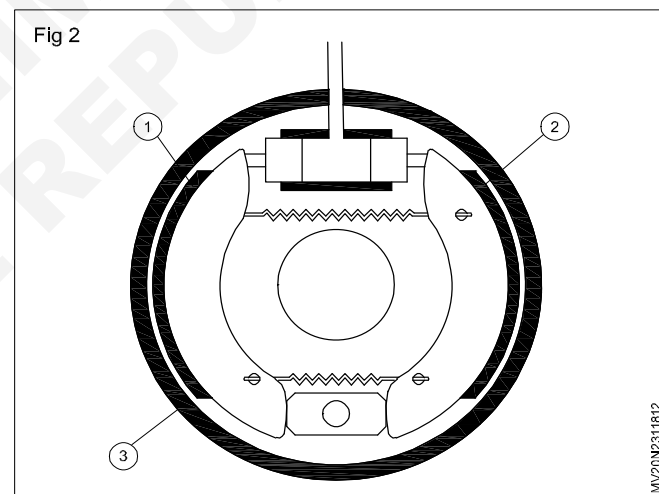
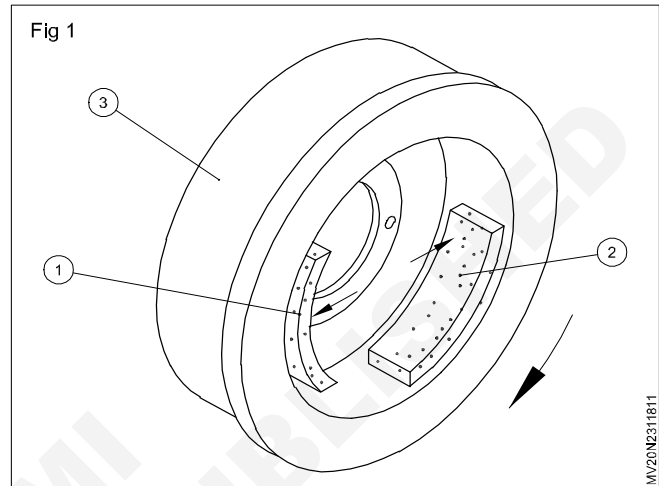
The brake which is applied by hand is called the hand brake, e.g. a scooter's front brake and a commercial vehicle's and car's parking brake.

Drum brake (Figs 1 & 2)

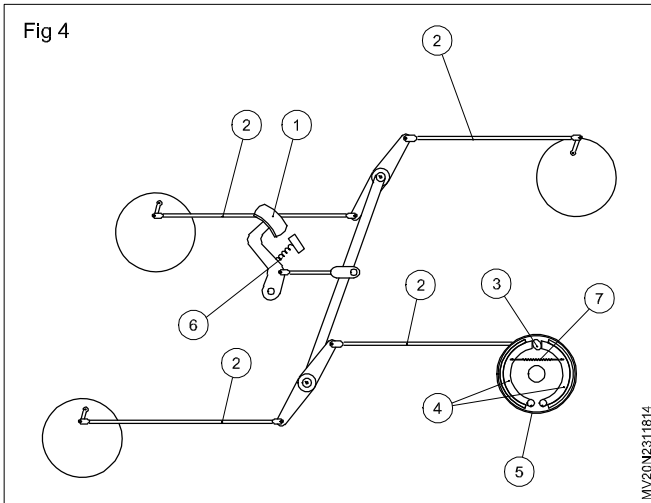
In this type of brakes, the brake shoes (1) & (2) are placed inside the brake drum (3). When the brake is applied, the brake shoes expand through linkages, come in contact with the brake drum and stop the wheels.

Disc brakes (Fig 3)

In this type the brake pads (4 & 5) are arranged at both the sides of the disc (6) which is connected with the wheel hub. When the brake is applied the pads (4 & 5) move towards the disc (6) and stop the wheels. The following types of disc brakes are used.



Mechanical brakes (Fig 4)



When the brake pedal (1) is pressed, the linkage (2) operates the cam (3) and expands the brake shoes (4). The brake shoe comes in contact with the brake drum (5) and stops the brake drum. When the brake is released the brake pedal goes back to its original position with the help of the pedal- return spring (6). The brake shoe comes to its original position with the help of the brake shoe retracting spring (7), and allows the brake drum to rotate. The mechanical brakes are used in two wheelers, three wheelers and the parking brakes of the commercial vehicles.

Mechanical advantage

Mechanical advantage is the ratio of force produced by a machine to the force applied to it. A simple machine that exhibits mechanical advantage is called as lever.

In brake system, the multiplied force is applied on the wheel by means of mechanical linkage, hydraulic power, pneumatic power or vacuum power.

Hydraulic brakes

Objectives: At the end of this lesson you shall be able to

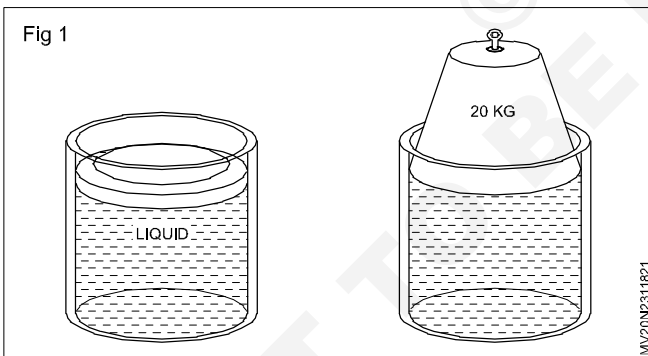
- state the principle of a hydraulic brake
- state the function of the master cylinder.

Principle

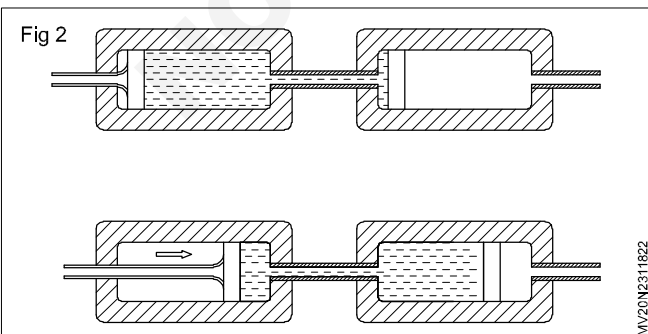
Hydraulic brakes work under the principle of Pascal's law.

Pascal's law

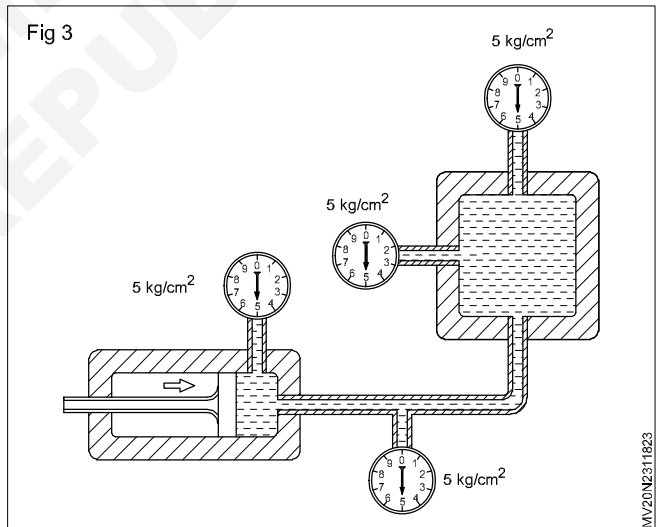
- Liquid cannot be compressed. (Fig 1)



- Motion can be transmitted through a liquid. (Fig 2)



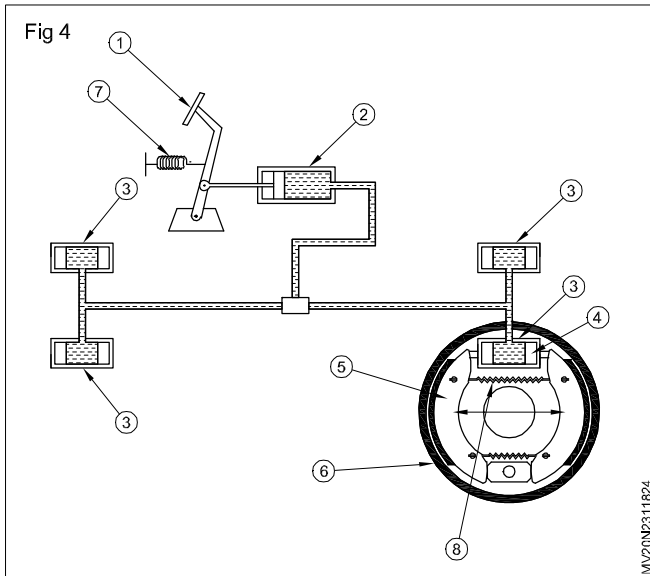
- Liquid pressure is transmitted equally in all directions. (Fig 3)



Operation (Fig 4)

When the brake pedal (1) is pressed the fluid inside the master cylinder (2) is pressurized and supplied to the wheel cylinders (3). The wheel cylinder pistons (4) push the brake shoes (5) towards the brake drum (6). The friction between the brake shoe lining and the brake drum stops the rotation of the brake drum (6).

When the brake is released the brake pedal comes to its original position with the help of the pedal return spring (7). The brake shoes come to their original position with the help of the brake shoe retracting spring (8). When the brake shoe returns to its position, it pushes the wheel cylinder pistons inside, and the pressurized fluid is sent back to the master cylinder.



Components of hydraulic brakes they are

Master cylinder

Wheel cylinder

Connecting pipes

Brake fluid

Brake fluid reservoir

Master cylinder

It serves as a pump to build up hydraulic pressure to operate the brakes. It maintains the level of the fluid in the system.

Types

- Single barrel master cylinder
- Tandem master cylinder
- Centre feed master cylinder
- Tank type master cylinder

Master cylinder (Types)

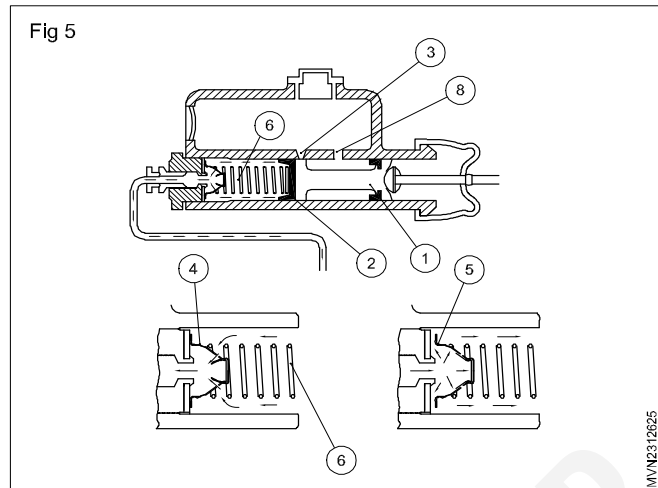
Objectives: At the end of this lesson you shall be able to

- state the different types of master cylinders
- state the advantage of a tandem master cylinder
- state the function of a tandem master cylinder
- state the function of the centre feed master cylinder
- state the function of the tank type master cylinder.

The other three types of master cylinders are

- tandem master cylinder
- centre feed master system
- tank type master cylinder.

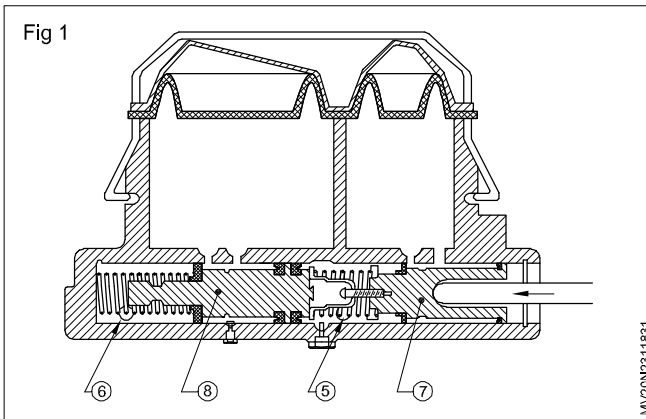
Single barrel master cylinder (Fig 5)



When the master cylinder reservoir is filled, the fluid reaches only on the back side of the primary cup.(2) When the pedal is pumped (pumping action) the master cylinder piston returns quickly, and a partial vacuum is created in front of the piston (1). Due to the partial vacuum in the front side of the primary cup, the fluid from the back side of the primary cup reaches the front side of the primary cup via the transfer port (8) by the folding edges of the primary cup. When the brake pedal is pressed the master cylinder piston (1) moves forward and the primary cup (2) covers the compensating port (3). The fluid inside the master cylinder is pressurized and supplied to the wheel cylinders through the non-return check- valve (4).

When the brake is released the pressurized fluid is sent back to the master cylinder by lifting the check-valve (4) from its seat (5) against the master cylinder spring (6) tension.

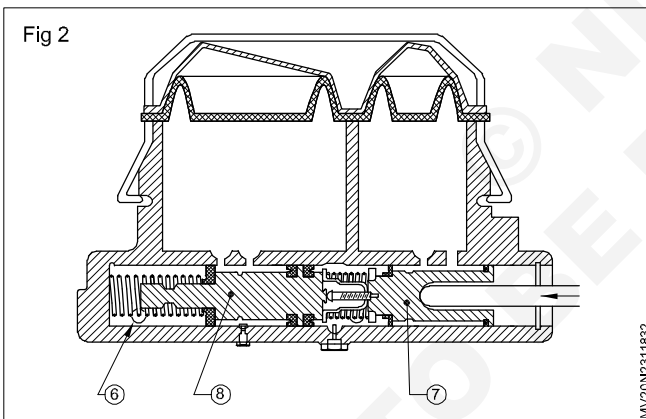
When the brakes are in a fully released position the master cylinder piston spring keeps the check-valve assembly to its seat trapping some pressure in the wheel cylinders and lines, normally about 15 to 17 lbs. This pressure is to keep the wheel cylinder cups and lines from leaking and avoid the possibility of air entering the system.



Operation

When the brake pedal is pressed, the primary piston (7) is forced in the cylinder. Fluid is forced to go to the pipelines passing through the check-valve (5) to the front brakes. Further pressing of the brake pedal forces the primary piston (7). The fluid pressure forces the secondary piston (8) into the cylinder. The fluid is forced through the check-valve (6) to the rear brakes. Further pressure on the brake pedal exerts equal pressure on the shoes of all the four wheels.

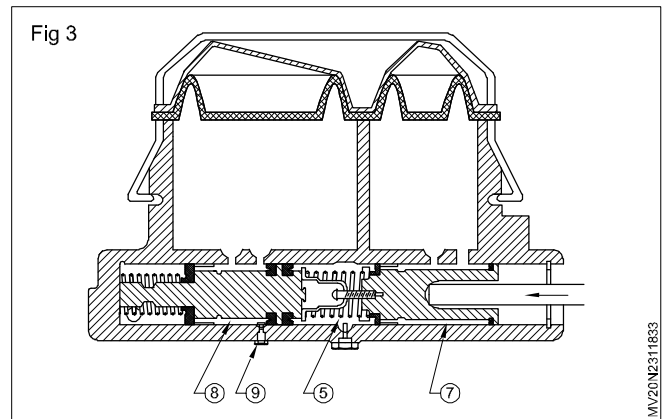
Failure of brakes (Fig 2): When the front brake fails the primary piston (7) is forced forward till it contacts the secondary piston (8). Now, both the pistons move together.



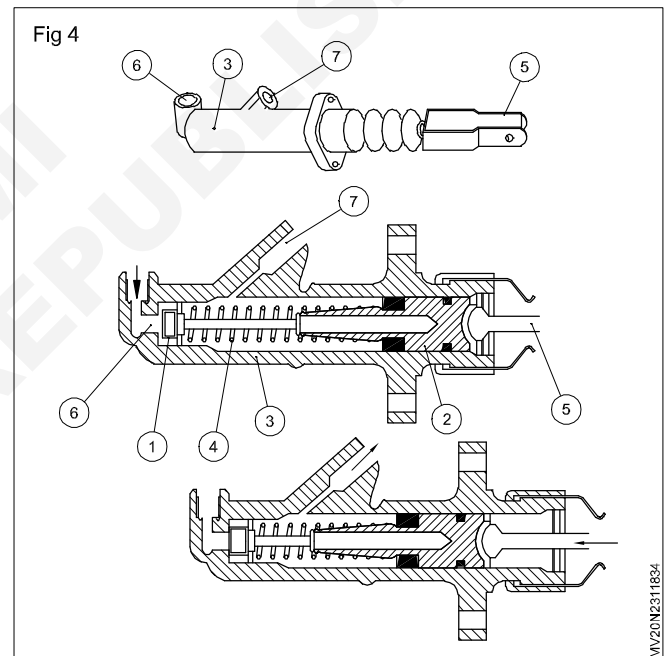
Pressure is created on the secondary side and this forces the fluid through the check-valve (6) to the rear brakes and the vehicle is stopped.

When the rear brake fails (Fig 3) there is no pressure on the secondary side. The pedal effort pushes the primary piston (7) which forces the secondary piston (8) to stop (9). Further movement of the piston (7) builds up the fluid pressure which is transmitted to the front wheel cylinders through the check-valve (5) and the vehicle is stopped.

Centre feed master cylinder (Fig 4): In this type of a master cylinder a non-return valve (1) is provided on the piston's (2) head. When the brake is released, a vacuum created by the rapid return of the piston causes the fluid to flow into the cylinder (3) by lifting the light coil spring



(4) and opening the non-return valve (1). When the system is at rest, the non-return valve sits on its seat and thus full compensating is effected through the bypass port. When the brake pedal is pressed the push-rod (5) moves inside the cylinder. The non-return centre valve (1) seals the inlet (6). The pressurized liquid is sent to the wheel cylinders through the outlet passage (7) to apply the brake.

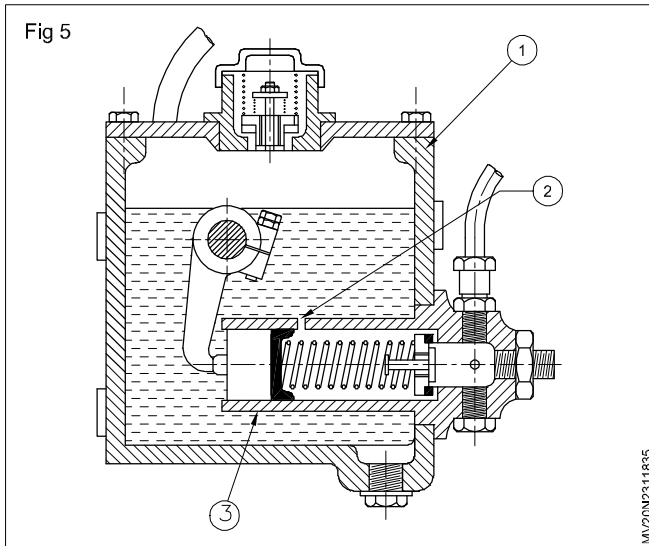


Tank type master cylinder (Fig 5)

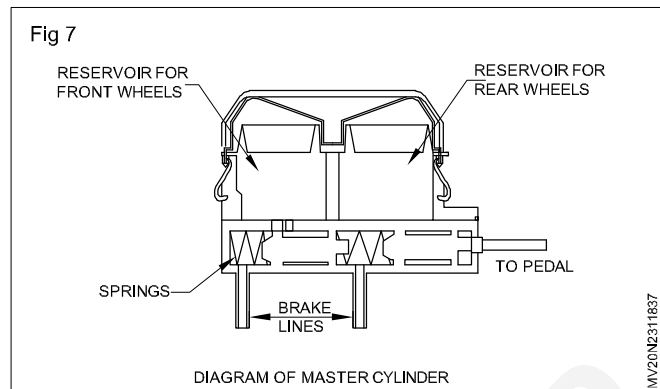
It is also called a submerged type master cylinder. In this type the master cylinder (3) is mounted in a reservoir (1) and a by-pass port (2) is provided on the top of the master cylinder to supply fluid to the master cylinder (3) from the reservoir (1). The operation of this type is the same as that of the ordinary barrel type master cylinder.

Brake proportioning valves (Fig 6)

The proportioning valve is installed on vehicle's with front disc, rear drum brake systems. They provide balanced braking during sudden, hard braking by restricting fluid pressure to the rear brakes. This helps prevent rear wheel lock up as the vehicle's weight is shifted toward the front wheels.



and secondary piston forces the secondary piston to compress the fluid in its circuit. When the brakes are operating correctly, the pressure will be the same in both circuits.



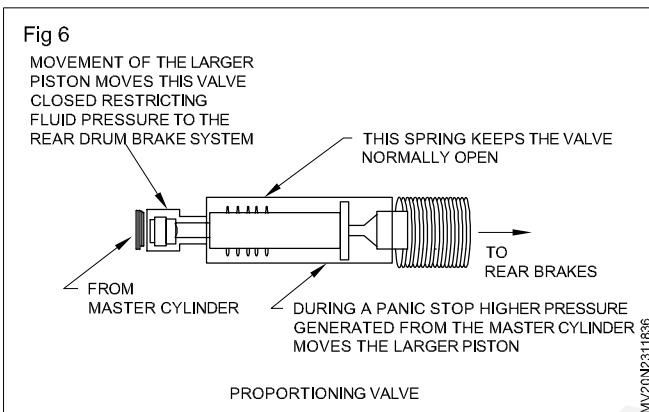
A proportioning valve is required on vehicles that have disc brakes on the front wheels and drum brakes on the rear wheels. Disc brake pads are normally contact with the disc, while the drum brake shoes are normally not in contact with the drum. If the pressure was not proportioned the disc brakes would engage before the drum brakes when you depress the brake pedal.

The proportioning valve compensates for this, allowing the drum brakes to engage first before the disc brakes. The proportioning valve does not allow any pressure determined pressure is low when compared to the maximum pressure in the braking system, this allows the drum brakes to engage before the disc brakes engage. Having the rear brakes engage first provides the control and stability needed to stop our vehicle safely.

Electro hydraulic brake (EHP) system: In an electro-hydraulic set-up, the required brake pressure is instead typically generated by a hydraulic pump and accumulator assembly. The distribution of brake pressure around the car is controlled by a hydraulic unit, feed with pressurised fluid from the accumulator and motor, while a brake ECU interprets various inputs and generates the appropriate control signals. This system is also a hydraulic brake by wire system.

When the driver press on the pedal. sensors monitor the pressure applied and the travel of the pedal itself. The ECU interprets these signals., along with other key inputs such as vehicle speed and steering angle and generates command signals for the hydraulic control unit.

Pressurised brake fluid is then discharged from the accumulator, travelling through solenoid-operated valves in the hydraulic control unit to the individual brakes, slowing the car. This approach has many advantages, such as the system being able to continue to increase braking pressure if an emergency situations detected - whereas a driver might otherwise let off slightly. In the EPB systems the master cylinder will feature a pressure simulator which generates increased pressure as the pedal is depressed in order to ensure suitable brake pedal feel. The master cylinder is also hydraulically linked to the braking system. In some cases just the prompt wheels, in order to provide emergency stopping. (Power element of the EPB fail)



The typical inline proportioning valve remains open until a panic brake situation occurs. During a sudden braking situation, high pressure from the master cylinder moves the larger piston, closing the valve restricting fluid pressure. In late model vehicles these valves have been incorporated into the combination valve along with the metering valve and failure warning light switch. Many proportioning valves are mounted directly in the master cylinder outlet to the rear brakes. It is providing highly effective and well balanced braking of all the wheels.

A height sensing proportioning valve is installed in the hydraulic line leading to the rear drums. They are found on many light trucks, located between the vehicle's chassis and the rear axle. When a driver brakes hard, the rear lifts up and forward. This lightens the load on the rear tires increasing the chance of lock up. It incorporates a lever attached to a spring that moves a valve to restrict fluid pressure as the vehicle's chassis raises up and away from the axle.

An electronic brake proportioning EBP has replaced the conventional proportioning valve in many late model vehicles. This system monitors the speed difference between the front and rear wheels and utilizes the ABS system to prevent rear wheel lock-up. (Fig 7)

When the brake pedal is depressed, it pushes on the first (primary piston) through a linkage. The pressure builds in the cylinder and lines as the brake pedal is depressed further. The pressure between the primary

Power assisted servo brakes

Objectives: At the end of this lesson you shall be able to

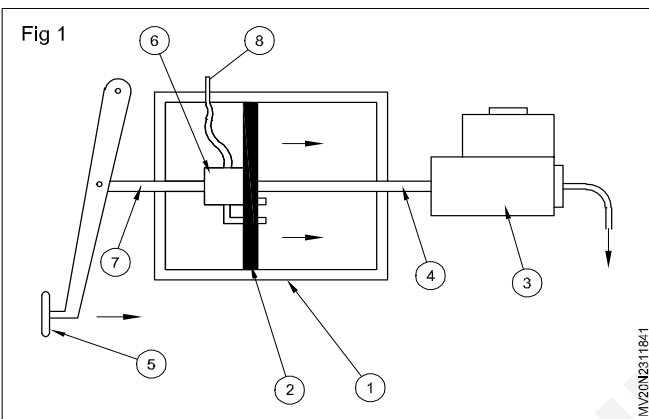
- state the need of power-assisted hydraulic brakes
- draw the layout of a vacuum-assisted hydraulic brake
- list out the various types and their functions in the vacuum-assisted hydraulic brake.

Power assisted servo brakes

It reduces the brake pedal effort without affecting the braking efficiency. Two types of power-assisted servo brakes are used.

- Vacuum-assisted power brakes
- Air-assisted power brakes

Vacuum-assisted power brakes (Fig 1)



The power brake unit uses the vacuum produced in an engine.

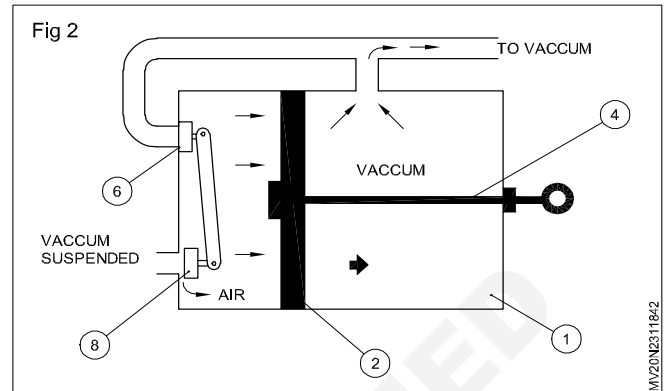
A booster cylinder (1) is a closed cylinder with a piston or diaphragm (2) inside. One side of the piston is connected to the master cylinder (3) through a push-rod (4). The other side is connected to the brake pedal (5) through a linkage (7). A vacuum control valve (6) is placed between the brake pedal linkage (7) and the piston (2).

The vacuum control valve (6) admits vacuum or atmospheric pressure to reach both sides of the piston (2). When a driver presses down the brake pedal (5), the vacuum control valve (6) cuts off the atmospheric pressure and opens the vacuum inlet passage (8) to the brake cylinder side. The atmospheric pressure acts on the piston to push the push-rod. This reduces pedal effort.

Vacuum-assisted power brakes are divided into two types.

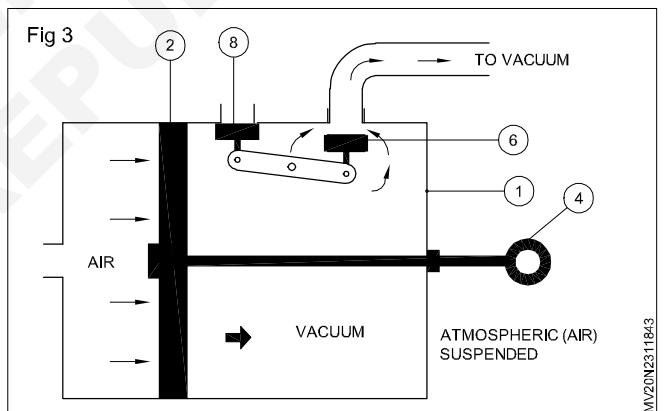
Vacuum suspended power brakes (Fig 2)

A booster (1) has a vacuum existing on both sides of the diaphragm or piston (2) when the booster is in a released position. When the brake is applied, the atmospheric pressure is admitted to one side of the piston by closing the vacuum valve (6) and opening the air valve (8). The difference in pressure on both sides of the piston causes the necessary movement of the piston along with the push-rod (4).



Atmospheric air-suspended power brakes (Fig 3)

The booster (1) has atmospheric pressure on both sides of the piston (2) when it is in the released position. When the brake is applied a vacuum is created on one side by closing the air valve (8) and opening the vacuum valve (6) to cause the piston to move along with the push-rod.(4)



This type of power-assisted brakes will not operate if the engine is not running. A small vacuum tank is included to provide enough vacuum for several brake applications after the engine has stopped.

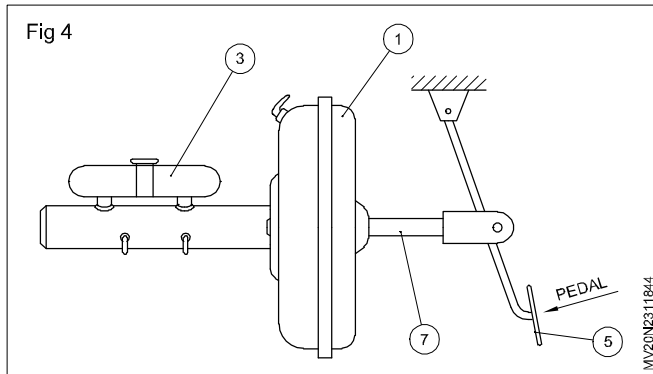
Types of brakes

- Integral type brake
- Multiplier type brake
- Pedal-assisted type brake

Integral type (Fig 4)

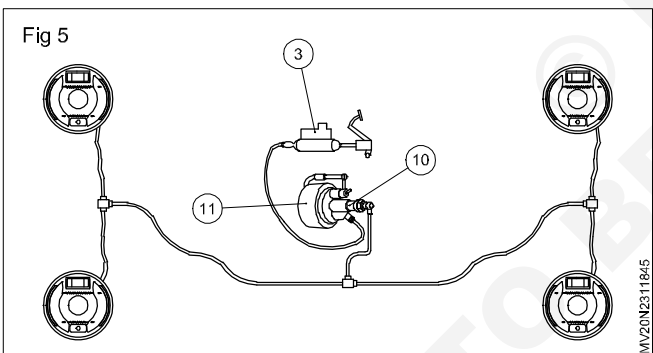
In this type the brake master cylinder (3) is an integral part of the power brake assembly (1). The booster assembly (1) is fitted between the brake pedal (5) and the master cylinder (3). When the brake pedal is operated the linkage (7) actuates a brake valve in the power brake assembly. An atmospheric pressure is applied to one

side of the piston or diaphragm and the vacuum to the other side. The difference in pressure causes the piston/diaphragm to move. This movement forces the master cylinder piston inside for effective braking. Most cars and light vehicles use this type of system.



Multiplier type (Fig 5)

This type multiplies the pressure produced by the hydraulic cylinder (10). When the brake is applied, the hydraulic pressure from the master cylinder (3) actuates a control valve in the multiplier unit (11). This causes to admit atmospheric pressure to enter at one side of the diaphragm. The other side of the diaphragm has a vacuum. Due to the difference in pressure the diaphragm is forced to move. This produces high hydraulic pressure which is transmitted to the wheel cylinders. A very light pedal pressure multiples several times and produces heavy braking action.

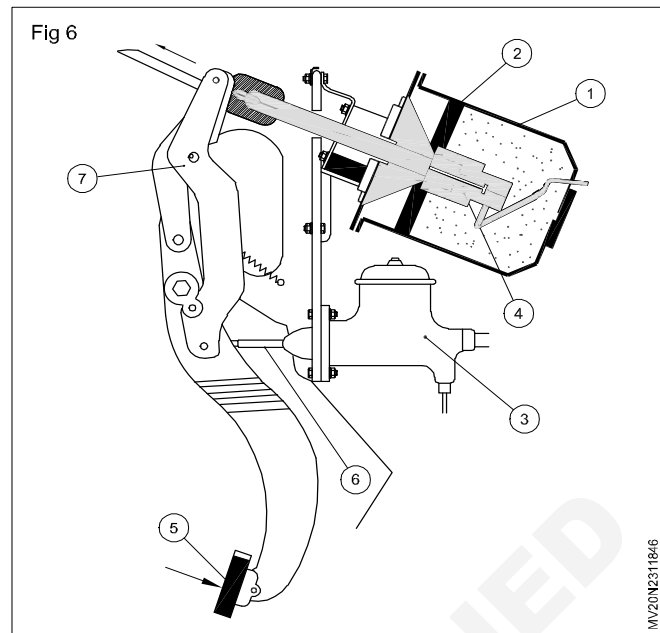


Pedal-assisted type (Fig 6)

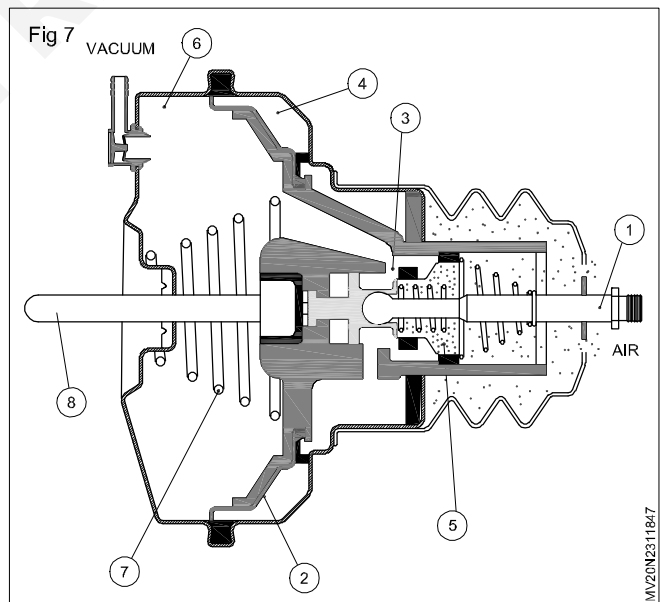
This system has a power cylinder assembly (1). It assists in applying the brakes through a mechanical linkage (7). When the brake pedal (5) is pressed the linkage to the power cylinder is actuated. It causes the valve (4) to open and moves the diaphragm (2) within the power cylinder (1). This movement is carried through the linkages (6) to the master cylinder (3) and increases the total force applied for the braking action. This set up applies the booster pressure to the brake pedal instead of directly to the master cylinder.

Vacuum booster (Fig 7)

A vacuum booster helps in reducing pedal effort. Inside the booster, vacuum is created when the engine is running and the brake is not applied. In this position the vacuum port (3) of the rear chamber (4) remains open

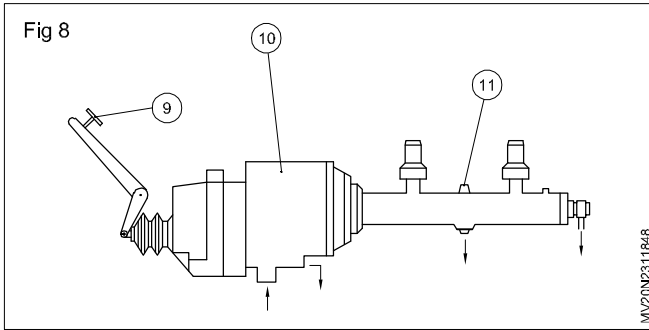


and the atmospheric port (5) remains closed. Thereby vacuum exists in both the front (6) and rear chambers (4). When the brake pedal is pressed its push-rod (1) pushes the diaphragm assembly (2). This causes the vacuum port (3) to close and the atmospheric port (5) to open. Now, vacuum exists only in the front chamber (6) and air at the atmospheric pressure exerts in the rear chamber (4). This forces the diaphragm assembly (2) to move towards the front chamber and pushes the master cylinder push-rod (8) to apply the brakes. When the brake is released the diaphragm assembly (2) comes back to its original position by the return spring (7), closing the atmospheric port (5) and opening the vacuum port (3).



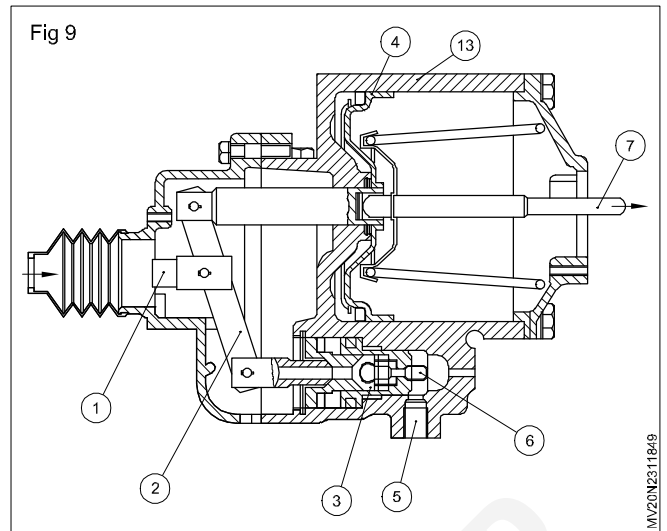
Air-assisted power brakes (Fig 8)

In this system instead of a vacuum, air pressure is used to assist in the application of brakes. It is a lever type servo-fitted (10) on the chassis. The front end is linked to the brake pedal (9) and the rear to the master cylinder (11). This will boost the force applied on the master cylinder at the time of application of the brakes. Details of servo unit 10 shown in Fig 9.



Operation: When the brake pedal is pressed, the fork rod (1) which is linked to the brake pedal presses the lever (2). The lever (2) is linked with the air control valve (3). The air control inlet valve (6) opens and allows high pressure air from the air compressor to reach into the cylinder (13) behind the piston (4) through the air inlet port (5). The piston (4) moves forward pushing the master cylinder piston rod (7). The brake fluid under high pressure goes to the wheel cylinders to actuate the brakes.

The functions of the other units in this system like the air compressor, unloader valve, flick valve etc, are the same as in the air brake system.



The piston rod (7) is linked to the brake pedal rod (9) in such a way that in the event of air pressure failure, the pedal rod (9) can press the master cylinder rod (7) and the vehicle can be stopped.

Drum brake

Objectives: At the end of this lesson you shall be able to

- state the various components of drum brake
- state the functions and operation of drum brake.

Types of brakes

There are two types of brakes

- 1 Drum brake
- 2 Disc brake
 - a fixed - caliper disc brakes
 - b floating - caliper disc brake

1 Drum brake

A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum.

Components of drum brake (Fig 1)

Back plate

The back plate provides a base for the other components. It attaches to the axle and forms a solid surface for the wheel cylinder, brake shoes, and assorted hardware. Since all braking operations exert pressure on the back plate, it must be strong and wear resistant.

Brake drum

It is positioned close to the brake shoe without touching it, and rotates with the wheel and axle. When a driver applies the brakes, the lining pushes against the inner surface of the drum which generates friction heat of high amount. So, the brake drum is generally made of a special type of cast iron that is heat conductive and wear resistant.

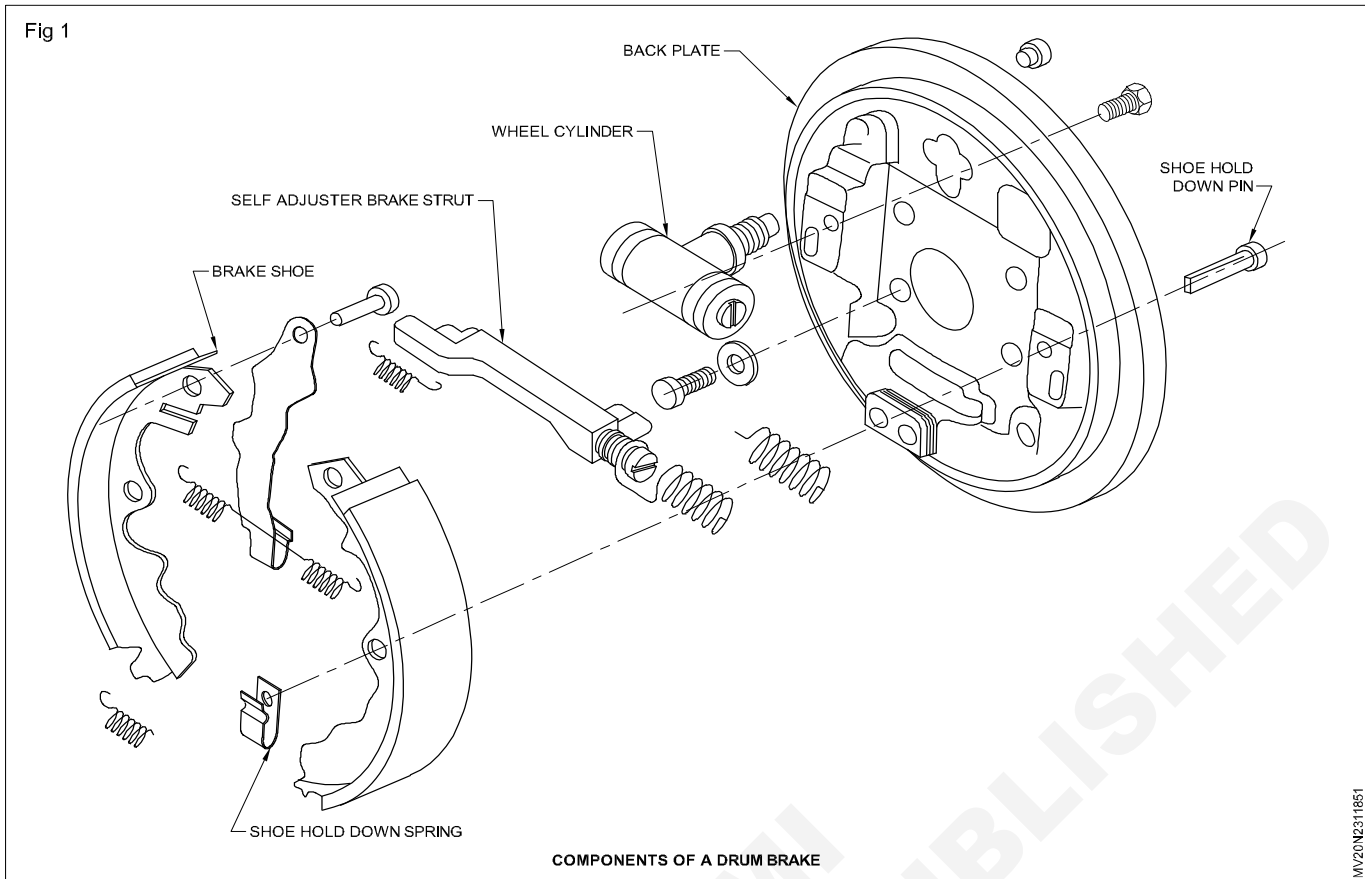
Wheel cylinder

The wheel cylinder consists of a cylinder that has two pistons, one on each side. Each piston has a rubber seal and a shaft that connects the piston with a brake shoe. When brake pressure is applied, the piston are forced out pushing the shoes into contact with the drum. One wheel cylinder operates the brake on each wheel. Hydraulic pressure from the master cylinder acts on the piston cup, pushing the pistons toward the shoes, forcing them against the drum. When the driver releases the brakes, the force of the brake shoe retract spring returns the piston to its original position.

Brake shoe

Brake shoes are typically made of two pieces of sheet steel welded together. The friction material is either riveted to the lining table or attached with adhesive. The crescent - shaped piece is called the web and contains holes and slots in different shapes for return springs, hold down hardware, parking brake linkage and self adjusting components. All the application force of the wheel cylinder is applied through the web to the lining table and brake lining. Each brake assembly has two shoes a primary and secondary. The edge of the lining table generally has three "V" shaped notches or tabs on each side called nibs. The nibs rest against the support pads of the backing plate to which the shoes are installed.

Fig 1



Self adjuster brake strut

The self - adjuster is used to adjust the distance between the brake shoe and the drum automatically as brake shoes wear.

Operation

When brake pedal is pressed, either through Mechanical / hydraulic / pneumatic means, brake shoes expands against the drum. Many drum brakes are self-actuating. The brake shoes contact the drum, there is a kind of blocking action, which has the effect of pressing the shoes into the drum with more force. Because of this action, the shoes must be pulled away from the drum

when the brakes are released. For which springs are provided to hold the brake shoes in place and return the adjuster arm after it actuates.

Advantages

Self reinforcement , Dirt-proof design, Parking brake easier to use.

Disadvantages

Maintenance is costly; Pad replacement is time consuming, Poor heat dissipation Tendency towards fading.

Disk brake

Objectives: At the end of this lesson you shall be able to

- state the various components of disk brake
- state the functions and operation of different types of disc brake.

Disk brake

Disc brake also works on the principles of the drum brake, disc which rotates along with the vehicle wheel and is partially held by a brake caliper assembly mounted on the suspension. When the brake pedal is depressed, the brake pads mounted on the inside and outside of the housing are pressed hydraulically against the rotating disc.

Major components of disc brake are

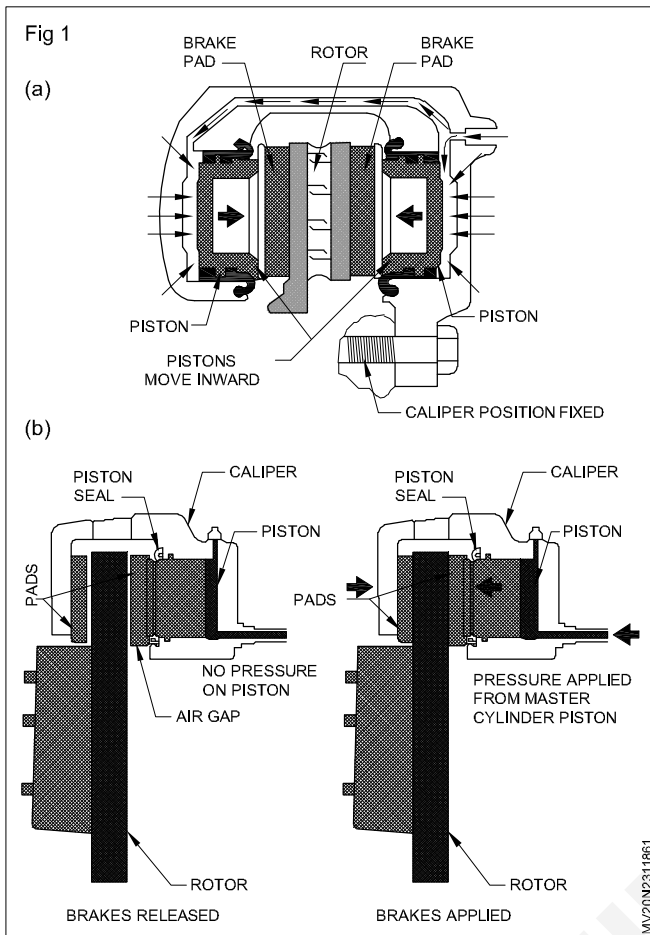
Disc, Piston, Brake pads and piston housing bracket.

Types of disc brakes

Disc brakes categorized into

a Fixed caliper disc brakes (Fig 1a)

It contains two pistons in housing and brake pads on the piston. On applying force over brake pedal, the hydraulic fluid passes through piston housing bracket and makes the two pistons move against the brake pads located in the housing and after closing the air cap these are pressed against the rotating brake disc. Nowadays, this type is rarely used.



b Floating caliper disc brakes (Fig 1b)

When the brakes are applied, the piston moves in the housing and recesses the inner pad against the rotating brake disc. The hydraulic pressure in the cylinder of the piston housing acts both on the surface of the piston and on the bottom of the piston housing. As a result, the piston housing slides on the locating studs in the opposite direction and the outer brake pad is drawn against the brake disc with same force from the wheel side. When the brake release, the air gap between the pads and the brake disc is restored by the force of the piston sealing ring.

Wheel cylinder

Objectives: At the end of this lesson you shall be able to

- state the function of a double piston wheel cylinder
- state the function of a stepped wheel cylinder
- state the function of a single piston wheel cylinder
- state the function of the baffle type wheel cylinder.

The fluid pressure of a pipeline is increased in the wheel cylinder by using a bigger diameter piston. This increased fluid pressure is applied on the brake shoes by the pistons, and braking action is achieved.

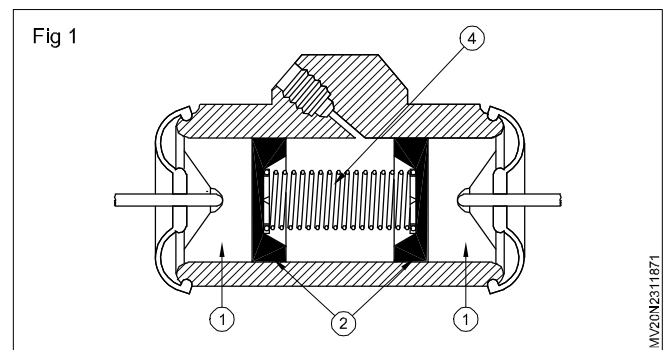
Operation of wheel cylinder

The space in the cylinder bore between the cups (2) always remains filled with fluid. When the brake pedal is pressed, additional brake fluid is forced into the cylinder bore under pressure. Due to this pressurized fluid, the cups (2) and pistons (1) move outward and expand the brake shoes. The expanded brake shoes come in contact with the brake drum and stop the vehicle.

There are four types of wheel cylinders used with drum brakes.

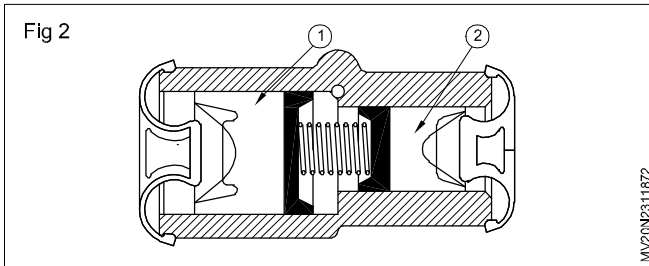
Double piston with straight bore (Fig 1)

In this type two pistons (1) are used in a single bore. These pistons are separated by a spring (3). Each piston is connected to one brake shoe.



Double piston with step bore (Fig 2)

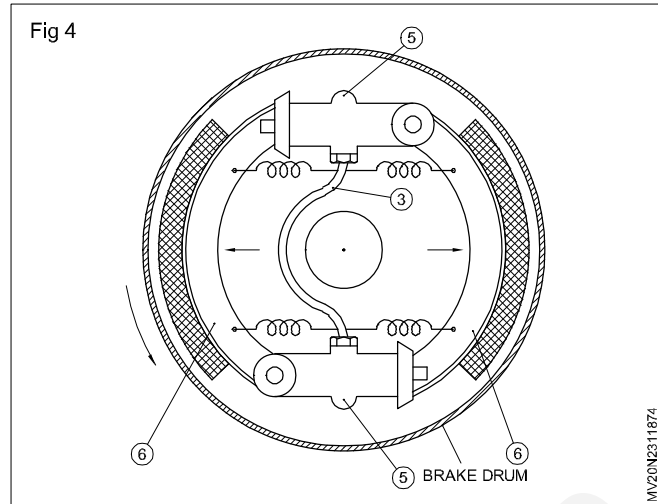
This type of wheel cylinder is similar to the double piston with a straight bore with the difference that a stepped bore is used instead of a straight bore. Both the pistons (1) & (2) have different diameters, so the pressure on each brake shoe is different.



Single piston wheel cylinder (Figs 3 & 4)

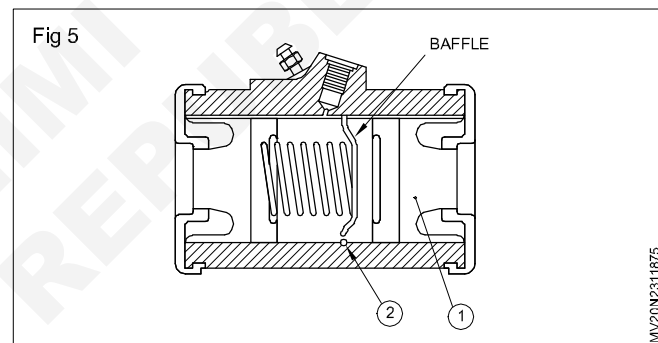
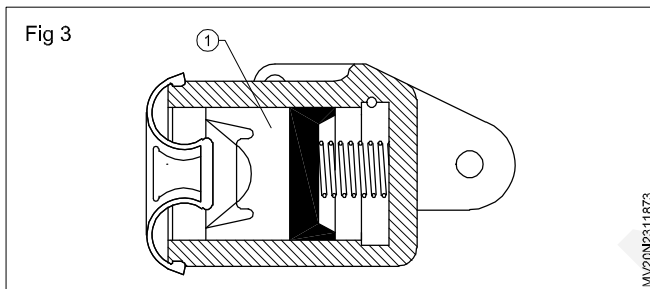
There are two wheel cylinders each of which will operate one shoe independently. In this type one piston (1) is used in one cylinder. One end of the wheel cylinder (5) is pivoted and the other end is connected to the brake shoe and actuates the brake shoe (6) when the pedal is pressed.

The two wheel cylinders are connected by a pipe line (3). Both the wheel cylinders have equal diameter; so equal pressure is exerted on both the brake shoes. In this type both shoes becomes leading shoes in the forward direction. This allows equal wear on both the brake shoes.



Baffle type piston wheel cylinder (Fig 5)

This type is used to avoid clinking noise during braking while the vehicle is moving in reverse. In this type an orifice (2) is drilled on the base of the cylinder. The orifice (2) reduces the flow of fluid from the front half to the rear half, thereby causing the primary shoe to operate first and the secondary shoe expands a little later. So the noise is avoided.



Brake fluid

Objectives: At the end of this lesson you shall be able to

- state the necessity of bleeding the brake system
- state method of brake pedal adjustment
- state the characteristics of brake fluid
- state the advantages and disadvantages of a hydraulic brake.

Bleeding of hydraulic brake system

The hydraulic brake system must be bleed whenever the fluid line has been disconnected or air gets into the system. A leak in the system may sometimes be indicated by a spongy brake pedal. Air trapped in the system is compressible and does not permit pedal effort to be transmitted to the brakes. The system must be absolutely free from air at all times.

Brake pedal adjustment

There should be always at least 12.7mm (1/2") free pedal travel, before the push rod engages the master cylinder piston. This adjustment is accomplished by shortening or lengthening of the brake master cylinder eye-bolt. This is done so that the primary cup will clear the bypass port

when the piston is in the off position. This will prevent the compensating action of the master cylinder against temperature changes of the brake fluid.

Brake fluids

Characteristics of brake fluid

- It should be able to flow freely at extremely high and low temperatures.
- It should be able to serve as a lubricant.
- It should be anti-corrosive and anti-rust.
- It should show resistance to evaporation.
- It should not damage or swell the rubber parts.

Use only approved brake fluids in a brake system. Any other fluid such as power steering fluid, automatic transmission fluid, or engine oil, which has a petroleum base, must never be used in the brake system. Petroleum based fluids will damage the rubber components in the brake system, like the piston cups and seals, and cause them to swell and disintegrate.

Advantages of a hydraulic brake

- Simple in construction.
- Equal braking at all the wheels.
- Wear of the parts is less.

Brake lining

Objectives: At the end of this lesson you shall be able to

- state the material required for the brake lining.

Two types of brake linings are used.

- Organic brake lining
- Semi-metallic brake lining

Organic brake lining

These linings are moulded from a mixture of asbestos, fibre glass, asbestos fibres etc. Resin is used as a binding material.

The blend of raw materials for our friction materials (brake pads, brake linings)

Disc brake pads and drum brake linings are made from a blend of 10 to 20 kinds of raw materials. Depending on their specific roles, the raw materials are divided into three categories; “blending material”, “stiffener” and “friction adjustment material”.

The bonding material hardens raw materials and gives the materials their intensity. Mainly phenol resin is used currently.

The stiffener gives the friction materials further intensity. Various kinds of organic and inorganic, fibers, such as aramid fibers and metal fibers are used.

The friction adjustment material mainly adjusts the effectiveness of friction materials. It is used for strengthening the effectiveness or stabilizing a lubricants, organic, fillers, inorganic fillers, abrasive material and metal powder are blended as necessary.

• 1 Sintered alloy

The phenomena where the particles of powder material join together and turns into a solid substance by pressurizing and fabricating the powder material and heating it at temperature below the melting point. Material that is not made by melting metal, but instead by sintering metal powders is called sintered alloy.

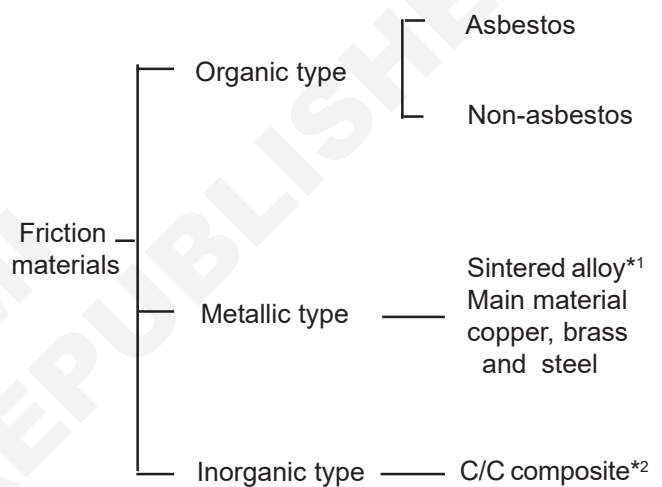
• 2 C/C composite

Carbon fiber reinforced carbon composite. Carbon composite material has been strengthened with carbon

- Little maintenance is required.

Disadvantages

- Any leakage of fluid in the line will lead to brake failure.
- Chances of the brake fluid reaching the brake shoes are very high. This will damage the brake shoes.
- If fluid enters the lining it reduces the braking efficiency.



fiber. It is extremely thermally stable and light-weight. This material is often used for brake rotors and brake pads for aircraft and racing cars.

Performance requirements for friction materials (brake pad, brake lining)

Further more, friction materials are required to exercise stable effectiveness (minimum fluctuation of effectiveness) under varying conditions, such as vehicle speed, laden weight or temperature change from brake, usage as well as under different environment influences including humidity, water and mud. Strength to withstand thermal disturbances and mechanical strength are also important design criteria.

Durability is another important property of friction materials as they wear with use. Moreover, when brakes are applied, squeal, noise and vibrations must be minimized. Further more, the friction materials should not cause damage to the material they get into contact, such as the disc rotors. Friction materials also require to have low thermal conductivity to prevent temperature buildup of the brakes themselves or brake oil.

Main performance requirements for friction materials are:

- Optimum effectiveness, i.e. appropriate friction coefficient (μ).
- Stable effectiveness under various usage and/or environmental conditions.
- Strength to withstand thermal disturbances and mechanical strength.
- High level of durability.
- Minimized brake squeal, noise and vibrations.
- Low damage to the contact material, such as the disc rotor.

- Low thermal conductivity.

Semi-metallic brake linings

These linings are mostly used for front disc brakes in front wheel drive vehicles. It is made of fine polished steel wool. It also includes iron powder and graphite. Plastic resin is used as a binder. The mixture is heated and pressed to form the lining. Semi-metallic linings are more wear and heat resistant than organic linings. Semi-metallic linings can retain their coefficient of friction when operating at very high temperatures.

Brake adjuster

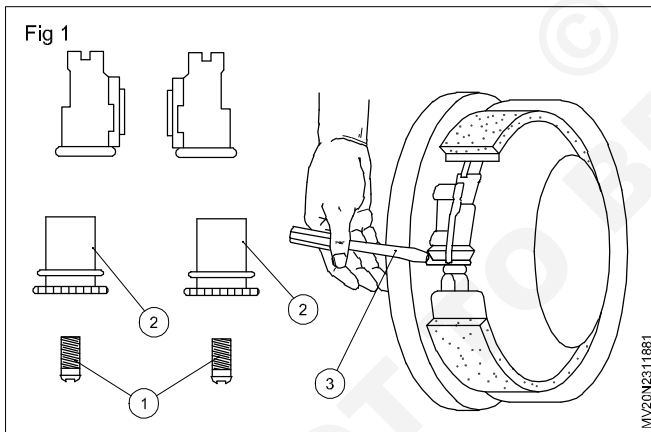
Objectives: At the end of this lesson you shall be able to

- list out the different types of brake adjusters
- state the operation of the different types of brake adjusters
- list out materials required for the brake drum
- state the need of the turning brake drum.

The following types of brake adjusters are used.

- 1 Serrated wheel brake adjuster
- 2 Slack adjuster for 'S' Cam brake
- 3 Wedge type brake adjuster
- 4 Snail and cam type adjuster.

Serrated wheel brake adjuster (Fig 1)

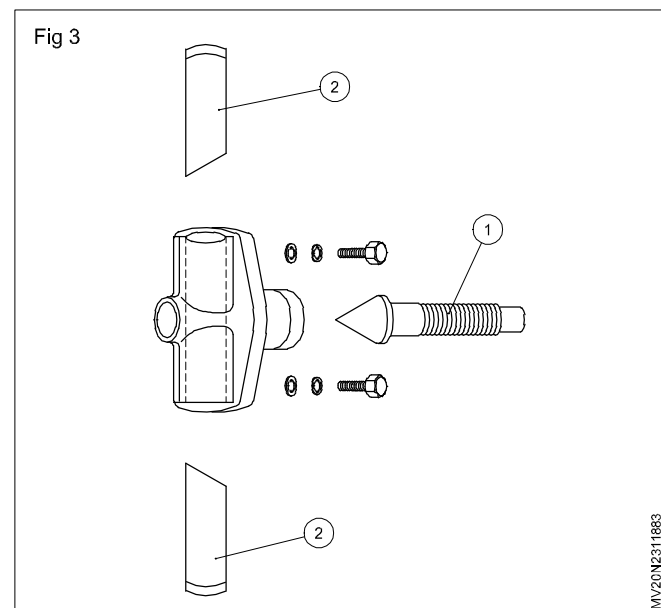
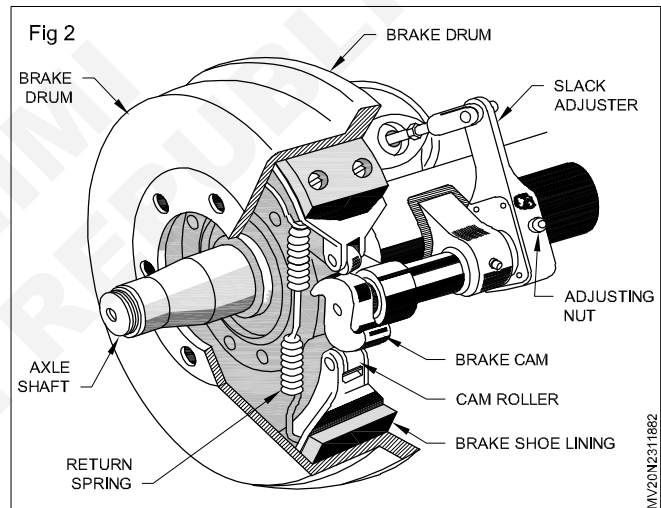


In this type an adjusting screw head (1) fixed with the serrated wheel (2) is screwed in the head of the wheel cylinder end covers. This adjusting screw (1) can be screwed in or out by moving the serrated wheel with a screwdriver (3) through an opening at the back of the end plate (4).

Slack adjuster for 'S' Cam brake (Fig 2)

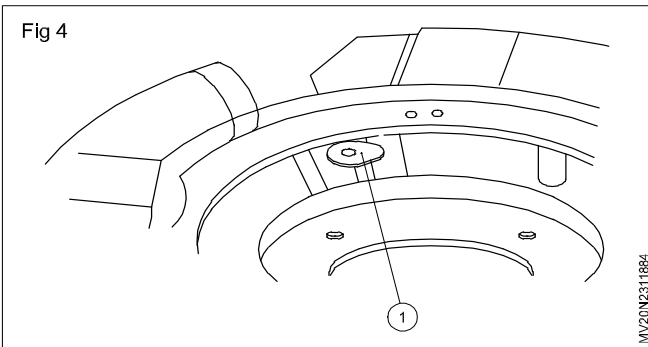
Slack adjuster adjusting nut is rotated to move the cam to set the required brake lining to drum clearance. Thereafter adjusting nut is locked.

Automatic brake adjusting slack adjuster have already been introduced and being fitted in commercial vehicles now a days. (Fig 3)



Wedge type adjuster (Fig 4)

In this type a bolt (1) called wedge is used. The wedge (1) has a taper end on which two links (2) rest. The links (2) are connected to the brake shoe. When the wedge (1) is screwed in, the links (2) move apart and expand the brake shoes.



Snail and cam type adjuster

In this type one end of the brake shoes rests on a cam (1). The cam's outer end is square or hexagonal. The cam can be rotated by a spanner. When it is rotated the brake shoes expand. It is simple and is widely used in small vehicles.

Dual line air brake system

Objectives: At the end of this lesson you shall be able to

- state the principle of an air brake
- draw the layout of the air brake system
- list out the various components of the air brake with functions.

Principle and working of air brakes

In the air brake system the pressure of compressed air is used to apply the brake.

Following types of air brakes are used.

Dual air brake system (Fig 1)

Compressed air from air compressor (1) passes through the unloader valve (2) & goes to the main air tank (3). The outlet of main air tank is connected to a system protection valve (4) which has four outlets. Outlet 1 connects to aux air tank (15) which supplies compressed air to front brake chambers (9) through E2 brake valve (7) outlet 2 connect auxiallery air tank (6).

Outlet 3 connects to graduated hand control valve (8) to the parking brakes at the rear brake chambers (10).

Air pressure gauges (11) are incorporated between auxiallery air tanks and E2 valve to indicate air tank pressure on front & rear brakes respectively.

Compressed air presses the diaphragm of front & rear brake chambers and actuates the push rods (12), which actuates the S cam through slack adjusters (13) and brakes are applied.

Brake drum

The brake drum is made of the following materials.

- Cast iron
- Steel
- Steel-backed with cast iron lining
- Aluminium alloy

Need of the turning brake drum

Brake drums gets scored due to mainly two reasons

- 1 Brake liner wearing nut upto the rivet which score the drum.
- 2 Entry of dust & foreign practical entering brake liner and drum. In the event of score, brake drum is to be turned in a lathe upto the prescribed limit of the manufacturers. Check taper and ovality of drum before and after the turning.

Layout of the air brakes system

The layout is given in the Fig 1

Major components of air brake system

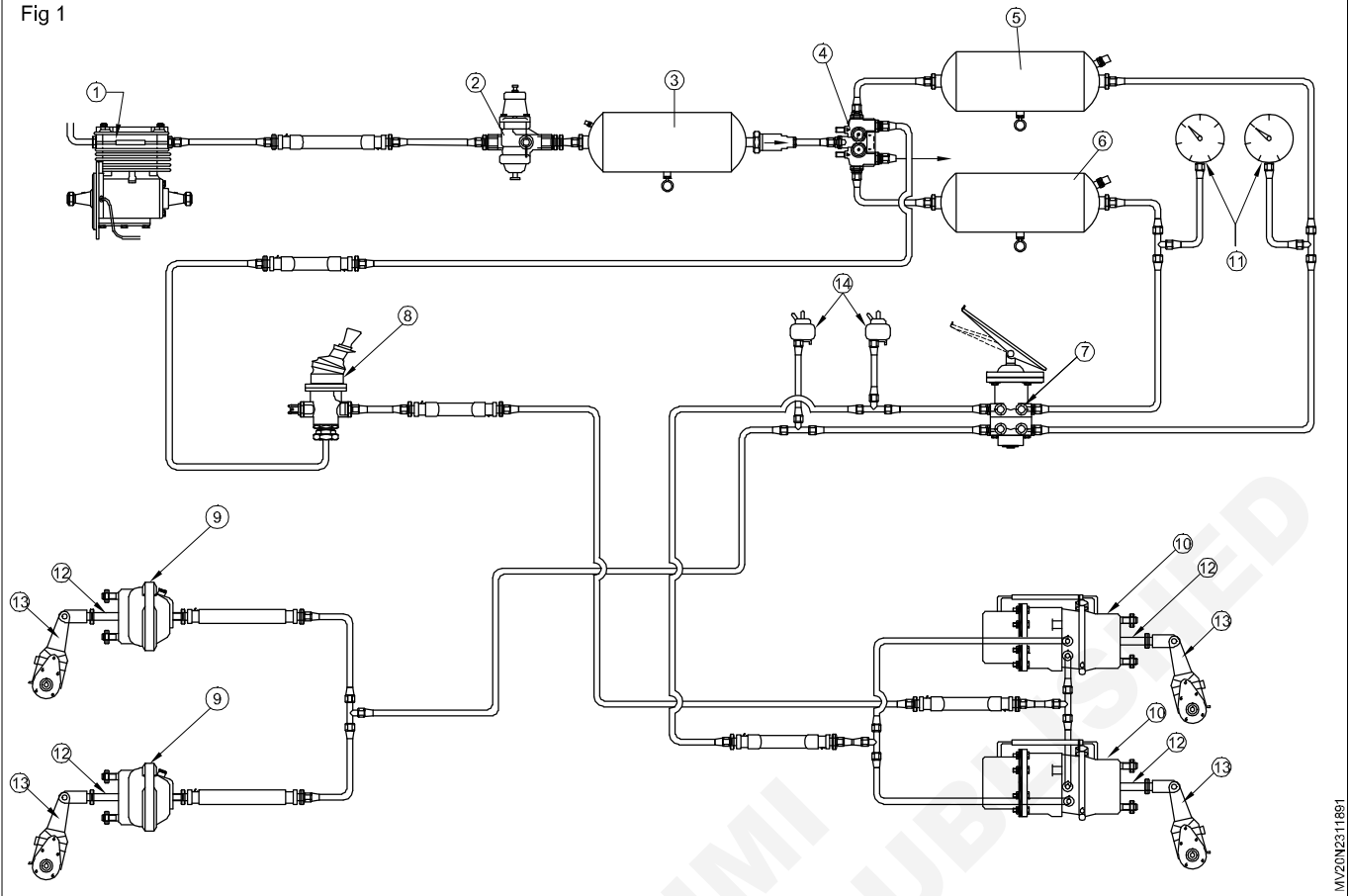
Air compressor

The air compressor develops air pressure and supplies it to the air tank. It is driven either by the camshaft or crankshaft of the engine. The air compressor used in an automobile is of the reciprocating piston type.

Air tank (Fig 2)

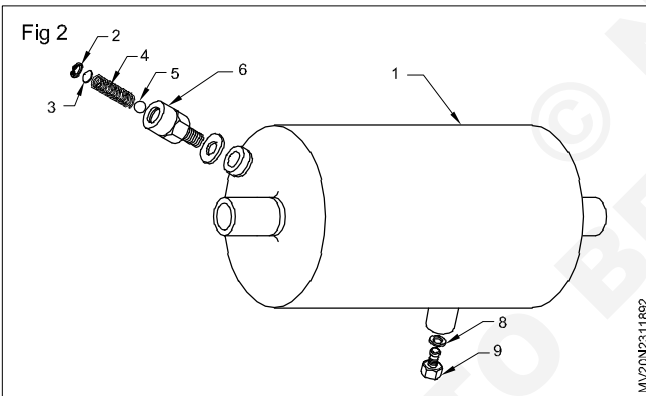
The air tank (1) is made of steel sheet, which stores compressed air for application of brakes. A safety valve (6) is provided on the top of the air tank with set pressure. The safety valve (6) opens at a set pressure and relieves excess air pressure from the tank which may otherwise result in the bursting of the air tank. A drain plug (9) is provided at the bottom of the tank. Water vapour present in the air condenses and get deposited in the air tank. Periodic draining of the tank prevents water accumulation in the tank and its reaching the brake valves.

Fig 1



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Fig 2

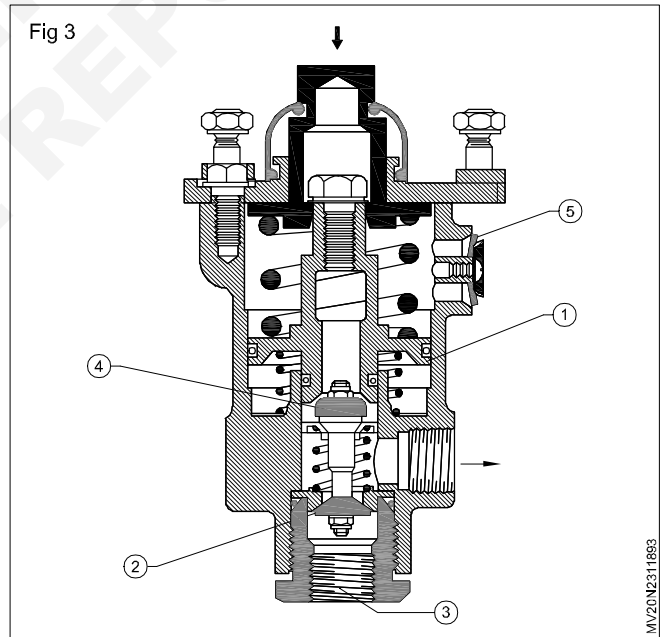


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Brake valve (Fig 3)

The brake valve consists of a plunger (1) which pushes the inlet valve (2) downward when the brake is pressed. Air from the inlet port (3) goes to the brake chambers to apply the brake. The air pressure reaching the brake chamber depends upon the opening of the inlet valve (2) and pedal movement. When the brake pedal is released the air pressure below the plunger (1) overcomes the mechanical force on the top of it. At this position the inlet valve closes and the exhaust valve (4) opens. All air pressure from the brake chamber is exhausted through the exhaust diaphragm (5). E1 brakes are used in single line air brake system and E2 valves are used in dual line brake system.

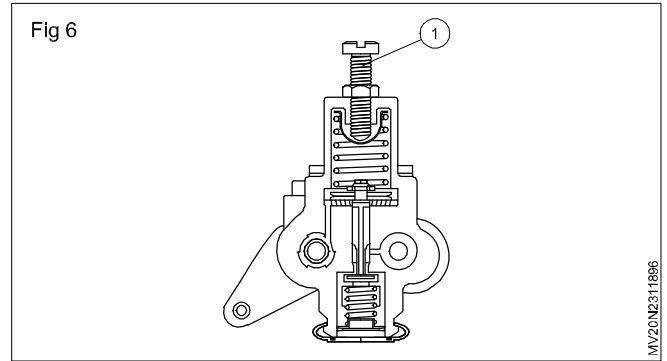
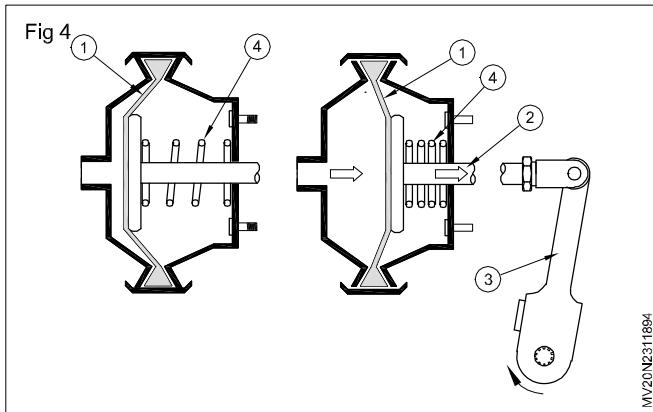
Fig 3



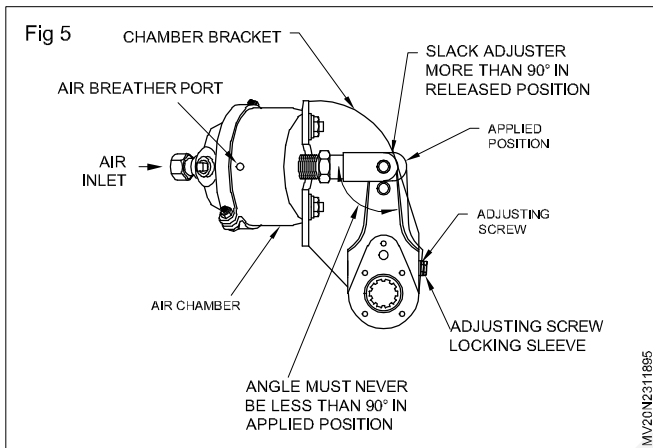
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Brake chamber (front) (Figs 4 & 5)

When the brake pedal is pressed the air pressure acts on the diaphragm (1) of the brake chamber. The diaphragm (1) pushes the push-rod (2) which is connected to the slack adjuster (3). The slack adjuster then rotates the 'S' camshaft. The brake shoe expands and the brake is applied. When the brake pedal is released, air pressure above the diaphragm is reduced and the push-rod returns to its original position by the return spring (4) thereby releasing the brake.

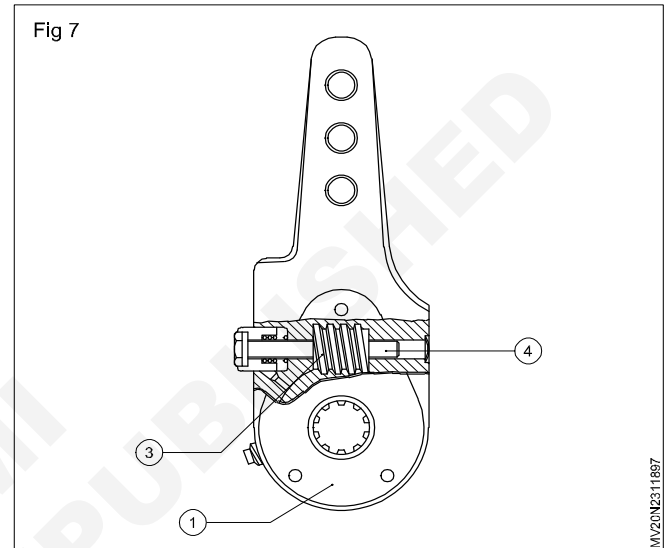


Slack adjuster (Fig 7)



Unloader valve (Fig 6)

The unloader valve controls the maximum air pressure in the tank. When the set air pressure is reached, it allows air to escape into the atmosphere. It also prevents the back flow of air from the air tank to the air compressor system. Air pressure can be increased by tightening the adjusting screw (1) provided at the top of the unloader valve.



A slack adjuster acts as a lever during braking and is used to adjust the clearance between the brake shoe and drum. Its worm gear (1) has an internal spline and is mounted on the 'S' camshaft to apply the brake. The worm (3) is in mesh with the worm gear (1). The worm (3) is rotated by the worm shaft (4) to adjust the clearance between the brake shoe and drum. When the worm shaft (4) is rotated, worm (3) rotates the worm gear (1), and the 'S' camshaft expands or closes the brake shoes.

Fail safe brake system

Objectives: At the end of this lesson you shall be able to

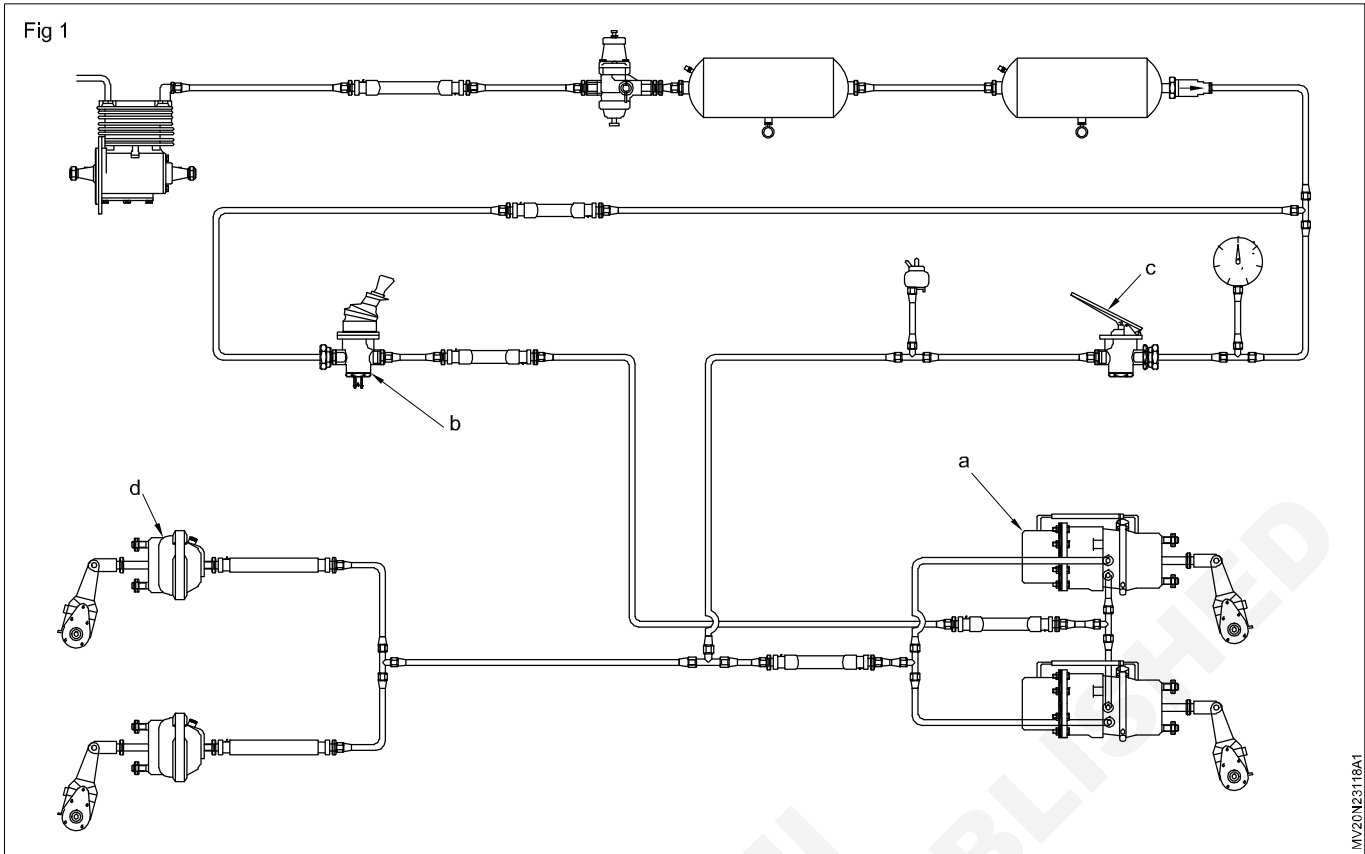
- draw the layout and function of the 'fail-safe' brake system
- state the function of spring brake actuators
- state the function of hand control valve
- state the need and function of the system protection valve
- state the advantage and disadvantage of air brake system.

Layout and function of fail-safe brake system (Fig 1)

In this system spring brake actuators (1) are used for the rear brakes. These actuators (1) are connected to a flick valve (2) and brake valve (3). When the flick valve (2) is in 'OFF' position air is supplied to the spring brake actuator. The air pressure keeps the spring of the brake actuator compressed. When the pedal is pressed the air pressure acts on the diaphragm of the front (4) and rear brake chamber (1) and the brake is applied. When the flick valve (2) is in the 'OFF' position its inlet remains

open and the exhaust remains closed. Air at pressure is supplied to the brake actuator (1) and keeps its spring compressed. When the flick valve's (2) sleeve is moved to the 'ON' position its inlet closes and the exhaust opens. This allows air from the spring brake actuator (1) to exhaust. The brake actuator's (1) spring expands and pushes the diaphragm and push-rod of the rear brake. When parking brake is applied, if there is any leakage in the system or the air pressure is less, then the spring of the brake actuator (1) automatically expands and the brake is applied.

Fig 1

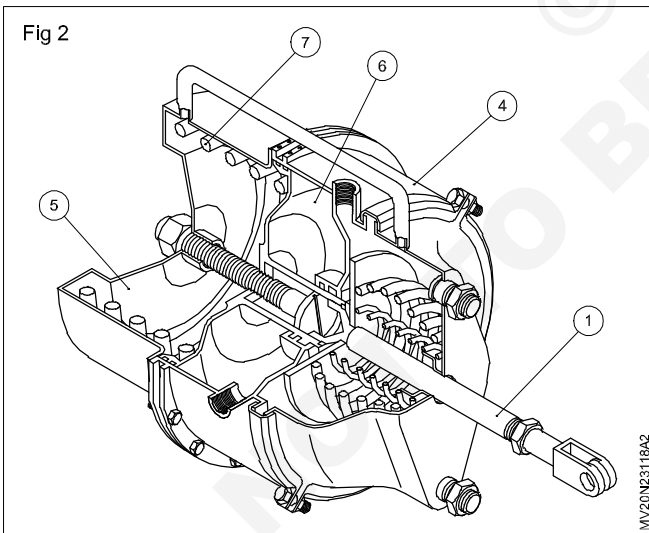


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Advantage

If air pressure is less or any leakage is there in the air line then the vehicle will automatically stop, thus reducing the risk of accidents due to brake failure.

Spring brake actuator (Fig 2)



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It is used in the dual brake and fail-safe brake system. It applies the brake when air pressure is less in the system and it is also used for parking brakes. During normal braking air pressure acts on the diaphragm above the push-rod (1) and pushes the push-rod. The push-rod assembly is fitted in the air pressure plate. The air pressure plate assembly is mounted on the cylinder (4) and the end cover assembly(5). In the cylinder (4) the piston (6) and spring (7) are fixed. The spring (7) is kept

compressed by the system air pressure working behind the piston(6). When the air pressure is less in the system, the spring (7) pushes the piston (6) which pushes the push-rod (1) and the brake is applied. Similarly for parking, air from the cylinder is exhausted by operating the flick valve, and the spring (7) exerts pressure on the piston (6) and push-rod (1) to apply the brake. To release the parking brake, air is supplied to the cylinder (4) by operating the flick valve, and air pressure acts below the piston(6) which compresses the spring (7) and brakes are released.

Hand control valve (Flick valve) (Fig 3)

A flick valve is used in the fail-safe and dual brake systems. It is operated for applying the brake in parking. In the 'OFF' position the plunger (1) is kept pushed down due to the cam's (2) profile. In this condition the inlet exhaust valve (3) remains open and air supply is maintained to the brake chamber.

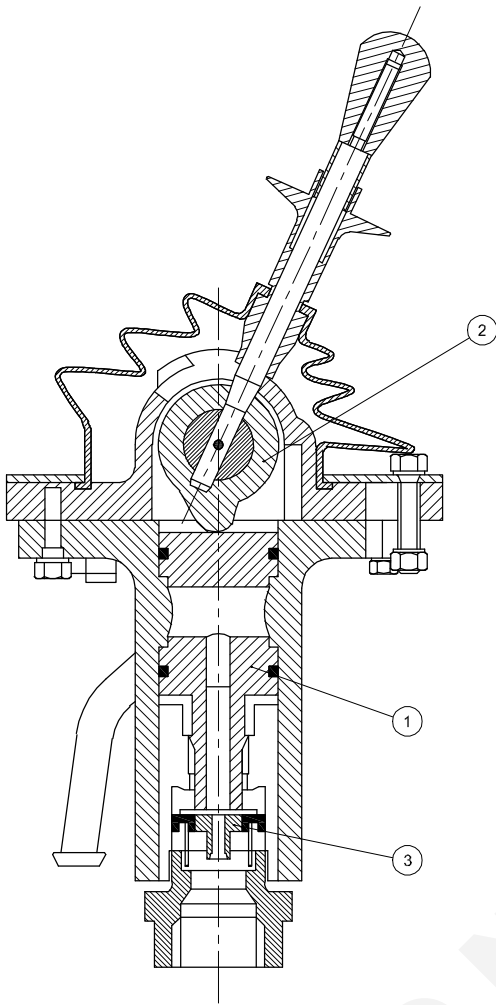
When the flick valve (4) is pushed to the 'ON' position the plunger (1) moves down and closes the inlet seat of the inlet exhaust valve (3) and opens the exhaust seat. Air from the brake chamber now exhausts to atmosphere.

System protection valve (Fig 4)

It is used in the brake system to distribute pressurised air to various circuits. Two types of system protection valves are used.

- Single element protection valve
- Multi-element protection valve

Fig 3



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to return from the circuit, and air pressure is maintained in the system. A multi-element protection valve is used when air is to be distributed to different circuits. The number of elements used is equal to the number of circuits. Each element functions independently like a single circuit protection valve. Since valves used in this are non-return valves, failure of any circuit does not affect the other circuits.

Advantages of air brake

- Braking action is quick.
- It can stop a large inertia force.
- Compressed air in the system can be used for other auxiliary units also (ie. tyre inflator).
- Brake linkages are simple.
- Air is available free.

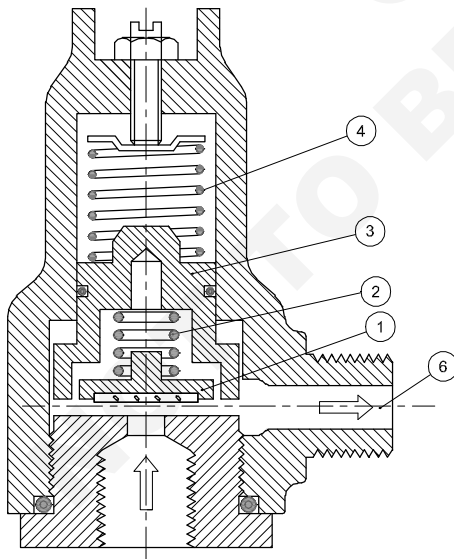
Disadvantages

- It involves more parts.
- Air compressor uses a certain power of the engine.

Electric brake

When the driver steps on the brakes it sends a current to the brake magnet in the back plate. The magnet is attracted by the drum face., the actuating arm pushes the shoes against the drum those shoes have a special brake pad material on there that resist heat caused by friction. When shoes press against the inside of the drum, they prevent the hub consequently the wheel touching the ground from spinning.

Fig 4



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A single circuit protection valve consists of a non-return valve (1) which is kept on its seat by a spring (2) and piston (3) by the piston spring (4). Air is supplied through the inlet port (5). When air is supplied it goes to the circuit through the exhaust (6) compressing spring (4) and lifting valve (1) and piston (3). Once pressure at the exhaust exceeds the spring's (4) load, the piston (3) remains lifted. The valve (1) being a non-return valve does not allow air

Parking brake

The Emergency brake by passes the hydraulic brake system to lock the wheels in place this mechanical system uses cables that are attached to the emergency brake lever. When engaged on cars with drum brakes, the cables pull another lever that puts pressure on the brake shoes to hold the vehicle. Auxillary brakes are more commonly called a parking brake, an emergency brake or a hand brakes are connected to callipers that grip on to the rear wheel rotors. Thsesse are not the same calipers that the normal brakes use because the emergency brake system is separte from the main brakes incase of brake failure.

Engine brakes

A compression release engine brake, frequently called a Jacobs brake or Jake brake, is an engine braking mechnism installed on some diesel engines. When activated, it opens exhaust valves in the cylinders after the compression stroke, releasing the compressed gas trapped in the cylinders and slowing the vehicle.

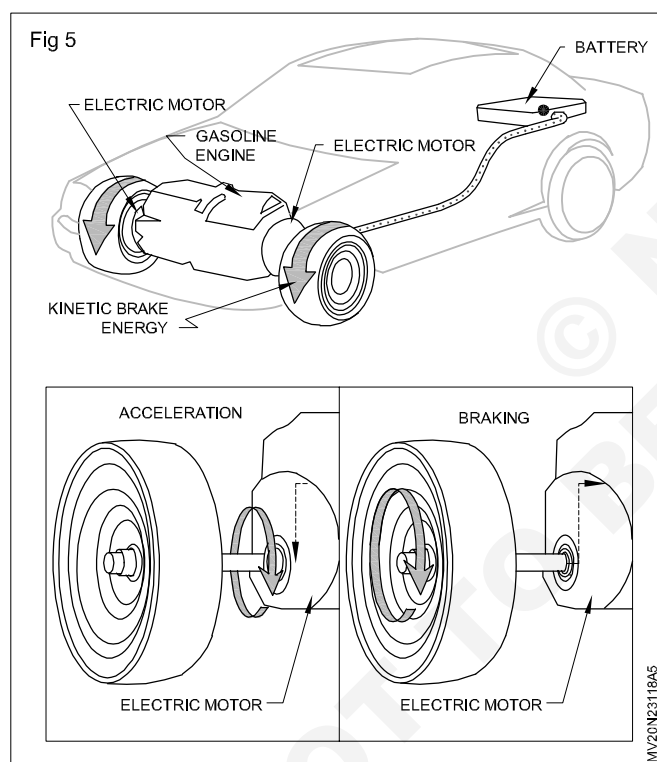
The typical compression release engine brake consists of an add-on hydraulic system using engine oil which transfers the motion of the fuel injector rocker arm to the engine exhaust valve(s). When activated, the exhaust valve opens very briefly near the engine's top dead center

and releases the compressed air in the cylinder so that the energy is not returned to the crankshaft. If used properly, a compression release brake can assist a vehicle to maintain or even reduce speed with minimal use of the service brakes.

Contrast a gasoline under deceleration, where a closed throttle prevents free flow of air into the cylinders. resulting in little pressure to release at the top of the compression stroke. The closed throttle provides engine braking by forcing the engine to generate a vacuum between the throttle and the cylinders.

Diesel compression release brake controls consist of an on/off and often a multi-position switch that controls the number of cylinders on which the brake is active. Throttle and clutch switches are integral with the system. Activation occurs when both the clutch and the throttle are released with the transmission in gear. It is the driver's job to ascertain the correct transmission gear to use, depending on, for example, the steepness of the grade and the truck's load.

Regenerative brake (Fig 5)



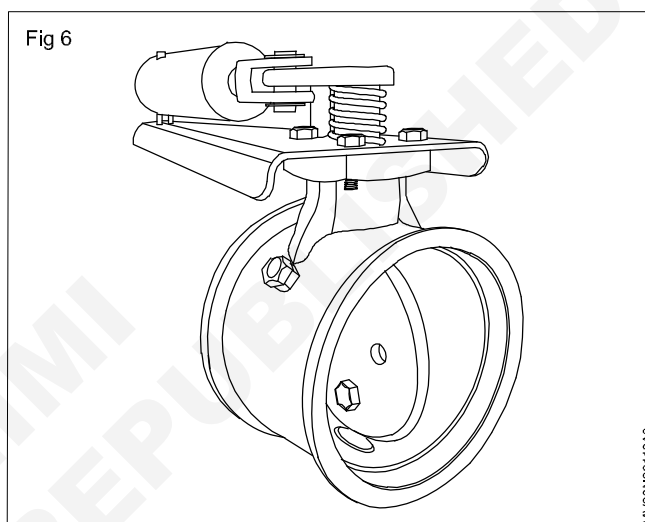
Regenerative braking is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. In this mechanism, the electric motor uses the vehicle's momentum to recover energy that would be otherwise lost to the brake discs as heat. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat by friction in the brakes or with dynamic brakes, where energy is recovered by using electric motors as generators but is immediately dissipated as heat in resistors. In addition to improving the overall

efficiency of the vehicle, regeneration can greatly extend the life of the braking system as its parts do not wear as quickly.

In a battery-powered electric vehicle, regenerative braking (also called regen) is the conversion of the vehicle's kinetic energy into chemical energy stored in the battery, where it can be used later to drive the vehicle. It is braking because it also serves to slow the vehicle. It is regenerative because the energy is recaptured in the battery where it can be used again.

Remember that, even though the battery-to-wheel conversion efficiency is good and the energy makes a full circle back into the battery and it gets converted twice for a net efficiency.

Exhaust brake (Fig 6)



An exhaust brake is a means of slowing a diesel engine by closing off the exhaust path from the engine, causing the exhaust gases to be compressed in the exhaust manifold, and in the cylinder. Since the exhaust is being compressed and there is no fuel being applied, the engine works backwards, slowing down the vehicle. The amount of negative torque generated is usually directly proportional to the back pressure of the engine.

An exhaust brake is a device that essentially creates a major restriction in the exhaust system and creates substantial exhaust back pressure to retard engine speed and offer some supplemental braking. In most cases, an exhaust brake is so effective that it can slow a heavily loaded vehicle on a down grade without ever applying the vehicle's service brakes. More advanced exhaust brakes have exhaust pressure modulation (EPM) that controls the back pressure which in turn improves the braking performances across a range of engine speeds.

There are several ways of stopping a vehicle such as using the normal brakes, the engine brake or for diesel powered vehicles; drivers can also use an exhaust brake. Exhaust brakes can be very efficient in the long run and it can considerably slow down a vehicle, regardless of its size or weight. It prevents overheating and is completely silent.

Anti lock brake system

Objectives: At the end of this lesson you shall be able to

- state the advantages of ABS
- list out the different types
- state wheel lock up condition
- state hold mode
- state normal braking
- state electronic brake distribution advantage
- Traction control system.

Anti lock brake system

Advantages of ABS

Anti-lock brake systems are designed to prevent wheel lockup under severe braking conditions irrespective of any type of road conditions.

The result is that, during heavy braking ABS:

- retains directional stability (vehicle stability)
- stops faster (shortened stopping distance)
- retains max. control of vehicle (steerability)
- If front wheels lock-up it is no longer possible to steer the vehicle.
- If rear wheels lock-up the car can become unstable and can start to skid sideways.

Split surface braking: When brakes are applied on a combination of slippery and high friction surfaces, the wheels on the slipper surface easily locks-up and the vehicle loose stability and will be dragged towards the high friction side, which may lead to accidents through the oncoming vehicle. But ABS prevent this and offers stability until the vehicle comes to a complete halt.

Types of ABS systems

4-Sensor 4-Channel type: This type is generally used for FF (Front engine Front driving) car. This type has four wheel sensors and four hydraulic control channels and controls each wheel independently.

4-Sensor 3-Channel type: This type is generally used for FR (Front engine Rear driving) car. This type has 2 channels for front wheels and the other one is for rear wheel control.

3-Sensor 3-Channel type: In this type the front wheels are controlled independently but rear wheels are controlled together by one wheel speed sensor (ex. On differential ring gear)

1-Sensor 1-Channel type: In this type only the rear wheels pressure are controlled by one sensor.

How ABS Detects wheel lock up condition

ABSS has got wheel speed sensors on all the four wheels. It continuously calculates the slip ratio of all the four wheels.

Slip ratio: It is the percentage ratio between difference of vehicle speed and wheel speed to vehicle speed.

$$\text{Slip ratio} = \frac{(\text{Vehicle speed} - \text{Wheel speed})}{\text{Velocity speed}} \times 100$$

While wheel speed information is directly taken from wheel speed sensor, vehicle speed information is not attained directly from vehicle speed sensor. There is no vehicle speed sensor information to ABS. It is attained with some logic using wheel speed sensor information only. The reason being exact vehicle speed cannot be attained from sensor, when the wheel is locked and vehicle skidding.

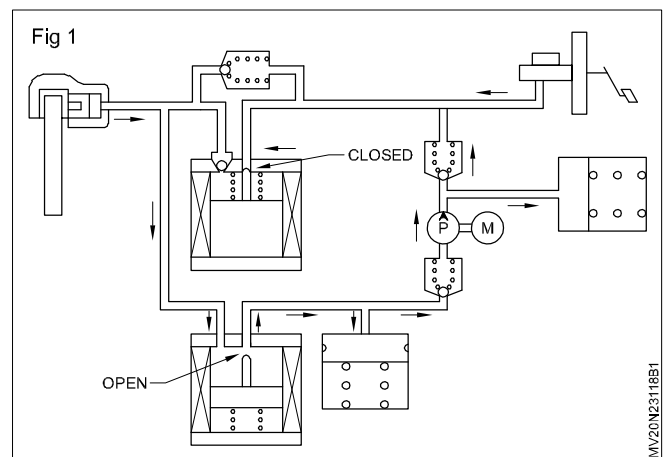
How Abs calculates vehicle speed

At the time of braking the speed of individual wheels differ hence slip ratio also differs. Two wheel drive vehicles uses the maximum wheel speed as vehicle speed at the time of wheel lockup. This gives a fairly correct information above vehicle speed, because the vehicle will tend to propel at that speed.

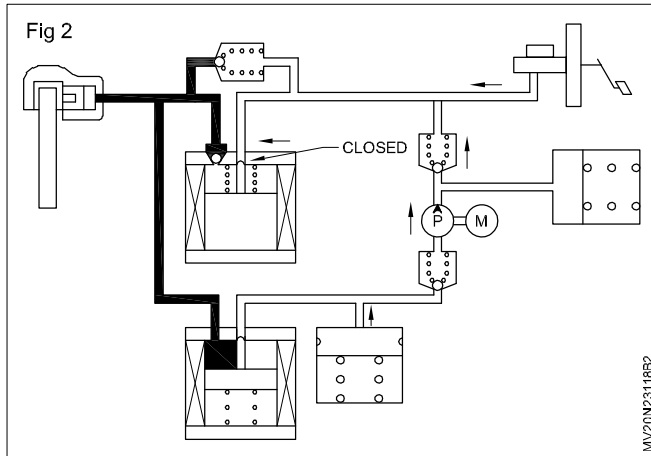
For ex: At braking if the wheel speed information from all the four wheels in car are 20, 30, 20, 20 Kmph. Then vehicle speed is taken as 30 Kmph for calculating slip ratio of individual wheels.

Dump mode (Fig 1)

When ABS unit detects a wheel lock up condition it tries to avoid wheel lockup by releasing pressure from wheel cylinder. In this case Solenoid Valve - In, Solenoid valve - Out and motor is ON. Solenoid Valve - In closes the passage from master cylinder. Solenoid Valve - Out opens the passage to pump, which pumps the fluid out reducing the pressure at wheel cylinder.



Hold mode (Fig 2)



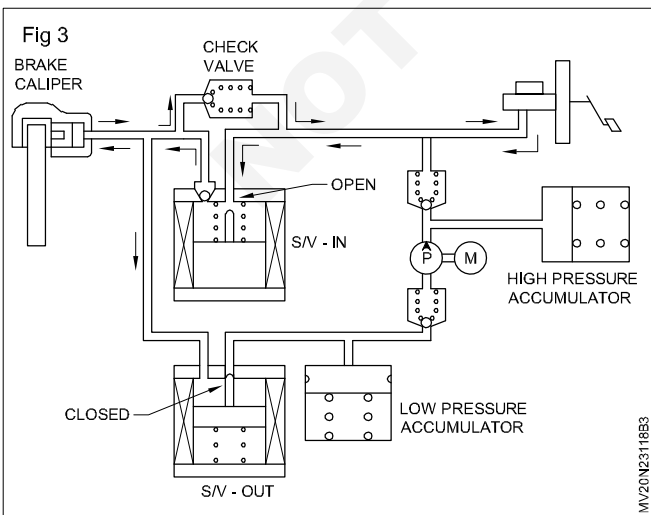
Once the pressure is released to some extent to avoid wheel lock up condition, pressure is locked inside wheel cylinder by switching off the Solenoid Valve - Out alone i.e. Solenoid Valve - Out closes the passage from wheel cylinder to pump locking the pressure inside wheel cylinder.

In four wheel drive vehicles since torque is transmitted to all four wheels the chances of four wheel lockup in low friction surfaces are more. Calculation of vehicle speed from wheel speed gives wrong result. Hence four wheel drive vehicle use additional "G" sensor to calculate vehicle speed.

G-Sensor (Acceleration sensor)

G-Sensor is used by the ABS for measuring the deceleration rate of the vehicle whenever brakes are applied. G-Sensor signal output is directly proportional to the Acceleration/Deceleration of the vehicle. Using wheel speed sensor logic has its own disadvantages as there are chances of all the four wheels getting locked up during braking on very low friction surfaces like on ice or slippery surfaces. Under these conditions, it is impossible to calculate the deceleration rate of the vehicle from the wheel speed sensors. In this case, ABS cannot perform efficiently.

Normal Braking (Fig 3)



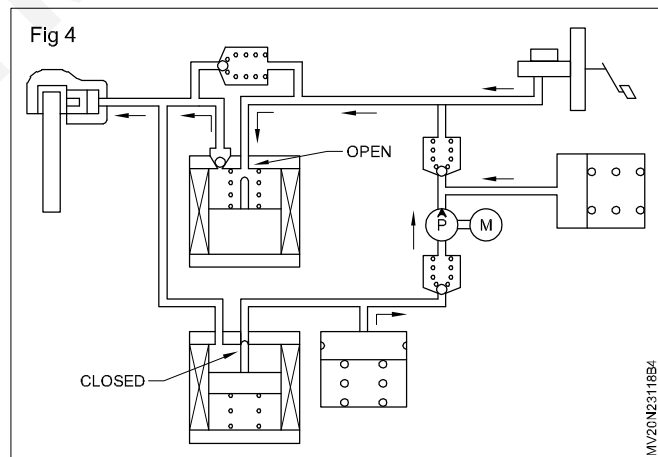
In normal braking Solenoid Valve - In, Solenoid Valve - Out and motor is off. Brake pressure applied to the master cylinder goes to wheel cylinder through Solenoid valve - In Solenoid valve - IN is normally open type (NO) i.e. it is open when it is off. Solenoid Valve - OUT is normally closed type (NC) i.e. it is closed when it is off. Brake fluid return to master cylinder through check valve in Solenoid valve - IN. This is like conventional braking. ABS operates in normal mode till lockup condition is detected. Once wheel lockup condition is detected ABS comes into operation i.e. Dump, Hold and Increase mode are executed.

Dump mode

When ABS unit detects a wheel lock up condition it tries to avoid wheel lock up by releasing pressure from wheel cylinder. In this case Solenoid Valve - In, Solenoid Valve - Out and motor is ON. Solenoid Valve - In closes the passage from master cylinder. Solenoid valve - Out opens the passage to pump, which pumps the fluid out reducing the pressure at wheel cylinder.

Increase mode (Fig 4)

In this mode pressure is increased to compensate for the released pressure. The Solenoid Valve condition is similar to normal mode except motor is ON. The pump pushes brake fluid into master cylinder circuit to increase the brake pressure applied to wheel cylinder. The pedal pressure applied by the driver and the motor pressure together from the pressure applied to wheel cylinder. Once the ABS unit does the dumping operator (pressure release) the pressure increase is done in steps of hold and increase for better steering control, stability and better stopping distance.



EBD (Electronic Brake-force Distribution)

The EBD system is a sub-system of the ABS system, it is very effective in controlling the effective adhesion utilization by the rear wheels. It controls the slip of the rear wheels in the partial braking range. The brake force is moved even closer to the optimum range, thus dispensing with the need for a mechanical proportioning valve.

The mechanical proportioning valve has its limitations when speaking about achieving the idea brake force distribution to both the front and rear wheels.

EBD doesn't have any new components in face the same ABS components like wheel speed sensor, electronic unit are used. It is only a logical extension of ABS logic in ECU memory. EBO system provide the solenoid valves to reduce the brake pressure to the rear wheels when the slip ratio of rear wheels ar emore than that of front wheels. EBD failure is indicated by glowing the parking lamp.

EBD advantage (Fig 5)

- Function improvement of the base-brake system
- Appropriate brake force distribution to front and rear wheels with respect to load variations
- Possible to achieve ideal brake force distribution with EBD
- Compensation for the different friction coefficients
- Elimination of the mechanical proportions valve
- Failure indication through warning lamp in cluster.

Maintenance of ABS Brake Systems

The following table should only act as a guide; the manufacturer's recommendations should always be followed.

Traction control system (TCS) (Fig 6)

The TCS system prevents the drive wheels spinning when pulling away and accelerating.

This stabilises the vehicle in the longitudinal direction, the cornering stability is maintained and the vehicle is prevented from breaking away at the powered axle.

The TCS is an enhancement of ABS. Both systems use common sensors and actuators and often have a common ECU where the data exchange is usually carried out via a CAN bus. When the vehicle is being driven with snow chains, the TCS can be deactivated. A distinction can be made between:

- TCS systems with engine intervention.
- TCS systems with brake intervention, otherwise known as ELSD Electronic Limited Slip Differential.
- TCS systems with engine and brake intervention.

TCS/ELSD brake circuit of a wheel

Advantages

- Improvement of traction when pulling away or accelerating.
- Increase of dirving safely at high motive forces.
- Automatic adjustment of engine torque to the grip rates.
- Driver information about reaching dynamic limits.

TCS with brake intervention/electronic limited slip differential ELSD

An electro-hydraulic system is used as a starting off aid. The lock effect is created as a result of brake intervention on the spinning wheel in order to achieve better traction.

Structure

Hydraulic system

This is composed of a hydraulic pump with suction and delivery valves inter and outlet valves, a hydraulic changeover valve and a check valve with pressure limiter.

Electrical system

This is composed of ABS/TCS (ELSD) ECU and wheel speed sensors.

Operating principle

Pressure build-up

If a driven wheel spins, this is detected by the ECU with a speed sensor. It activates the hydraulic pump and the check valve. The check valve (CV) closes and the pressure generated by hydraulic pump P brakes the spinning wheel.

Pressure holding The inlet valve (IV) is closed.

Pressure reduction

If the wheel has stopped spinning, then the inlet and check valves are opened and the pressure is relieved to the expansion tank via the master cylinder.

TCS with engine and brake intervention (Fig 7)

The system works with engine or brake intervention, according to the driving situation. The block collaboration of engine and brake intervention for preventing unreliable wheel slip when pulling away. (TCS operation/ELSD operation) or in overrun mode. (EDTC operation)

Fig 5

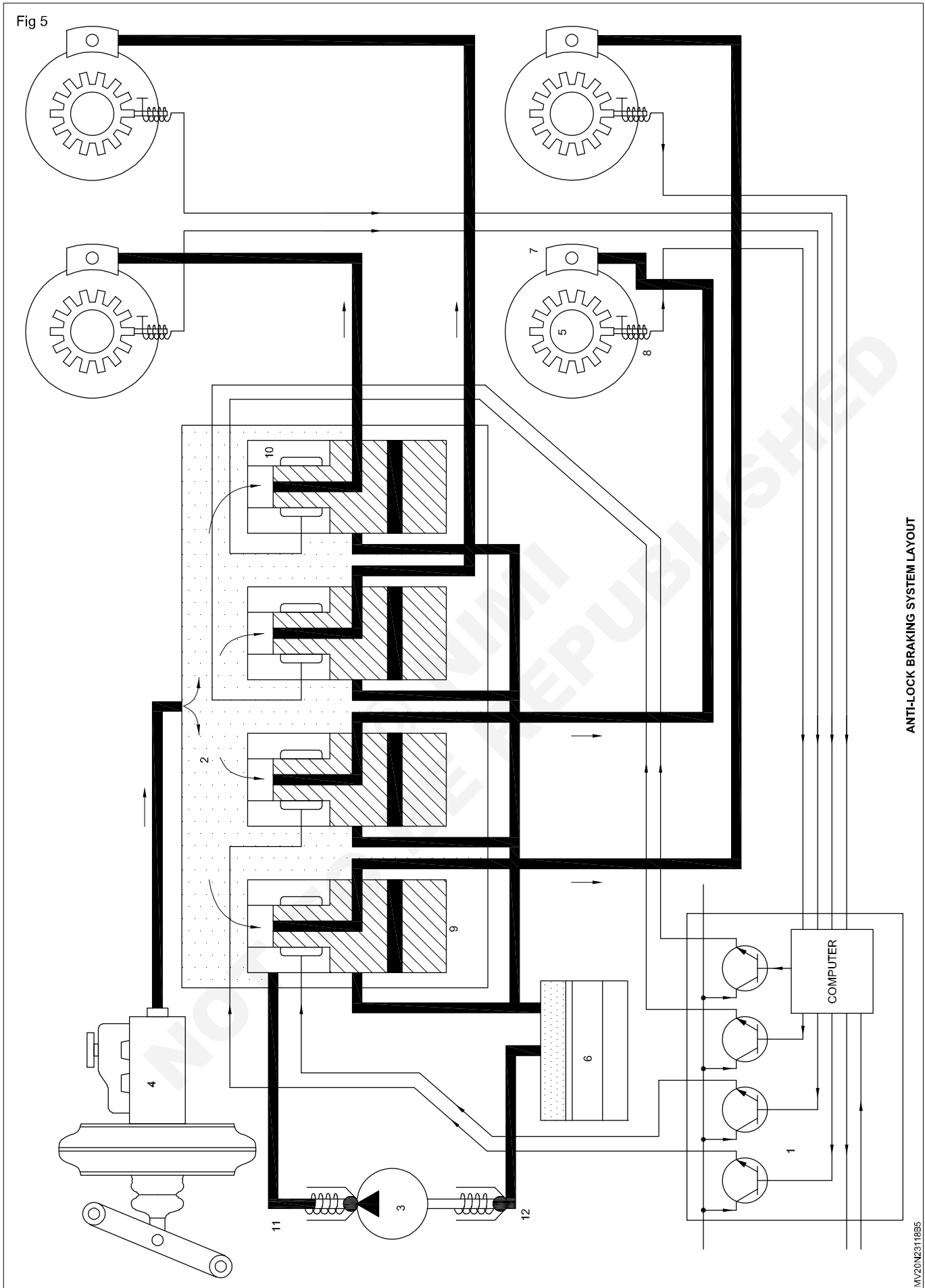
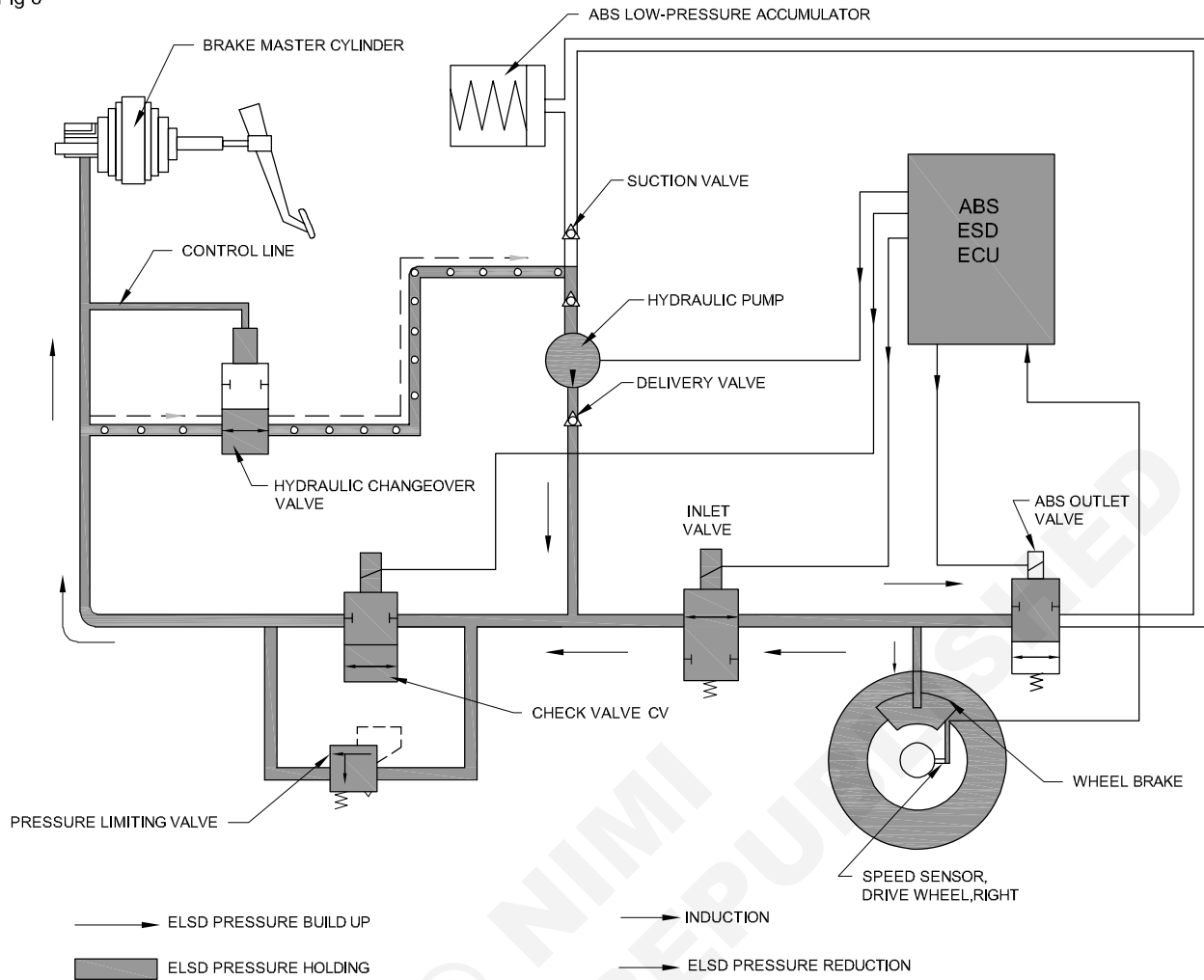
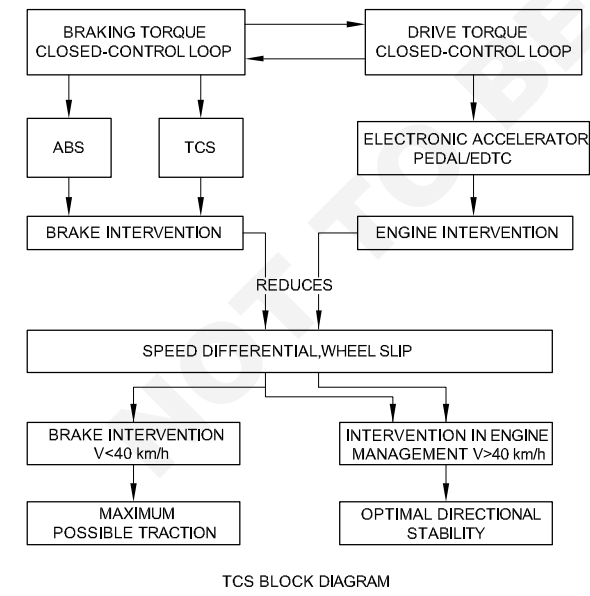


Fig 6



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Fig 7



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Trouble Shooting (Causes and Remedies)

Objectives : At the end of this lesson you shall be able to

- **causes and remedy for engine does not start**
- **causes and remedy for high fuel consumption**
- **causes and remedy for over heating**
- **causes and remedy for low power generation**
- **causes and remedy for excessive oil consumption**
- **causes and remedy for low oil pressure and high oil pressure**
- **causes and remedy for engine noise**

Engine does not start

Probable causes	Remedies
Low fuel in tank	Fill fuel
Choked fuel hose	Replace
Clogged fuel filter	Replace
Air lock in fuel system	bleed the air lock
Clogged exhaust ports	Clean
Reptured cylinder head gasket	Replace
Worn piston rings	Replace worn piston and rings
Broken valve timing belt/chain	Replace
Poor valve seating	Repair
Valve seat pitted	Replace
Main fuse is blown off	Replace
Defective starting relay	Repair/Replace
Main ignition switch open circuited	Repair or Replace
Defective brushes in starter	Replace
Open in field or armature circuit of starter	Repair/Replace
Loose battery terminal connection	Clean and retighten
Run down battery	Recharge

High fuel consumption

Causes	Remedies
Weak compression	Replace pistoning/liner/piston
Fuel leakage in fuel system	Repair or Replace
Idle speed adjusting screw set in correctly	Adjust as prescribed
Clogged /dirty air filter	Replace or clean
Leakage of combustion gases from cyliner head	Retighten or replace head gasket
Valve inproper seating	Repair
Valve clearance improper adjustment	adjust as prescribed
Injector defective	Overhand the injector
Inter cooler defective	Repair or Replace
Wrong injection timing	Set proper timing
Defective fuel pump	Overhaul / replace

Engine overheating

Causes	Remedies
Excessive carbon deposit in engine	Decarbonise
Loose or broken fan belt	Adjust or replace
Not enough coolant	Clean / topup coolant
Lack of lubrication	Top up engine oil
Erratically working thermostat	Replace
Radiator core tubes clogged	Repair or Replace
water pump performance poor	Repair or Replace
Wrong injection timing	Set proper timing

Engine overheating Contd.....

Causes	Remedies
Leaky radiator core tube	Repair
blocked silencer	Clean
Closed radiator shutter	Open
Closed radiator fins	Straighten the fins
Clogged oil filter	Replace
Poor performance of oil pump	Repair or replace

Low power generation

Causes	Remedies
Leaky cylinder head gasket	Replace
Improper valve seating	Repair
Broken valve spring	Replace
Worn piston ring/bore	Replace or rebore
Piston rings sized in grooves or broken	Replace
Exhaust port clogged	Clean
Weak compression	Adjust valve clearance
Defective fuel feed pump	Repair or Replace
Clogged fuel filter	Replace
Clogged air cleaner	Replace
Wrong injection timing	Set properly
Wrong tappet clearance	Adjust correct clearance
Defective injector	Repair or Replace

High oil consumption

Causes	Remedies
External oil leakage	Rectify the leakage
High oil level	Remove excess oil
Vave oil seal damaged	Replace oil seal
Piston/rings wornout	Replace piston/rings
Engine oil low viscosity	Replace the oil
Oil reaching in exhaust manifold	Replace exhaust valve guides and valve
Oil reaching to combustion chamber	Replace the piston rings

Low oil pressure

Causes	Remedies
Low oil viscosity	Replace oil
Oil strainer blocked	Clean
Wornout oil pump gear	Replace gears
Strainer pipe mounting loose	Tighten
Defective oil pressure gauge	Replace
Defective pressure relief valve	Replace
Crank/camshaft bearing wornout	Replace bearing
Low oil level in the sump	Top up

High oil pressure

Causes	Remedies
High oil viscosity	Replace oil and use correct viscosity
Defective oil pressure gauge	Replace
Defective pressure relief valve	Replace or adjust correct value
Oil passages blocking	Clean the oil passages
High oil level in the sump	Maintain the correct oil level

Engine noise

Causes	Remedies
Wornout gudgeon pins	Replace
Wornout piston and rings	Replace
Piston ring broken	Replace
Vehicle over load	Avoid over loading
Tighten wheel bearing	Adjust
Clutch slipping	Adjust or Replace
Big end bearing wornout	Replace

Multi point fuel injection / Electronic fuel injection system

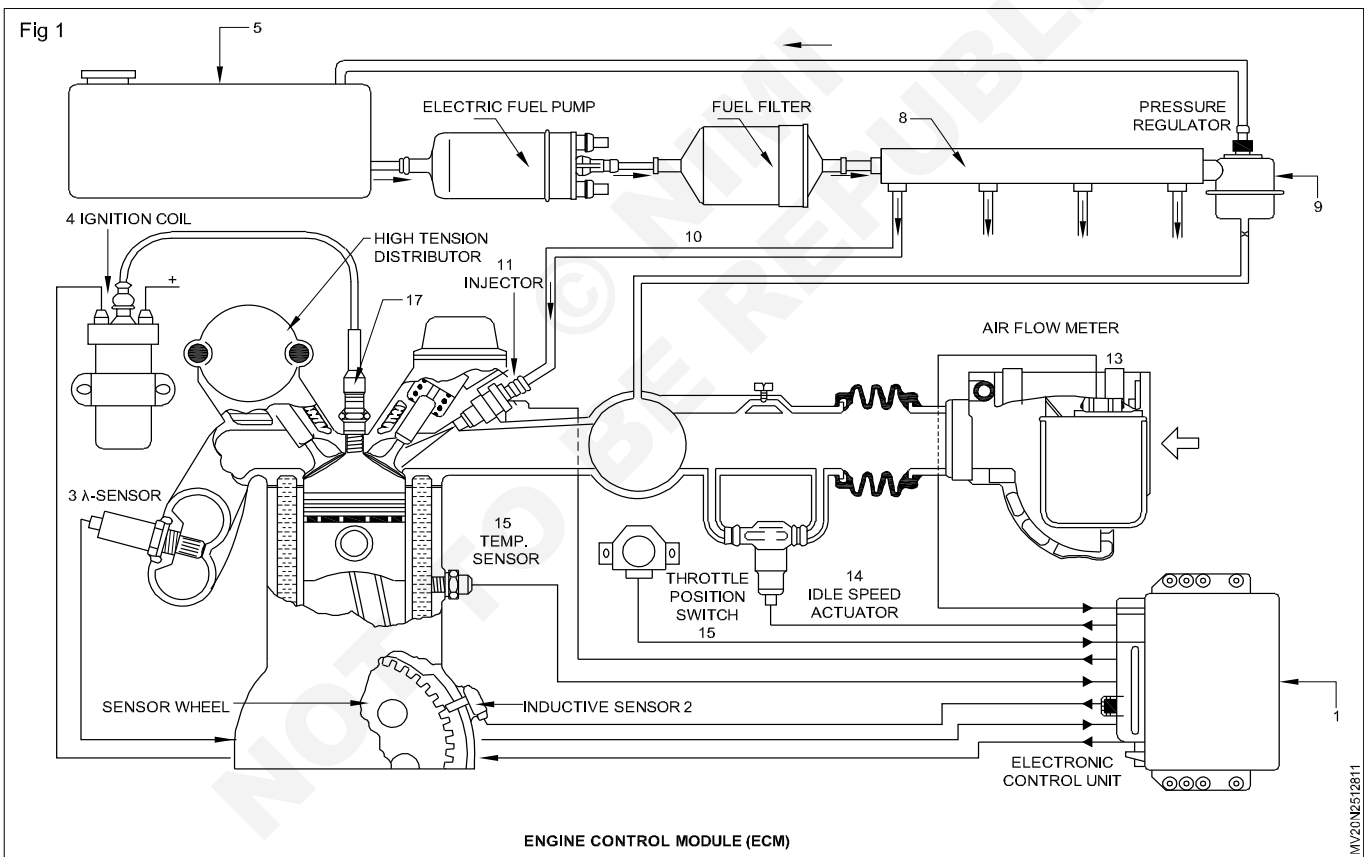
Objectives: At the end of this lesson you shall be able to

- state introduction of MPFI
- state the main components of MPFI
- explain the working principle.

Petrol vehicles uses device called carburetor for supplying the air fuel mixture in correct ratio to cylinders in all rpm ranges. Due to construction of the carburetor is relatively simple, it has been used almost exclusively on gasoline engines in the past. However in response to recent demands for cleaner exhaust emission, more economical fuel consumption, improved drivability, etc., the carburetor now must be equipped with various compensating devices, making it more complex system. So in place of the carburetor, therefore, the MPFI (Multi point fuel injection) system is used, assuring proper air fuel ratio to the engine by electrically injecting fuel in accordance with various driving conditions.

MPFI system injects fuel into individual cylinders, based on commands from the 'on board engine management system computer' - popularly known as the engine control unit/ECU. These techniques result not only in better 'power balance' amongst the cylinders but also in higher output from each one of them, along with faster throttle response. The electronic fuel injection system supplies the combustion chambers with air/fuel mixture of optimized ratio under widely varying driving conditions.

Main components of MPFI system (Fig1)



This system has four major components they are:

- 1 Air intake system (Fig 2)
- 2 Fuel delivery system (Fig 3)
- 3 Electronic control system

Air intake system (Fig 2)

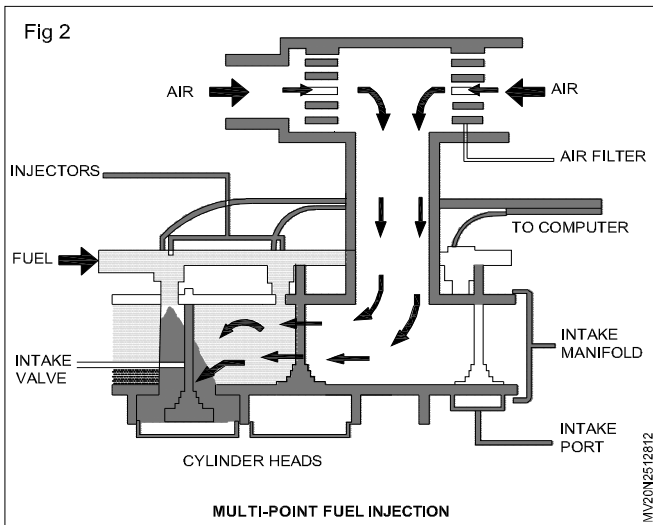
The air (corresponding to the throttle valve opening) is filtered by the air cleaner, passes through the throttle

body, and is distributed by the intake manifold and finally drawn into each combustion chamber. When the IAC (intake air control) valve is opened according to the signal from ECM, the air bypasses the throttle valve through bypass passage and is finally drawn into the intake manifold.

Throttle body

The throttle body consists of the main bore, air bypass passage and the following parts. Throttle valve, which is

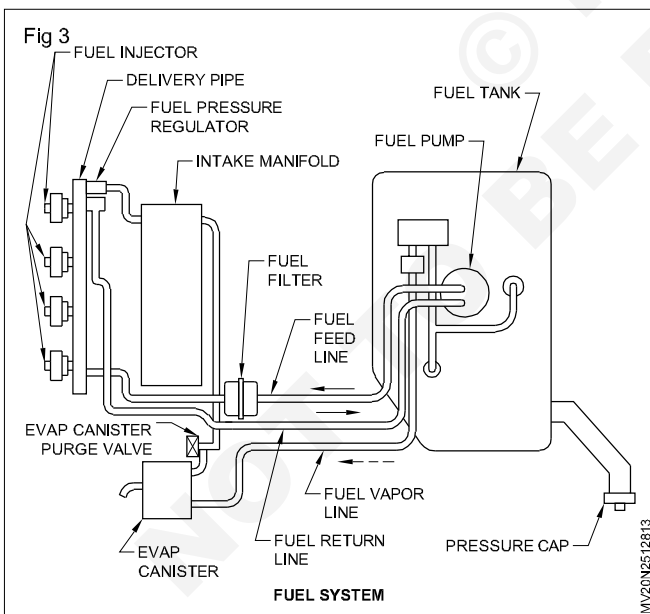
interlocked with the accelerator pedal and controls the amount of the intake air. TP sensor which detects the throttle valve opening and sends a signal to ECM. IAC valve, which supplies the bypass, air depending on engine condition.



Idle air control valve

The IAC valve controls opening of the bypass air passage. The air bypass the throttle valve through bypass passage and is finally drawn into the intake manifold. Opening and closing of the valve itself is determined by operation of the magnet, which is connected to it. The magnet operates according to electric current from ECM.

Fuel delivery system (Fig 3)



The fuel in the fuel tank is pumped up by the fuel under pressure to each injector through the delivery pipe. As the fuel pressure applied to the injector is always kept a certain amount higher than the pressure in the intake manifold by the fuel pressure regulator, the fuel is injected into the intake port of the cylinder head when the injector opens according to the injection signal from ECM. The fuel relieved by the fuel pressure regulator return through the fuel return to the fuel tank.

Fuel pump

The electrical fuel pump located on the fuel tank consists of armature, magnet, impeller, brush, check valve etc. The ECM controls its operation. When the power is supplied to the fuel pump, the motor in the pump runs and so does the impeller. This causes a pressure difference to occur between both sides of the impeller, as there are many grooves around it. Then the fuel is drawn through the inlet port, and with its pressure increases, it is discharged through the outlet port, the fuel pump also has a check valve to keep some pressure in the fuel feed line even when the fuel pump is stopped.

Electronic control system

The electronic control system consists of various sensors which detect the state of engine and driving conditions, ECM which controls various devices according to the signals from the sensors and various controlled devices. The systems are,

- 1 Fuel injection control system,
- 2 Idle speed control system
- 3 Fuel pump control system
- 4 Ignition control system
- 5 Radiator fan control system.

Fuel injection control system

The electronic fuel injection system supplies the combustion chambers with air/fuel mixture of optimized ratio under widely varying driving conditions. It uses the sequential multi-port fuel injection system, which injects fuel into each intake port of the cylinder head. In this system ECM controls the time and timing of the fuel injection from the fuel injector into the cylinder head intake port according to the signals from the various sensors so that suitable air/fuel mixture is supplied to the engine in each driving condition. The factors to determine the injection time are the basic injection time which is calculated on the basis of the engine speed and the intake manifold pressure and various compensation which are determined according to the signals from various sensors that detect the state of the engine and driving conditions.

Idle speed control system

This system controls the bypass airflow by means of ECM & IAC valve for the following purposes. To keep the engine idle speed as specified at all times. The engine idle speed can vary due to load applied to engine, to improve starting performance of the engine to compensate air fuel mixture ratio when decelerating to improve drivability while engine is warmed up. IAC valve operates according to duty signal sent from ECM. ECM detects the engine condition by using the signals from various signals and switches and controls the bypass airflow by changing IAC valve opening. When the vehicle is at a stop, the throttle valve is at the idle position and the engine is running, the engine speed is kept at a specified idle speed.

Fuel pump control system

ECM controls ON/OFF operation of the fuel pump by turning it ON, the fuel pump relay under any of the conditions. For two seconds after ignition switch ON. While cranking engine (while engine start signal is inputted to ECM). While crankshaft position sensor or camshaft - position sensor signal is inputted to ECM.

Ignition control system

This system controls electronically the time of electric current flow to ignition primary coil as well as ignition timing. ECM judges the engine and vehicle conditions by using signals from various sensors, selects the most suitable electric current flow time and ignition timing for that engine and vehicle conditions from among those prestored in its memory and sends an ignition signal to the igniter in ignition coil assembly. Controls of this system include three different types as follows. Ignition timing control as follows. Ignition timing control at engine start, ignition timing control after engine start, electric current flow time control.

Radiator fan control system

This system controls operation (ON/OFF) of the radiator fan motor. Radiator fan motor is turned ON and OFF by its relay when ECM controls. Radiator fan motor turned ON at below 98°C and OFF at below 93°C.

Engine control module (ECM)

ECM is installed to the underside of the instrument panel at the passenger's seat side. ECM is a precision unit consisting of microcomputer, analogue / digital converter input/output unit etc. It is an essential part of the electronic control system for its functions include not only such a major function as to control fuel injector, IAC valve, fuel pump relay, etc. But, also onboard diagnostic system (self diagnosis function) and fail - safe function.

Definition

Till in the 90's, a good carburetor was responsible for sending the appropriate amount of fuel into the cylinders. Carburetors atomize mix and supply the proper air fuel mixtures in the petrol / gasoline engines today, the electronic fuel injection replaces the carburetors and they have a injection separately and have a electronic throttle control to ensure good efficiency and exhaust control.

Function of each part

Air supply

The design of the intake system determines how much air can be drawn into a cylinder at any given engine RPM. EFI can achieve uniform distribution of the air delivered to the cylinders.

Air volume

The amount of air entering the engine must be measured, so that the amount of fuel injected into it forms a mixture to suit the engine operating conditions at that time.

MPFI

For any injection duration, if fuel is held at constant pressure, then as manifold pressure varies, so does the amount of fuel delivered through multipoint injectors with the use of computer technology. That means fuel pressure must be held constant above manifold pressure.

Simultaneous in multi point injection

The injectors can all be triggered simultaneously, twice per cycle. In a throttle-body system the central injector is normally triggered on each ignition pulse. With two injectors, alternate triggering may be used injection.

Efficient combustion

Adaptive learning is a form of feedback that lets fuel settings for different operating conditions and stores them for future use.

Fuel pumps

Fuel pumps operate electrically to provide fuel under pressure to the fuel rail and the injectors.

Fuel filters

EFI fuel filters remove contaminants from the fuel, so that clean fuel can be supplied to the injectors.

Tanks and lines

Most fuel tanks are in two parts joined by a weld around the flanges where the parts fit together. Baffles make the tank more rigid, prevent surging of fuel and ensure fuel is available at the pickup tube.

Fuel lines

The fuel tank is connected to the engine by fuel lines. A return line may carry excess fuel back to the tank, to keep fuel system components cool.

Fuel rail

The fuel rail supplies fuel to the injectors under constant pressure.

Fuel pressure regulator

The fuel pressure regulator controls the return of fuel to the fuel tank, to maintain the pressure in the fuel rail at a constant value above intake manifold pressure.

Injectors

Injectors are solenoid - operated valves which deliver fuel in the form of an atomized spray, into the intake manifold, or the intake ports.

Tachometric relay

The tachometer indicates engine RPM

Thermo time switch

The thermo time switch senses engine coolant temperature, to control the operation of the cold start injector, during cranking conditions.

EFI sensors

EFI sensors include: Wide band oxygen sensor twin oxygen sensors, knock sensors, oil deterioration sensor, exhaust gas recirculation sensors and switches.

Potentiometer

A potentiometer is a mechanically variable resistor.

Auxiliary air valves

Auxiliary air valves allow additional air to bypass the throttle plate during cold start, and warm - up conditions.

EFI engine management system

Objectives: At the end of this lesson you shall be able to

- **define engine management system**
 - **explain function of the each part of the engine management**
 - **explain function of each part of ECU**
 - **explain each sensor used in EFI.**
-

Definition

Engine management system includes the fuel system, airflow system, ignition, injection, temperature and emission control system having sensors, ECM and other gauges and controls.

Modes of EFI

A mode of injection describes the timing and sequence of injecting fuel.

Electronic fuel injection (EFI)

EFI is now the most common fuel system, the injectors spray fuel into the air/intake ports for combustion inside the engine.

Idle speed control system

Idle speed control systems maintain a suitable idle speed to prevent stalling, when additional loads are placed on the engine.

Feed back and looping

Feedback from the exhaust gas oxygen sensor is used to maintain closed loop control of the air - fuel mixture.

Cold start system

Cold start systems provide additional fuel during starting conditions, according to engine temperature.

Air measurement

The vane - type airflow sensor measures the quantity of air flowing into the engine by deflecting a spring - loaded vane across a potentiometer. This provides a signal voltage to the ECU.

Air flow monitoring

Depending on the application, different kinds of sensors measure different properties of the air entering the engine, including its temperature, volume, density and mass.

Idle speed control devices

Idle speed control devices allow the preset idling speed to be maintained automatically when additional loads are placed on the engine, during idling conditions.

Inertia sensors

Inertia sensors shut off the fuel pump in the event of an accident, to minimize the danger of fuel spillage from a leak in the system.

Variable intake manifold system

Variable intake manifold systems vary the effective manifold pipe length, to extend the torque curve over a wider RPM range.

Electrical functions

The ECU continuously receives information from sensors in the form of electrical signals, to determine injector pulse width.

EFI wiring diagram (Fig 1)

In electronic fuel system, fuel supply and timing are controlled by electronic means. Electronic fuel injection has developed with the development of solid - state electronic devices such as diodes, transistor.

This system consists of following units:

1 Fuel delivery system

This system consists of an electrically driven fuel pump which draws fuel from the fuel tank through filter and forces it into the pressure line at the end of which is situated a fuel regulator. The pressure difference is kept constant so the fuel injected depends only on the injection open time.

2 Air induction system

The incoming air from atmosphere flows initially through air filter and then through air flow sensor. This air flow sensor measures the amount of air flow in the manifold and generates a voltage signal which is dependent on the amount of air flow.

Spiral coil spring is used to return back the rectangular plate placed in the air flow meter.

3 Sensors and air flow system

A cold start valve is fitted just behind the injection valve to inject additional fuel or cold start. This valve has exceptionally good atomization characteristics. The extra

fuel needed by ordinary starting and warm up period is also supplied by this valve. This signal results in additional fuel required for acceleration through electronic control unit.

Advantages

- 1 A very high fuel distributions is obtained.
- 2 Increased volumetric efficiency and hence increased power and torque.
- 3 Freedom from blow backs and icing.
- 4 Lower specific fuel consumption due to better distribution of mixture to each cylinder.
- 5 Better starting and acceleration.

Electronic control unit

The basic function of the ECU is to control the pulse width of the injector. In engine management systems,

the ECU controls additional functions, such as idle speed ignition timing, and fuel pump operation.

ECU settings

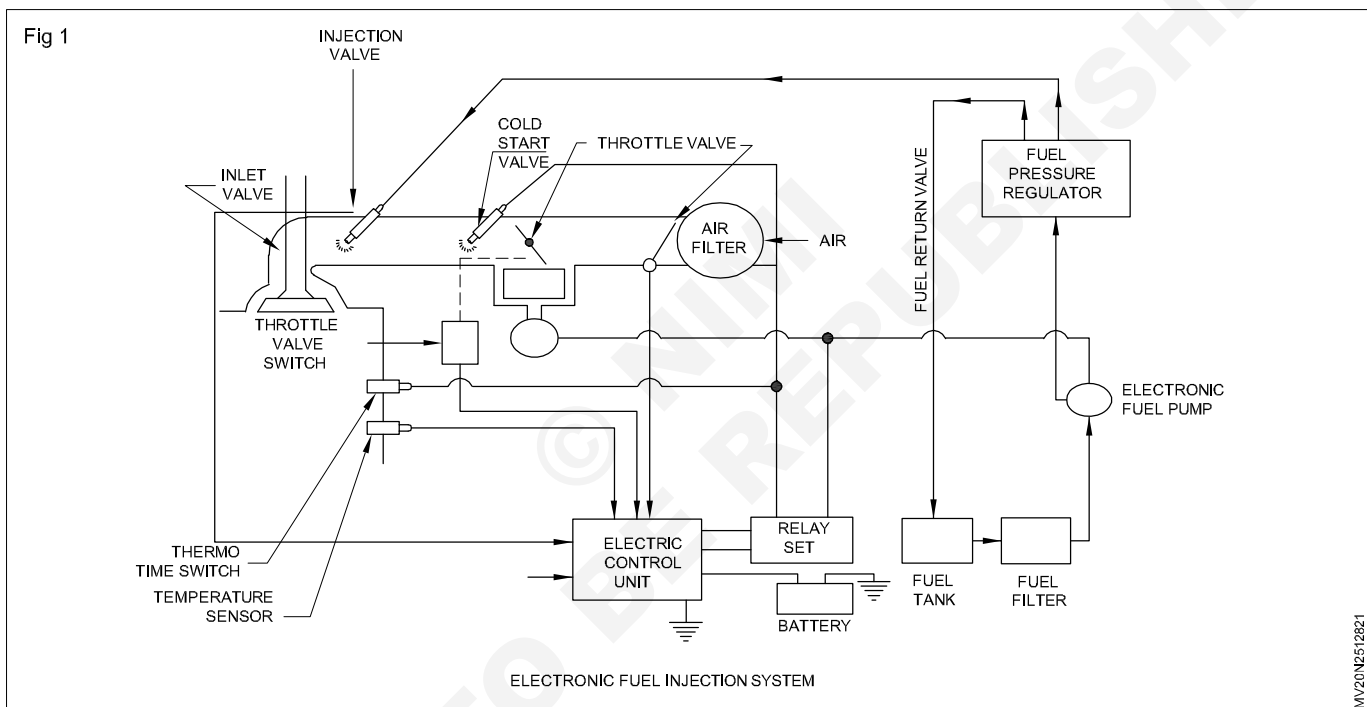
The ECU corrects ignition timing to achieve the optimum setting for each operation condition.

Engine speed limiting

An ECU can control engine speed limiting, the fuel pump, exhaust gas recirculation, idle speed control, a variable intake manifold, and the evaporative emission container.

Malfunction indicator lamp

A check engine lamp or a data scanner can be used to indicate problems in the engine management system. A code indicates where the fault may be.



Types of sensors and their applications

Objectives: At the end of this lesson you shall be able to

- define the sensors
- state the names of sensors
- explain their applications.

Definition

Sensors are essential components of automotive electronic control systems. Sensors are defined as "devices that transform or transduce physical quantities such as mass, pressure, volume, temperature, or acceleration (called measurands) into output signals (usually electrical) that serve as inputs for control systems.

Various types of sensors

- 1 Air-fuel ratio sensor
- 2 Blind spot sensor
- 3 Crankshaft position sensor
- 4 Curb sensor, used to warn driver of curbs
- 5 Defect sensor, used on railroads to detect axle and signal problems in passing trains.
- 6 Engine coolant temperature sensor, or ECT sensor, used to measure the engine temperature.
- 7 Hall effect sensor, used to time the speed of wheels and shafts.
- 8 MAP sensor, manifold absolute pressure used in regulating fuel metering.
- 9 Mass flow sensor, or mass airflow (MAF) sensor, used to tell the ECU the mass of air entering the engine.
- 10 Oxygen sensor, used to monitor the amount of oxygen in the exhaust.
- 11 Parking sensors, used to alert the driver of unseen obstacles during parking maneuvers.
- 12 Radar gun, used to detect the speed of other objects.
- 13 Speedometer, used to measure the instantaneous speed of a land vehicle.
- 14 Speed sensor, used to detect the speed of an object.
- 15 Throttle position sensor, used to monitor the position of the throttle in an internal combustion engine.
- 16 Tire-pressure monitoring sensor, used to monitor the air pressure inside the tires.
- 17 Torque sensor, or torque transducer or torque meter measures torque (twisting force) on a rotating system.
- 18 Transmission fluid temperature sensor, used to measure the temperature of the transmission fluid.

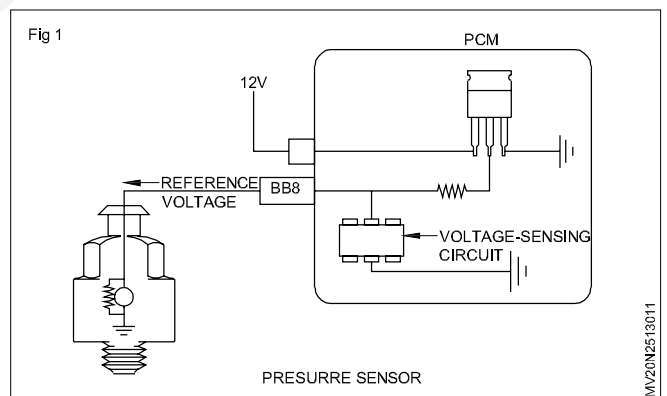
- 19 Turbine speed sensor (TSS), or input speed sensor (ISS) used to measure the rotational speed of the input shaft or torque converter.
- 20 Variable reluctance sensor, used to measure position and speed of moving metal components.
- 21 Vehicle speed sensor (VSS), used to measure the speed of the vehicle.
- 22 Water sensor or water in fuel sensor, used to indicate the presence of water in fuel.
- 23 Wheel speed sensor, used for reading the speed of a vehicle's wheel rotation.

Application of some commonly used sensors

1 Temperature sensor

This type of sensor monitors the intake air temperature, engine coolant temperature. Once the temperature rises they lose the resistance and supply more voltage so that the ECM senses the problem and cuts off the necessary supply and gives signal.

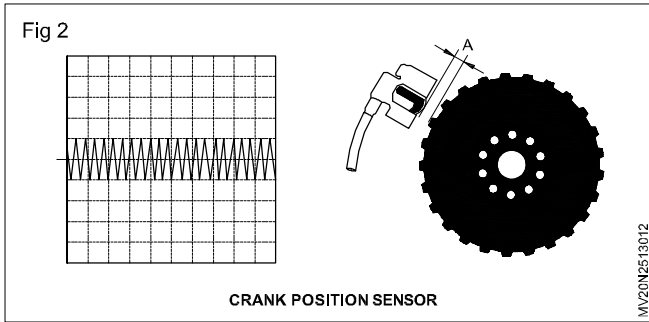
2 Pressure sensor (Fig 1)



This sensor monitors, senses, manifold air pressure, atmospheric pressure, in-cylinder pressure and fuel injection pressure. Once there is a change in the pressure level, it sends a signal to the ECM in terms of millivolts. Thus, the engine can be monitored by the ECM.

3 Crank, cam shaft position sensor (Fig 2)

These sensors are located in the crank case, crank pulley. Mainly, these sensors are used to monitor the injection timing and ignition timing of the engine, which depend upon the speed of the vehicle. So that qualitative and quantitative analysis and control can be done and the efficiency can be monitored.



4 Throttle position sensor

It is located in the throttle body; it is used to record the angle of rotation of the throttle valve and the speed of its movement. This information is required to measure the engine load, timing, delivery, EGR, converter clutch operation.

5 Mass air flow sensor

It is located in the intake manifold or throttle body on MPFI it is used to find out the volume and density of air entering the engine at any given time. This information is very vital to balance and deliver correct fuel mass to the engine.

6 Engine knocking sensor

It is located in the engine block, cylinder head or intake manifold. It is used to sense vibrations caused by the engine knock. This information is very useful to set the injection and ignition timing in diesel and petrol engine respectively.

7 Oxygen sensor

It is located at the exhaust manifold. It is used to measure the free oxygen in the exhaust gas, it is very vital in deciding the timing and quantity of the fuel.

8 Hall effect sensor

It is a device that is used to measure the magnitude of a magnetic field, its output voltage is directly proportional to the magnetic field strength through it. H.E. sensors are used for proximity sensing, positioning, speed, detection and current sensing application.

9 Vehicle speed sensor (V.S.S)

This sensor monitors vehicle speed so the computers can regulate torque converter, clutch lock up, shifting etc., The sensor located on transmission, transaxle or speedometer head.

10 Air vortex sensor

This sensor detects these vortices which are converted to an electrical frequency signal.

11 Voltage sensor

This sensor manage manages the idling speed of the car and ensures the speed is increased or decreased as necessary

ECM and sensors used in engine

Objectives: At the end of this lesson you shall be able to

- state the location and uses ECM and various sensor
- describe the working of ECM
- state the functions and working principle of sensors.

Electronic Control unit - ECU

Electronic Control unit receives the variety of information from different sensors and controls a series of actuators on an internal combustion engine to ensure the optimum running. ECU may be named as Engine control unit (ECU), Engine control module (ECM), Powertrain control module (PCM) etc. For explanation purpose ECU is divided into two portion inside and outside.

Inside the ECU we have a micro computer. Micro computer consists of RAM - Data supplied by the sensor is stored. Here the information are stored temporarily. It also records strategy results in RAM including adaptive strategy values such as fuel trim. Diagnostic trouble codes are also recorded in RAM when the computer determines that a fault exists. There are two types of RAM, Volatile and non-volatile. A volatile RAM must have constant source of voltage from battery, memory gets erased when disconnected from power source. A nonvolatile RAM does not lose its stored information if its power source is disconnected.

ROM - Software (reference value) stored permanently

It contains permanently stored information that instructs the micro processor on what to do in a very basic and in response to input data.

PROM

It is same as that of ROM but programmed with regard to specific vehicle. Information stored in the PROM is stored in the form of electronic charts or tables. These tables are referred as Maps. These charts enable microprocessor to respond to a specific combination of input conditions when making a decision concerning an actuator. In modern vehicle PROM IC may be reprogrammed on order to update the computer strategies as needed. The term ROM, PROM and RAM are standard through the computer industry but vehicle industries may not use the same term.

Microprocessor

It is a heart of a computer and has the task of making all decisions. It records input information, then compares with internal program. It then sends the proper commands.

Outside the ECU we have socket or connectors

Inputs for ECU

Circuits which feed information to ECU. Sensor circuits - Sensor either generates a voltage or changes resistance and then modified voltage sent to ECU.

Diagnostic Monitor circuit

Feed back circuit which monitors the output values. Feed back circuit informs the ECU whether the relay has actually energized or not. The use of such feedback circuits enhances the computer ability to aid the technician in diagnosis of these systems.

Informational input circuits

Information from other ECUs shares with each other for better co-ordination. Output of one ECU is input to other ECU. Signals from the driver or passenger such as switching on A/C etc. Signals from the technician so as to identify the various causes for malpractice of sensors and others.

Output for ECU

Actuator Circuit. These circuit allow the computer to control the required actuators viz. warning lights, relay of motor, solenoid etc.

Informational output circuits

Messages to other ECUs Signals to driver or passenger, viz coolant temperature more, rear de-fogger turned on etc. Signals to technician, when the technician makes a request to ECU for diagnostic trouble code, the ECU will respond by talking back to the technician in some way. On modern vehicle the computer communicates the same information via scan tool through binary code.

Data buses

When ECU communicates with other ECU they communicate through circuits called serial data bus.

Manifold air pressure

It is located at Inlet manifold, it is used to measures the absolute pressure in the intake manifold and compares it with a reference vacuum. This information is required to know how much load the engine is under. This data is the basis for fuel delivery and timing control.

How it works : It is comprised of a silicon chip in which a thin diaphragm has been etched micromechanically. Four deformation resistors are diffused on the diaphragm. their electrical resistance changes when mechanical force is applied the measuring element is surrounded on the component side by a cap which, at the same time encloses the reference vacuum.

Throttle position

It is located on the throttle body, it is used to register the angle of rotation of the throttle valve and the speed of its

movement. This information is required to measure engine load, adjust timing, fuel delivery, EGR, converter clutch operation. It is an emergency signal in case of a failure of the primary load sensor (MAF).

How it works : Resistive type sensor based on potentiometric sensor. The sensor's rotor is attached to the throttle valve shaft, and when the throttle valve moves, the sensor's special wipers move over their resistance tracks so that the throttle's angular position is transformed into a voltage ratio.

Intake air temperature

It is located at the air intake track, it is used to detect temperature of the incoming stream. It is the part of MAF sensor. This information is required, to heat the incoming air by engine if intake air temperature is below the requirement.

How it works: Resistive sensor, based on thermistor principle. There is a heated wire is maintained at a predetermined temperature above the intake air's temperature at sensor body. When there is change in temperature of air, it tends change in resistance and accordingly intake temperature is measured.

Coolant temperature

It is located at coolant passage before the thermostat. It is used to measure the engine coolant temperature. This information is required to switch on the electronic cooling fan as well as to adjust fuel injection and ignition timing, variable valve timing.

How it works : Resistive type based on thermistor. As temperature is subject to the sensor the internal resistance change.

Exhaust gas oxygen sensor (lambda sensor)

It is located at the exhaust gas manifold. It is used to measure the free oxygen in the exhaust gas. This information is used to control the fuel injection. Because this information is a direct result of the air/fuel ratio, rich mixture yields little free oxygen while lean mixture yields more free oxygen as not all oxygen consumed during combustion and accordingly the injection is controlled.

How it work : The important component of oxygen sensor is a hollow ceramic body that contains zirconium dioxide, a white crystalline compound. The inner and outer surface of body is attached with platinum plate.

The inner area is exposed to atmosphere and the outside is exposed to the exhaust. When the sensor is heated approximately 300 to 850 deg C, zirconium di oxide becomes oxygen ion conductive, electrically charged oxygen ions form on the platinum plates. The amount of oxygen to which each plate (inner and outer) is exposed determines how many ions on the plates. When there is a difference in the number of ions on the plates, a difference in potential of voltage occurs between the two plates. If less oxygen in exhaust, greater voltage produced and more oxygen less voltage.

Crankshaft and camshaft position sensor - Engine Speed sensor

It is located at main crank pulley, the flywheel, the camshaft or on the crankshaft itself. It is used to determine which cylinder is firing and find engine speed. This information is required to establish injector synchronization & coil firing sequence in Direct ignition system.

How it works : Inductive type sensor based on magnetic inductance. This type of sensor consists of permanent magnet, yoke and coil. This sensor is mounted close to a toothed gear. As each tooth moves by the sensor, an AC voltage pulse is induced in the coil. Each tooth produce a pulse. As the gear rotates faster there more pulses are produced. The ECU determines the speed the component is revolving based on the number of pulses. The number of pulses in one second is the signal frequency.

When it fails, there is a chance the engine will not start, or cut out while running. Crank or camshaft position sensors and engine speed sensors are similar devices that operate based on pulse detection and counting.

Vehicle speed sensor

Vehicle Speed Sensors are much the same as a camshaft or crankshaft sensor. The sensors can be mounted either in the transmission case or rear differential assembly. Those in the transmission are typically gear driven.

Vehicle information is required to regulate power steering pressures for higher assist at slow speeds, making parking lot maneuvers easier to perform. And also used at ABS to determine when the wheel is locked up and accordingly releases pressure to that wheel to maintain directional stability.

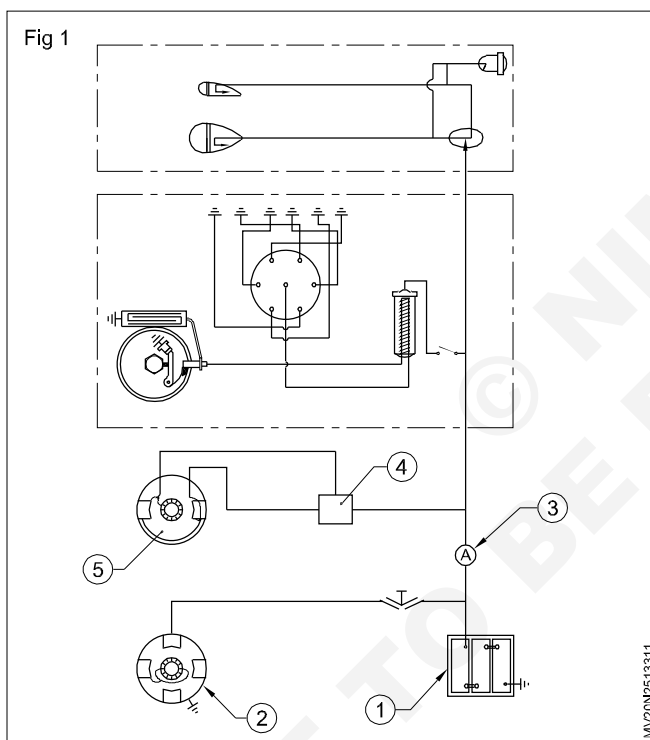
Ignition Circuit

- Objectives:** At the end of this lesson you shall be able to
- explain the different electrical circuits in automobiles
 - explain the ignition circuit
 - explain the need of ignition coils
 - explain the need of condensers
 - explain the need of spark plugs.

Description of automobile electrical circuits

The present day automobile almost contains an electric power plant under its hood and stores electrical energy. This energy is delivered either at low voltage or in the form of high voltage surge.

The automotive electric system is classified under five main headings (Fig 1)



- Generation, storage and distribution system (charging system)
- Starting system
- Ignition system
- Lighting system
- Auxiliary system

All the circuits are connected together and linked to the car battery (1). The starting or cranking system is connected directly to the battery (1) through cables and switch to provide a low resistance path for the large current required by the starter motor (2).

The generating circuit is connected to the battery via the ammeter (3) which register in the charge when current is supplied to the battery (1). A control box (4) is provided in the circuit to control voltage and current. The control box (4) connects and disconnects the battery (1) and the generator (5).

the ignition primary circuits, the lighting circuit and the auxiliary circuits are connected to the same side of the ammeter (3) as in the generator so that when the generator is in operation they receive current directly from the generator (5). When the generator is not running, these circuits draw current from the battery. (1) All the circuits are controlled by the individual switches in between the battery and the load.

Faraday's Law of Induction

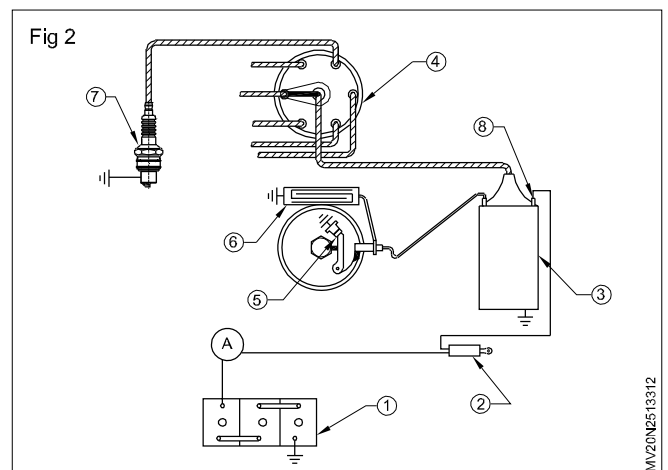
Faraday's law of induction which states that the induction of electromotive force (EMF) in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit.

Ignition system

All spark ignition engines require an ignition system to ignite a fuel mixture in the cylinder. A very high voltage is required to generate sparks to ignite the cylinder charge at the set time. Two types of ignition systems are used.

- Battery ignition system
- Magneto ignition system

Battery ignition system (Fig 2)



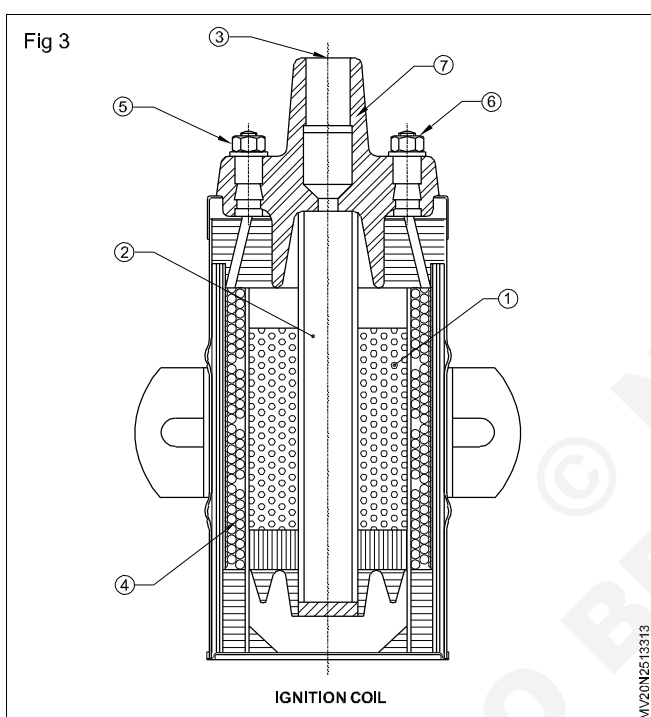
The battery ignition is used in passenger cars, light trucks and a few two wheelers. This system consists of the following parts.

- i Battery
- ii Ignition switch
- iii Ignition coil
- iv Distributor
- v Contact breaker
- vi Spark plug

Ignition switch

It is fitted on to the panel board in between the battery and the ignition coil. It connects or disconnects the primary circuit from the battery (1).

Ignition coil (Fig 3)



It is used to step up low voltage to high voltage to generate sparks. It consists of two windings, one is wound over soft iron core. The secondary windings (1) is grounded over the core (2). It consists of about 21,000 turns. One end of the windings is connected to the secondary terminal (3) and the other end of the primary

Spark plug

Objectives: At the end of this lesson you shall be able to

- state the purpose of spark plug
- explain the cross-section and working of spark plug
- types of spark plug.

Purpose of spark plugs

A spark plug (Fig. 1) is basically two electrodes positioned to form a gap. The gap is between the insulated center electrode and the ground electrode. This is the gap that

winding (4). The primary winding (4) is wound over the secondary winding (1) and consists of about 200 - 300 turns. The ends are connected to the external terminal (5,6). the backlite cap (7) insulates the secondary terminal from the container and primary terminals.

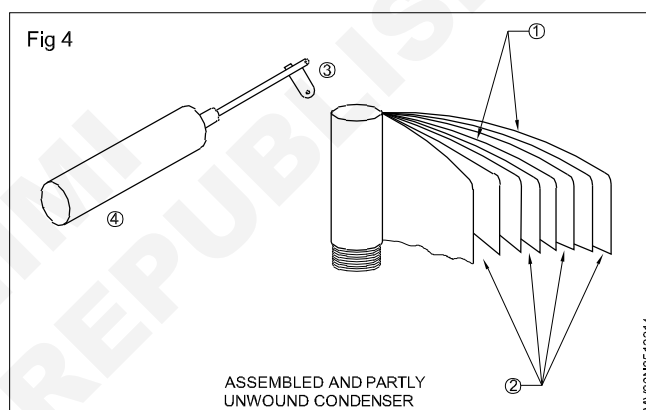
Distributor

A distributor is fitted on the engine. It is driven by the engine camshaft. The distributor opens and closes the primary circuit of the ignition coil. It distributes the resulting high tension surges from the secondary winding of the ignition coil to the various spark plugs of the engine at a set time.

Contact breaker

It connects and disconnects the primary circuit at regular intervals to produce high voltage in the secondary winding of the coil. The points are two in number, one is directly fitted to the base plate and the other is insulated and operated by the rotating cam.

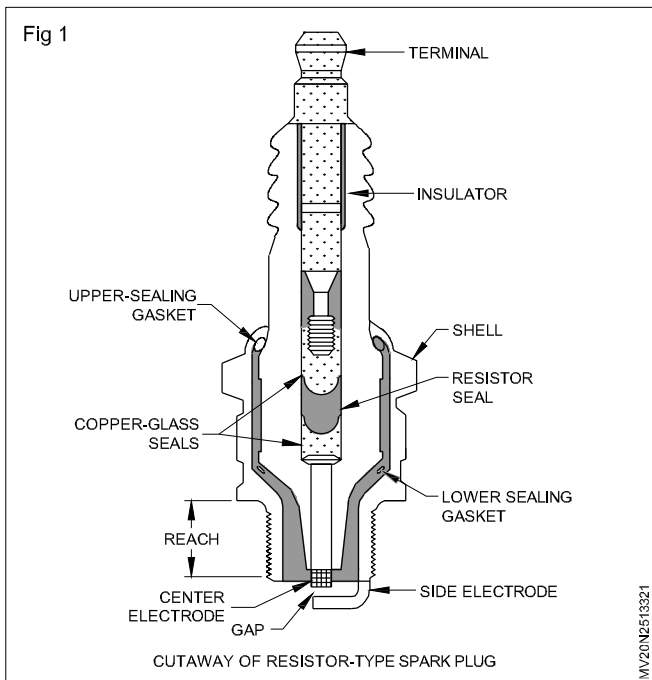
Condenser (Fig 4)



The condenser is fitted on the base plate of the distributor. It is connected in parallel to the contact breaker's points. The condenser absorbs current in the primary circuit which passes through the ignition points but which is suddenly stopped by their separator. It consists of aluminium or lead foil (1). Foils are insulated from each other. One end of the foil is connected to the condenser terminal (3) and the other end of the condenser case (4).

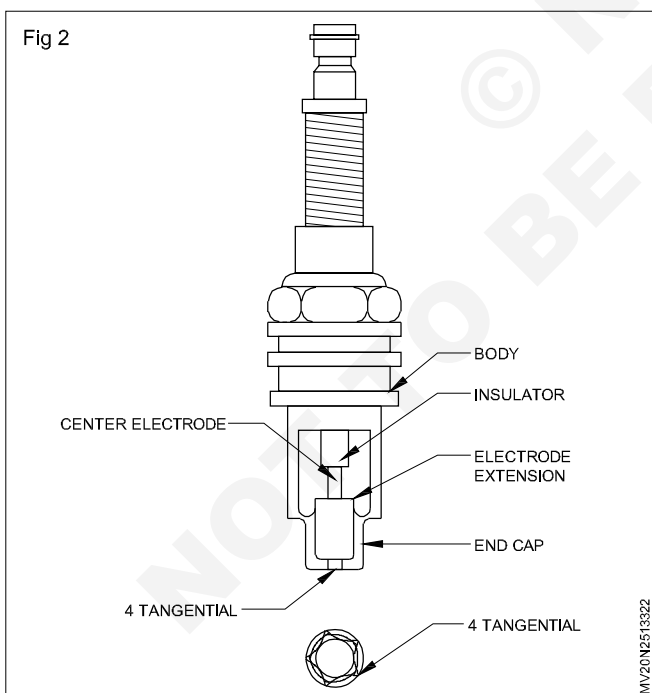
The condenser prevents arcs at the points and helps the ignition coil to release its energy in the form of high voltage surge through the secondary winding.

the spark jumps to start the ignition of the compressed air - fuel mixture in the engine cylinder.



Explain the working of spark plug

The number one job of the ignition system is to produce the high - voltage surges that cause the sparks at the spark plug gaps. Fig 2 shows in simplified form, how this is done. The ignition coil has two windings: a primary winding of a few hundred turns of relatively heavy wire, and a secondary winding of thousands of turns of very fine wire.



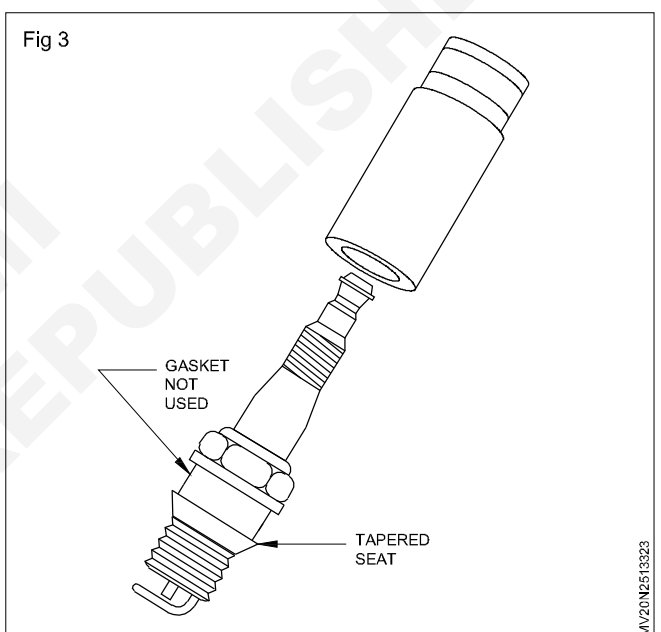
Now see what happens when the ignition switch is turned on, and the trigger has closed the circuit between the ignition coil primary winding and ground (the other battery terminal). Battery current will flow through the primary winding. This causes a magnetic field to form around the winding.

Now, when the trigger opens the circuit between the winding and ground, current stops flowing. The magnetic field collapses.

Spark plug with end cap designed to improve combustion swirl. (Fig 2)

Spark plug has an end cap with a gap to the end cap. When the air fuel mixture is compressed, some of it enters the cap. Then, when the spark occurs, ignition starts in the cap. The burning mixture streams out through the orifices to ignite the rest of the compressed mixture. Note that the tangential orifices are at an angle. As the burning mixture streams out through these orifices, it sets up a swirling motion that speeds the burning of the mixture. This is said to improve engine performance.

Some spark require gaskets when installed in order to assure a leakproof seat. Many engines use plugs with tapered seats (Fig 3) which produce a good seal when installed.

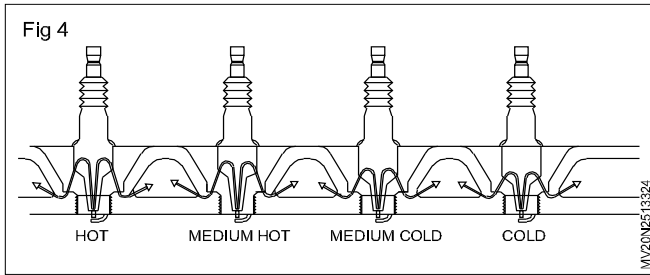


Precautions

Spark plugs for modern engines with electronic ignition systems have gaps of up to 0.080 inch (2.03mm), as previously noted. They are not interchangeable with the plugs used on earlier systems, which used gaps of less than half as much. Use only the specific spark plugs specified for the engine. Attempting to use the earlier type of plug by bending the outer electrode to get the right gap can cause trouble. The plug will not fire right.

Types of spark plug (Fig 4)

Two important characteristics of spark plugs are their heat range and their reach. The heat range of the plug determines the temperature the spark plug will attain in the engine, that is, how hot the plug will get. This controlled by the shape of the plug and the distance heat must travel from the center electrode of the plug to reach the cooler cylinder head. If the path the heat must travel is long the plug will run hot. If the path is short, the plug will run cooler.



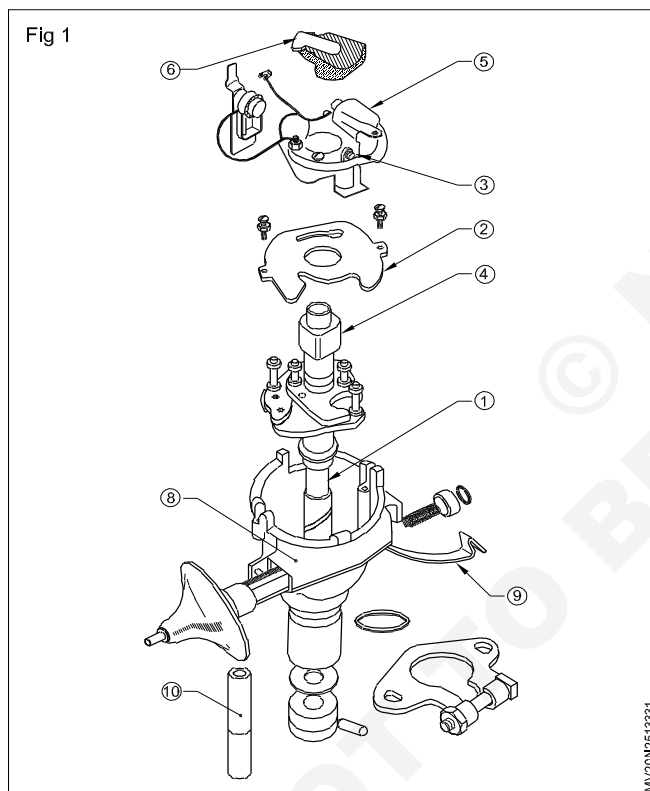
If the plug runs too cold, it will not become hot enough to burn away sooty deposits that collect on the insulator around the center electrode. It can foul and miss. That is, the high voltage surges will leak across the sooty deposit and not jump the spark gap. If the plug runs too hot, it will wear, or burn the electrodes more rapidly. This also can lead to a miss because the gap becomes too wide for the spark to jump.

Distributor

Objectives: At the end of this lesson you shall be able to

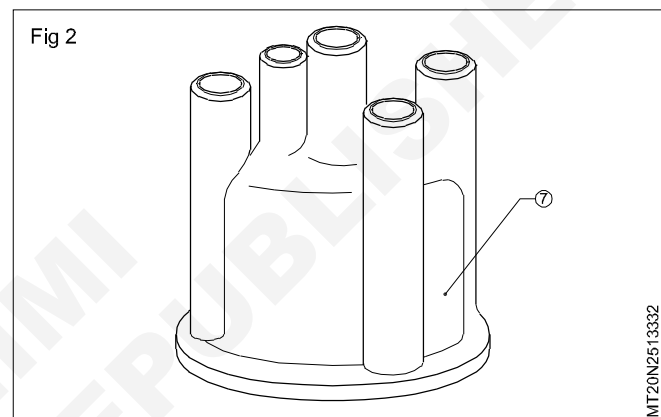
- state the need of a distributor
- state the constructional features of the distributor
- state the different types of advance mechanism
- state the function of the centrifugal advance mechanism
- state the function of the vacuum advance mechanism.

The distributor (Fig 1) is used to distribute the high voltage surges from the ignition coil to the individual spark plugs in a specified sequence and at the set time.



The distributor consists of a distributor shaft (1), advance mechanism, bushes, breaker plate (2) carrying C.B. points (3), cam (4) condenser (5) rotor (6) and distributor cap (7) (Fig 2).

The bowl shaped distribution housing (8) closed from the top by a distributor cap (7) and clip (9) is made of high quality moulded insulating material (bakelite). The cap has segments terminal towers equal to the number of cylinders. These towers are connected by high tension leads with the spark plugs as per the firing order. The center tower of the cap is connected with the H.T terminal of the ignition coil. A spring loaded carbon brush conducts



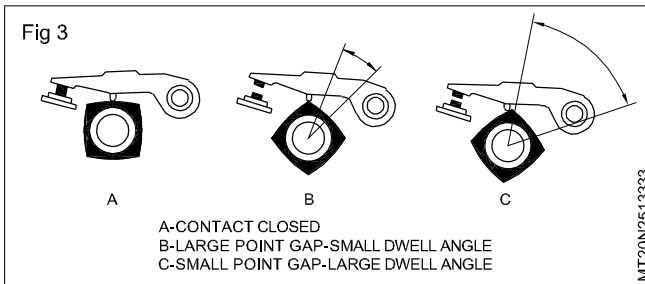
the ignition surge to the electrode of the rotor (6). From the rotor arm (6) the H.T. current/ surge flows to the side segment of the distributor cap. (7), provided on its circumference.

The distributor housing has a cylindrical shaft supported by bush bearing (10). A shield made of a metal called 'breaker plate' (2) is fitted in between the distributor compartment and the contact breaker compartment. This shield also prevents dirt, carbon and moisture from entering into the distributor section.

A platinum contact and breaker points are provided in the distributor, which is operated by rotating the cam (4). When the point breaker's level rides on the rotating cam (4) it results in breaking the primary circuit of the ignition coil. During each rotation of the camshaft the contact breaker opens and closes an equal number of times, as the engine has cylinders. The points remain closed when the moveable point fiber block rests on the base circle dia. of the cam (4). It is called the dwell period is known as the dwell angle. During this period the ignition in the secondary winding of the coil drops is less.

The condenser or capacitor (5) is feed on the plate of the distributor. It is made of a number of aluminium and tin foils with a separator. The foils are rolled up in a solid roll. One end of the foil is attached to the terminal and the other to the body. It is connected to the moveable

C.B point in parallel. (Fig 3) When the C.B. points close the condenser absorbs current and preserves it. When the C.B points open, the stored current is reversed to the ignition coil, to impulse high tension surge in the secondary winding. The condenser also prevents arcing at the C.B. points.

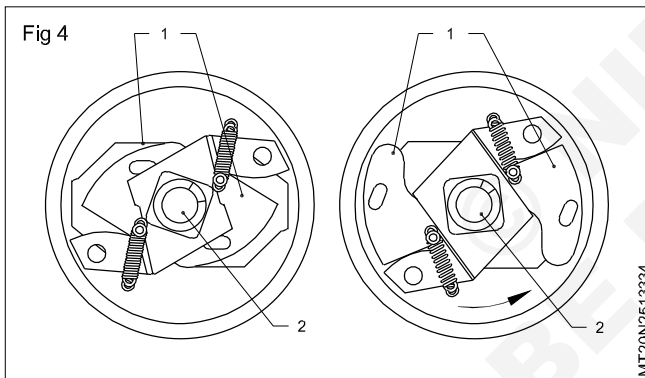


An advance mechanism is provided in the distribution to ensure that under every condition of engine operation, ignition take place at the set time. The advance angle is set in such a way that ignition occurs before the T.D.C of the piston to have better fuel economy.

There are two types of advance mechanism.

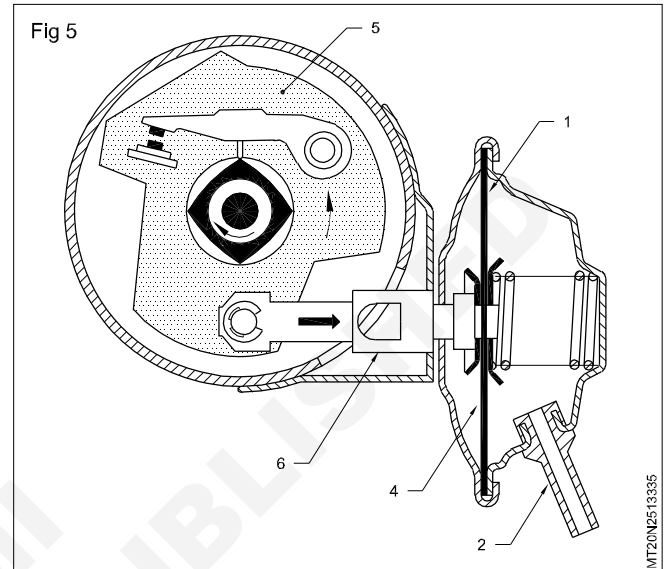
- i Centrifugal advance mechanism
- ii Vacuum advance mechanism

Centrifugal advance mechanism (Fig 4)



The centrifugal advance mechanism consists of a pair of weights (1) attached with the distributor shaft (2). As the speed of the shaft increases, the flyweights (1) swing outward and shift the cam in the rotation of the shaft. As a result the cam lobe contact the moveable C.B. points fiber block a little early. Hence, the contact also opens a little early. Thus the ignition point is shifted in the 'early' or 'advance' direction.

Vacuum advance mechanism (Fig 5)



The vacuum advance mechanism consists of a vacuum unit (1) fitted on the distributor. A hose (2) is connected with the carburetor vacuum. The diaphragm (4) of the vacuum unit is moved by the carburetor. An engine which is running under light or moderate load above the idle speed, requires additional spark advance, to increase fuel economy. When vacuum is applied to the diaphragm from the carburetor throat, the breaker plate (5) is pulled with the arm (6) in the direction opposite to the cam rotation. This causes the points to open earlier. When the throttle is in the idle or closed positions there is no vacuum available to pull the diaphragm and ignition takes place at the set time.

Electronic ignition system

Objectives: At the end of this lesson you shall be able to

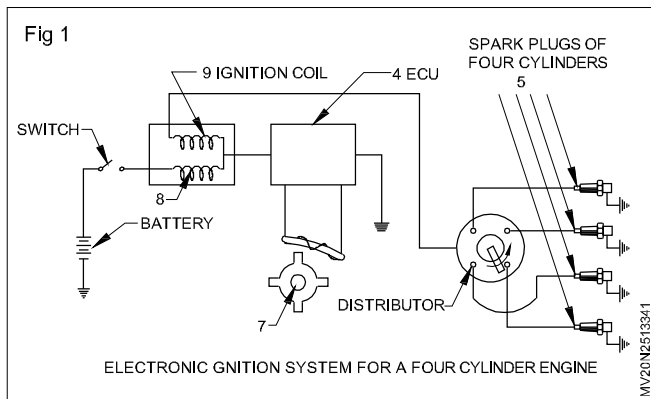
- describe the principle of electronic ignition system
- describe the pulse generator
- describe the hall effect sensor
- state the factors of electronic spark advance
- describe the distributor less ignition system.

Principle of electronic ignition system (Fig 1)

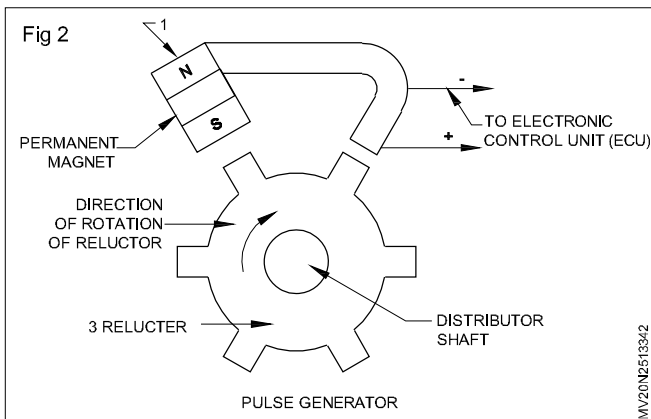
A timer (7) is used in the distributor(6) of electronic ignition system. It sends electrical pulses to an electronic control unit (4)(ECU) which switches off the flow of current to the primary winding (8). As a result, a high voltage is induced in the secondary winding(9) which is then distributed to the spark plugs(5) as in the case of the breaker point ignition system.

The electronic control unit later switches on the flow of current to the primary circuit so that the primary circuit current can be built up for the next cycle.

The timer may be a pulse generator or a hall effect sensor.



Pulse generator (Fig 2)



A pulse generator consists of a permanent magnet (1), a timer (2) coil and reluctor(3). The permanent magnet and the time coil remain stationary. The reluctor is fitted to the distributor shaft and is in the shape of a wheel with teeth.

When the distributor shaft revolves, the reluctor wheel rotates, its teeth moving very near to the pole plates of the permanent magnet.

The reluctance of the air gap between the other inductor tooth and the timer coil is reduced. At the same time, the reluctance of the air gap between the reluctor tooth and the magnet is also reduced. This results in a strong magnetic field around the timer coil.

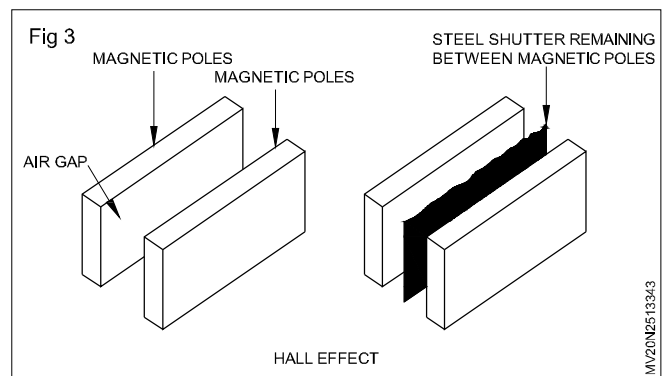
Current is permitted to flow through the timer coil to the electronic control unit, where the primary current flows. As a result, the ignition coil builds up a strong magnetic field.

As the reluctor wheel rotates slightly further, the reluctor tooth moves away from the timer coil. The air gap becomes wider offering a high reluctance. This results in a weaker magnetic field for the timer coil and the induced voltage reverses. The flow of current to the primary circuit is stopped.

The magnetic field in the ignition coil collapses and enough high voltage is produced for producing spark at the spark plug.

The reluctor wheel in the figure has six teeth. This wheel is used for a six - cylinder engine. The reluctor wheel has the same number of teeth as there are cylinders in the engine.

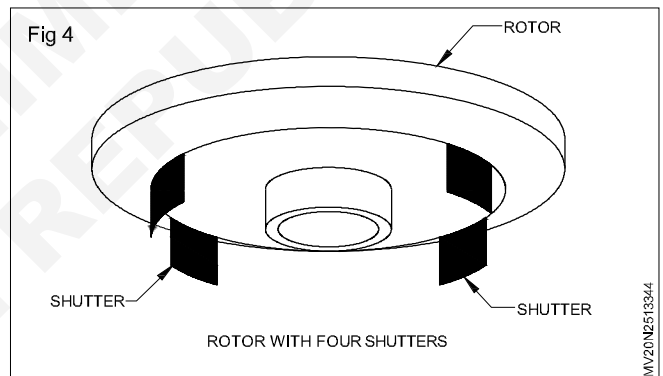
Hall effect sensor (Fig 3)



The hall effect was named after the scientist who discovered the effect. Magnetic sensors used in electronic distribution utilize the principle of Hall effect.

As shown there is magnetism in the air gap between the two poles of a magnet. When a steel shutter is placed or moved between these poles, the magnetism in the air gap is cut off. This principle is called Hall effect.

A rotor with curved plates is used in the Hall effect distributor of an electronic ignition system. These curved plates are called shutters (Fig 4). The shutters are curved in such a way that they can move between the two poles of the magnetic sensor with the movement of the rotor.



The number of shutters is the same as the number of cylinder in the engine.

Whenever a shutter passes between the two poles of the magnetic sensor, it cuts off the magnetism in the air gap between the poles. This sends a signal to the electronic control unit.

When a shutter moves away from the air gap, the magnetic sensor develops a voltage. ECU then receives a signal from the magnetic sensor, to permit the current to pass through the primary winding of the ignition coil. However, when a shutter passes between the poles, the magnetic field is cut off and the signal voltage comes to zero.

When the ECU suddenly cuts off the flow of current to the ignition coil primary winding, the magnetic field collapses. This results in the production of high voltage in the secondary winding which gives rise to a spark in the spark plugs.

The Hall effect magnetic sensor is more accurate than the magnetic pulse generator explained earlier.

Electronic spark advance

The mechanical centrifugal advance mechanism and the vacuum advance mechanism are not used in some electronic ignition systems. However, the electronic spark advance systems are adopted in the electronic ignition system.

To control the spark advance, several engine sensors feed information to a computer.

The following information is fed to a computer:

- (i) Movement of the throttle
- (ii) Pressure of air
- (iii) Temperature of air coming to the air cleaner.
- (iv) Temperature of engine coolant.
- (v) Vacuum in the intake manifold.
- (vi) Speed of the engine.
- (vii) Position of the piston.

The sensors send the appropriate signals to the computer which then correlates the signals. After processing the information, the computer provides the best spark advance for the operating conditions.

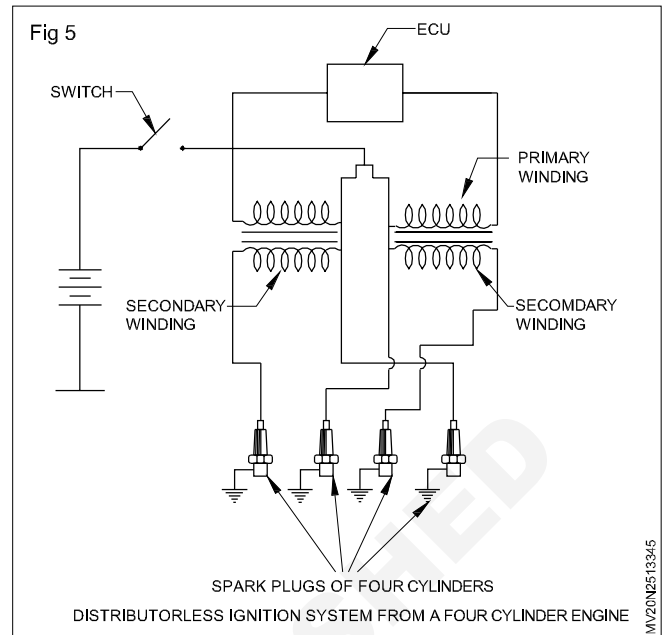
Distributor less ignition system (Fig 5)

This engine has no distributor. In this system, two spark plugs are ignited at the same time. Out of these two spark plugs, one provides ignition in one cylinder during its exhaust stroke. However, the ignition has no effect, as only burnt gases are present inside the cylinder during the exhaust stroke.

The other spark plug ignites the mixture in another cylinder when the piston is at the end of the compression stroke. Here normal combustion takes place.

In the ignition coil, there are two primary and two secondary windings. The rotary hall effect sensor on the crankshaft controls the flow of current through the

primary winding and consequently, the production of high voltage in the secondary winding.



The trigger has two triggering points, one for each primary winding. Each triggering point sends a signal to the electronic control unit (ECU) so that the flow of current through one of the two primary windings is stopped. When the flow of current is stopped, the magnetic field in the primary winding collapses suddenly and a high voltage is produced in the secondary winding.

A four cylinder engine with the firing order 1,3,4,2 has a special arrangement in which cylinders 1 and 4 and cylinders 3 and 2 are paired.

In a six cylinder engine, which has no distributor, there are three pairs - cylinders 1 and 4, cylinders 5 and 2, and cylinders 6 and 3.

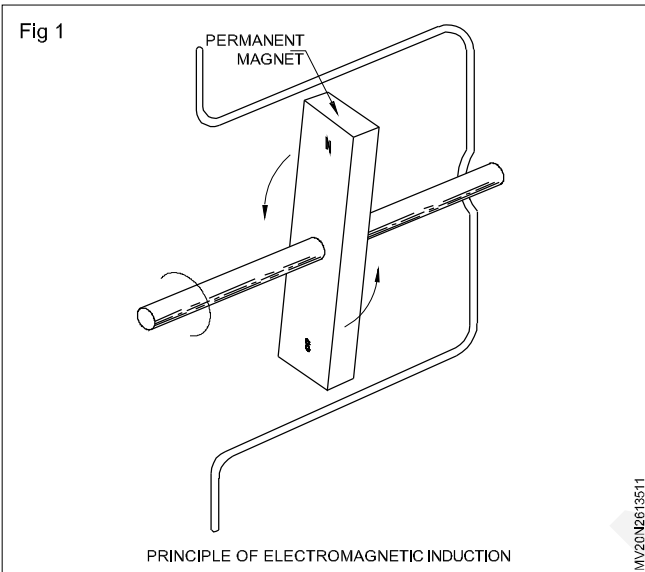
Each ignition coil is a true transformer.

Alternator

Objectives: At the end of this lesson you shall be able to

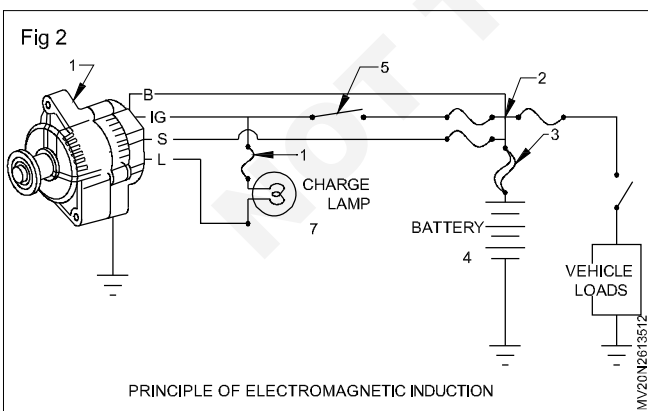
- state the principle of alternator
- describe the circuit of the alternator
- describe the purpose of alternator
- explain the functions of the various parts of an alternator
- explain the working of an alternator.

Principle of electromagnetic induction (Fig 1)



Alternator design is based on the principle of electromagnetic induction and the fact when an electrical conductor cuts through the lines of force of a magnetic field, an electrical potential (electromotive force-e.m.f) is induced in the conductor. This principle is shown in its simplest form which shows how a permanent magnet rotated in a loop of wire will cause an e.m.f. to be induced across the ends of that loop of wire.

Alternator wiring circuit in a vehicle (Fig 2)



The alternator (1) output terminal (B) is connected to the battery (4) through the junction (2) and fuse (3) in the alternator charging circuit fig (2). The alternator field terminal (1G) is connected to the battery through the

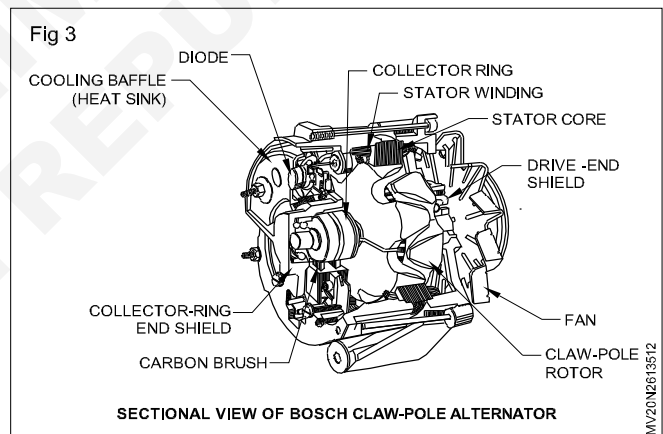
ignition switch (5). The charging indicator lamp (7) connected between the (1G) terminal and (L) terminal of an alternator through the another fuse (6).

Components of charging system

It consists of the following components

- 1 AC generator (or) alternator
- 2 Rectifier and regulator
- 3 Charge indicator
- 4 Ignition switch
- 5 Battery

Purpose of alternator (Fig 3)



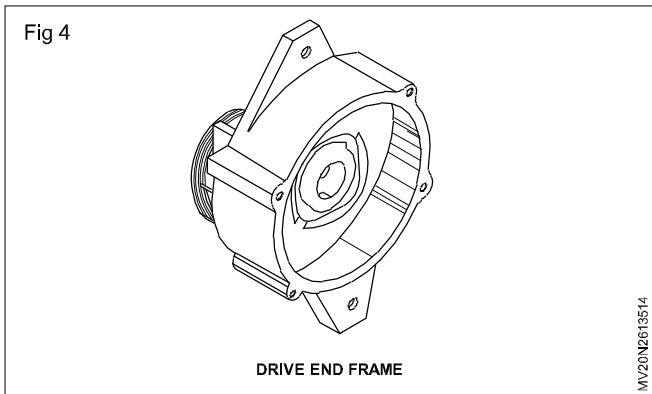
Right from the beginning, vehicles were fitted with dynamos for producing electricity. In present day vehicles the number of electrical accessories used has increased. Thus the demand for higher capacity generators has arisen. This can only be met by increasing the capacity of the generator and also by running it at higher speeds.

The vehicles in large cities have to, often, move at very slow speeds due to heavy traffic. Normally a DC dynamo will not be able to charge the battery at such low speeds. The speed of the dynamo cannot be increased beyond a certain limit. Therefore, an alternator or AC generator is used. An alternator can produce more electricity at low r.p.m.

Description of parts of an alternator

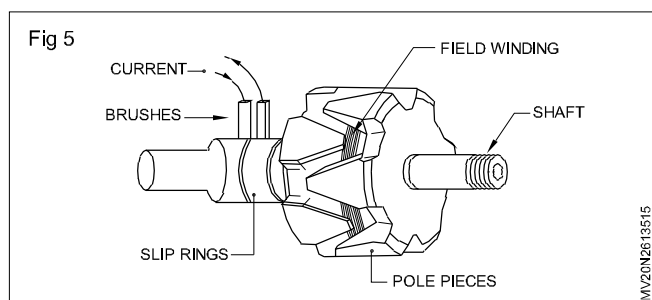
Drive end frame (Fig 4)

The drive end frame supports a pre-lubricated sealed bearing in which the drive end of rotor shaft rotates.



The rotor and its shaft is mounted and encased between drive end frame and slip ring end frame.

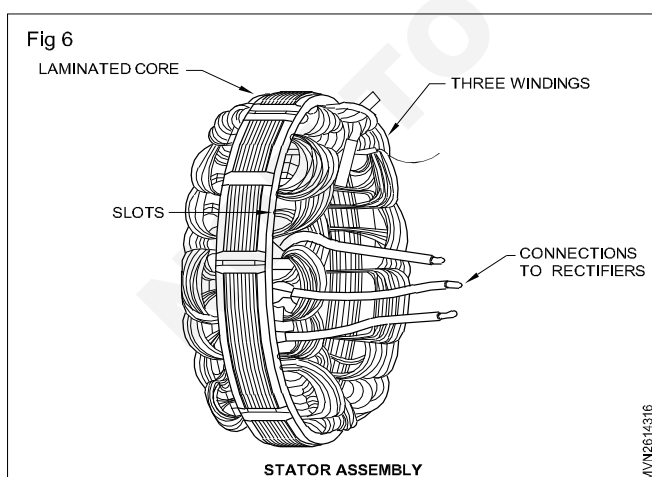
The rotor assembly (Fig 5)



This consists of a steel shaft which carries the driving pulley and cooling fan, a cylindrical iron core, and two insulated slip rings. A large number of turns of insulated wire are wound over the core to form the field winding. Each end of the winding is connected to its own slip ring and spring-loaded brush. The winding is enclosed by two iron pole pieces with eight interlocking fingers which become alternate north and south poles when direct current is passed through the winding via the brushes.

Stator assembly (Fig 6)

It is a stationary part which is held between two end covers. (Fig 6)



This consists of a laminated, cylindrical, iron core which is slotted to permit the fitting of three sets of insulated windings. In the lighter units these windings are star connected and in the heavier units delta connected. The

number of coils depends on the number of poles.

The 'N' pole and 'S' pole of the magnet pass each stator winding and due to interruption of the magnetic flux the current is generated in the stator windings.

Diodes

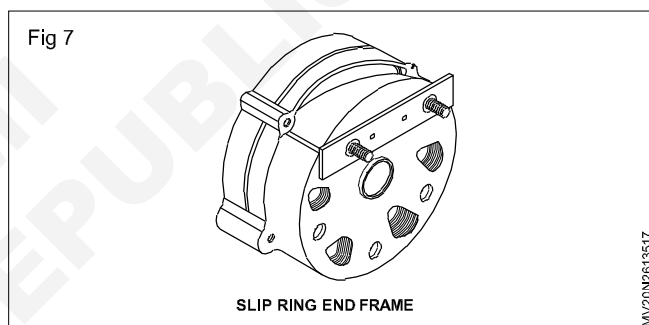
The diodes are made of silicon and these allow current to flow in one direction only. They are so connected as to allow the current to flow from the alternator to the battery but not in the opposite direction.

Three diodes on the negative side are connected to the rear end housing and three diodes on the positive side are mounted on an insulated heat sink.

The diodes convert the AC produced by the alternator to DC since the automobile accessories are designed to utilise DC current.

Slip ring end frame (Fig 7)

The slip ring end frame supports the rectifier mounting plates and a pre-lubricated bearing for rotor/shaft rotation. The rectifiers are pressed into the slip ring end head or heat sink and are connected to the stator leads.



Voltage regulator

A voltage regulator is used to keep the output voltage of the alternator constant to prevent severe damage to the battery and other electrical accessories.

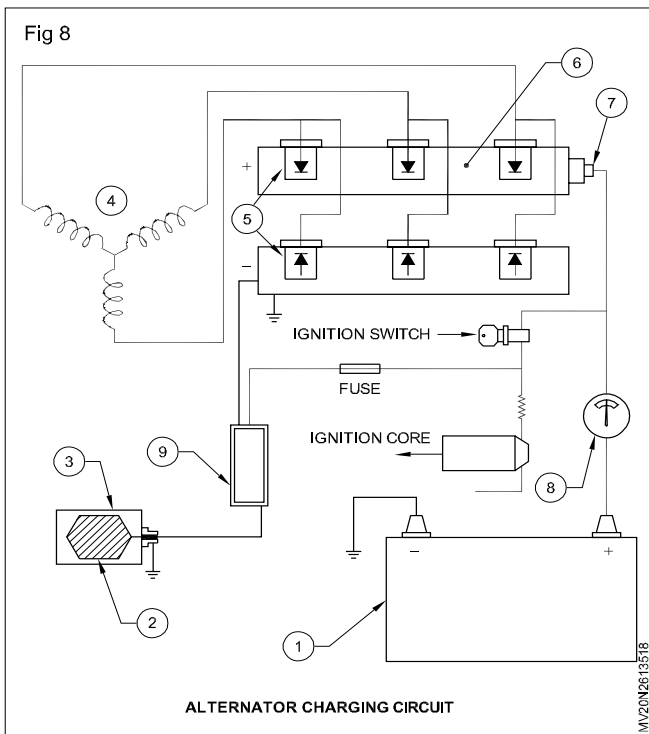
The voltage regulator is fitted outside or inside the alternator.

Current regulator

Most automobile alternators do not require a current regulator because they have been provided with current limiting action. The stronger magnetic field produced in the stator windings due to increase in the current flow results in this action. This magnetic field counteracts the rotating field and at one stage the stator and the rotating fields are practically in balance and hence higher outputs are prevented.

Also no current regulator is required because the alternator is inherently self-limiting. Since the alternator diodes have a high resistance to the flow of current in one direction, they are connected in a manner which will not allow current to flow from the battery to the alternator and no circuit breaker is required.

Operation of alternator (Fig 8)



When the engine is started, the belt drives the rotor (3) assembly.

During rotation the 'S' poles and 'N' poles of the rotor magnet pass through each stator coil (4).

Due to this rotation of the rotor assembly the current is generated in the stator coil (4), alternatively positive and negative.

If more rotor magnets pass through each stator coil (4) in a given time, the generation of current will be more, since they form the ends of metal fingers, each finger acting like a magnet. These fingers interlock but do not touch each other.

The current produced is allowed to pass through silicon diodes (5) mounted on the heat sink (6). The diodes convert the AC to DC.

The heat produced in the diodes is dissipated by the heat sink.

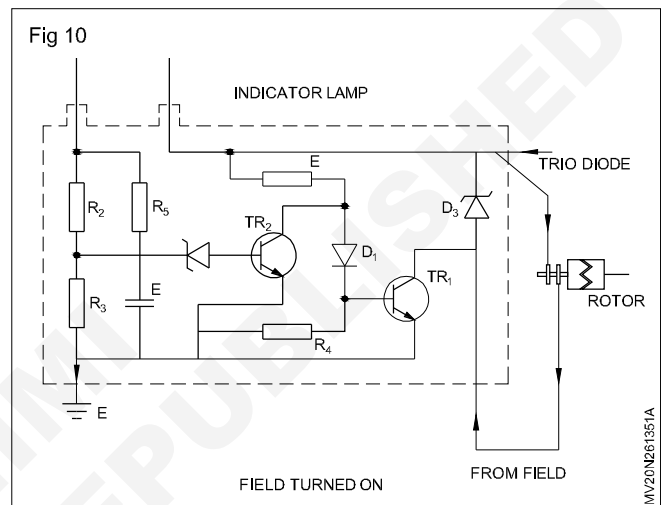
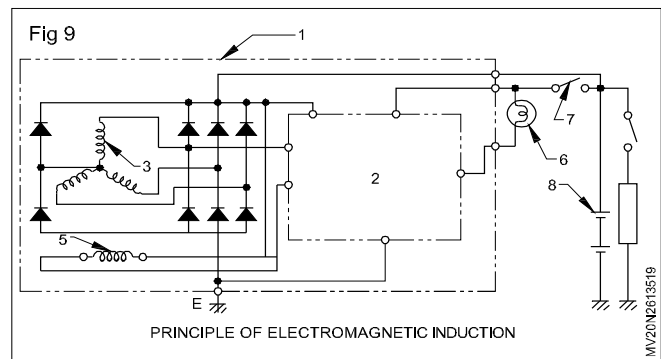
The current passes through the battery terminal (7), the ammeter (8) and to the battery (1) for charging.

Operation of charging system (Figs 9 & 10)

To protect the battery and the accessories against high voltage, the alternator voltage must be controlled. This is done by using a voltage regulator which varies the current flow to the rotating field (rotor). The regulator work is done by electronically.

A transistor regulator consists primarily of resistors, capacitors (condensers), diodes and transistors. It is a complete static unit which controls the alternator voltage. It is durable and efficient. It safely allows a high field current flow and it has a longer service life than the

vibrating contact regulator. An equally important feature is the ease with which it can be tested, adjust and serviced.



When the permanently magnetized rotor rotates, an alternating voltage is induced in the stator winding which is rectified by the three negative and three positive diodes and DC current flows into the battery. The rectified current of each phase winding also flows over diodes D1, D2, D3 into the regulator to resistor R1, to the collector of resistor TR2 and to the resistor R3 to ground. The transistor TR3 is not switched on because the low voltage allows zener diode D6 and diode D5 to block the base circuit. However, transistors TR2 and TR1 are switched on because current can now flow over both emitter bases to ground.

With both transistors switched on, current from the output terminal of the alternator supplies current to the regulator over resistor R5 to the field coil and transistor TR1 (collector elements) to ground. Output current also flows from resistor R5 to resistors R2 and R4 to ground. As charging voltage increases, the voltage impressed across resistor R4 is also impressed across diode D5 and zener diode D6.

When the breakdown voltage is reached, transistor TR3 switches on because the emitter base circuit ground is completed. This causes TR2 and TR1 to shut off since current now flows over the lower resistance circuit from resistor R1, transistor TR3 (collector - emitter) to ground, robbing the current flow from transistor TR2. The field current flow stops. As system voltage decreases, diodes

D5 and D6 stop conducting current and transistor TR3 shuts off. This cycle repeats many times per second to maintain present alternator voltage. The capacitors C1, C2 and C3 and diode D4 perform the same function.

Fan

Fan is fitted on an alternators rotor shaft between the frame and 'V' pulley at the front end of it. When the

alternator is working, heat developed in the alternator coil, should be cooled. For this purpose, fan is used to pass the air over the coil inside the alternator for cooling.

'V' pulley

'V' pulley is used to rotate the alternator rotor through the 'v' belt. It takes power from the crank shaft.

Common troubles and remedies in alternator

Objectives: At the end of this lesson you shall be able to

- state the causes and their remedies for no charge when engine is running
- state the causes and their remedies for low output voltage
- state the causes and their remedies for excessive output (charging at high rate)
- state the causes and their remedies for noisy alternator.

Trouble	Causes	Remedy
1 No charge when engine is running.	Blown fuse wire in regulator. Drive belt loose. Broken drive belts. Worn out or sticky brush. Open field circuit. Open charging circuit. Open circuit in stator winding. Open rectifier circuit. Defective diodes. Worn or dirty slip rings. Loose connections.	Locate cause and rectify and then replace fuse. Adjust belt tension. Replace. Rectify. Replace. Rectify. Rectify. Rectify. Rectify. Replace. Replace. Tighten.
2 Low voltage output from alternator.	Drive belt loose. Faulty regulator. Grounded stator. Low regulator setting. Shorted rectifiers. Loose connections on alternator. High resistance in charging system. Slip rings dirty and worn out.	Adjust belt tension. Replace. Rectify. Adjust regulator. Replace. Tighten. Correct it. Clean/replace.
3 Charges at high rate.	Voltage regulator's setting too high. Regulator voltage winding open. Poor regulator ground connection. Sticky regulator contacts.	Reset. Replace. Rectify. Rectify.
4 Alternator noisy.	Loose mountings. Worn out/Loose fan belt. Worn out/damaged bearings. Open or shorted stator winding. Shorted rectifier. Fan mountings loose. Brushes not seating properly. Loose drive pulley	Tighten. Replace. Replace. Rectify. Replace. Tighten fan's mountings. Rectify. Tighten

Starting system

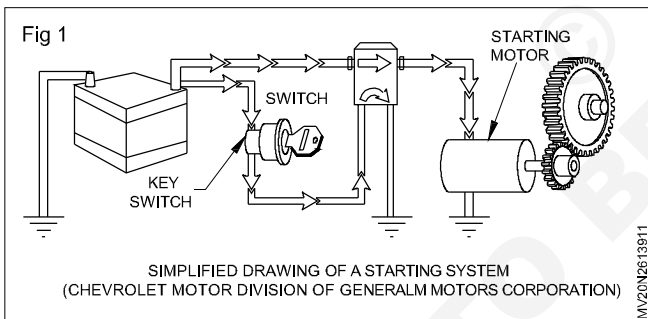
Objectives: At the end of this lesson you shall be able to

- state purpose of the starting system
- describe the starting circuit
- state the principle of starting motor
- explain construction of starting motor
- explain operation of starting motor.

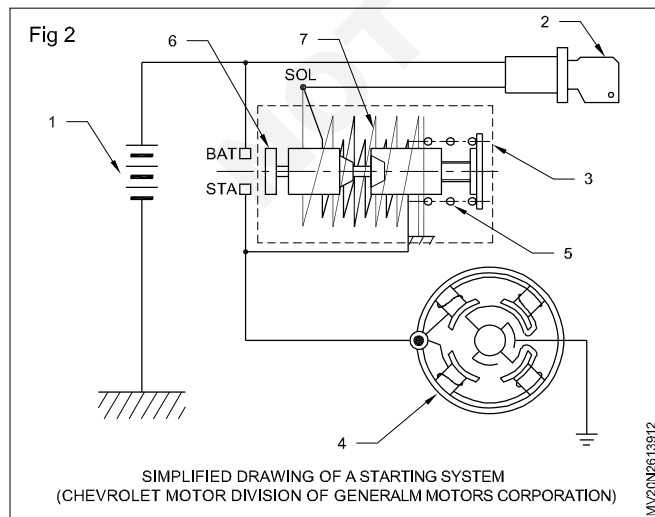
Purpose of the starting system

The starting system is used to start the engine when the starter switch is pressed / turned current flows to the starter motor from the battery and the starter motor's shaft rotates. A drive pinion is connected to the starter motor shaft. The drive pinion turn the engine fly wheel till the engine starts

The starting system, which includes the starting motor, switch, battery and cables, does the cranking. Fig 1 is a simplified drawing of the starting system. When the key switch is closed, it connects the main switch to the battery. The main switch then magnetically closes the main contacts between the battery and the starting motor. The starting motor shaft begins to turn. A small pinion gear on this shaft is meshed with a large gear on the engine flywheel. When the small pinion gear turns, it rotates the flywheel. The crankshaft is attached to the flywheel, and so the crankshaft rotates and the engine starts.



Description of a starting circuit (Fig 2)



The -ve terminal of the battery (1) is connected to earth. The +ve terminal of the battery (1) is connected to the solenoid switch's (3) battery terminal. From there a wire is connected to the starter switch's (2) input terminal. From the input terminal of the starter switch (2), a wire is connected to the solenoid winding's (7) input terminal. The other end of the winding is connected to earth. From the starter terminal of the solenoid switch a connection is given to the starter motor's (4) input terminal. In a starter motor an internal connection is given to connect the field windings as well as the armature through the brushes and the other end is connected to earth.

When the key switch is turned, a small amount of current flows from the battery (1) to the starter solenoid (3). This current energizes the solenoid windings and the plunger (6) moves to connect the battery's and starter motor's terminal in the solenoid switch (3). Current now flows directly to the motor (4). When the switch is released the current flow stops and the return spring (5) pulls the plunger (6) back, disconnecting the starter motor from the battery.

Starter motor function

The engine crankshaft must be rotated at a speed of a minimum 100 r.p.m. to start the engine. This action is called engine cranking. As it is hard to rotate the engine at that speed by hand or with a lever, a starter motor is used to crank the engine.

Location of the starter motor

The starter motor is fixed in the rear side of the engine, when the starter is switched on the starter motor's pinion engages with the flywheel ring gear and rotates the flywheel.

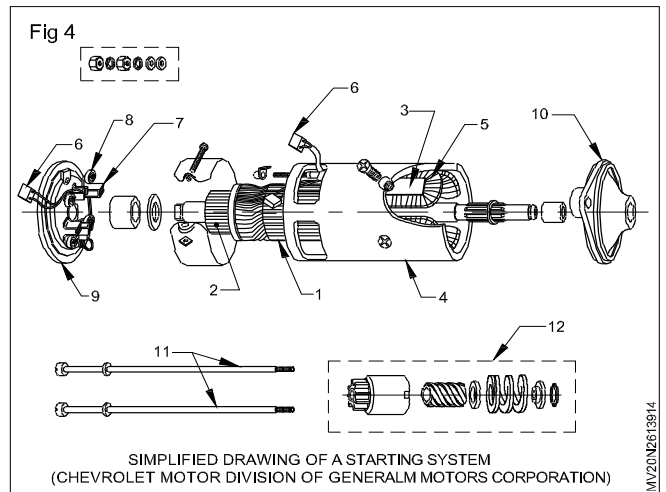
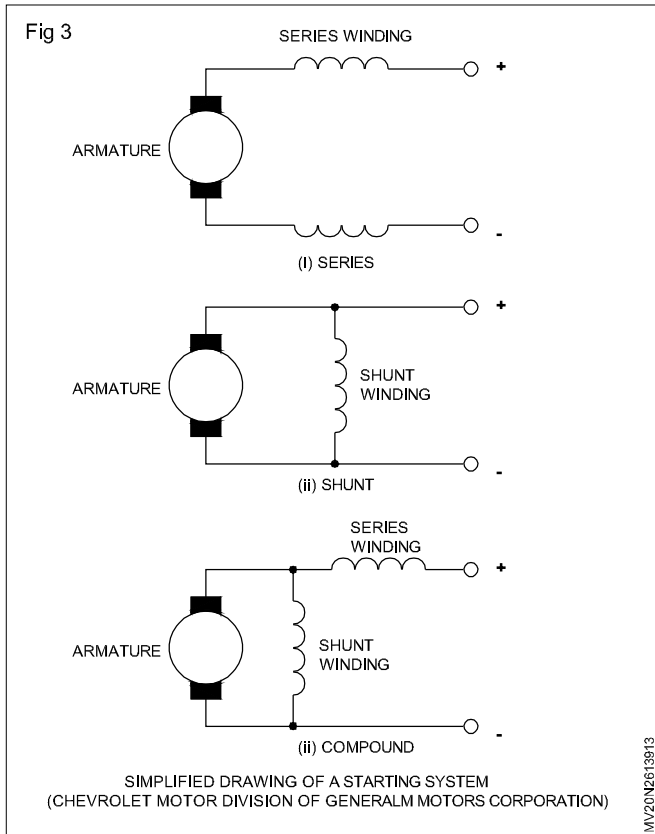
Principle

When a current is passed through an armature coil which is placed between two stationary magnets an e.m.f. is induced and the armature coil starts rotating.

Construction

Three kinds of DC starter motors are used. (Fig 3)

- Series
- Shunt
- Compound



The commutator end is covered by a bracket called commutator end bracket (9). At the drive end, it is covered by the drive end bracket (10). Both the brackets are connected by through bolts (11). At the drive end in the armature shaft, a drive mechanism (12) is fitted.

Operation of starter motor

Current from the battery is supplied to the armature's (1) coil by two or four stationary brushes (6). These brushes (6) are in contact with the commutator's (2) segments. The same current is also supplied to the field coils (5). Both the field coil (5) and the armature's (1) magnetic field attract and repulse each other and cause the armature to rotate. Each coil of armature (1) is connected to one pair of copper segments of the commutator (2). The brushes come in contact with each coil of the armature (1) by turn, and in the process the armature's speed increases further.

Once the engine starts running under its own power it attains a speed up to 4000 r.p.m. (depending upon the design). Since the flywheel ring to starter pinion ratio is very high, the starter pinion will rotate at a much higher speed than the engine. This speed will damage the starting motor by throwing the windings out of the armature slots and also the commutator segments due to centrifugal force. In order to prevent this it is necessary to disengage the starter pinion from the flywheel ring gear once the engine has started. To achieve this three types of drive mechanisms are used.

In automobiles the series wound type is generally used. In this the field and armature coils are connected in series. This enables the motor to produce a high starting torque. The armature windings (1), (Fig 4) are fixed in slots and their ends are soldered to the commutator segments (2). The pole shoes (3), two or four in number, are screwed to the yoke (4) and they have field windings (5). These windings help to produce the magnetic field. The insulation pieces are placed between the pole shoes (3) and metal yoke (4). Copper segments are provided with mica insulation in between the commutator brushes (6).

These brushes (6) slide in the brush holders and are kept in contact with the commutator with the help of small springs (8). The brushes (6) are given a curvature at the bottom to have more contact with the commutator (2). The armature is supported either on bushes or coil.

Starting system drives

Objectives: At the end of this lesson you shall be able to

- explain operation of bendix drive
- explain operation of over running clutch drive
- explain operation of sliding armature drive.

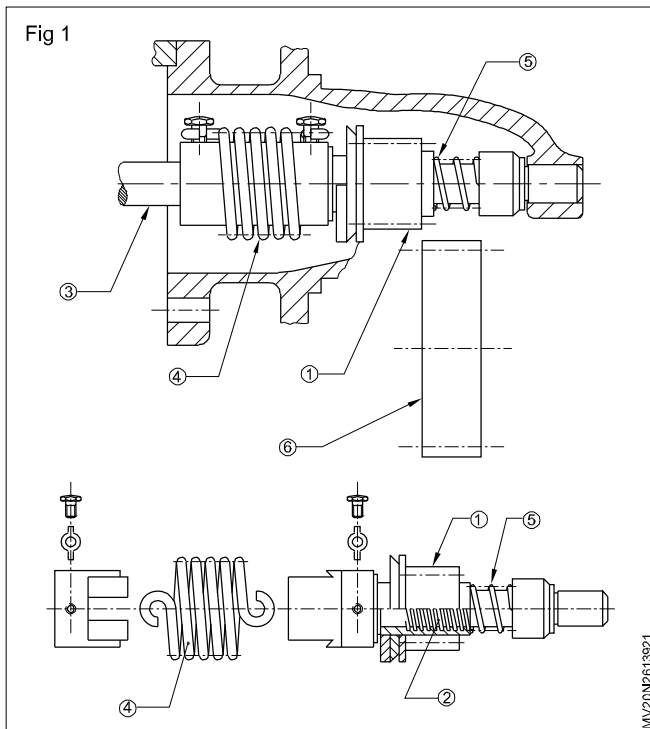
Starting system drives are three types

- Bendix drive
- Over-running clutch drive
- Axial or sliding armature type and non coaxial type

Bendix drive (Fig 1)

This is a most commonly used mechanism. It consists of a pinion (1) which is mounted on a hollow sleeve. The pinion (1) has internal screw threads and is loose fitted on the sleeve (2). The armature shaft (3) is supported by

bearings at both the ends. A bendix drive spring (4) is provided to limit the turning of the sleeve on the armature shaft. An anti-drift spring (5) is provided to prevent the pinion from striking the flywheel (6).



When the motor is switched on, the drive head rotates with the armature shaft (3). This motion is transmitted to the sleeve. The pinion (1) rotates along with the sleeve and travels forward to come in mesh with the flywheel ring gear (6). Now the engine's crankshaft rotates and the engine is started. When the engine speed increases the pinion (1) is thrown back to its original position due to inertia.

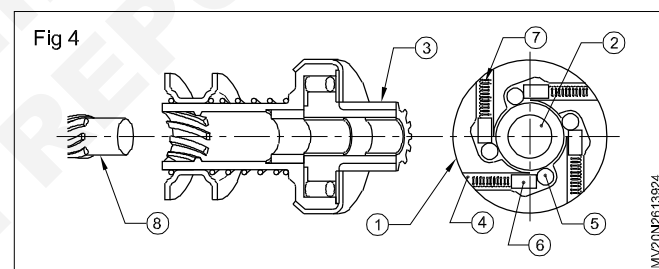
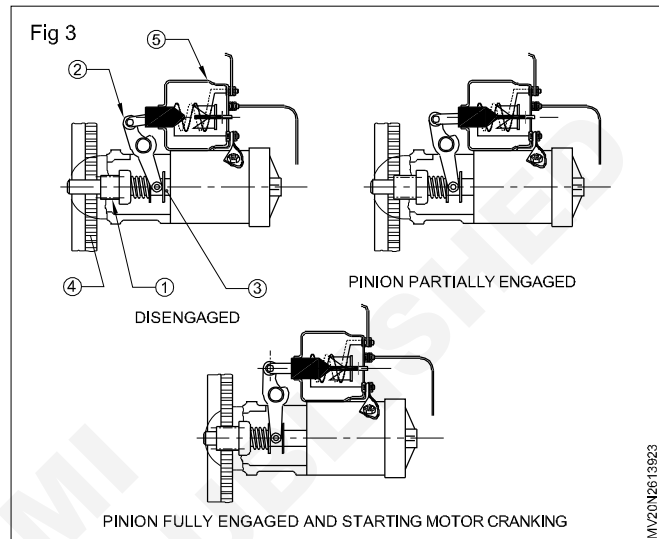
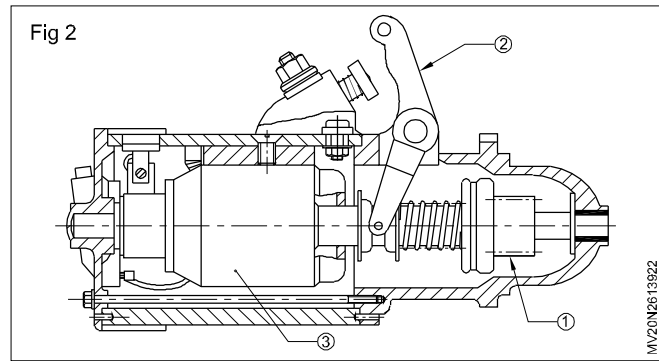
Over running clutch drive (Figs 2 & 3)

The shift lever (2) is used by the over-running clutch to slide the pinion along the armature shaft (3) for meshing into or out of the flywheel teeth (4). The shift lever (2) is operated either by a solenoid (5) or by manual linkage. The over-running clutch permits the drive pinion (1) to run faster than the armature for a brief period during which the pinion (1) remains in mesh with the ring gear (4) once the engine has started. This protects the armature from damage due to over-speeding.

The over-running clutch (Fig 4)

The over-running clutch, which consists of a shell and a sleeve (1) assembly, is splined to the armature shaft (8), so that the shell is driven by the shaft.

The pinion gear (3) is fastened to a collar which is fitted inside the clutch shell. Four tapered notches (4) cut in the shell contain steel rollers (5). These are held in the small ends of the notches by spring (7) and plunger assemblies so that the rollers contact the collar.

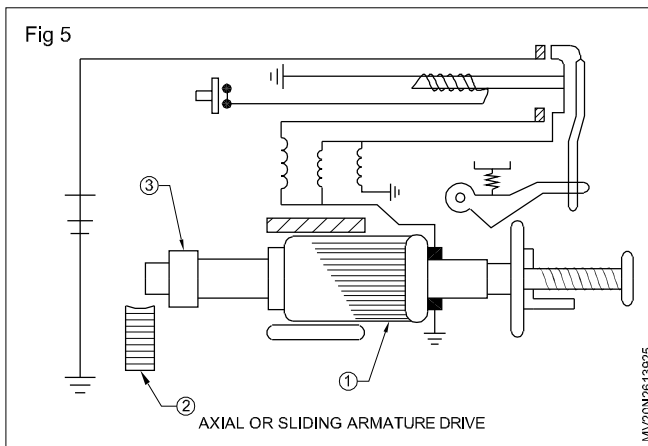


The pinion (3) is forced to rotate with the armature shaft and cranks the engine. When the engine starts its attempts to drive the armature shaft (8) cause the rollers (5) to rotate out of the small ends of the notches. This will release the collar (3) from the shaft. This allows the pinion (3) to rotate at high speed without driving the armature.

Axial or sliding armature drive (Fig 5)

This type of drive allows its armature (1) to slide in order to enable its pinion to come in mesh with the flywheel ring gear (2). When the starter switch is operated, the solenoid coil is energised. This completes the circuit of the shunt winding and also of an auxiliary series field winding. The armature is pulled due to the magnetic field and the pinion (3) engages with the flywheel ring gear (2). A clutch is provided between the armature (1) and pinion (1). When the starter switch is released, the

armature returns to its original position by the return spring. Since the pinion (1) is still in mesh with the flywheel (2).



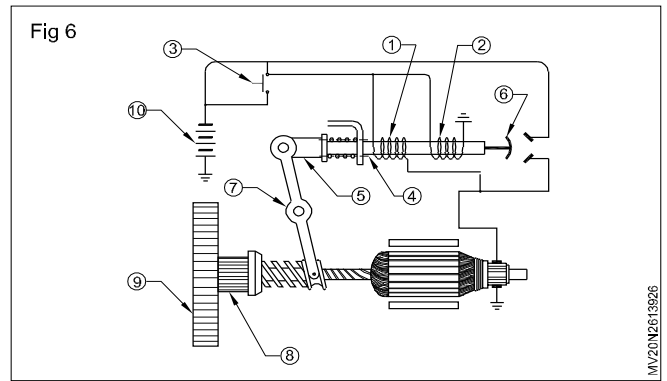
It rotates at very high speed but the clutch prevents the rotation of the armature at the pinion's speed and prevents damage to the armature. The pinion is held in mesh until the starter switch is released by the auxiliary shunt winding. When the engine starts, the current falls down and the magnetic field is reduced. Now the pinion is pulled back to its position by the spring.

Need of solenoid switch

The solenoid switch is a strong electromagnetic switch. It is used to operate the over-running clutch drive pinion to engage with the flywheel ring gear. It also acts as a relay to close the contacts between the battery and the starting motor.

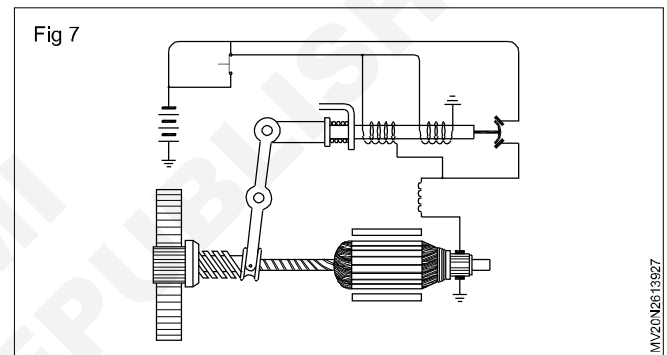
Construction of solenoid switch (Fig 6)

In a solenoid there are two windings, a pull-in winding (1) and a hold-in winding (2). The pull-in winding (1) is wound with thick wires (series winding) and the hold-in winding (2) is of thin wires (shunt winding). The pull-in winding (1) is connected to the starter switch (3) in the solenoid.



The hold in winding (2) is connected across the switch terminal and ground. The two windings are wound around a hollow core (4). An iron plunger (5) is placed inside the core (4). The other end of the plunger moves a shift lever (7) to engage the pinion (8) with the flywheel ring gear (9).

Function of solenoid switch (Fig 7)



When the starter switch (3) is turned, current flows from the battery to the solenoid windings (1) and (2). This energises the windings which pull the plunger (5). The plunger (5) operates the shift lever (7) to engage the pinion (8) on the flywheel ring gear (9). Then it closes the circuit between the battery (10) and the starting motor.

Trouble shooting in starting system

Objectives: At the end of this lesson you shall be able to

- engine not running
- starting motor running but too slow
- starting motor running but not cranking engine
- noise.

Condition	Possible cause	Correction / Reference item
Motor not running (No operating sound of magnetic switch)	Battery discharged.	Recharge battery
	Battery voltage too low due to battery deterioration	Replace battery.
	Poor contact in battery terminal connection.	Retighten or replace

Condition	Possible cause	Correction / Reference item
	Loose grounding cable connection Fuse blown off Poor contacting action of ignition switch and magnetic switch Lead wire coupler loose in place Open circuit between ignition switch and magnetic switch. Open circuit in pull in coil Brushes are seating poorly or worn down Poor sliding of plunger and/or pinion Faulty starting motor control relay Faulty ECM and its circuit	Retighten. Replace fuse. Replace ignition switch and/or magnetic switch. Retighten Repair. Replace magnetic switch. Repair or replace brush assembly Repair Replace starting motor control relay. Check ECM
Motor not running (operating sound of magnetic switch heard)	Battery discharged. Battery voltage too low due to battery deterioration Loose battery cable connections Brushes are seating poorly or worn down Weakened brush spring Burnt commutator Layer short-circuit of armature Crankshaft rotation obstructed	Recharge battery Replace battery. Retighten. Repair or replace brush assembly Repair or replace brush assembly. Replace armature. Replace armature. Repair.
Starting motor running but too slow (small torque) (If battery and wiring are satisfactory inspect starting motor)	Insufficient contact of magnetic switch main contacts Layer short circuit of armature Disconnected, burnt or worn commutator. Worn brushes Weakened brush spring Burnt or abnormally worn end bush	Replace magnetic switch Replace armature. Repair or replace armature. Replace brush assembly. Repair or replace brush assembly. Replace bush.
Starting motor running, but not cranking	Worn pinion tip Poor sliding of over-running clutch Over-running clutch slipping Worn teeth of ring gear	Replace over-running clutch. Repair. Replace over-running clutch. Replace flywheel.
Noise	Abnormally worn bush Worn pinion or worn teeth of ring gear	Replace bush. Replace over-running clutch, flywheel.

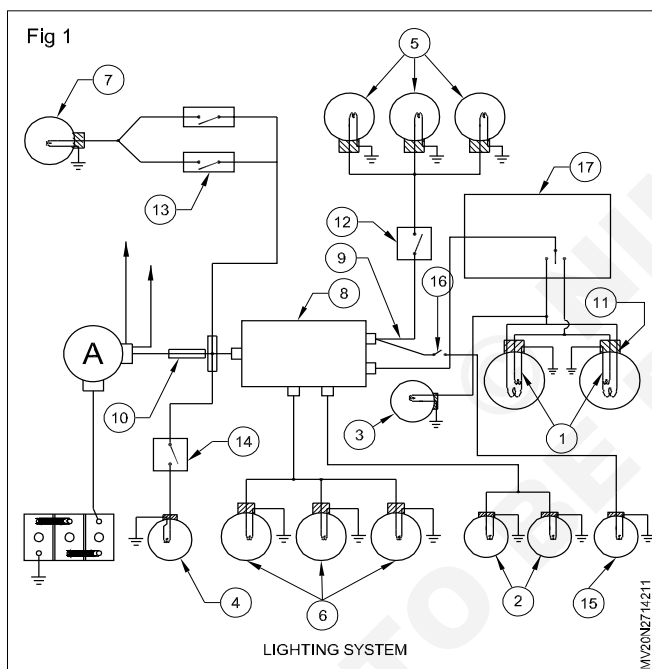
Lighting circuit

Objectives: At the end of this lesson you shall be able to
 • explain the headlight and other circuits.

Introduction

Technicians must understand basic light circuits to be able to maintain, diagnose, and service these systems. When these circuits are understood, diagnosing becomes much easier and faster.

The lighting system (Fig 1) provides illumination on the road to ensure good visibility for the driver, and illumination inside the vehicle besides for other purposes. The headlamp (1), fog lamp (15), parking lamps (2), warning lamps (3), brake lamps (4), panel instrument lamps (5), tail-lamp (6) and the interior dome lamps (7) constitute the lighting system.



The lighting system consists of switches (8), lamps, wiring harness (9) and fuse (10).

The different lighting systems used in the vehicle are

- headlight circuit
- parking light circuit
- panel light circuit
- top light circuit
- fog light circuit
- v stop light circuit
- reverse light circuit
- flasher light circuit.

Headlight circuit

Provides illumination on the road to have enough visibility for the driver. It consists of a double filament, a pre-focused bulb (1), a reflector holder (11), a headlight switch (8), a dim and dip switch (17) and a fuse (10).

Parking light circuit

Two small lamps (2), at the front and rear of the vehicle are fitted. It is used when the vehicle is parked on the road. It is sometimes operated with the head light switch (8) or by an independent switch.

Panel light circuit

Small miniature bulbs (5) are used behind each panel board to see the working of the gauges during night, by the driver. These lamps are connected by a separate switch (12) of the panel board.

Top or dome light circuit

The dome lamp (7) is fitted at the top of the roof of the vehicle.

It is operated by a separate switch (13) located either in the panel board or door post. It provides interior illumination in the vehicle.

Fog light circuit

The ordinary head light beam is almost ineffective during snowfall (mist). The mist reflects the light backward. The fog light (15) provides effective illumination during this condition. It consists of a yellow lamp (15), a reflector and a switch (16).

Stop light circuit

In order to give indication to the traffic behind the vehicle for slowing down or for stopping the stop/brake lights (4) are fitted. It consists of a lamp (4) and brake switch (14), fitted on the master cylinder or air valve. When the brake pedal is pressed, the switch is made to close, thereby completing the circuit of the additional filament in the rear red light.

Tail-light

In order to give indication to the vehicles behind when driving in night, the tail-lights (6) are provided in the vehicles. They illuminate the back of the car, so that other vehicles coming behind can see it at nights. The tail lights will burn with the head lights i.e. whenever the head light switch is on, the tail-lights will also burn.

The reverse light circuit

Some cars are provided with reverse lights. They come into operation by the movement of the reverse gear which actuates a switch. Normally a single red lamp of 24 watts

is fitted at the rear of the vehicle. This reverse lamp has a fluted type cover which disperses the beam laterally, thereby helping the driver to see the full width of the road. (Refer to the manufacturer's Manual).

Some vehicles have more than one fuse and relay center. The location of these centers is shown in the service manual. Some vehicles have the flasher(s) mounted separately from the fuse and relay center.

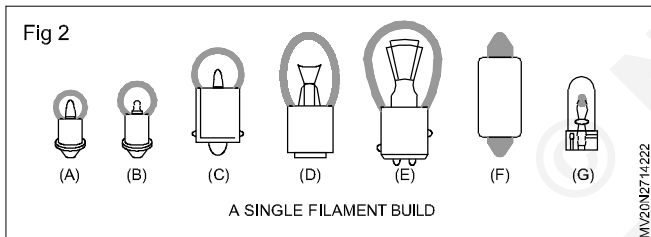
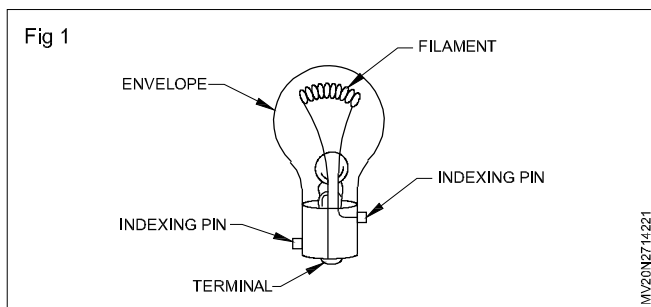
When the headlight switch is moved to the park position, voltage is supplied through the fuse and the headlight switch contacts to the park, tail, and side marker lights. Voltage is also supplied through the variable resistor to the instrument panel lights. Each instrument panel bulb is grounded to the instrument panel. The variable resistor controls the brilliance of the instrument panel lights by varying the voltage supplied to these lights.

Lighting system - Lamp and sealed beam

Objectives: At the end of this lesson you shall be able to

- describe sealed beam headlights
- describe halogen head cornering, interior smart light system.

Lamps (Figs 1 & 2)



An automotive light bulb usually contains one or two filaments. In a single filament bulb, the terminal is connected to one side of the filament and the opposite end of the filament is usually connected to the bulb case (Fig.1). Voltage is supplied to the bulb terminal and current flows through the filament to the bulb case. The circuit is completed from the bulb case through the vehicle ground back to the battery. The indexing pins on the sides of the case retain the bulb in the socket. Many automotive bulbs have two filaments and two terminals that supply voltage to the filaments. These dual filament bulbs serve two purposes such as stop and tail lights. The indexing pins position the bulb terminals properly in the socket. A variety of different bulbs are used in a typical vehicle.

When current flows through a bulb filament, it becomes very hot. The electrical energy in the filament is changed to heat energy and this action is so intense that the filament glows and gives off light. This process of changing electrical energy to heat energy that produces light is called incandescence. The filament is surrounded by a vacuum that prevents overheating and destruction of the filament. When a bulb is manufactured, a vacuum is sealed inside the glass envelope surrounding the bulb.

When replacing automotive bulbs, be sure the replacement bulb is the same as the original bulb, including the position of the indexing pins. Most bulbs have the part number stamped on the bulb case.

A, B - Miniature bayonet for indicator and instrument lights

C - Single contact bayonet for license

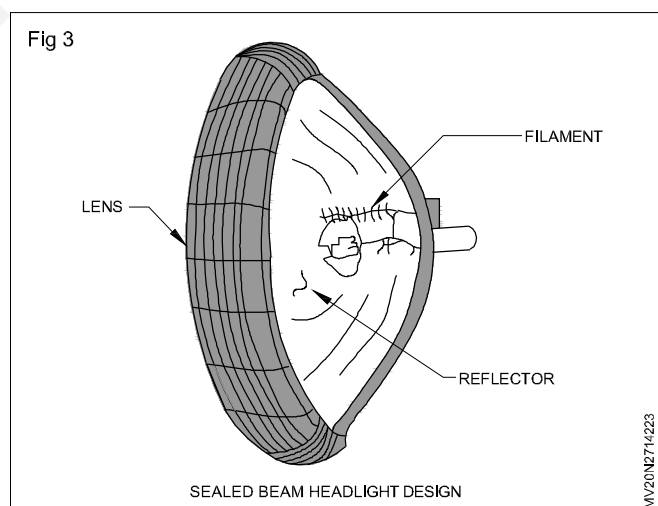
D - Double contact bayonet for trunk

E - Double contact bayonet with staggered indexing lugs for stop, turn signals, and brake lights.

F - Cartridge type for dome lights

G - Wedge base for instrument lights

Sealed beam headlights (Fig 3)

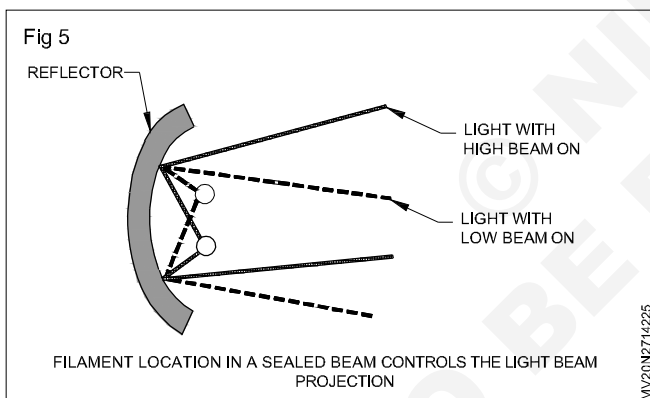
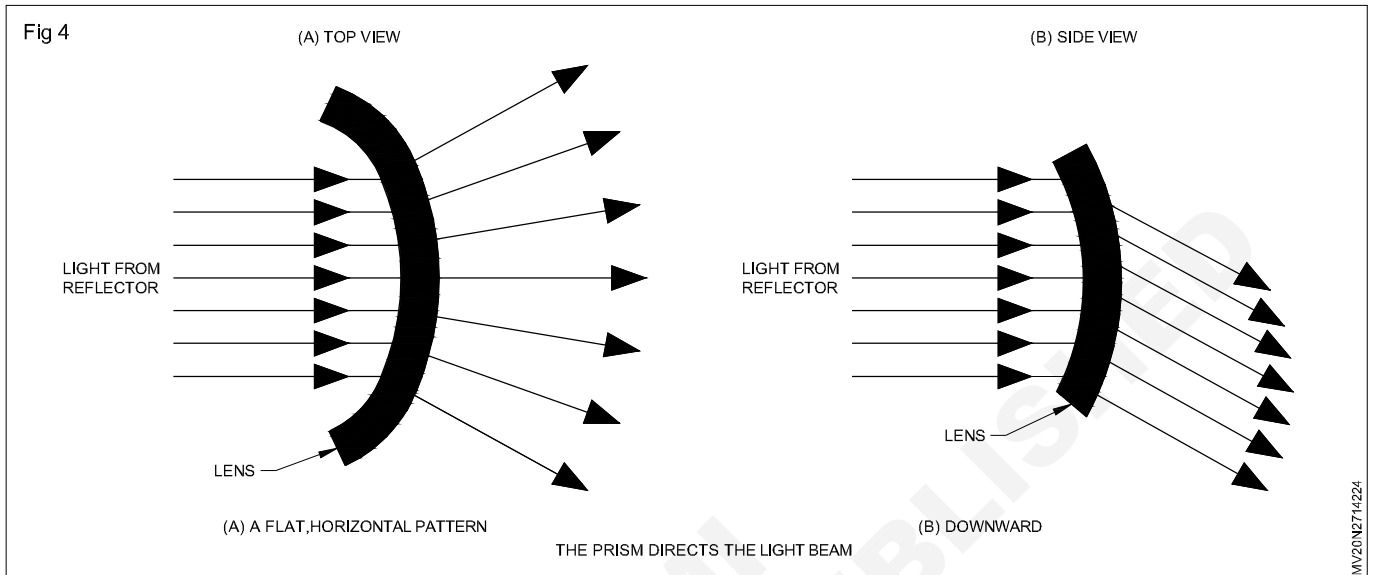


Sealed beam headlights may be round or rectangular shaped. Sealed beam headlights have a parabolic reflector sprayed with vaporized aluminum in the rear of the sealed beam. This reflector is fused to a glass lens in the manufacturing process. All the oxygen is removed from the sealed beam and then it is filled with argon gas. If oxygen were allowed to remain in the sealed beam, the filament would become oxidized and burn out quickly.

Sealed beams may contain one or two filaments. If the sealed beam operates on both high and low beam, it has two filaments and three terminals. Some sealed beams that operate only on high beam contain a single filament and two terminals.

The light from the filament in a sealed beam is reflected from the reflector through concave prisms in the lens (Fig 4). The prisms in the lens direct the light beam

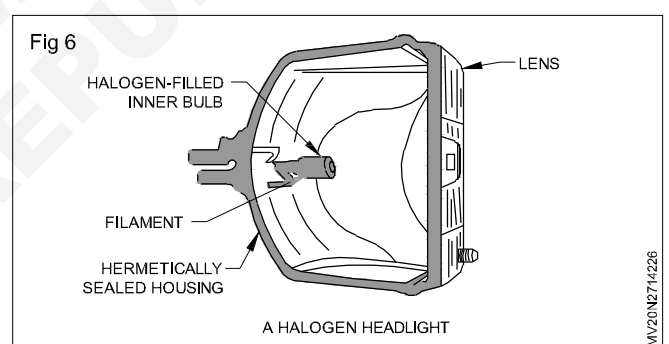
downward in a flat, horizontal pattern (Fig 4). The filaments are precisely located in the reflector to properly direct the light. If a sealed beam has two filaments, the lower filament is for high beam and the upper filament is for low beam (Fig 5)



Light emitting diodes (LED). A certain number of diodes are interconnected with a physical unit according to the brightness required and the desired light colour. The multiple allocation reduces the probability of failure of the overall function. Light emitting diodes have a service life of approximately 10,000 hours. They are used in particular for brake lights, as they achieve their maximum bright less in a significantly shorter time than filament lamps or halogen lamps (approximately 2mm)

Halogen headlights (Fig 6)

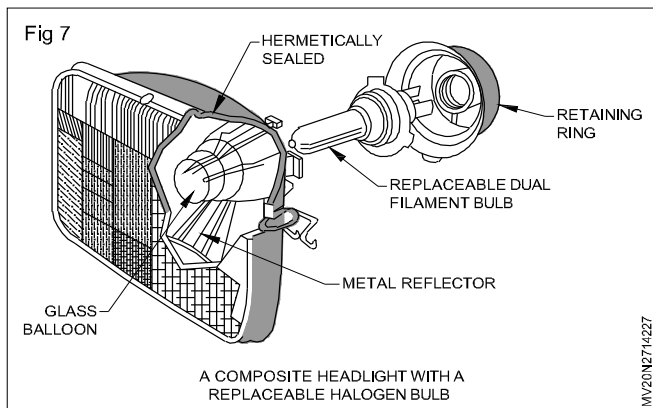
Many newer vehicles have halogen headlights. This type of headlight contains a small bulb filled with iodine vapor. The bulb has a glass or plastic envelope surrounding a tungsten filament. The bulb is installed in a sealed glass housing. Halogen is a term for a group of chemically related nonmetallic elements including chlorine, fluorine and iodine.



The tungsten filament can withstand higher temperatures and burn brighter because of the halogen added to the bulb. Halogen headlights produce approximately 25 percent more light compared to sealed beam headlights.

Because the bulb in halogen headlight is self contained, a cracked lens does not prevent headlight operation. However a cracked lens should be replaced because it results in poor light quality.

Many vehicles are presently equipped with composite headlights and replaceable halogen bulbs (Fig 7). The composite headlights allow the vehicle manufacturers to design the headlights in various shapes to conform to more aerodynamic body styling. For example, some composite headlights wrap around the front corner of the vehicle.



Interior lights

Lights are fitted to illuminate the interior of the vehicle usually these lights are switched on independently. In some cars interior light wires are connected with door switch, for cabin lights on, when door is opened. The earthing switches are used on each door to make an earthing contact for the lamp when the door is opened. security alarm system also utilize the door switches to trigger the alarm system.

Reading lamp

Small miniature LED bulbs are used near the passenger's seat to read the papers during night. These lamps are

connected by separate switches to operate independently.

Vehicle cornering light

Cornering lights are usually small lights housed in the headlights assembly or in the fog lamps there generally switch on at low sparks, or during the reverse gear or when the steering is turned in a particular direction sensors activated the cornering light to turn in the direction of the car. Cornering lights highlight the blind spots during bends making it easier for the driver to spot and danger while adaptive lights provided extra brightness in the corners.

Smart lighting system

Smart lighting technology designed for energy efficiency. This may include high efficiency and automated controls, that make adjustments based on conditions such as occupancy or daylight availability. Lighting is the deliberate application of light to achieve some aesthetic or practical effects. It includes task lighting, accent lighting and general automobile lighting and wireless lighting system that is easily control the lights and create the right ambiance for every moment.

Car lighting equipment data

Head lamps	2
Double filament bulb:	
High beam	45W
Low beam	40W
Front parking and direction indicator lamps	2
Parking	5W
Direction indicator	20W
Direction indicators side mounted reflectors	2W
Bulb	2.5W
Rear parking, direction indicator and stop lamps	2
With reflex reflector bulbs:	
Single filament (direction indicator)	20W
Double filament : Parking	5W
Stop	20W
Rear number plate lamps	2
Bulb	5W
Outer lighting control	Switch on panel by lower switch under steering
Front outer lighting change over control	Wheel
Bulb incorporated in rear view mirror	3W
Switches: Toggle type	On mirror flame
Jam type	On steering wheel side
Pillar lamps, 2 with incorporated switch	Door pillar 3W
Dome light: Lamp with toggle switch on panel	2.5W

Car lighting equipment data

Engine compartment light:

2 Lamps with jam switch actuated by the opening of lid	5W
Indicators - 4 bulbs in instrument cluster, each	2.5W
Direction indicators pilot light	1
Bulb	2.5W
Fuses, 4	8 Amps.

Flasher circuit and flasher unit

Objectives: At the end of this lesson you shall be able to

- state the need of the side indicator
- list out the types of side indicators
- explain the flasher wiring circuit
- explain the working of the flasher unit
- study the wiring circuit of electronic flasher.

Need of a side indicator in a vehicle

All modern vehicles have been provided with flasher type direction indicators. These direction indicators permit the driver of the vehicle to signal his intentions to make a right or left turn during driving a vehicle on road. These also help to allow free flow of traffic from behind the vehicle and to prevent accidents between two vehicles while turning right or left, on cross-road junctions.

These flashing type of indicators are a standard requirement as per Motor Vehicle Act.

Types

- Mechanical type (Obsolete)
- Electrically operated arm type (Obsolete)
- Flasher type or blinkers

Flasher wiring circuit (Fig 1) (Electrical)

It is used in all the vehicles.

The circuit consists of a battery (1), flasher unit (2), a two way switch (3), an indicator warning lamp (4) and flasher lamps (5) & (6).

The 'B' terminal (7) of the flasher unit (2) is connected to the battery (1) through the fuse (8).

The 'P' terminal (9) of the flasher unit is connected to the pilot lamp (4) on the panel board.

The 'L' terminal (10) of the flasher unit (2) is connected to the two-way switch (3).

The A₁ terminal of the switch is connected to the right side front and rear lamps (6) and A₂ terminal to the left side front and rear lamps (5).

The flasher unit (2), the flasher lamps (5 & 6) and the warning lamps (4) are earthed (11).

Flasher unit (Parts) (Fig 2)

The flasher unit is fitted between the battery and lamps.

It consists of an iron core (12) with windings (13).

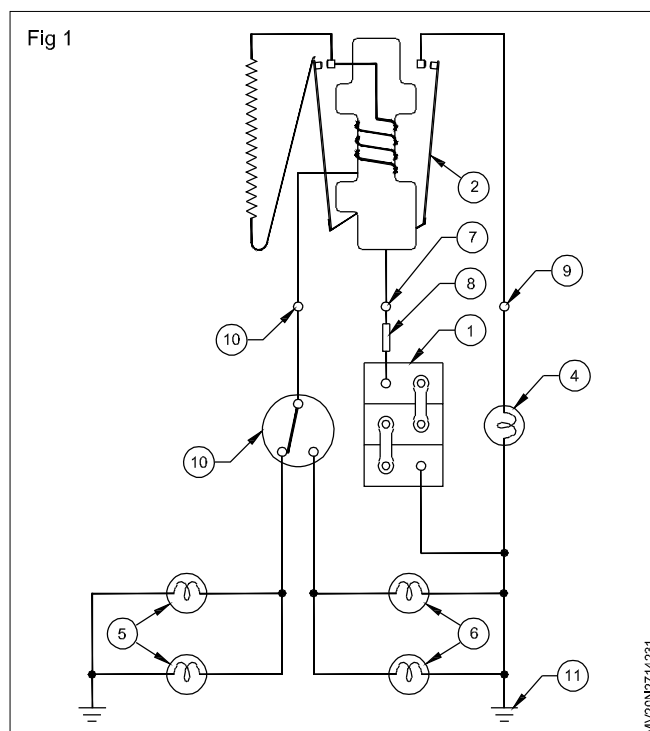
One end of the winding (13) is connected to the main contact (14) and the other end to the 'L' terminal (10) of the unit.

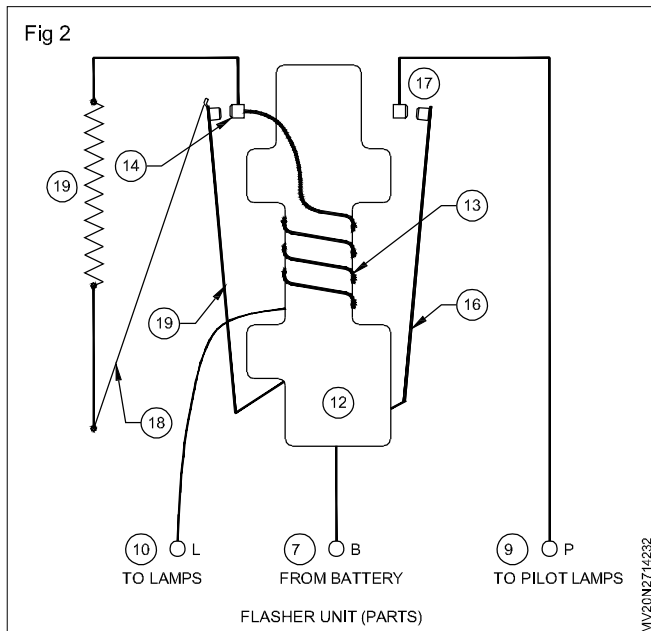
There is one main armature (15) with the contacts and another secondary or auxiliary armature (16) with the pilot contacts (17).

The main armature (15) is connected with the actuating wire (18) and ballast resistor (19).

The actuating wire (18) is made of Nichrome, which increases in its length due to the heat and shortens when it is cold.

The indicator warning lamp is connected to the secondary armature's (16) contact.





Working

When the flasher switch (3) is operated to the left or right the current flows through the main armature (15), actuating wire (18), ballast resistor (19) and then to the coil (13) of the iron core (12).

The current from the coil (13) flows to the flasher lamp filaments and to the earth.

The lamps do not illuminate at this stage as the current is limited by the ballast resistor (19). But the filaments are preheated and ready to flash.

When the current is flowing, the actuating wire (18) gets heated up resulting in increasing its length. This causes the lamp contacts (14) to close in the supply circuit of flasher lamps and at the same time short circuiting the actuating wire (18) & ballast resistor (19). Now the full lamp current flows into the coil (13) of the iron core (12) and the lamp contacts are held firmly together in the closed position by the electro magnetic attraction of the armature (15) to the core. At the same time, the spring-loaded auxiliary armature (16) is also attracted to the iron core (12) and closes the pilot warning lamp circuit.

Now both the contacts (14) and (17) remain in the closed position.

The current flows to the two lamps of the same side (5) through the main points and they begin to flash at the regulation of 70-100 times/min. At the same time current also flows to the indicator warning lamp (4) through the pilot contacts (17) and the pilot lamps are now lit.

When the actuating wire (18) gets cooled down, it becomes short in its length and the points (14) reopen.

When the contacts are made open the actuating wire (18) and the ballast resistor (19) are in circuit.

Now reduced current flows to the coil through the ballast resistor (19). This current is not sufficient to illuminate the lamps (5) & (6).

The circuit breaks and no current flows to the lamps and the light signals are extinguished off.

The reduction of electro magnetism in the iron core (12) allows the auxiliary armature to return to its original position and the pilot warning lights go off at the same time as the indicator lamps.

The above sequence of operations continues to be repeated till the indicator switch is returned to its off position.

Bulbs

Main bulbs - 12 volts - 21 watts

Pilot bulbs - 12 V - 2.2 watts

Colour of indicator lamps

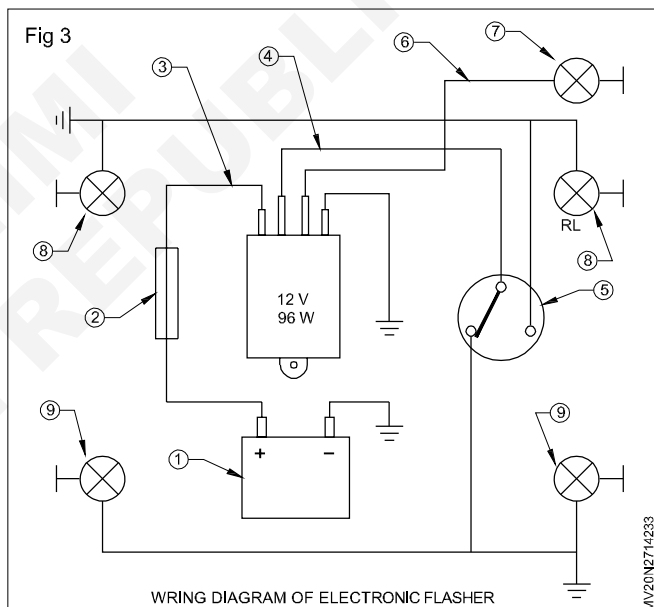
Front - White

Rear - Red/amber

Pilot lamp - Green

Wiring circuit of electronic flasher

Electronic flasher (Fig 3)



Electronic flasher (10) has four terminals B.L.P.E. 'B' connects the battery (+) (1) through fuse (2), 'L' terminal connects to lamps (9) (FR & RR) and (8) (FL & RL) through two way switch (5).

The terminal (P) of electronic flasher connects the pilot lamp (7) and earth terminal (E) is earthed.

When two way switch is moved towards right, the turn signal lamp FR & RR will glow.

When two way is moved toward left, the turn signal lamp FL & RL will glow.

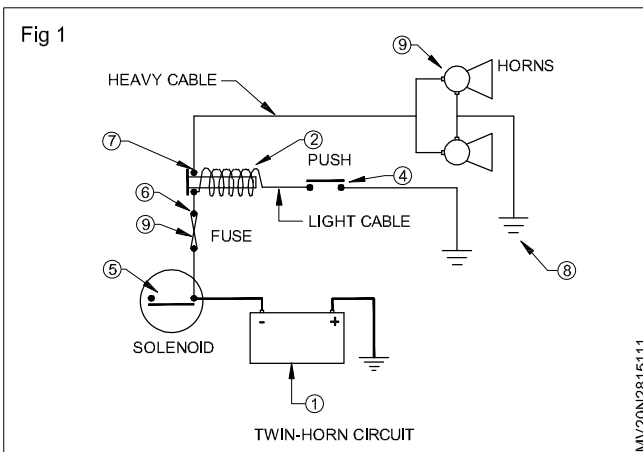
Simultaneously the signal lamp (left or right) will flicker in the dash board.

Horn

Objectives: At the end of this lesson you shall be able to

- explain the horn circuit
- state the types of horn
- explain the parts and working of relay type of horn
- explain the working of horn switch
- state common troubles and remedies in horn.

Horn circuits (Fig 1)



- Battery (1)
- Horn push-button (4)
- Horn relay (2)
- Horn (single or pair) (3)
- Fuse (9)

The circuit is connected in the following ways.

Battery (1) to the solenoid switch input terminal through a cable.

Solenoid switch (5) input terminal to horn fuse (9).

Ammeter is not connected in the horn circuit.

Horn fuse (9) to the horn relay 'B' (6) terminal.

Horn relay 'S' (6) terminal to the horn push switch (4).

Horn relay 'S' (7) terminal to the horn (3) terminal.

Horn grounded; terminal is earthed (8).

Function

When the horn switch (4) is pressed, the current from the battery (1) flows to the fuse relay (2) and then to the horn(3).

The circuit completes to operate the horn relay (2).

The relay (2) connects the horn (3) direct with the battery to supply more current. The horn (3) produces sound waves.

When the horn button (4) is released the horn circuit is opened.

The relay (2) disconnects the horn from the battery (1) current.

The horn (3) stops producing sound waves.

Need of a horn

The electromagnetic horn is fitted generally in the front end of the vehicle. It produces sound waves due to the vibration set up in the diaphragm to clear or warn the traffic on the road. It is used single or in pairs to produce sound and is operated through the horn switch in the driver's cabin. The horn switch does not operate the horn directly. It operates the horn relay.

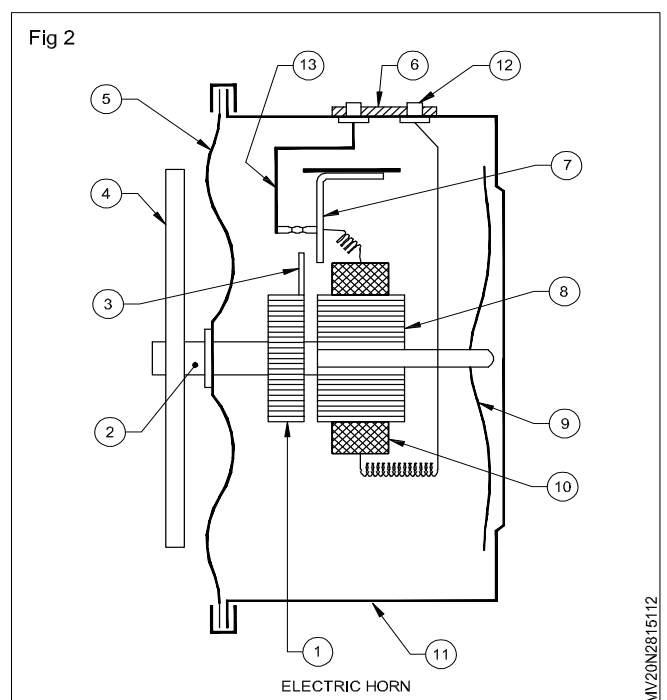
Purpose

To produce powerful sound waves so as to indicate and warn the traffic in front of the vehicle.

Types of horn

- Electric horn
 - a Vibrating type
 - b Wind-tone type
- Air horn (Wind horn)
- Bulb horn

Construction (Electric horn) (Fig 2)



The electric horn consists of a shell or body (11) in which a laminated magnet core (8) is fitted. The winding (10) is wound over the core. One end of the winding (10) is attached to the horn terminal (12) and the other end to the movable contact breaker (7). The movable point connects with the fixed point (13) which is earthed. The armature (1) is attached to a central spindle (2). One end of the spindle (2) is supported by a guide spring (9) and the other end by a diaphragm (5). The armature carries a striker plate (3). The tone disc is at the outer front end of the diaphragm (5) and the diaphragm is clamped to the horn shell.

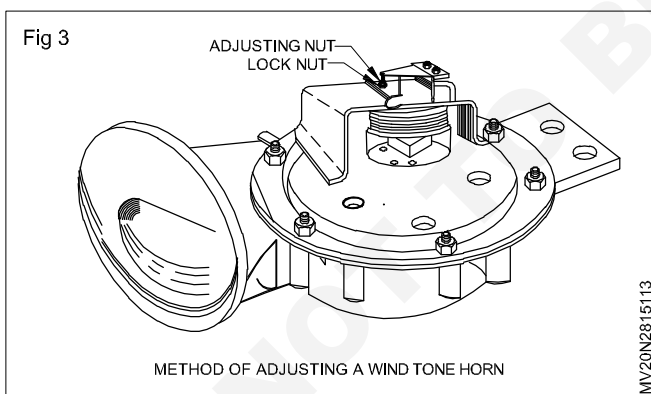
Operation/working

When the horn switch is pressed the current flows through the contact breaker (7) & (13) and the solenoid circuit is completed; the laminated core (8) is magnetised. The magnet attracts the armature (1). The armature (1) moves towards the magnet core (8). The spindle (2) and diaphragm (5) also move towards the core (8). Thus the striker plate (3) on the moving armature (1) separates the contact point (7) & (8). Immediately the iron core (8) is demagnetised. The armature (1) then returns to its normal position with the diaphragm guide spring (9) in tension. This cycle of operation sets the vibration in the diaphragm (5), about 300 vibrations per second. The tone disc (4) at the end of the horn gives a frequency of about 2000 vibrations per second. This produces the sound of the horn.

In the vibrating type, the sound is emitted directly from the diaphragm.

In the wind-tone type, the sound from the diaphragm is made to pass through a wind pipe, which is like a bugle or trumpet.

Air horn (wind tone horns) (Fig 3)

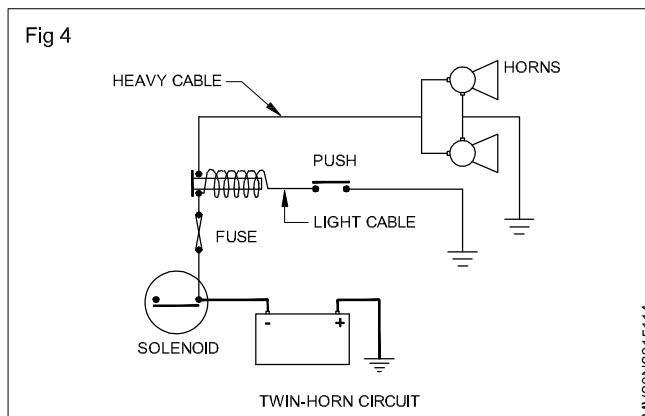


Principle of operation

These horns operate over the same electrical principle as the high frequency types, but a diaphragm is arranged at the inner end of the trumpet.

This diaphragm is vibrated in the centre of the air column by an electromagnet. This vibration produces sound waves which travel down the length of the trumpet, which decides the note produced by air in motion. The diaphragm is so mounted that its centre is attracted by the electromagnet.

Circuit of these horns & current drawn by them (Fig 4)



These air horns draw a heavy current intermittently than that of high frequency horns. Two such horns are connected in series with a relay and current from the battery is supplied through this relay and through a fuse of 50 amps. Each horn carries a current of 13 amps in a 12 volt system, but the adjusting amperage for these horns is from 6 amps to 8 amps.

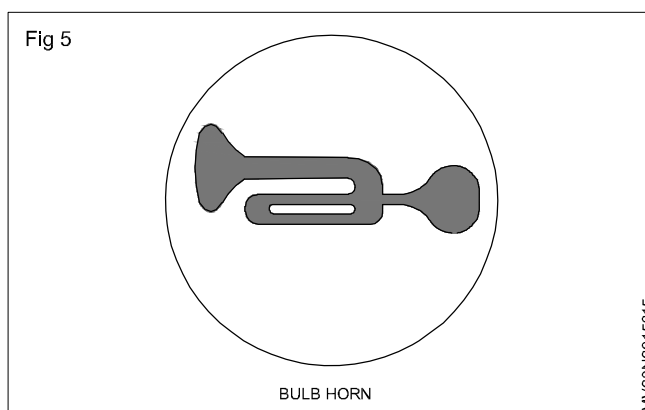
Special construction

The trumpet is coiled for occupying less space in its mounting. The heavy currents are being carried by heavier and short cables and the relay current (being small) is carried by lighter cables. The relay contacts are protected by a pellet type resistance.

Wind horns (Compressed air operated type)

A number of vehicles incorporate an electrically driven air pump or compressor which forces air through two or more plastic trumpets in sequence. The length of trumpets differ and so provide different notes. These are also operated via relays.

Bulb horn (Fig 5)



Application: These bulb horns are fitted to motor vehicles such as trucks (closed), lorries, auto-rickshaws in addition to electric horns.

These are generally used by drivers when electric horns fail to function due to short circuit or lack of current supply from the battery. These are also compulsory as per M.V. Act and Rules.

Construction

In the bulb horn a reed (metallic) is fitted on a metal base and the unit mounted on the windpipe near the bigger end of the horn tube. The windpipe is coiled for space consideration. The wind pipe is bigger in diameter at one end (called mouth) and is less in diameter at the small end. A hollow rubber bulb is fitted at the small end. It is simple in construction, can be mounted near driver cabin easily and its maintenance is less. The reed can be replaced when it goes out of order.

Operation

When the rubber bulb is pressed a number of times, the air in the wind pipes pass through the reed, making it to vibrate and produce the sound. This sound is transmitted through the bigger dia. of the horn tube in a high tone to the outside atmosphere.

Horn circuit connection

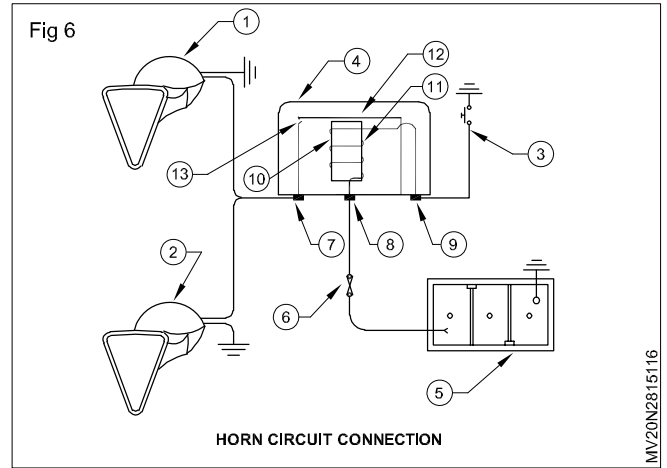
The horn used in a vehicle must give good quality sound and penetration.

The relay type of horn

When more powerful horns are employed - as in the larger cars - the current needed to operate the horn can be appreciable and would cause severe pitting of the horn's contacts, due to sparking action. To obviate this it is now usual to employ a relay unit. Thus, the horn switch would require a current of 3 or 4A, but when operated would energize a solenoid which in turn would cause a pair of contacts to close so as to switch in the larger current of some 8 to 12A at 12 volts.

Horn relay and its description (Fig 6)

The horn relay (4) consists of a base with three terminals (7,8 & 9) marked as H,B and S. Inside the horn relay an iron core (10) is wound with a coil (11). One end of the coil (11) is attached to the 'B' terminal (8) and the other end is connected to the armature (12) which carries the contact breaker point (13). The fixed point of the contact breaker point is connected to the 'H' terminal (7). In relay the 'H' terminal (7) is connected to the horns (1 & 2), the 'B' terminal (8) is connected to the battery (5) via the fuse (6) and the 'S' terminal (9) to the horn button (3).



Operation/working

When the horn button switch (3) is pressed, the current from the battery (5) flows through the coil (11) and to the horn switch (3), thus completing the circuit. Now the iron core (10) becomes an electromagnet. The armature (12) is attracted by the iron core (10). The movement of the armature (12) closes the contact breaker points (13) together. Maximum current starts flowing to the horns (1 & 2) via 'H' terminal (7) and the horns start produce sound waves.

When the horn button switch (3) is released, the current to the horn button (1) is cut off and the circuit breaks. The iron core (10) is demagnetised and the armature (12) is pulled back by the spring tension. The point (13) gets opened and the current to horns (1 & 2) is cut off and the horn stops working.

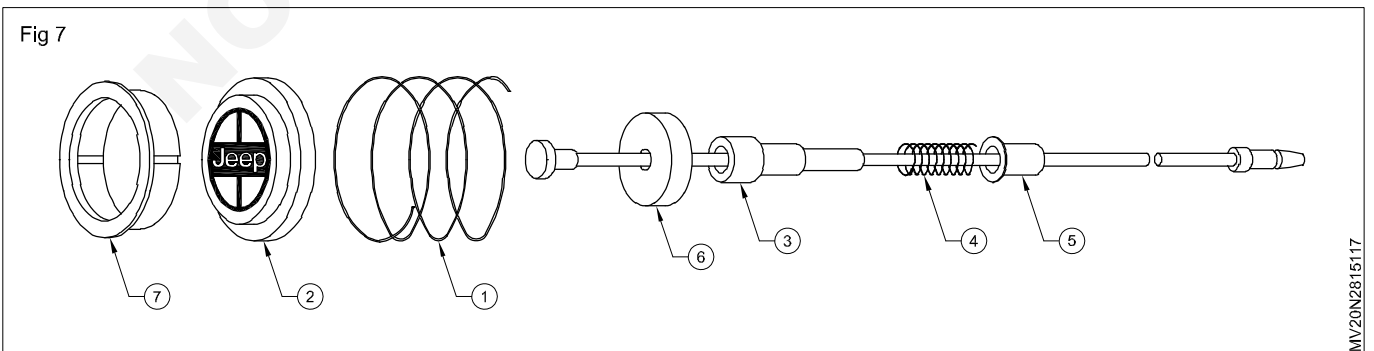
Location of horn switch (Fig 7)

The horn switch is fitted normally at the centre of the steering wheel hub. In some vehicles the horn switch is fitted on the dashboard.

Purpose

The horn switch is part of the horn circuit and is used to operate the horn relay.

The horn switch is operated by a button or ring or lever. The horn switch does not connect the horns directly to the battery. It consists of a spring loaded button (2), horn



cable (3) with spring (4) and cup (5). The cable runs through the inner steering column and the end is attached to the horn button and the other end to the 'S' terminal of the horn relay. The horn button (2) is kept disengaged from the steering wheel hub's grounded plate (6) by the spring (1). The horn button is retained in the steering wheel hub by the retainer (7).

When the horn button (2) is pressed, the button touches the grounded plate (6) thus completing the electrical circuit. When the circuit is completed, the relay comes into action and supplies maximum current to the horns.

When the horn button is released, the spring (1) pushes the button (2) back to its position. The horn circuit breaks and stops the working of the horn.

SI.No	Defects/Faults	Causes	Remedies
1	Horn does not produce any sound.	1 Broken circuit wire connections 2 Defective horn points (burnt or broken off) 3 Defective switch 4 Incorrectly adjusted relay 5 Battery charge is low or dead. 6 Fuse blown off 7 Open field coil winding	Rectify. Replace. Rectify or replace. Readjust. Charge the battery. Provide new fuse of correct ampere age. Rectify.
2	Horn sounds continuously (when button switch is in the off position).	1 Short circuit of switch wire 2 Relay points stuck up	Rectify. Rectify.
3	Horn produces low improper sound (unsatisfactory tone).	1 Voltage at horn terminal is too low or too high 2 Voltage drop in the circuit excessive 3 Low battery voltage 4 Loose cover & bracket screws 5 Cracked diaphragm 6 Incorrectly adjusted horn points 7 Tone disc damaged 8 Poor electrical connections	Check & adjust generator output voltage. Rectify fault. Recharge. Tighten. Replace. Readjust. Replace. Rectify.

Wiper circuit and wind screen wiper

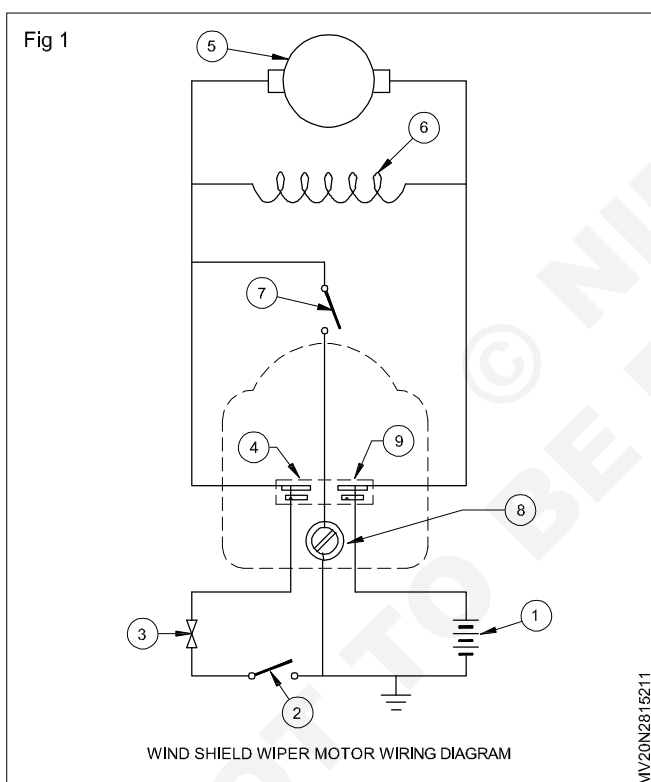
Objectives: At the end of this lesson you shall be able to

- explain the need of wiper unit in vehicle
- describe the wiper wiring circuit and operation
- types of wiper
- explain care & maintenance
- attend defects, cause and remedies.

Need of a wiper unit

During the rainy season when the vehicle is driven on the road the rain water falls on the wind shield glass of the vehicle. Due to this it becomes very difficult for the driver to see the road and traffic clearly. The water layer on the wind shield glass is wiped off by an accessory called wind shield wiper.

Description (Wiring circuit) (Fig 1)



The wiper circuit consists of a battery, fuse, wiper switch and a wiper unit.

The circuit consists of the following.

The battery (1) is connected to the wiper switch (2).

The wiper switch (2) to the wiper fuse (3).

The wiper fuse (3) to the wiper electric motor terminal (4).

Motor terminals (4) to the armature brush (5) and field coil (6).

The other terminal of the wiper motor (9) is grounded.

The limit switch's (7) one end is connected to the wire from the terminal (4) and the other end to the earth screw (8).

Operation

When the wiper switch (2) is switched 'ON' the current from the battery (1) flows to the wiper motor terminal (4) via the fuse (3).

The current flows to the motor field (6) and armature (5) through the brushes. The motor rotates like a starter motor.

When the wiper switch (2) is switched 'OFF' the current from the battery is cut off; so the motor stops rotation.

Windscreen wiper unit

The wiper unit is fitted at the top or bottom of the wind shield glass frame/pillar.

Types

The following types of wiper units are used in vehicles

- Hand operated.
- Vacuum operated.
- Compressed air operated.
- Hydraulically operated.
- Electrically operated.

Short description of the types

(A) Hand-operated wiper unit

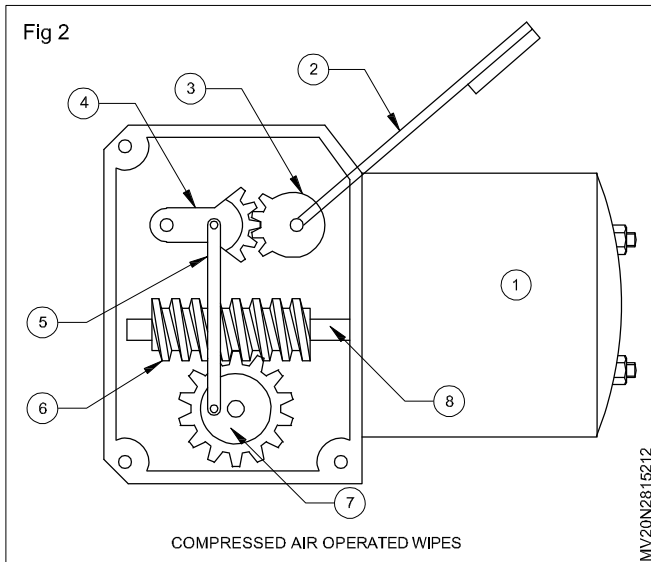
These are no longer used in vehicles and have been replaced by electrically operated wiper units.

(B) Vacuum operated wiper

The wiper units work under the engine vacuum for their function. In certain vehicles (old models like jeep, land rover) a double AC pump (petrol) was used for operation of these wipers. The vacuum required for their operation is developed by the AC pump diaphragm having valves in its body.

(C) Compressed air operated wipers (Fig 2)

The vehicles fitted with air compressors use this kind of wipers. These are used in heavy motor vehicles (diesel trucks & heavy haulage vehicles)



(D) Hydraulically operated wipers

These are not popularly used in vehicles nowadays.

(E) Electrically operated wipers

These are widely used in all motor vehicles nowadays. Their construction and operation are described briefly in this lesson.

Explanation

The motor is of a self-switching, two-pole design, having a permanent magnet field system provided by high-energy magnets, together with a gearbox housing a two-stage reduction gear. The power from the motor is transmitted by a three-start worm gear provided on the extension of the armature shaft through a low stage reduction gear system. The drive to the blades is transmitted via a shaft and rotary link assembly. It is incorporated with a special limit switch which ensures application of regenerative braking to the armature on completion of the wiper cycle during which the control switch is turned to OFF position. It thus ensures consistent parking of the wiper arms and blades in the correct position.

Electrical connections are made to the motor via a non-reversible in-line plug and socket assembly. This type of connection ensures the maintenance of correct motor

polarity during the course of motor connecting to the vehicle wiring. The working of the wiper unit is explained below.

Working

When the wiper switch is operated, the current passes to the electric motor and the motor shaft (8) rotates. A worm (6) is fixed on which the motor shaft drives the gear (7).

The gear wheel operates the cranking link (5).

The cranking link (5) operates the sector (4).

The sector (4) operates the pinion (3) with the arm shaft.

The arm shaft oscillates the arm (2) and moves the blade to and fro on the glass.

When the wiper switch (7) is put off the motor stops working.

The arm (2) returns to the edge of the wind shield glass and stops due to limit switch action.

The blade is provided for 50 to 100 oscillations per minute depending on the speed of the wiper motor and the drive arrangement of the blades.

The wind shield wiper motor consumes a current of 2.7 amps to 3.4 amps at 12 volts under normal operating conditions.

A 5-amps fuse is provided in the motor circuit.

Care and maintenance

Keep the wiper unit secure on its mounting.

Keep the electrical connection tight.

Never operate the wiper on dry glass.

Do not attempt to turn the arms on the spindle.

Fit the arms to the driving drums at the correct angle.

Replace the perished or worn wiper blade immediately.

A drop or two of machine oil should be applied to the outside cranking link and hinge pin joints.

Power window

Objectives: At the end of this lesson you shall be able to

- explain the purpose of power window
- explain the operation of power window
- state safety for power window.

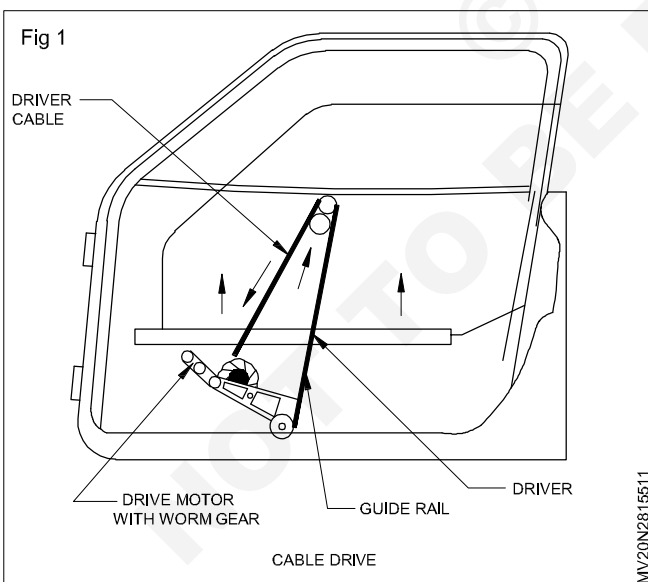
Power windows are usually inoperable when the car is not running. This is primarily a security feature. It would be a simple thing to allow electric power windows to be operable when the ignition is turned off, however it would also make the car much easier to steal. As a compromise, some systems offer the compromise of leaving power applied to the windows until a passenger door is opened at which time the window power is removed.

Electric power windows operation

Comfort and convenience systems

This allows electric opening and closing of the windows and where fitted, sliding sunroof via a rocker switch (pushbutton switch).

To power the windows up and down, a cable drive system is normally used (Fig. 1). The drive motor actuates a cable via a worm gear mechanism, which will open or close the window depending on the direction of motor rotation. The self-locking effect of the worm gear mechanism prevents the window from opening in response to application of force.



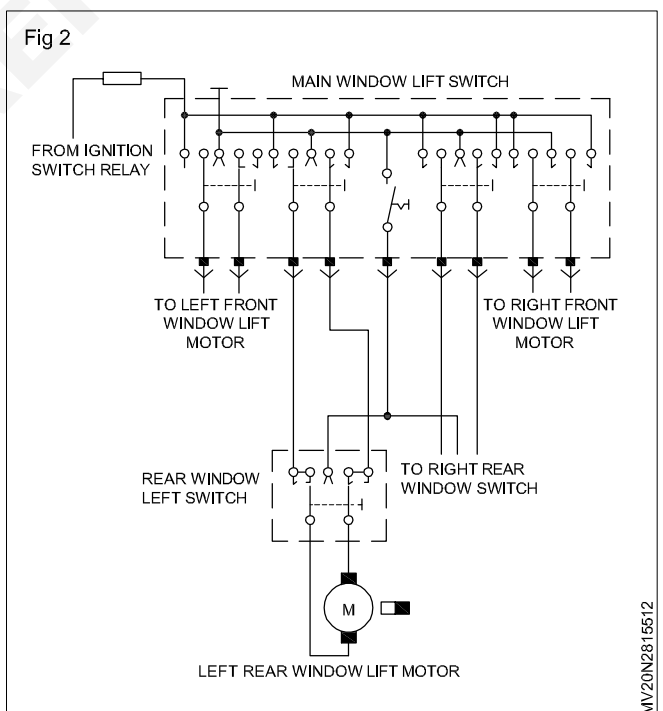
Electrically - operated windows

In this system a DC permanent magnet motor is normally used to operate each window, and a three position rocker switch changes the polarity of providing up and down motion of the window. Four main window switches one for each window are installed on the drivers panel, and an isolation switch is also added to disconnect the supply to the rear windows. Two relays control the current to each motor and are powered by a common feed.

A gearbox forms the drive between the motor and the window glass and amplifies the torque sufficiently to undertake upward motion of the window, which is more difficult than the downward motion.

To limit the current during overloading one or more thermal cut out switches are installed in the circuit, sometimes in the motor. The cut out is opened if the operating switch is held closed when the window has reached its limit of movement or in case where free movement of the glass is arrested by ice. A main overload switch, if used, is generally of a requiring resetting after encountering an overload situation.

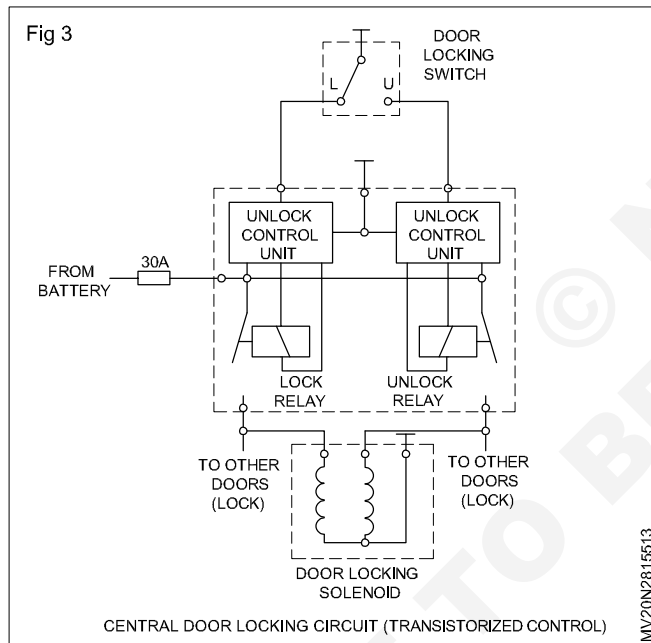
Fig 2 shows the circuit for electric operation of a rear passenger window, but the balance of the circuit has not been shown for simplicity. The motor in this layout is powered directly through the ignition switch. The ganged switch supplies the current with suitable polarity to rotate in the required direction during the operation of the window.



Safety: Power windows have come under some scrutiny after several fatal accidents in which children's necks have become trapped, leading to suffocation. Some designs place the switch in a location on a hand rest where it can be accidentally triggered by a child climbing to place his or her head out of the window. To prevent this many vehicles feature a driver controlled lockout

switch, preventing rear-seat passengers (usually smaller children) from accidentally triggering the switches. This also prevents children from using them as toys and pets riding with their heads out windows from activating the power window switch.

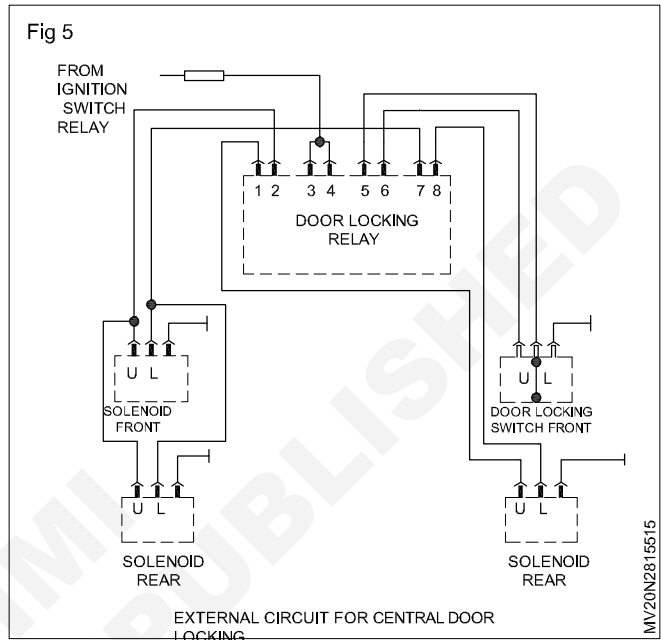
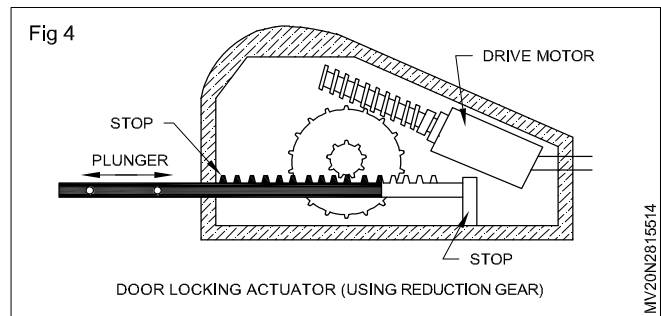
Central door locking: A door locking system normally locks all doors, including the tailgate or boot simultaneously when the driver's door lock is activated. When the key is turned or the driver's door lock button is operated the electrical system actuates all the locking activators installed adjacent to the door locks. Unlocking the door takes place in the similar way except the locking actuators work in the opposite direction. Both for convenience and safety reasons, a mechanical latches system is fitted which unlocks each door manually from inside the car. Various types of control are incorporated to provide the locking / unlocking pulse for operation of the actuators. In some designs two relays are used, one for locking and the other for unlocking the doors. A transistorised switching circuit controls these relays. The circuit timed by the charge - discharge action of capacitor to provide a current pulse length sufficient to actuate the locks. (Fig 3)



Now a days almost all door actuators use small motors which, via suitable gear reduction, operate a linear rod in either direction to lock or unlock the doors. A simple motor reverse circuit is presented in Fig 4 & 5, where the driver's door switch operates the locks on four doors. More sophisticated systems are now becoming popular for consideration of safety as well as improved comfort.

Key less entry system

A keyless entry system is an electronic locks that controls access to a building or vehicle without using a traditional mechanical key. The term keyless entry system originally meant a lock controlled by a keypad located at or near the driver's door, which required entering a predetermined numeric code. Such systems now have hidden touch - activated keypad and are still available on certain modern cars.



Remote control locking refers to a lock that uses an electronic remote control as a key which is activated by a handheld device.

Keyless entry system performs the functions of standard car key without physical contact. When within a few yards of the car, pressing a button on the remote car lock or unlock the doors, and may perform other functions. A remote keyless entry system which unlocks the doors.

Car anti theft system

Though most of the car modes are with immobiliser, still the number of cars stolen are on raise. Gear locks considered one of the base defense a car thief would be in a very rare circumstance puts up time to break gear lock in the car.

Ignition cut off: A key operated or hidden manual switch that interrupts the power supply from the battery to the ignition system. This manual switch can be taken out by the driver once the car is locked.

Introduction

What is a hybrid? A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/ battery. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems. Thus to be a True hybrid, the vehicle must have at least two modes of propulsion.

For example, a truck that uses a diesel to drive a generator, which in turn drives several electrical motors for all-wheel drive, is not a hybrid. But if the truck has electrical energy storage to provide a second mode, which is electrical assists, then it is a hybrid Vehicle.

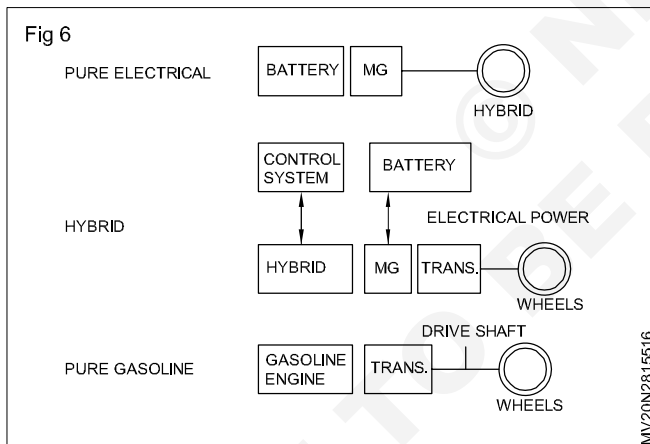
These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly.

Hybrid electric vehicle (HEV)

Consistent with the definition of hybrid above, the hybrid electric vehicle combines a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor.

Fig 6 shows the components of a hybrid Vehicle that combines a pure gasoline with a pure EV.

As shown in Fig 6, a HEV is formed by merging components from a pure electrical vehicle and a pure gasoline vehicle. The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. In Honda hybrids, the M/G is connected directly to the engine. The transmission appears next in line. This arrangement has two torque producers; the M/G in motor mode, M-mode, and the gasoline engine. The battery and M/G are connected electrically.

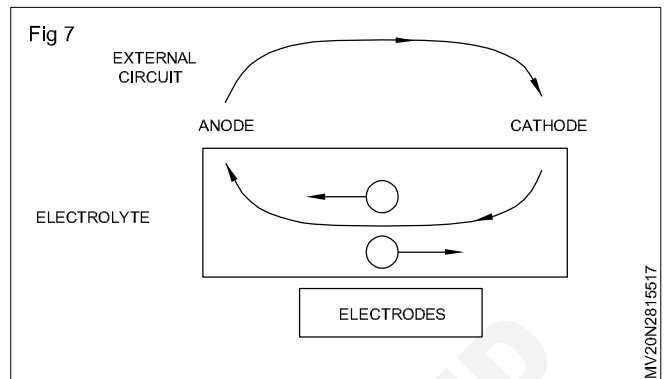


HEVs are a combination of electrical and mechanical components. Three main sources of electricity for hybrids are batteries, FCs, and capacitors. Each device has a low cell voltage, and, hence, requires many cells in series to obtain the voltage demanded by an HEV. Difference in the source of Energy can be explained as:

- The FC provides high energy but low power.
- The battery supplies both modest power and energy.
- The capacitor supplies very large power but low energy.

The components of an electrochemical cell include anode, cathode, and electrolyte (shown in Fig 7). The current flow both internal and external to the cell is used to describe the current loop.

Fig 7 shows An electrode, a circuit for a cell which is converting chemical energy to electrical energy. The motion of negative charges is clockwise and forms a closed loop through external wires and load and the electrolyte in the cell.



A critical issue for both battery life and safety is the precision control of the Charge/Discharge cycle. Overcharging can be traced as a cause of fire and failure.

Applications impose two boundaries or limitations on batteries. The first limit, which is dictated by battery life, is the minimum allowed State of Charge. As a result, not all the installed battery energy can be used. The battery feeds energy to other electrical equipment, which is usually the inverter. This equipment can use a broad range of input voltage, but cannot accept a low voltage. The second limit is the minimum voltage allowed from the battery.

Hydrogen is used in cars two ways: a source of combustible heat or a source of electrons for an electric motor. Hydrogen fuel cells create electricity.

Internal combustion vehicle

Hydrogen internal combustion engine cars are different from hydrogen fuel cell cars. The hydrogen internal combustion car is a slightly modified version of the traditional gasoline internal combustion engine car. These hydrogen engines burn fuel in the same manner that gasoline engines do; the main difference is the exhaust product. Gasoline combustion results in carbon dioxide and water vapour, while the only exhaust product of hydrogen combustion is water vapour.

A hydrogen vehicle is a vehicle that uses hydrogen as its onboard fuel for motive power. Hydrogen vehicles include hydrogen-fueled space rockets, as well as automobiles and other transportation vehicles. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or, more commonly, by reacting hydrogen with oxygen in a fuel cell to run electric motors. Widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy.

As of 2016, there are three models of hydrogen cars publicly available in select markets: the Toyota Mirai, the Hyundai Nexo, and the Honda Clarity. Several other companies are working to develop hydrogen cars. As of 2014, 95% of hydrogen is made from natural gas. It can be produced by thermo chemical or pyrolytic means using renewable feed stocks, but that is an expensive process. Renewable electricity can however be used to power the conversion of water into hydrogen: Integrated wind-to-hydrogen (power-to-gas) plants, using electrolysis of water, are exploring technologies to deliver costs low enough, and quantities great enough, to compete with hydrogen production using natural gas. The drawbacks of hydrogen use are high carbon emissions intensity when produced from natural gas, capital cost burden, low energy content per unit volume at ambient conditions, production and compression of hydrogen, and the investment required in filling stations to dispense hydrogen.

Hydrogen

Hydrogen does not exist in convenient reservoirs or deposits as do fossil fuels or helium and is produced from feed stocks such as natural gas and biomass or electrolyzed from water. A suggested benefit of large-scale deployment of hydrogen vehicles is that it could lead to decreased emissions of greenhouse gases and ozone precursors. However, as of 2014, 95% of hydrogen is made from methane. It can be produced by thermo chemical or pyrolytic means using renewable feed stocks, but that is an expensive process. Renewable electricity can however be used to power the conversion of water into hydrogen: Integrated wind-to-hydrogen (power to gas) plants, using electrolysis of water, are exploring technologies to deliver costs low enough, and quantities great enough, to compete with traditional energy sources.

Hydrogen fuel-cell vehicles would generate only three-fifths the carbon dioxide as a comparable vehicle running on gasoline blended to 10 percent ethanol. While methods of hydrogen production that do not use fossil fuel would be more sustainable, currently renewable energy represents only a small percentage of energy generated, and power produced from renewable sources can be used in electric vehicles and for non-vehicle applications.

The challenges facing the use of hydrogen in vehicles include chiefly its storage on board the vehicle. While the well-to-wheel efficiency for hydrogen from the least efficient manner of producing it (electrolysis) is less than 25 percent, it still exceeds that of vehicles based on internal combustion engines.

Electrical and electronic architecture

Instead of simply being modes of conveyance as in the past, today cars are also expected to entertain and inform passengers in a safe and protected environment. Further, they are supposed to ease the complexity of driving by providing different forms of assistance to the driver. To support these increasing demands, automotive - specific buses and gateways. Moreover, emerging functionality like car - to - car and car to infrastructure communication, as well as infotainment and driver assistance systems have increased the number of vehicle components with communication interfaces to the outside world. Such complex E/E and connected automotive architectures are increasingly vulnerable to malicious attacks and recent this topic considering security side - by - side with safety is crucial for the overall reliability of an automotive E/E architecture, since a vulnerable electronic component might undermine the passenger's safety to the extent as a faulty one. However, in the highly competitive automotive domain, the cost of security features often pose an obstacle to their adoption.

Immobilizer system

Objectives: At the end of this lesson you shall be able to

- description of immobilizer system
- state immobilizer circuit.

Engine immobilizer

The engine immobilizer is a theft protection system that prevents someone from starting the engine with an incorrectly coded key.

Do not shield the car keys with metal objects. This may prevent the receiver from recognizing that key as a valid one.

Engine immobilizer system description

The engine immobilizer system is designed to prevent the vehicle from being

This system uses a transponder key ECU that stores the key codes of authorized ignition keys. If an attempt is made to start the engine using an unauthorized key, the ECU sends a signal to the ECM to prohibit fuel delivery and ignition, effectively disabling the engine.

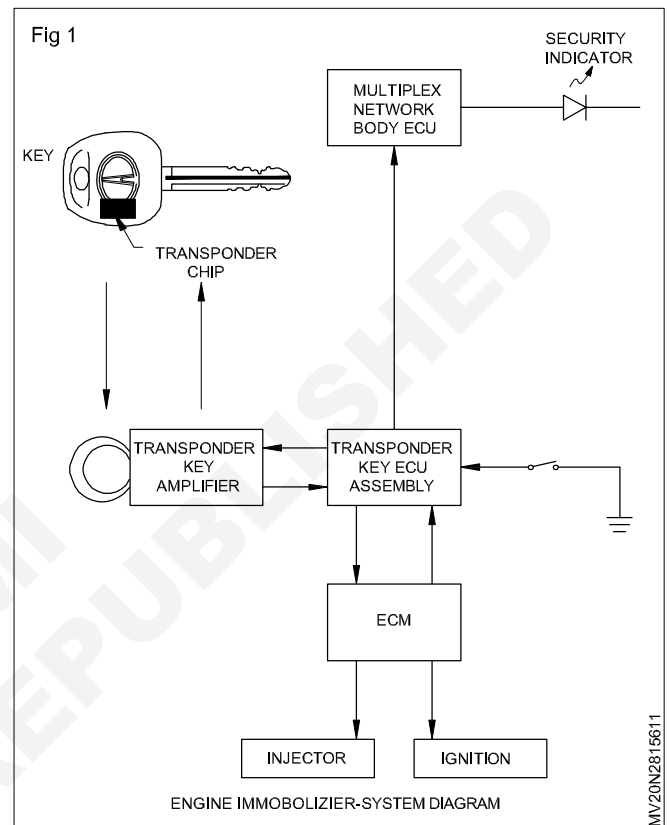
When the ECU detects that the unlock warning switch is ON, the ECU provides current to the transponder key coil and produces a faint electric wave. A transponder chip in the key grip receives the faint electric wave. Upon receiving the faint electric wave, the transponder chip outputs a key ID code signal. The transponder key amplifier amplifies it, and then the signal is transmitted to ECU. The ECU matches the key's ID code with the vehicle's this signal, the transponder key amplifier amplifies it, and then the signal is transmitted to the ECU. The ECU matches the key's ID code with the vehicle's ID code, which was previously registered in the ECU and then communicates the results to the ECM using the SFI communication.

After the identification results show that the key's ID code matches the vehicle's ID code and the ECU has confirmed their match: 1) the immobilizer system is canceled and the engine starting controls (fuel injection control and ignition control) enter standby mode; and 2) the ECU transmits a security indicator signal that communicates "indicator OFF" to the multiplex network body EXU. Then, the multiplex network body ECU turns OFF the security indicator lamp.

Immobilizer circuit (Fig 1)

Car alarms

There are several alarm systems that will serve to deter or discourage vehicle thefts and alert others of forced entry into the car. You need sure that these noise speakers should be installed in such a way as not to be easily accessible on glance, else will be forced disabled by them.



Steering lock

A long metal bar with a lock that fits on the steering wheel and is designed to prevent the steering wheel from turning, steering wheel locks are effective.

ICAT

ICAT means Intelligent Computerised Anti - Theft system under this system the car starts only when car starts only when the sensor in the vehicle accepts the chip in the key. Even sensors creates alarms buzz, when someone tries to insert the fake key in a car.

GPS tracker

A GPS facility, which can help tracking a stolen car. In fact, it can also alert a misuse of your car by any service station.

Tyre lock

Tyre lock device is very difficult to lock and unlock the car wheel, but its cost is very lower than other anti theft system device.

Air bag & seat belt

Objectives: At the end of this lesson you shall be able to

- state need of air bag and seat belt
- state functions of seat belt
- state the types of seat belt restraints
- describe the passive seat belt restraints
- state safety points for driver & passengers
- describe the air bag system
- describe air bag system warning light
- describe the multi stage air bag deployment
- describe seat belt pre tensioners.

Need of air bag & seat belt

Vehicle safety is one of the most important considerations of the average vehicle buyer today. In simple terms, safety sells vehicles! Therefore, vehicle manufacturers have spent a large amount of money engineering improved safety systems. Passive restraints at the present time include the drivers air bag, passenger side air bag, side - impact air bags, air bag curtains, and seat belt pre tensioners. The seat belt and air bag systems are intended to work together to protect the driver and passengers.

Functions of seat belts

An air bag equipped vehicle, conventional seat belts perform these functions:

- 1 Hold the occupants in proper position when air bags inflate.
- 2 Reduce the risk of injury in a less severe collision in which the air bags do not deploy.
- 3 Reduce the risk of occupant ejection from the vehicle and thus reduce the possibility of injury.

State types of seat belt restraints

All vehicles manufactured and sold vehicles must have passive restraints.

Passive restraints may be air bags or automatic seat belts. Most vehicles with air bags also have active restraints.

These are

- 1 Passive restraints
- 2 Active restraints

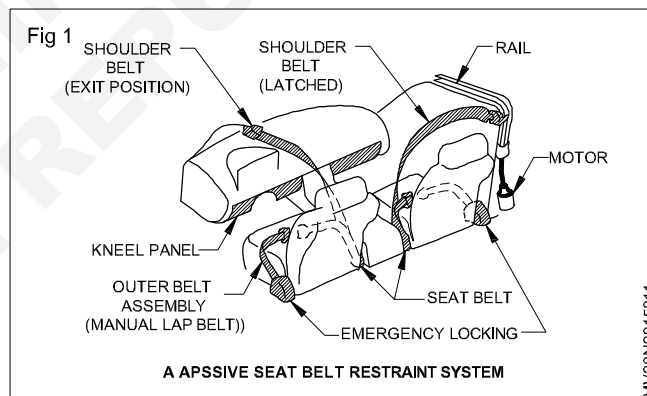
Passive restraints

Operate automatically with no action required by the driver. Active restraints require action by the driver or passengers before the restraints provide any protection.

Passive seat belt restraints

A passive seat belt system uses electric motors to automatically move the shoulder belts across the driver and front seat passenger. The upper ends of the belts

are attached to a carrier mounted in a track just above the top of the door frame. The other end of each shoulder belt is secured by an inertia lock retractor that is mounted in the center console. When a front door is opened, the outer end of the shoulder belts move forward in the door tracks to allow easy entry and exit from the vehicle (Fig 1). When the door is closed and the ignition switch turned on, the shoulder belts move rearward in the door tracks to secure the front seat occupants. The active lap belt must be buckled by the driver or passenger and must be worn with the shoulder belt.



Safety points for driver and passenger (Fig 2)

Some of the better modern front seats embody an adjustable lumbar support in the backrest. Where the seat must hinge forward to give access to the rear compartment, a catch is usually fitted on recent models to secure it in a collision. Fascias and parcel shelves are now well padded to minimize injury, and some inside mirrors are designed to break from their mountings on impact, instead of shattering.

Comfort

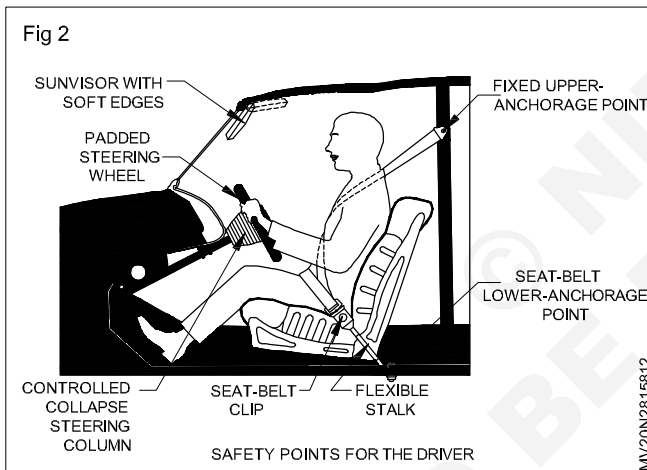
The seat belt anchorage, which incorporates the retaining clip, should be so located that the belt can be put on and taken off quickly, using only one hand. The belt must fit comfortably and must not slip off or cut into the wearer. A settled, restful position reduces strain and fatigue a considerable safety factor.

Air bag system components

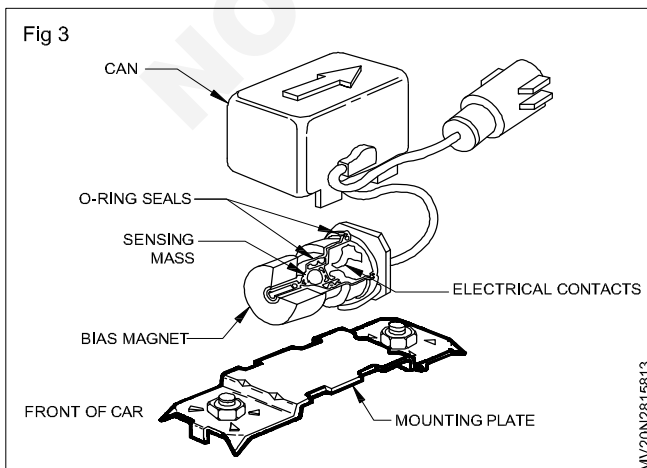
Understanding air bag system components is essential to comprehend the complete system operation. A knowledge of air bag system operation is absolutely necessary to maintain, diagnose and service air bag systems quickly and accurately.

Sensors

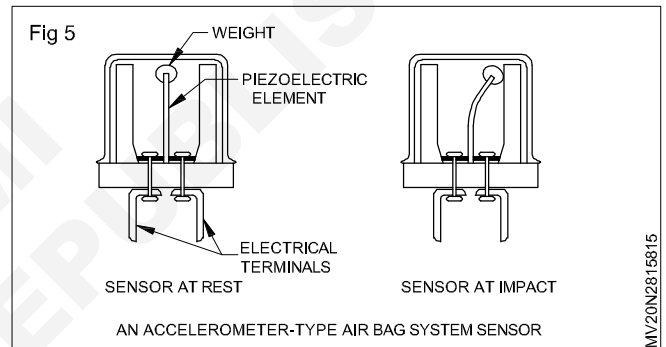
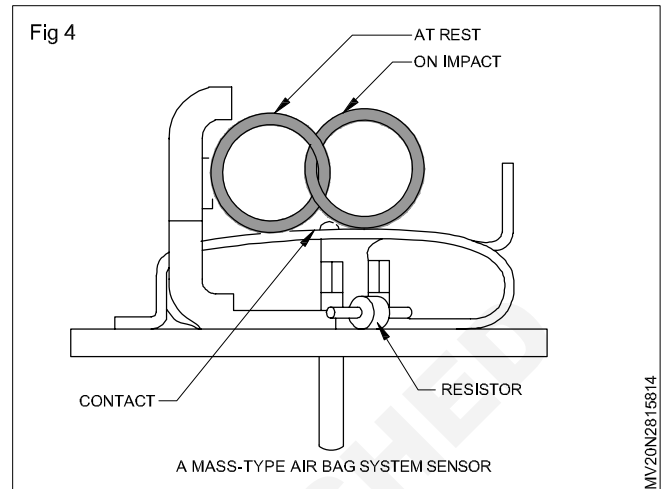
Some air bag system sensors contain a set of normally open, gold plated contacts and a gold plated ball that acts as a sensing mass (Fig 2). This ball is mounted in a stainless steel - lined cylinder. A magnet holds the ball about 1/8 in away from the contacts. When the vehicle is involved in a collision of sufficient force, the ball moves away from the magnet and closes the switch contacts. These contacts remain closed for 3 milliseconds before the magnet pulls the ball away from the contacts. The sensor is completely sealed in epoxy to prevent contaminants and moisture from entering the sensor. Sensors must be mounted with the forward marking on the sensor facing toward the front of the vehicle. To operate properly, sensors must be mounted in their original mounting position and sensor brackets must not be distorted.



Some air bag sensors contain a roller on a ramp. This roller is held against a stop by small, retractable springs on each side of the roller. If the vehicle is involved in a collision of sufficient force, the roller moves up the ramp and strikes a spring contact completing the electrical circuit between the contact and the ramp. (Fig 3)

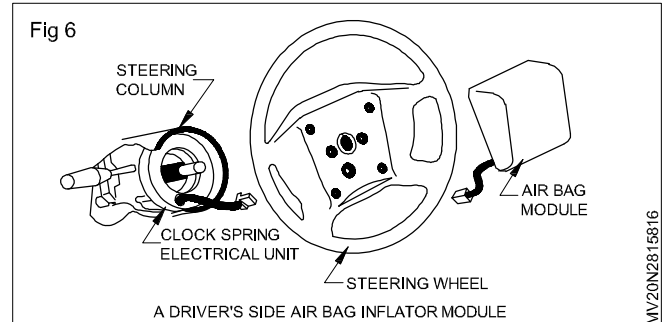


Some air bag sensors contain an accelerometer that contains a piezoelectric element (Figs 4 & 5). If the vehicle is involved in a collision, this element is distorted. The voltage signal from the sensor to the air bag system module depends on the force of the collision and the amount of element distortion.



Inflator module

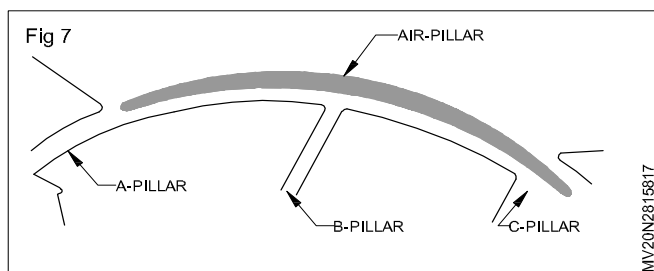
The inflator module contains the air bag, air bag container and base plate, inflator, and trim cover. The retainer and base plate are made from stainless steel and are riveted to the inflator module. The air bag is made from porous nylon and some air bags have a neoprene coating. The purpose of the inflator module is to inflate the air bag in a few milliseconds when the vehicle is involved in a collision. A typical driver's side air bag has a volume of 2.3 cubic feet. The driver's side air bag inflator module is usually retained with four bolts in the top of the steering wheel. (Fig 6)



Air bag system warning light

The air bag system warning light is mounted in the instrument panel. The air bag system warning light should come on when the ignition switch is turned on. If the ignition switch is left in the on position without starting the engine or when the engine is started, the air bag system warning light should flash a few times and then go out. This light action indicates the air bag system is satisfactory. If the air bag system warning light is on with the engine running, there is an electrical defect in the air bag system and the air bag system may not be operational in a collision.

Side impact air bags (Fig 7)



Some vehicles are now equipped with side impact air bags that protect the driver or passengers during a side collision. The side impact air bag systems are separate from the drivers side and passengers side air bag systems. Side impact air bag systems have their own sensors and ASDM. (Adaptive Security Device Manager). Separate ASDMs are usually installed for each side impact air bag. The ASDMs for the side impact air bags may be under the front seats or behind the B-pillar panels.

Left and right side ASDMs for side impact air bags are not interchangeable.

Some vehicles have a side impact air bag that deploys out of the door paneling. In other systems, the side air bags are mounted in the side of the seat back near the top. Some vehicles have a side air bag curtain that deploys out of the headliner just above the doors. This type of air bag protects the front and rear seat occupants from head injury.

Global positioning satellites (GPS)

Objectives: At the end of this lesson you shall be able to

- state the uses of global positioning satellites (GPS)
- describe working of GPS
- describe the uses of crash sensors
- describe on integrated communications system
- describe the uses of proximity sensor
- describe the uses of reflective displays
- describe triangulation / trilateration
- describe telematics
- describe networking & multiplexing.

Global positioning satellites (GPS)

A system known as a Global Positioning System, or GPS can be used to determine the exact location of a vehicle on the earth's surface.

Smart air bag systems

Some air bag systems have a switch in the passenger's side of the front seat. This switch informs the ASDM if anyone is sitting in the front passenger seat or not. If no one is sitting in this seat, the passenger's side air bag does not deploy if the vehicle is involved in a collision. Some smart air bag systems can detect from the passengers weight. If a child below a certain weight is occupying this seat, the air bag does not deploy. In some air bag systems, the weight of the person in the passenger's side air bag deploys.

On some smart air bag systems, if a rearward facing child's seat is placed in the front passenger's seat, the passenger's side air bag does not deploy.

If a child in a rearward facing child's seat is placed in the front passenger's seat and the air bag deploys, the deployed air bag may force the seat and the child against the vertical part of the front seat causing the child to suffocate.

Some vehicles have a small knee air bag that deploys out of the dash in front of the drivers knees. This air bag protects the driver from knee injury and also keeps the driver from sliding under the seat belt during an accident. This action maintains the driver in a better position to be protected by the driver's side air bag.

Seat belt pre tensioners

Some vehicles have seat belt pre tensioners on the seat belts. The pre tensioners contain materials similar to a single stage air bag inflator module. The pre tensioners may be mounted on the buckle side of the seat belt (Fig 7). If the front air bags are deployed, the ASDM also fires the pre tensioners. A thin cable is connected between the buckle and a small piston in the pre tensioner. When a pre tensioner is fired, the piston moves up the cylinder and the cable pulls the buckle tight. This action holds the occupant tightly against the seat and helps to prevent injury.

Thousands of satellites, service a variety of purposes, are continually in orbit high above the earth. The use of satellite technology in vehicle systems provides an ever increasing array of options for vehicle manufacturers. It

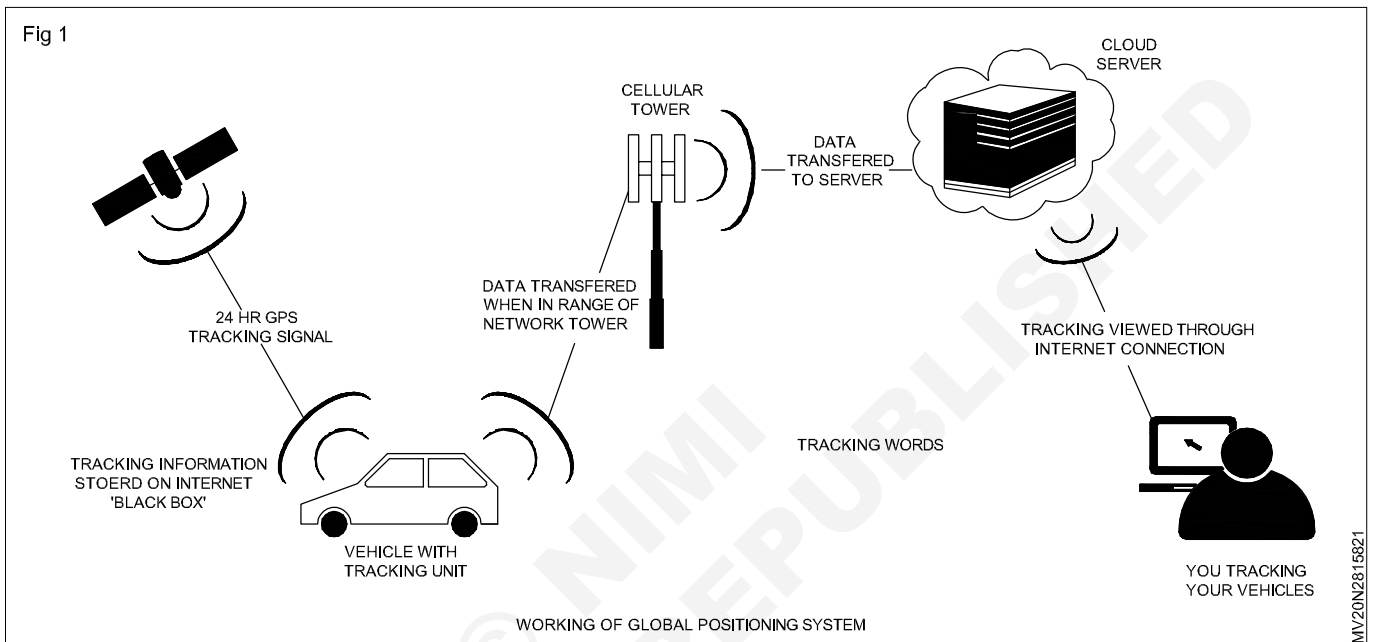
is an area of automotive technology that increases the flexibility and power of many onboard systems.

Satellite technology is used in: Navigation, vehicle tracking, vehicle theft recovery, communication and internet access.

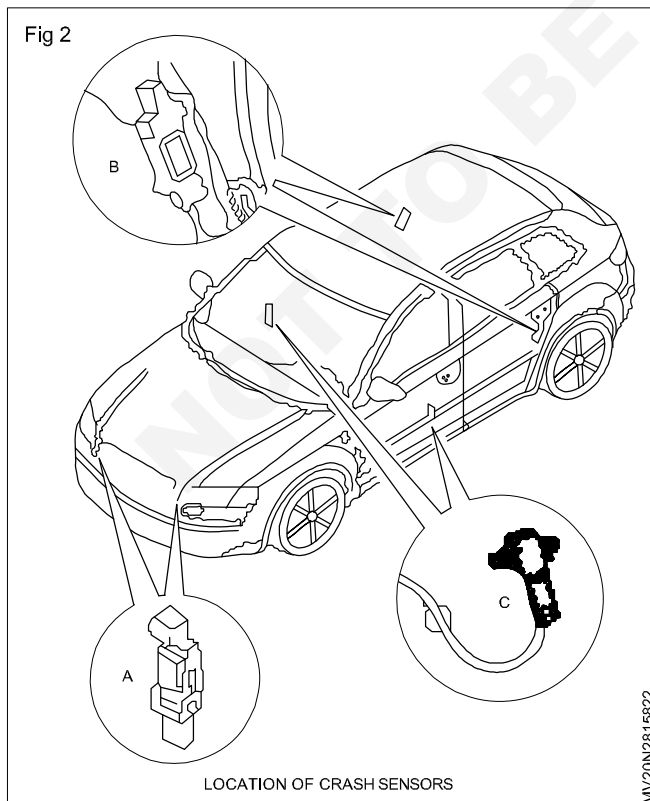
Mountains, tunnels, large buildings and other objects can interfere with satellite communication and make it unreliable. Most vehicle tracking systems can work very accurately without satellites once their initial position has been determined. On board sensors can be used to keep track of the exact vehicle location.

Working of global positioning system (Fig 1)

The basis of the GPS is a constellation of satellites that are continuously orbiting the earth. These satellites, which are equipped with atomic clocks, transmit radio signals that contain their exact location, time and other information. The radio signals for the satellites, which are monitored and corrected by control stations, are picked up by the GPS receiver. A GPS receiver needs only three satellites to plot a rough, 2D position, which will not be very accurate. Ideally, four or more satellites are needed to plot a 3D position, which is much more accurate.



Crash sensor (Fig 2)



Sensors are located behind the front bumper, headlights, dash and doorsill or 'B' pillar. Some manufacturers also place sensors with the electronic control unit.

Crash sensors can be fitted in various positions throughout the vehicle. Their location depends upon the direction of deceleration they are designed to detect.

Some manufacturers place the sensors within the electronic control unit. Others are located behind the front bumper, headlights and dash.

Side impact sensors are located in the doorsills or "B" pillar. They will inform the SRS control unit of side impact and whether to deploy the left or right side air bags.

When the sensors indicate that a predetermined deceleration rate has been exceeded and it is from the appropriate direction, the SRS control unit deploys the relevant air bags.

If the collision is from the front, the driver and passenger air bags will deploy.

If the collision is from the side, the sensor determines whether the seat mounted air bag, or curtain air bags for one side of the vehicle will deploy.

With more refined designs, the passenger air bag deploys only if there is an occupant in the seat. Deployment can also depend on the weight of the occupant and whether the passenger air bag switch, if fitted, is turned on.

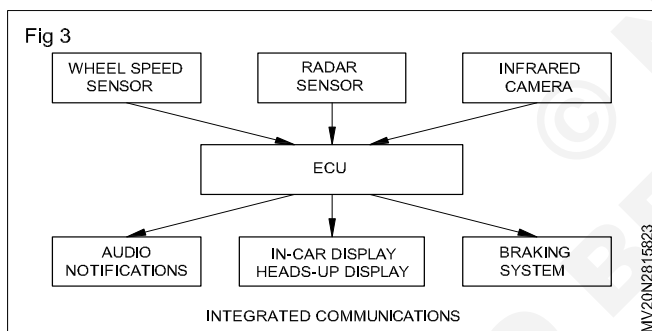
To prevent incorrect and unnecessary deployment, systems include a safing sensor mounted within the SRS control unit. The SRS control unit will only pass current through the squib if both the safing sensor and a crash sensor indicate simultaneously that a predetermined deceleration rate has been exceeded.

The SRS warning light is illuminated, and stays on, if a fault is detected in the system.

Capacitors within the SRS (Supplemental Restraint System) control unit are used to store electricity and act as a back up power supply. If a vehicle has its battery destroyed or disconnected in an accident, the capacitors supply the electricity required to keep the SRS system operational.

Some seat mounted side impact air bags also operate without electricity. When the side of a vehicle is crushed inwards, a detonator mounted on the lower outside edge of the seat is detonated. Pyrotechnic tubes connect the detonator to the air bags, which in turn ignite the squib. Many vehicles use two stage side impact bags. This provides protection to the upper chest over a more extended time.

Integrated communications (Fig 3)



Modern vehicles integrate audio, video and communication systems into a network.

Modern vehicles integrate audio, video and communication systems into a network. This allows for a high quality, compact and ergonomic system, which combines entertainment features with simple operation.

Controls are centralized with hardware, such as CD stackers, and DVD players located remotely.

Communication between components uses a combination of hard wiring and data buses.

With data being used, audio messages can be broadcast over the audio system that relate to other vehicle systems. For example, a voice message can say "the park brake is on" or "left rear tire is under inflated".

The system allows for features such as the interruption or replacement of audio entertainment when there is an incoming phone call, or simply muting the audio to allow for safer driving.

The music played on a system usually comes from one of several sources. Magnetically on a cassette tape, optically on a CD or DVD, by radio frequency from radio stations or satellites, or from other portable devices.

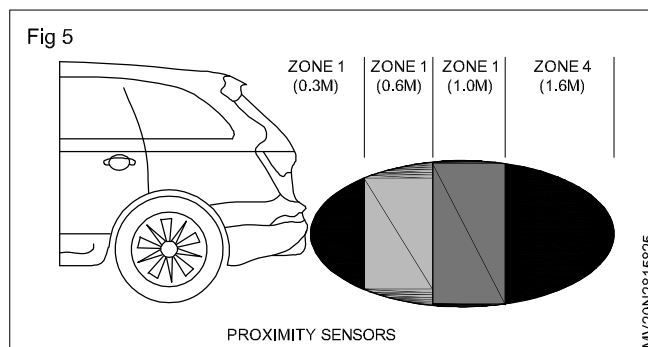
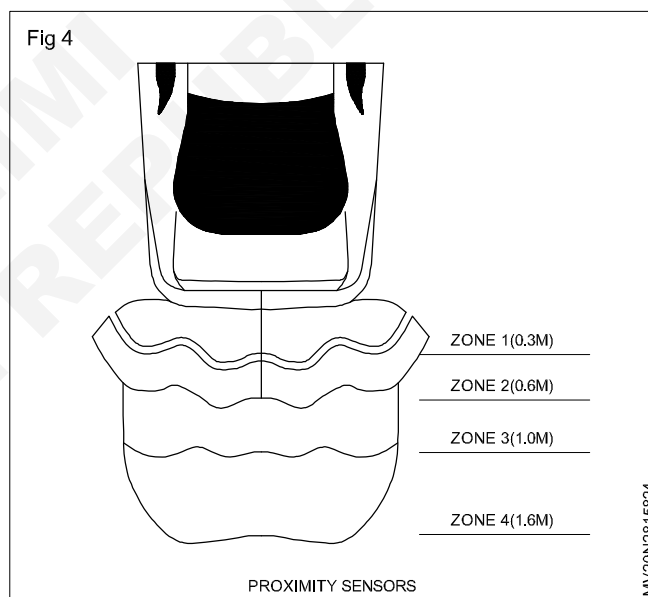
The information is decoded or processed by the control unit and outputted to drive speakers located throughout the vehicle.

Another function provided by the body control unit is that of speed dependant volume. The control unit has an input from the vehicle speed sensor, which allows it to gradually increase audio system volume proportionally with road speed. As speed and therefore engine and road noise increases, the audio volume will increase. As speed decreases the audio volume will decrease.

Viewing screens for onboard TV, DVD and games can be located in the dash, however, if the screen is viewable by the driver it must be disabled when the vehicle is in motion. Other mounting points are from the roof or integrated into the rear of seat headrests.

Control units can be hard wired, or wireless using an infrared remote control.

Proximity sensors (Figs 4 & 5)



Proximity sensors are mounted in the front or rear bumpers. The control unit determines the distance between the sensor and an obstacle by measuring the time taken for sound waves to leave and return to the sensor.

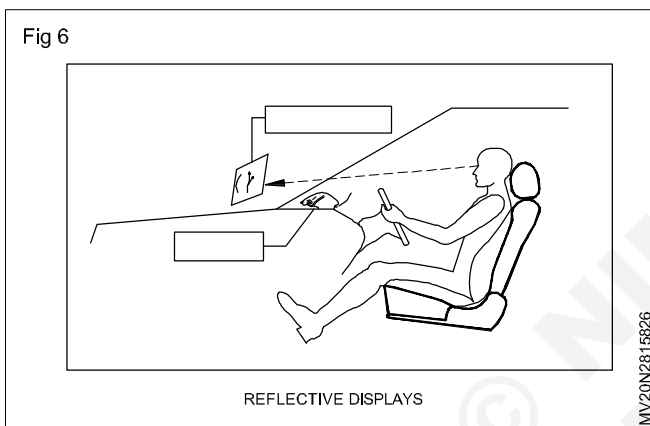
To allow for safer parking, proximity sensors can be mounted in the front or rear bumpers.

These color matched sensors emit ultrasonic sound waves that the human ear cannot detect.

These piezo sensors are used to transmit and receive coded sound waves. The control unit determines the distance between the sensor and an obstacle by measuring the time taken for the sound wave to leave and return to the sensor. Normally 4 sensors are used to allow for full coverage across the width of the vehicle.

Proximity to obstacles can be indicated by separate audible and visual alarms, or by integrating warning sounds with the vehicles audio system. If a trailer is attached to a coupling, the rear sensors are disabled automatically when the harness plug is inserted. Front sensors can be disabled manually in start or stop and go traffic.

Reflective displays (Fig 6)



Reflective displays use a mirror embedded in the dash so the instruments appear further away than they are actually, This way the drivers focal point changes less when looking from the road to the instruments and back.

Conventional instrument panels require the driver to change the line of sight and their visual focal length to read information on the instrument cluster. This means the driver is looking away from the road for a significant distance when travelling at speed.

Reflective displays are mounted within the dash panel. They use a mirror embedded in the dash, forward of the driver, to reflect an image of the instrument cluster. The actual instruments are hidden in the dash and it is a reflected view of them that the driver sees.

This has the effect of the instruments appearing to be located further away than they actually are. The benefit of this system is that the drivers focal point changes less when looking from the road to the instruments and back.

Triangulation / trilateration

Trilateration or triangulation is the system whereby a vehicles location is determined by forming a triangle with a group of four or more satellites.

The Global Positioning System or GPS uses a group of at least 24 satellites orbiting approximately 12 600 miles

or 20 200 kilometers above the earth. The vehicle is equipped with a receiving antenna and computer system. The GPS receiver on the vehicle has to locate four or more of these satellites, determine the distance to each, and use this information to establish its own location. This operation is based on a mathematical principle called "trilateration".

"Trilateration" in three dimensional space is quite complex. For ease of understanding, the term that is generally used in the automotive industry to describe how the GPS positioning system operates, is "Triangulation". "Triangulation" is the process of finding the position of an unknown point based on forming a triangle with two known points.

For simplicity, the dimensions used to determine these points are commonly known as latitude, longitude and elevation.

If a group of three satellites are taken to form a triangle, 12 600 miles or 20 200 kilometers above the earth, the shape and size of this triangle will never change.

Equally any fixed point on the surface of the earth will triangulate with the satellites. The numbers of fixed points are infinite.

What the GPS does to work, is form many triangles with triangulate with the satellites. The numbers of fixed points are infinite.

What the GPS does to work, is form many triangles with different pairs of satellites.

Each satellite has an atomic clock onboard and regularly transmits a unique radio frequency signal simultaneously with all other global positioning satellites. The RF signals travel out across space in all directions.

The speed at which RF signal travels in space is approximately 186,000 miles or 300,000 kilometers per second, the speed of light in a vacuum.

Each of these transmitted signals will reach the GPS antenna of the vehicle. The time taken for the RF signal to travel from each satellite and arrive at the vehicle is dependent on the distance each satellite is from the vehicle. The greater the distance the longer the time taken.

The vehicle's onboard GPs system needs to know three things to determine the location of the vehicle.

The time it takes for the signal to travel from the satellites to the vehicle.

The location of each satellite.

And accurate time.

Given these facts, enough information is available to form a three dimensional figure of a pyramid with a triangle base.

The base of the pyramid is formed by the location of the satellites and the apex of the pyramid is the location of the vehicle on the earth, a point derived from triangulation of the known points of the base.

The GPS equipment knows that all of the apexes (the position of the GPS) of each triangle must be in the same literal position.

Telematics

Automotive telematics is a satellite based system that combines two way communication and information technology within the vehicle.

Using this system allows for: vehicle tracking, monitoring of onboard systems, messaging, travel information, entertainment, security, safety and fleet management systems which monitoring of onboard systems, messaging, travel information, entertainment, security, safety and fleet management systems which monitor information such as location, distance traveled, speed, stops and fuel usage.

A vehicle manufacturer may offer telematics as a service to its customers. The benefits of this can include: the location & immobilization of a stolen or lost vehicle, notification to emergency services after SRS deployment, engine shut down and door unlocking in the event of a severe accident, roadside assistance and remote diagnosis.

Car becomes a connected mode on the network

Network & multiplexing

A multiplex network reduces the number of wires in the wiring harness and greater vehicle content flexibility.

Even the most basic vehicles include many electronically controlled systems. If each electronic system had its own ECU, harness and sensors, the weight of the added components would negate any efficiency it provided. A vehicles multiple electronic systems could require over 1 mile or 1.6 kilometers of insulated wiring, consisting of around 1000 individual wires and many terminals.

One solution to the problem is the use of a system that integrates sensors into a common wiring harness by combining all the individual systems, where possible, into a multiplexed serial communications network, so they can share the information.

An added advantage of such a system is that if there is less wire and connections there is less chance of dirty connections causing faults.

This system is referred to as a controlled Area Network BUS or BUS and it uses two thin wires to connect, or multiplex, all the control units and their sensors to each other. The output devices are referred to as nodes.

The advantage of a multiplex network is that it enables a decreased number of dedicated wires for each function, and therefore a reduction the number of wires in the wiring harness, reduced system cost and weight, improved reliability, serviceability and installation.

In addition, common sensor data such as vehicle speed engine temperature etc. are available on the network, so data can be shared, thus reducing the number of sensors.

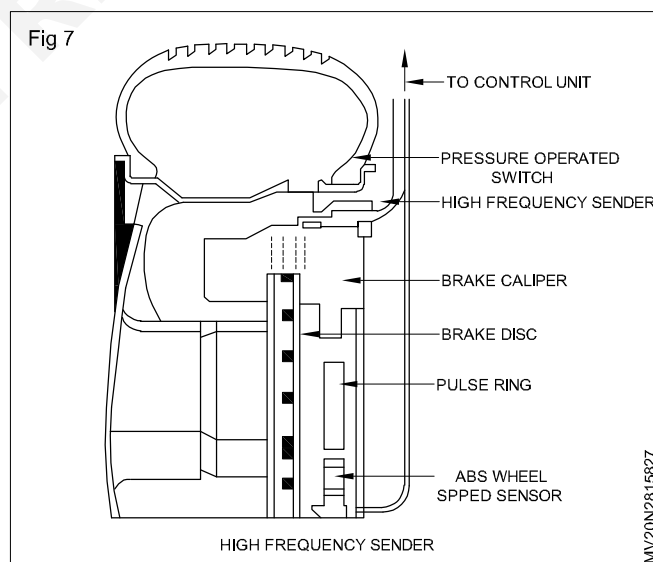
Also, networking allows greater vehicle content flexibility because functions can be added or modified through software changes.

Other control units can be added to the system by simply connecting them to the network.

A diagnostic tool can be connected to the CANBUS to extract operation information to assist in diagnosis and fault.

Tyre pressure warning

Poorly inflated tyre causes loss of control and increase fuel consumption. Fig 7 shows the layout and circuit of the tyre pressure warning system. The main idea is to give the driver warning of reduced pressure. There are three basic components used in the system. A pressure operated switch is mounted in the wheel rim, the contacts of which close when pressure falls. This is recognized by a high frequency pulser transmits an appropriate pulse to the electronic evaluator. When the pressure drops below the set value, the switch contacts close. this causes the high frequency pulser to interrupt its stream of pulses to the evaluation circuit so that the warning lamp lights up. The system measures the tyre pressure with an accuracy of $\pm 5\text{kPa}$. The design of the switch is such that changes in the temperature of the air in the tyre do not cause false readings. If a tyre pressure warning system is used in conjunction with wheels fitted with limp home tyres.



Fundamentals of air conditioning

Objectives: At the end of this lesson you shall be able to

- state that typical air conditioning system
- define the operating principle in air conditioning
- list the parts of an auto air conditioning system.

Fundamentals of air conditioning

Air conditioning lowers the temperature of the incoming air before it enters the inside of the vehicle. It therefore cools and dehumidifies the air space in the driver passenger compartment and when rapidly de-mist the insides of the surrounding window. As a result an improvement in comfort, alertness and reduction in driving fatigue is achieved for both driver and passenger.

Operating principle

Air conditionings main principles are **Evaporation and Condensation**, then **Compression and Expansion**.

Evaporation: Heat take away from the object.

Eg. If you rub a little surgical spirits on your hand, then you hand will feel cold. It is because the spirits on the back of your hand start to evaporate. As the spirit evaporates, it takes away heat from the surface of your skin. It's evaporation.

Condensation: It is the change of water from its gaseous form (water vapor) into liquid water.

Eg: When somebody walks in form the cold, their glasses steam up?. The moist air of the take away cools as it contacts the cold surface of the glasses and the air has less capacity to hold moisture, so it condenses into water on the glasses. It's condensation.

Heat of compression: Have you ever noticed when you pump up a bicycle tyre with a hand pump, that the end of the pump gets hot? This is because the energy that you have put into the air by pumping it has not only compressed it, but has also caused the air molecules to push closer together so giving off heat with the friction.

Compression: At some point all gases will eventually become liquid

Eg: Deodorant - its liquid inside the can (because you can hear it when you shake it) but is a gas when it comes out and hits your underarm. The pressure inside the can is higher, so the propellant inside is liquid.

Cooling by expansion: Going back to the deodorant, you will notice also how cold it feels that's because the propellant has just expanded in volume quickly.

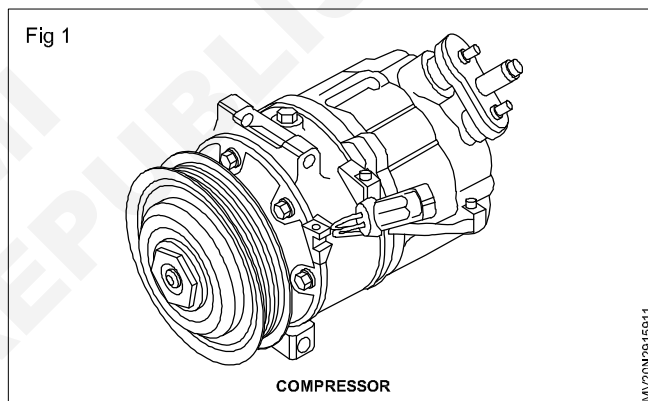
Basic components of A/C system

- 1 Compressor,
- 2 Magnetic clutch
- 3 Condenser,
- 4 Drier/receiver
- 5 Evaporator,
- 6 Blower

7 Expansion valve

1 Compressor

The compressor (Fig 1) takes low-pressure, cool refrigerant and makes it hot by compressing it. Two to six pistons that resemble the ones in your engine do the actual compressing. A V-belt from the engine drives the unit, and a magnetic clutch on its front disconnects it when the air conditioner is switched off. (Some systems cycle the compressor on and off to control the temperature inside the car. In these the magnetic clutch is wired to the on/off switch and a thermostat.



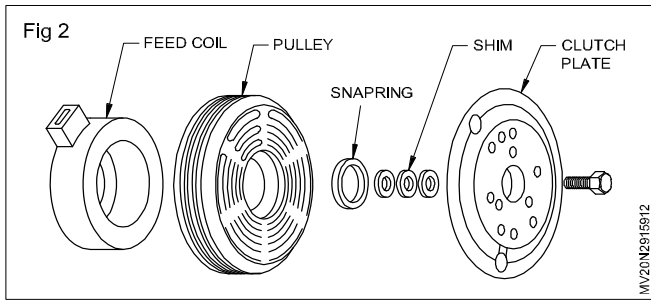
The compressor should be easy to find. Look for a comparatively large object with a pulley and fan belt, two rubber hoses about an inch in diameter, and valves on top that look like the ones on your tires. When you find it, track down the compressor clutch wire (there should be only one wire going to the compressor), and see if there's fuse inline nearby. If so, note its rating, and buy a replacement to keep as a spare in the glove compartment.

2 Magnetic clutch (Fig 2)

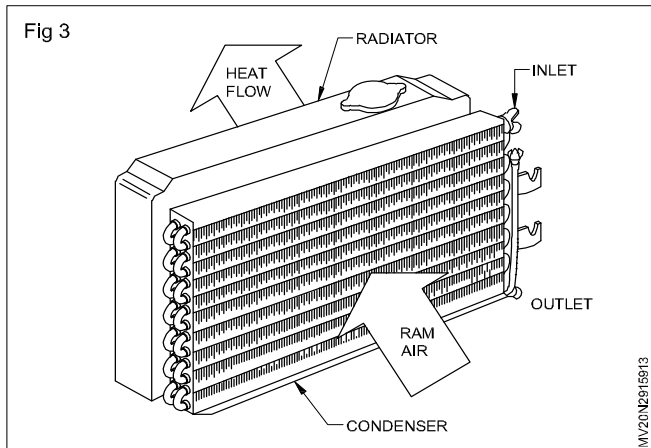
Function: A magnetic clutches is used to connect or disconnect the drive to the compressor.

Operation: When the voltage is applied to the clutch field coil, the clutch plate (which is connected to the compressor shaft) is drawn into contact with the pulley and the compressor rotates.

When voltage is disconnected from the clutch field coil the clutch plate is released and the compressor ceases to rotate.



3 Condenser (Fig 3)



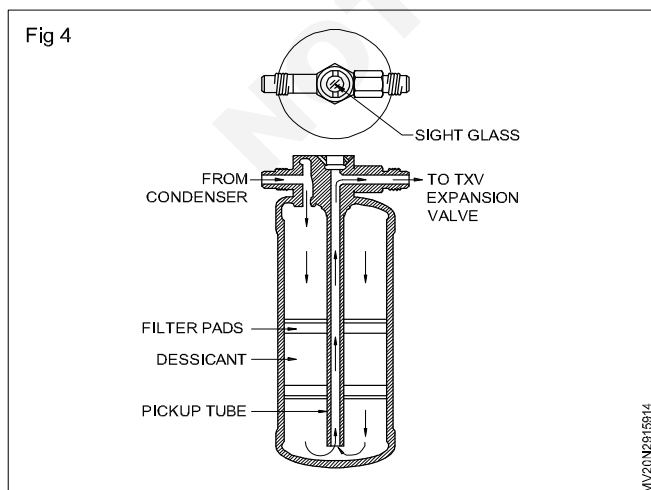
The condenser is very similar to evaporator except for the fact it is used to cool the refrigerant i.e hot refrigerant (high pressure high temperature) vapour is converted into liquid by air flowing over the tubes also made of brazed copper or aluminium tubes.

Function: The function of the condenser is to cool the hot refrigerant vapour ensuring it condenses into a liquid.

Operation

- Condenser receives refrigerant vapour from the compressor under high pressure.
- The refrigerant vapour enters the top of the condenser and flows down through the condenser tube.
- As cool air passes the condenser fins the refrigerant is cooled and it condenses before leaving the bottom of the condenser as liquid.

4 Drier / receiver (Fig 4)



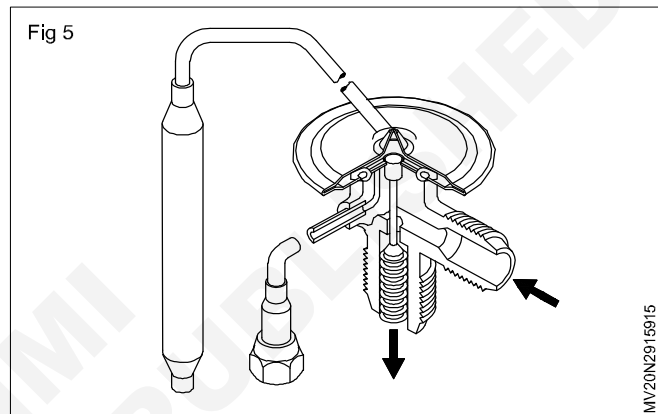
Function

- 1 The primary function is to ensure that only liquid refrigerant is passed on the expansion valve.
- 2 Filters the impurities in the system
- 3 Absorbs moisture in the system

Operations

- 1 High pressure liquid refrigerant passes from the condenser through the inlet line into the drier, and a drying element absorbs moisture from the refrigerant and filters foreign matter/particles.
- 2 From the drier the refrigerant reaches the expansion valve.

5 Expansion valve (Fig 5)



Expansion valve controls refrigerant flow into evaporator.

A temperature sensitive power element bulb is attached to the evaporator outlet, a capillary tube (length of tubing of small diameter which acts as a throttle on refrigerant) control.

Accumulator drier dehydrator is located in system low-pressure side, between evaporator and compressor. The receiver - dehydrator filters and removes moisture through means of a desiccant (drying agent).

Function

- 1 Controls the flow of refrigerant into the evaporator.
- 2 Ensures complete evaporation of the liquid refrigerant.

Expansion valves are not adjustable and are changed as a complete service unit.

Expansion device

There must be a flow restriction between condenser and evaporator, so that there exists a pressure difference with which the refrigerant will flow. The refrigerant should be at low pressure in an evaporator so that it gets converted to vapour taking up heat, this is achieved by means of an expansion device.

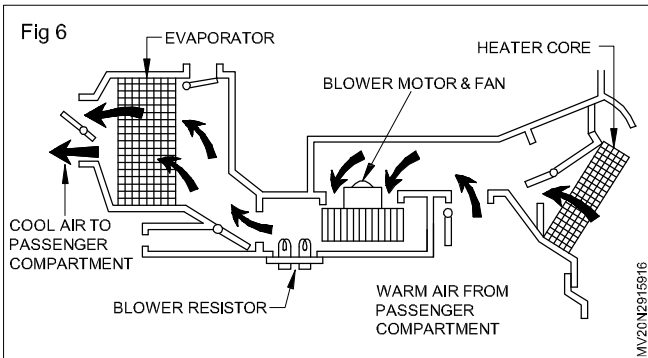
The flow restriction is produced by two devices

- i Orifice tube.
- ii Thermostatic expansion valve.

iii Orifice tube is a fixed diameter tube through which refrigerant flows. It is mainly used in domestic refrigerators.

iv Thermostatic expansion valve.

6 Evaporator (Fig 6)



Purpose evaporator: A heat exchanger which removes the heat from air circulating in the passenger compartment air distribution system and transfer that heat to the refrigerant in the A/C system.

Purpose - blower motor assembly (Fig 7)

The blower, which is always an integral part of the heater/air conditioning case assembly, performs two functions:

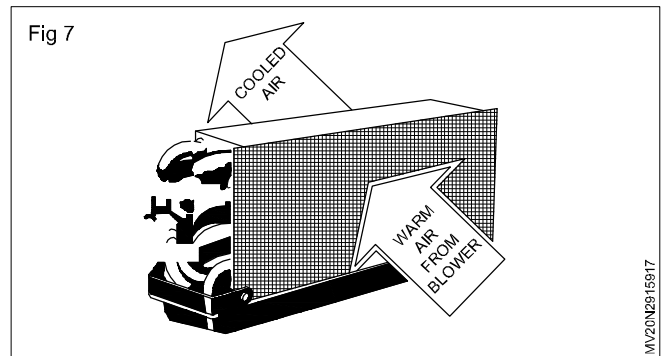
Working of car A/C system

Objectives: At the end of this lesson you shall be able to

- describe working of an air-conditioner
- locate the A/C controls.

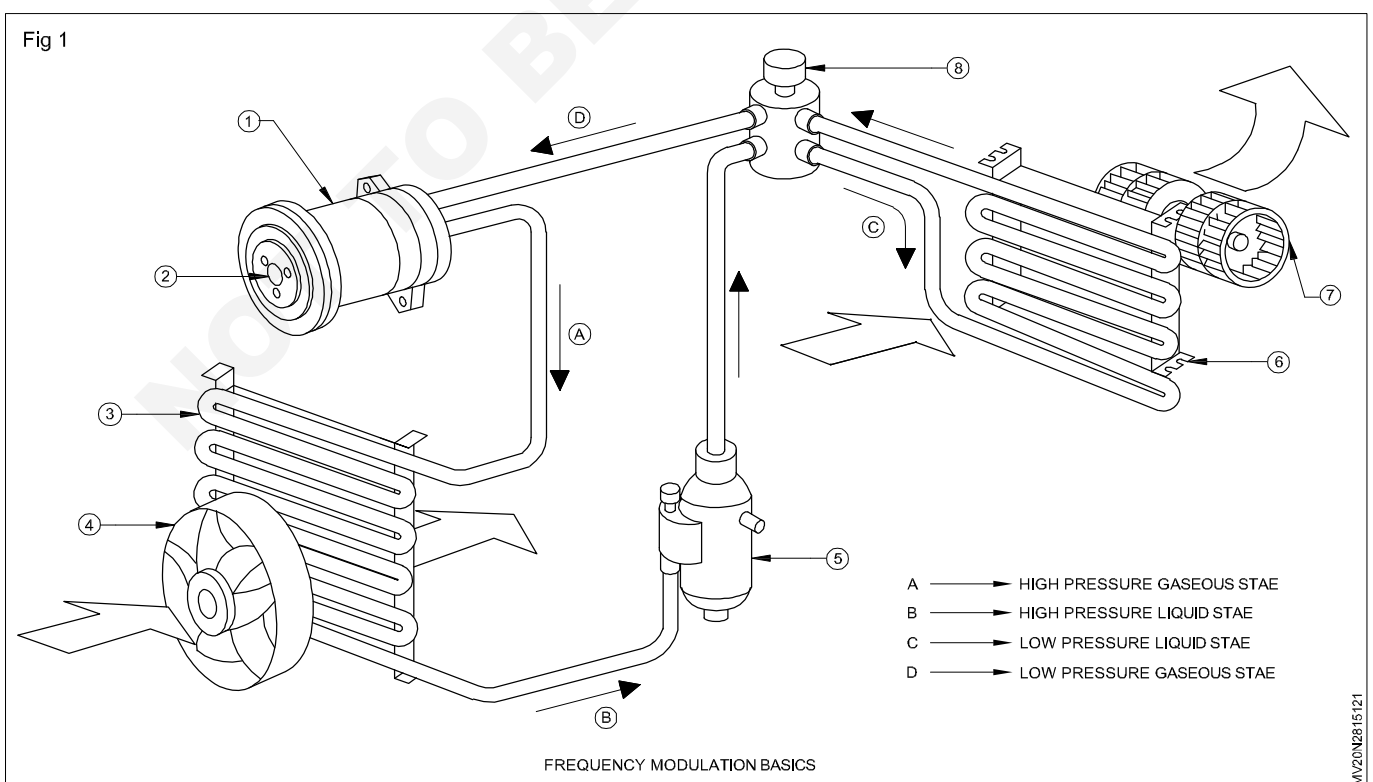
The layout of refrigeration system for car air condition is shown in Fig 1

When the A/C knob is turned on, magnetic clutch (2) connected in the compressor (1) drawn into contact with



- 1 It pulls air from the passenger compartment, or from outside of the vehicle, into the heater and air conditioners case assembly. (ventilating system)
- 2 It flows air through the heater core or the evaporator, or by passes both the flows it straight out the dash vents depending on the position of the doors in the heater case. (heating system)

The motor input ranges from 60V(5A) to 150W(12.5A) the motor speed is controlled by resistors in 3 to 6 steps.



(6). Then it compresses this refrigerant vapour, the pressure and temperature of refrigerant increases. This high pressure refrigerant vapour is sent to the condenser (3).

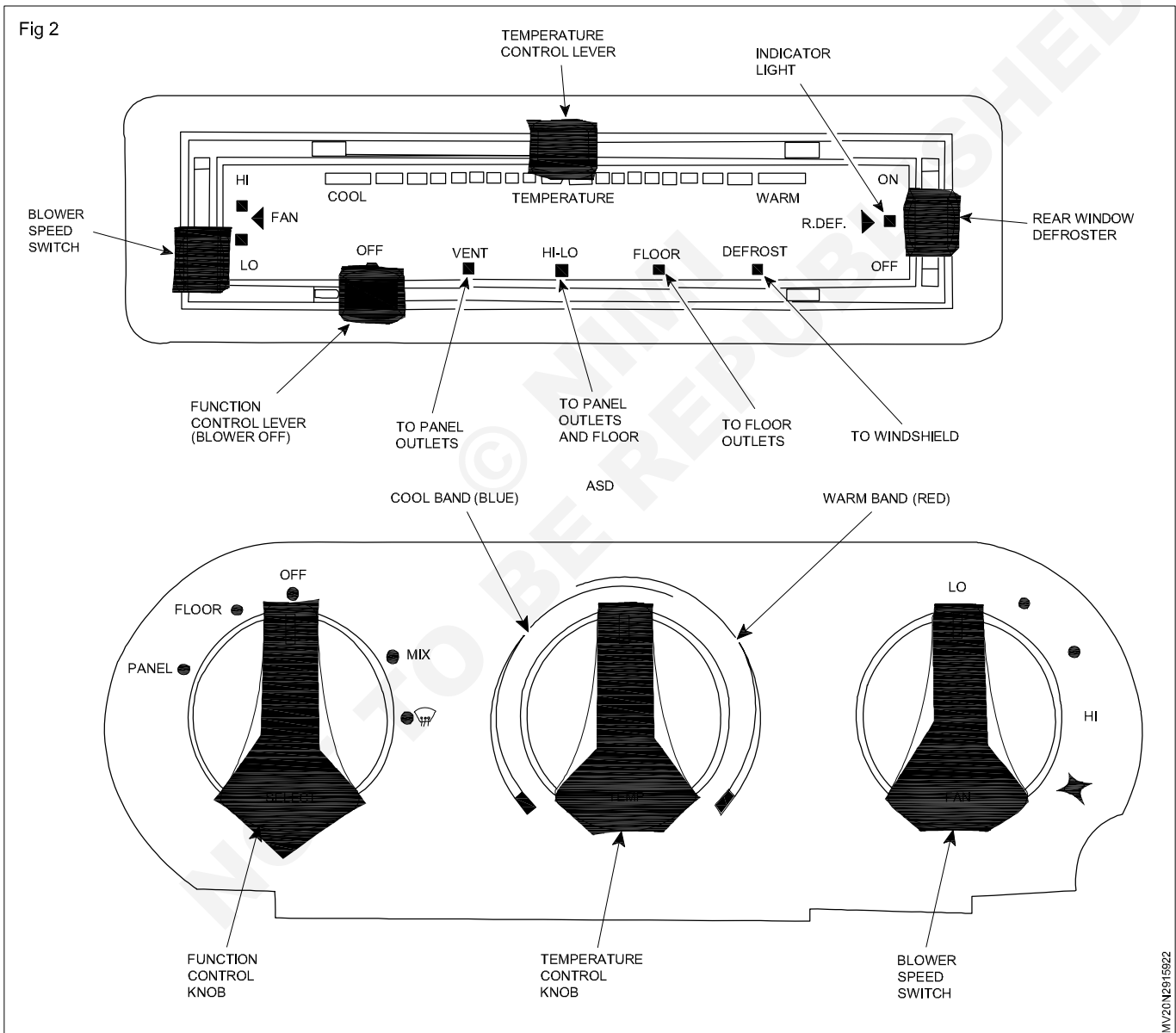
The air produced while driving and by the action of engine fan are allowed to flow across the condenser. At this stage vapour loses heat to air passing through the air passage in the condenser. Due to the loss of heat, the vapour condenses to a liquid.

The air from the condenser is flown into the receiver/driver (5), where it stores the liquid refrigerant and it is passed through dehydrator that extracts any moisture from the this liquid. Now the refrigerant liquid is completely dry. Dry refrigerant from receiver / driver (5) is made pass through expansion valve (8).

Expansion valve (8) permits the refrigerant liquid to expand to low pressure in the evaporator (6). This expansion process makes the refrigerant to evaporate. As it evaporates, it takes the heat from air passing through the air passage in the evaporator (6), where cooling effect achieves. Blower (7), is used to throw the cooling effect to the cabin. Condensed moisture with the impurities from the evaporator drip into a tray and the same is drained out from there.

Due to the above process, the refrigerant pressure and it vaporizes, thus refrigerant is low pressure and the cycle low temperature vapour which flows to compressor and the cycle rotates.

A/C controls: The Fig 2 shows the air distribution in an air-conditioning system. The different controls are



1 A/C control

- i Blower alone ON
- ii Blower and A/C ON

2 Air flow mode

- i Air under fresh mode
- ii Air under recirculation mode

3 Air flow distribution

- i Cool air to passenger cabin
- ii Defroster mode
- iii Cool air to passenger and on to the front passengers feet
- iv Cool air to defroster and front passengers feet.

4 Blower speed

Blower alone ON

Blower alone ON means AC is switched off the blower just circulates atmospheric air like a fan.

A/C ON: A/C ON means compressor is working and refrigerant is circulated through the evaporator which cools the cabin air.

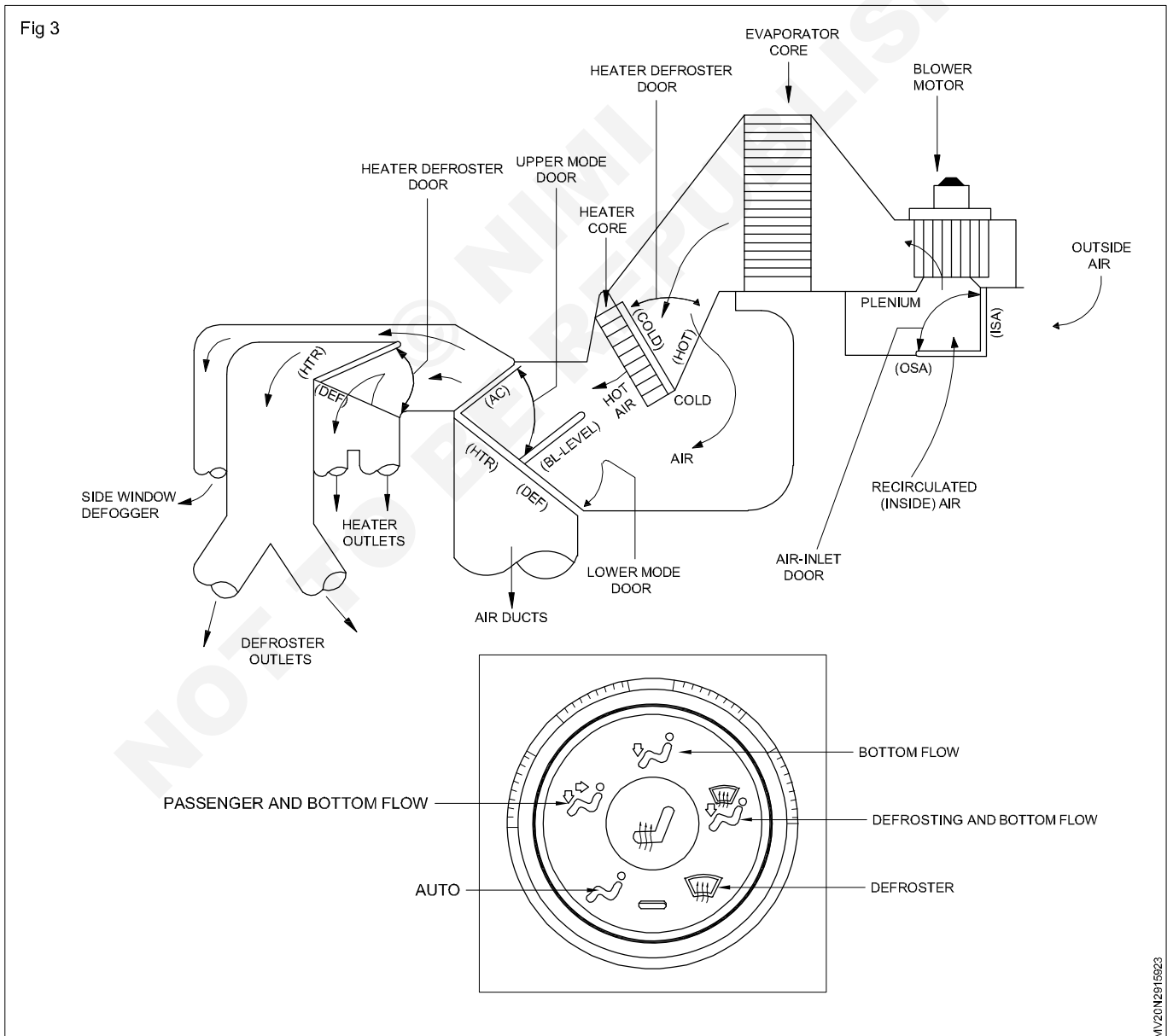
Flow mode: When outside is dusty and contaminated to avoid the dusty air, air inside the cabin is recirculated by moving the air flow mode to recirculation.

When going on highway or clean areas the air flow mode is kept under "fresh".

This minimizes any contaminated air being circulated as the cabin air may be dirty.

Heater: When the A/C mode is under "Heating" the hot coolant from radiator system is circulated which heats the incoming air. This hot air is then circulated to the cabin by means of the blower.

Fig 3 shows air distribution in an automatic A/C system.



Check and replace thermostatic expansion valve, thermostat switch and driver

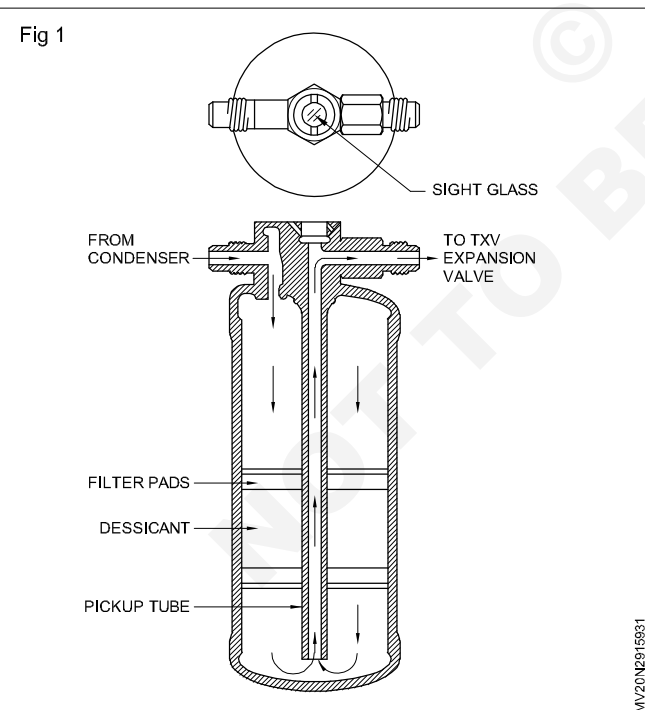
Objectives : At the end of this lesson you shall be able to

- explain the function and operation of receiver drier
- explain about thermostat switch
- explain the function of thermostatic expansion valve
- explain the construction of thermostatic expansion valve
- explain the purpose of thermostat switch in an automobile A/C system.

The fluid container and drier

The fluid container and drier in the refrigerant circuit with expansion valve, the fluid container serves as a refrigerant expansion tank and reservoir. Different amounts of refrigerant are pumped through the circuit when operating conditions such as the thermal load on the evaporator and condenser and compressor rpm are variable. The fluid container is integrated in the circuit in order to compensate for these fluctuations. The drier binds chemically moisture which has entered the refrigerant circuit during installation. The drier can absorb between 6 and 12g of water, depending on type. The amount of water that can be absorbed is temperature-dependent. The amount of water absorbed increases as the temperature drops. Abraded material from the compressor, dirt arising from installation work and similar is also deposited. High pressure liquid refrigerant passes from the condenser through the inlet line into the drier, and a drying element (Desiccant) absorbs moisture from the refrigerant and filters foreign matter/particles. From the drier the refrigerant reaches the expansion valve.

Function (Fig 1)



The liquid refrigerant coming from the condenser enters the container at the side. The refrigerant is collected in the container, then it flows through the drier and along the riser to the expansion.

Valve in an uninterrupted flow containing no bubbles. The fluid container must be kept closed as long as possible prior to installation in order to minimise absorption of moisture from the ambient air in the drier. The primary function is to ensure that only liquid refrigerant is passed on to the expansion valve. Filters the impurities in the system. Absorbs moisture in the system.

The fluid container is replaced every time the refrigerant circuit is opened.

Expansion valve: The expansion valve is the point where the refrigerant in the evaporator expands and cools down. It forms the interface between the high pressure side and low pressure side of the refrigerant circuit. The expansion valve is used to regulate the refrigerant flow to the evaporator. In dependence upon the temperature of the refrigerant vapour at the evaporator outlet. No more refrigerant than is necessary to maintain a steady "refrigerating climate" in the evaporator is expanded in the evaporator. The closed control loop. The refrigerant flow is controlled by the expansion valve in dependence upon temperature. When the thermostat expands. The flow rate of the refrigerant to the evaporator at the globe valve increases. When the temperature of the refrigerant leaving the evaporator drops, the refrigerant volume in the thermostat decreases. The flow rate to the evaporator at the globe valve is reduced.

There are three forces at play in the thermostatic expansion valve.

Pressure

Expansion valve pressure in the sensor line is dependent on the temperature of the superheated refrigerant. This pressure acts upon the membrane as an opening force.

- 1 The evaporator pressure acts upon the membrane in the opposite direction.
- 2 The pressure exerted by the regulating spring acts in the same direction as the evaporator pressure.

The expansion valves are set. Their setting may not be altered. Do not bend the sensor line, because it is filled with a special gas.

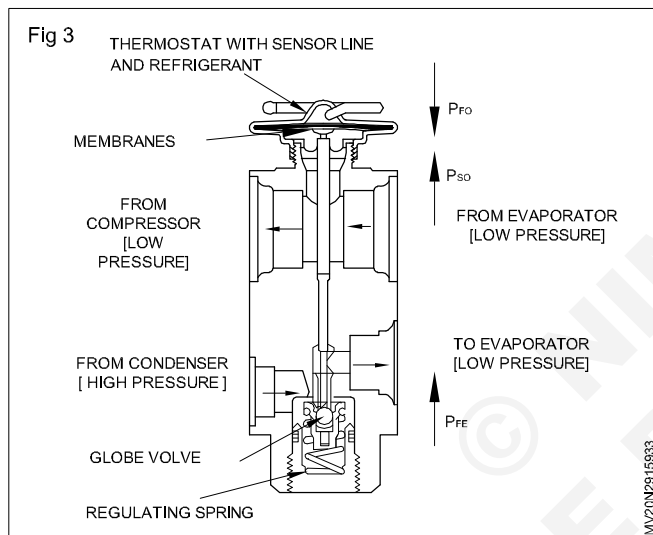
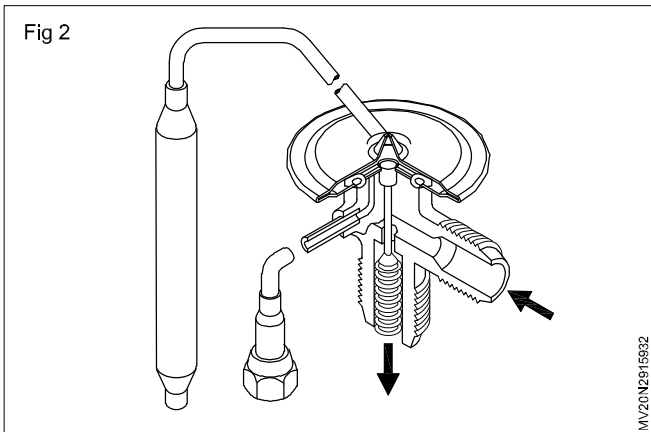
Function of TXV

Thermostatic expansion valve is a constant superheated valve it is effective in large capacity plant when provides external equalizer.

- 1 Controlled correct refrigerant flow at evaporator as per the load demand.
- 2 It modulate the refrigerant flow.

Construction of TXV

It consists of power element which may be bellows or the diaphragm. In side bellows and power elements preferably same refrigerant filled to transmit the power to open and close the valve orifice with in the valve body. Fig 2 and 3.

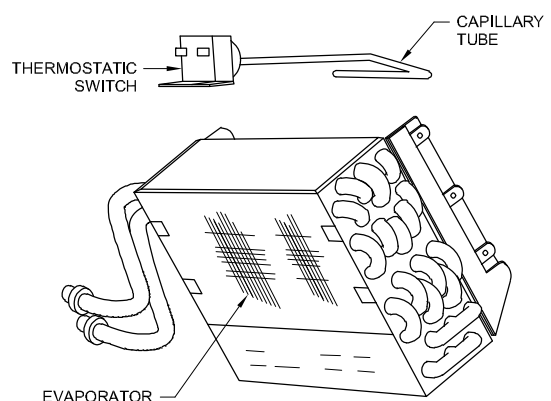
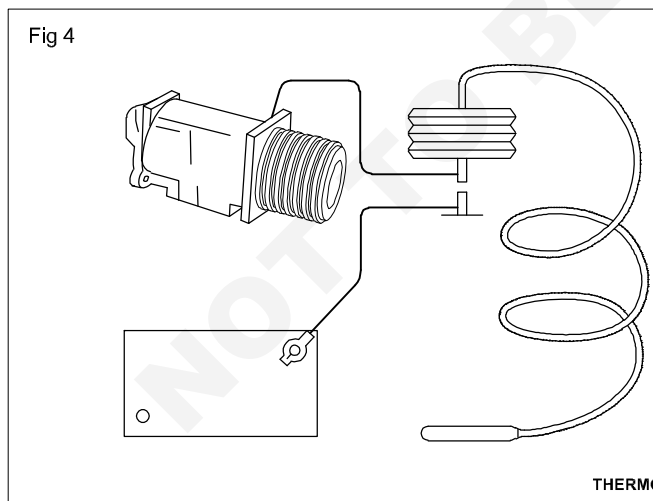


Expansion valves are not adjustable and are changed as a complete service unit.

Thermostatic switch purpose (Fig 4): The thermostatic switch is an evaporator temperature sensing switch. It is used with cycling clutch air conditioners. It has a temperature sensitive capillary tube which is located where it can respond to changes in the evaporator outlet temperature. The capillary tube reaction will either open or close the contacts inside the switch. This action, in turn, will cause the compressor clutch to be engaged or disengaged. The thermostatic switch is built to work within a preset temperature range. It has 2 temperature preset-one for OFF and one for ON. When temperature in the evaporator coils approaches freezing, the switch contacts open, disengage the compressor clutch and allow the evaporator to absorb more heat. The temperature then rises in the evaporator due to lack of refrigerant flow. At a present high temperature, the switch closes, engages the clutch and compressor operation resumes.

Some of these switches are adjustable so the ON and OFF points can be varied according to system and operator requirement.

State of refrigerant R134a: In the cycle in an air conditioner in addition to the vapour pressure curve, the cycle shows the change of state of the refrigerant under pressure and temperature in addition to the energy balance at which the refrigerant returns to its original state. The diagram is an excerpt from the state diagram of refrigerant R134a for a vehicle air conditioner. Different absolute values are possible in dependence upon the demand of a vehicle type for refrigeration capacity. The energy content is a key factor in the design of an air conditioner. It shows what energy is required (evaporator heat, condenser heat) to achieve the intended refrigeration capacity.



Physical data of R134a

Boiling point:-26.5°C

Freezing point:-101.6°C

Critical temperature:100.6°C

Critical pressure:4.056 MPa (40.56 bar).

Performance checking

Performance checking is very important after repair the unit because "in-car climate" has a direct bearing on the driver, fatigue-free driving and driving safety. A comfortable interior temperature is dependent upon the prevailing ambient temperature and upon sufficient air flow.

Low ambient temperature, e.g. -20°C

Higher interior temperature 28°C

High air flow rate: 8 kg per min.

Moderate ambient temperature, e.g. 10°C

Low interior temperature 21.5°C

Low air flow rate: 4 kg per min.

Air conditioning ECU

The air conditioning ECU has following controls

- Blower control
- Air outlet control
- Air inlet control
- Variable capacity compressor control
- Outer temperature indication control
- Rear window defogger control
- Micro dust and pollen filter control
- Self diagnosis

Blower control

Controls the blower motor in accordance with the airflow volume that has been calculated by the neural network control based on the input signals from various sensors.

Air outlet control

Automatically switches the outlets in accordance with the outlet mode ratio that has been calculated by the neural network control based on the input signals from various sensors.

Air inlet control

Automatically controls the air inlet control damper in accordance with the airflow volume that has been calculated by the neural network control.

Variable capacity compressor control

Controls the compressor to turn ON/OFF and the discharge capacity based on the signals from various sensors.

Outer temperature indication control

Based on the signals from the ambient temperature sensor, this control calculates the outside temperature, which then corrected in the air conditioning ECU and shown in the multi - information display in the combination meter and air conditioning panel.

Rear window defogger control

Switches the rear defogger on for 15 minutes when the rear defogger switch is switched on. If the switch is pressed while it is operating.

Micro dust and pollen filter control

Quickly removes pollen from the face areas of the driver and front passenger when the micro dust and pollen filter switch is pressed.

Self diagnosis

Checks the sensors in accordance with operation of air conditioning switches, then clock displays a DTC (Diagnosis Trouble Code) to indicate if there is a malfunction or not (sensor check function).

Drives the actuators through a predetermined sequence in accordance with the operation of the air conditioning switches (actuator check function).

Ambient air temperature sensor

Location

Fig 5 and 6 shows the ambient air temperature sensor is located behind the grill. It's typically located behind the grill or front bumper.

This is why they are sometimes damaged in a front end collision.

The ambient (ATC) or outside air temperature sensor is an (NTC) negative temperature coefficient sensor that informs the semiautomatic / automatic temperature control system of outside air temperature. The NTC sensor's resistance decreases as the outside air temperature increases. The computer uses this input, along with other in car temperature sensors to control temperature and blower speed. When there's a problem with this sensor, performance will suffer and the compressor's clutch may not engage.

Ambient air temperature sensor symptoms, like an inoperative clutch or input problems are diagnosed with a scan tool and a multimeter. Factory and many generic scan tools have the capability to activate certain components, the compressor clutch is one of them. If the clutch engages with the scan tool, there is likely a problem with one of the inputs. Verify any suspicious with a visual inspection of the sensor and its connector. Use a multimeter and verify manufacturer's specification, (220 - 240 ohms at 70° - 80° F), to test sensor for proper resistance.

Automotive air conditioning systems use NTC sensors to monitor air temperature. The in car temperature sensor (ICTS) is an NTC that monitors the air temperature of the passenger compartment. The ambient temperature sensor (ATS) monitors the air temperature outside of the vehicle. The EATC compares these values and makes output decisions based on the difference of these air temperatures.

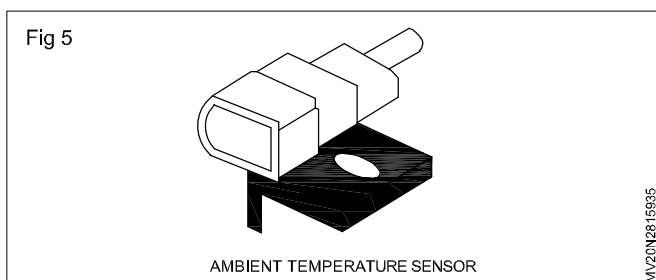
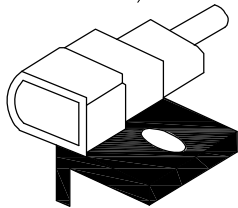
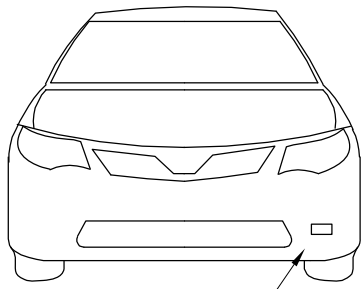
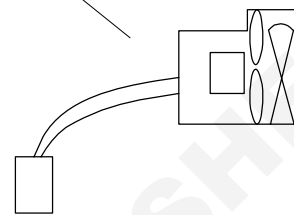
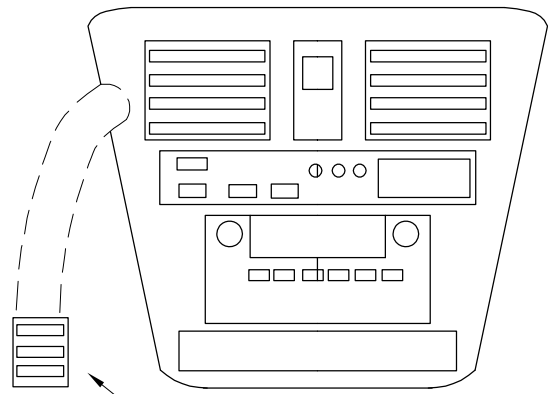


Fig 6



AMBIENT TEMPERATURE SENSOR



IN CAR TEMPERATURE SENSOR

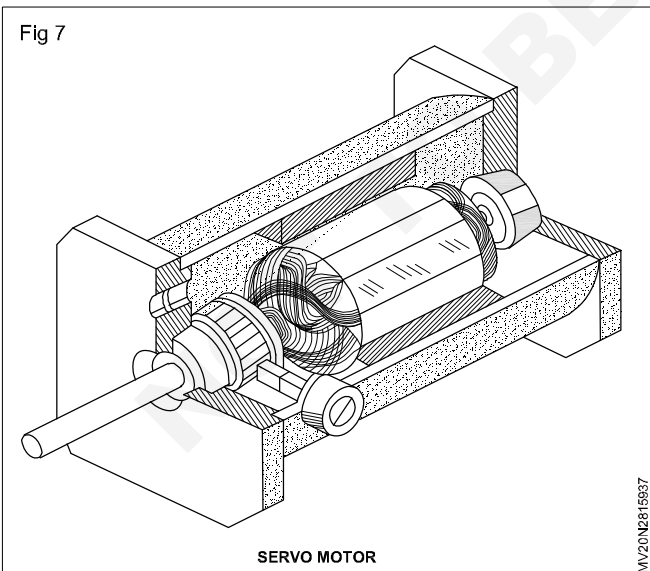
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Servo motor (Fig 7)

Servo implies an error sensing feedback control which is utilised to correct the performance of a system, generally sophisticated controller, often a dedicated module designed particularly for use with servo motors. DC motors that allows for precise control of angular position. they are actually DC motors while speed is slowly gears. The servo usually have a revolution cutoff from 90° to 180°. A few servo motors also have revolution or more. But servo motors do not rotate constantly. Their rotation is limited in between the fixed angles.

- A position sensing
- A control unit

The DC motor is connected with a gear mechanism which provides feedback to a position mostly a potentiometer. From the gear box, the output of the motor is delivered via servo spline to the servo arm servo motors, the gear is normally made up to plastic whereas for high power servos, the gear is made up of plastic whereas for high power servos, the gear is made up of metal.



SERVO MOTOR

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The servo motors is actually an assembly of four things:

- A normal DC motor
- A gear reduction unit

A servo motor consists of three wires- a black wire connected to ground, a white/yellow wire connected to control unit and a red wire connected to power supply.

The function of the servo motor is to receive a control signal that represents a desired output position of the servo shaft and apply power to its DC motor until its shaft turns to that position.

It uses the position sensing device to figure out the rotational position of the shaft, so it knows which way the motor must turn to move the shaft to the instructed position. The shaft commonly does not rotate freely around similar to a DC motor, however rather can just turn 200 degrees.

From the position of the rotor, a rotating magnetic field is created to efficiently generate torque. Current flows in the winding to create a rotating magnetic field. The shaft transmits the motor output power. The load is driven through the transfer mechanism. A high-function rare earth or other permanent magnet is positioned externally to the shaft. The optical encoder always watches the number of rotations and the position of the shaft.

Working of a Servo Motor

The Servo Motor basically consists of a DC Motor, a Gear system, a position sensor and a control circuit. The DC motors get powered from a battery and run at high speed and low torque. The Gear and shaft assembly connected to the DC motors lower this speed into sufficient speed and higher torque. The position sensor senses the position of the shaft from its definite position and feeds the information to the control circuit. The control circuit accordingly decodes the signals from the position sensor and compares the actual position of the motors with the desired position and accordingly controls the direction of rotation of the DC motor to get the required position. The Servo Motor generally requires DC supply of 4.8V to 6 V.

Controlling a Servo Motor

A servo motor is controlled by controlling its position using Pulse Width Modulation Technique. The width of the pulse applied to the motor is varied and send for a fixed amount of time.

The pulse width determines the angular position of the servo motor. For example a pulse width of 1 ms causes a angular position of 0 degrees, whereas a pulse width of 2 ms causes a angular width of 180 degrees.

Advantages

- If a heavy load is placed on the motor, the driver will increase the current to the motor coil as it attempts to rotate the motor. Basically, there is no out-of-step condition.
- High-speed operation is possible.

Disadvantages

- Since the servomotor tries to rotate according to the command pulses, but lags behind, it is not suitable for precision control of rotation.
- Higher cost.
- When stopped, the motor's rotor continues to move back and forth one pulse, so that it is not suitable if you need to prevent vibration.

Automatic Climate Control (Automatic A/C) in Cars (Fig 8)

The Automatic Climate Control system is the most advanced of all the air conditioning systems in cars. It effectively controls the cabin temperature and humidity levels. In Climate Control, you can set the cabin temperature of your choice. However, the system controls it regardless of the outside air temperature and humidity. Some advanced systems offer Dual-zone climate control with automatic re-circulation mode.

Automatic AC Control Panel

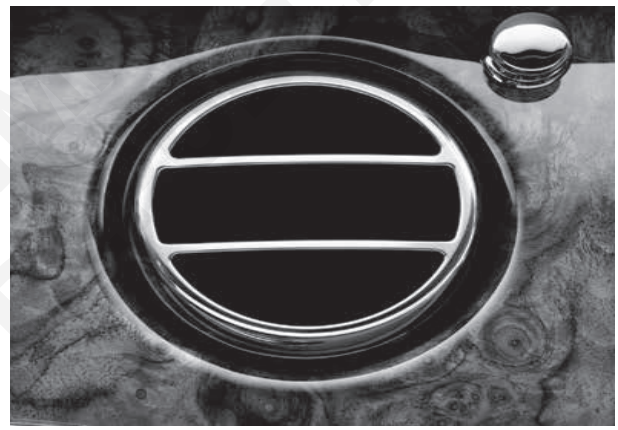
The automatic climate control system provides an individual feel-good climate for the occupants. It automatically controls the temperature, air-flow and air distribution inside the cabin. The climate control system also controls the fan speed and air circulation.

Fig 8



In some cases, the automatic climate control system provides electronic regulation of the air temperature, air flow rate, and air distribution. Some systems provide the defroster nozzles for the windscreen and side windows to eliminate the fogging effect. Nowadays, an Automatic Air-Conditioner (a step-down version of Automatic Climate Control) with touch screen panel for the ease of use. (Fig 9)

Fig 9



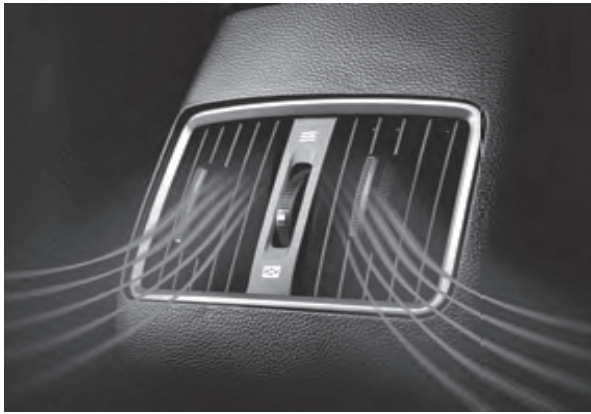
Features of Climate Control System

The automatic climate control system also measures the quality of the cabin air through various sensors. Some provide a separate climate control ECM to control various sensors/actuators such as cabin air quality sensor and humidity sensor. The driver and front passenger can control the temperature separately for themselves. You can also precisely adjust the temperature levels, direction and intensity of the airflow through a touch-screen.

The Climate Control system can also maintain the temperature depending on the sunlight and the quality of the intake air through key-coded settings. Manufacturers use custom acronyms to brand their automatic climate control systems in cars, uses the term THERMOTRONIC for the Automatic Climate Control systems fitted in its cars.

Some manufacturers take the climate control to a new level. The driver and front passenger can independently set the temperatures of their choice for their respective areas. The rear passengers can also get better air quality with rear ventilation and re-circulation option. (Fig 10)

Fig 10



Car also provides a separate control unit with a display for the rear a/c. It also comprises of additional air outlets in the air vents in the center console and a booster blower for the purpose. This ensures that the ideal temperature is maintained at the rear. Some manufacturers also provide 'roof a/c' or blowers in the roof in some bigger models to achieve the desired effect.

Automatic Climate Control in Luxury Cars

Some ultra-luxury cars offer the state-of-the-art 4-zone air-conditioning. It includes an additional rear cabin air-conditioning unit with controls at the front and rear for fan speed and temperature. (Fig 11)

Fig 11



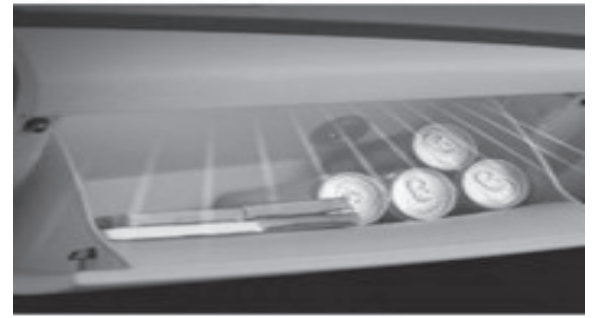
Rear Climate Control in Luxury cars (Fig 12):

Furthermore, some manufacturers, nowadays, provide an air-conditioned or cooled glove-box as a convenience option. So, it is getting popular among the budget car buyers. It keeps the water bottles/beverage cans cool. The cooled glove-box uses the cool air generated by the car's air conditioner to cool the stuff put in it. So, you can keep water-bottles and the cans of aerated drinks to cool them.

Tips for using the Climate Control effectively

- 1 Always keep the front grill clear of any obstructions for the proper functioning of the air conditioner.
- 2 Always keep the windows rolled up to maximize the efficiency of the A/c.
- 3 Keep the air conditioner in the recirculating mode when in use

Fig 12



- 4 Use the 'Fresh-Air' mode only when it is necessary.
- 5 To improve fuel efficiency, use the air-conditioner only when it is necessary.

Sensors

Infrared sensor

It measures the actual body temperatures temperatures of passengers.

Sunload sensors

Sunload sensors compensate for sunlight entering the vehicle through the glass.

Smog sensors

Smog sensors causes off the out side air inlet or other odours.

Interior temperature sensors

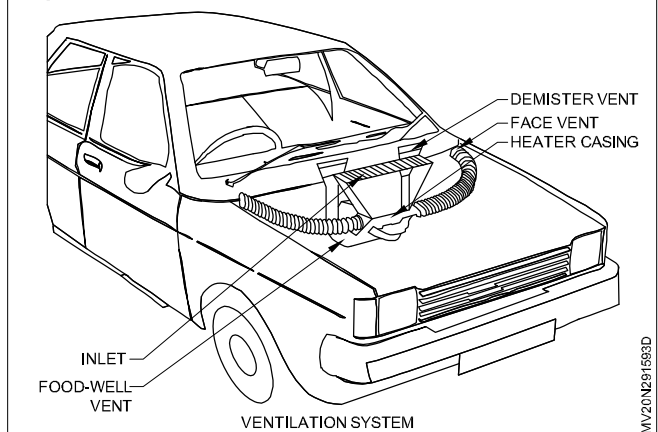
It is able to measure the interior temperature of any given moment and can send the data to the A/C system. The A/C system is able to adjust the temperature according to the wishes of the driver.

Ventilation system (Fig 13)

A typical heating system

Modern cars are designed to have a constant through-flow of fresh air that keeps the interior atmosphere pleasant even with all the windows shut. The incoming air can be heated by the engine to keep the windows clear of mist and the car interior at a chosen temperature.

Fig 13



Air flow: Air enters a large duct at the front of the car, placed so that when the car is moving the entry point is in a high-pressure area and air is forced in. From there it goes to the heater, which warms it if required. Another common entry point is through grilles on top of the bonnet.

Air enters the car interior through the front foot-wells and through vents on the dashboard. The vents can be adjusted to point at the faces of the front-seat occupants.

Some cars also have ducts to the rear-seat area.

Slots in the ledge at the bottom of the windscreen - and, in later cars, by the front side-windows - allow a stream of warm air to be blown on to the glass to prevent misting.

On later cars, all the entry points have flaps for opening and closing them as needed.

At the rear there are exit vents to the outside. They are in an area of low pressure when the car is moving, and so extract air, thus giving a constant through-flow.

The heater: In a water-cooled car, the heater casing contains a matrix - a small radiator - that takes hot water from the engine through a hose.

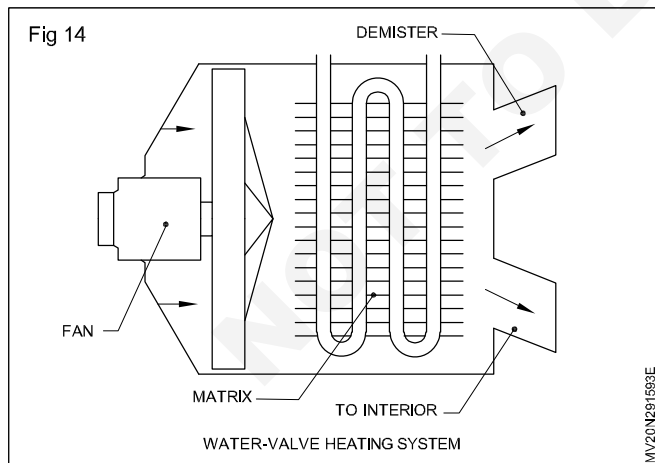
Incoming air goes through the water-heated matrix and is warmed.

There is also an electric fan, which can be switched on to blow air through the system when the car is stationary, or when extra ventilation is called for.

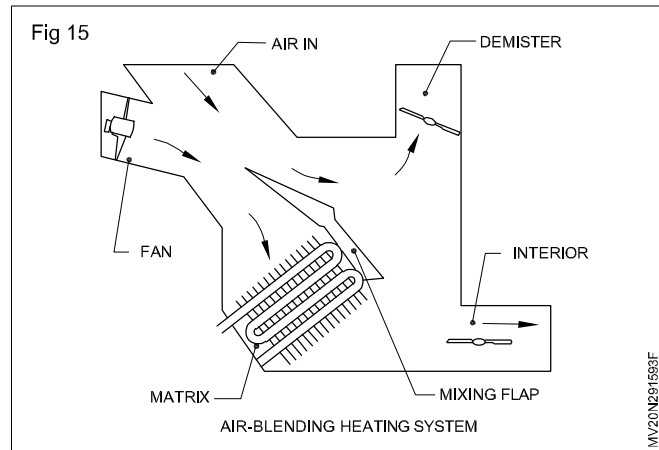
The fan can be adjusted to run at different speeds, according to need.

Two methods of heat control

Water-valve heating system (Fig 14): In a heater worked by a water valve, all the air goes through the matrix. The matrix temperature is controlled by regulating the amount of hot water going through it.



Air-blending heating system (Fig 15): In an air-blending heater the matrix is at a constant temperature - warm air from it is mixed with cool air as temperature-controlled flaps open and close.



The temperature to which the air is warmed is controlled by either a water valve or an air-blending system. The water-valve type is found mainly on earlier cars.

The temperature control on the dashboard works a tap which lets either more or less hot water through the matrix. The setting is slow to respond to change and difficult to regulate exactly.

The air-blending system has a matrix that is heated constantly. The temperature control opens and closes flaps that blend heated air with cold air from outside.

With either system there may be extra flaps to admit a separate supply of cold air to the face vents, even when the rest of the system is supplying warm air.

The air-control flaps inside the heater box may be moved mechanically by sliding knobs on the control panel, which are linked to the flaps by cables.

More expensive cars may have power-assisted controls worked by the vacuum in the inlet manifold acting on a diaphragm, as in a power-brake servo (See How the braking system works).

Air-cooled cars

In cars with air-cooled engines, air for the interior heater can be warmed by ducting it around fins on the hot exhaust manifold.

The warmed air is mixed to the right temperature by an air-blending system, including a heat-sensitive valve that keeps the temperature steady and at a comfortable level for the occupants.

If necessary, the air may be warmed further by an electrically ignited petrol-burning heat exchanger.

The heat exchanger also allows the heater to work with the engine off - unlike a water-heated type. The rest of the system, the way in which the heat is distributed, is like that of any other car.

The evaporative temperature sensor

It is a sensor or switch is a component commonly found on many road going vehicles. It is a part of the vehicle's A/C system and as it's name implies, detects and monitors the temperature of the A/C system evaporator.

Fan speed controller

Blower fan speed controller or low ambient fan controller is a control that is used to control the fan speed of the air cooled condenser in a heat pump direct expansion system heat pump is used in temperature.

When used as a heating mode in winter the indoor coil acts as a condense and outdoor coil as evaporator.

When the unit is set to cooling mode in summer, the indoor coil will operate as an evaporator and the out door coil as condenser.

This is accomplished by the use of 4 way valve that reverse the flow of the refrigerant in the system. Especially when the reversing valve is on the system will operates in cooling mode and when its off in heating mode.

Car has a ventilation system that provides a constant through flow of fresh air, heated by the engine to keep the windows clear of mist and the car interior at a chosen temperature.

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Traffic rules, signals & controls






Objectives: At the end of this lesson you shall be able to

- state the different type of regulatory traffic sign
- state the different type of cautionary traffic sign
- state the different type of information traffic sign
- state the different type of parking sign
- state the different type of prohibitory signs
- state the speed limit and vehicle control signs
- state the different type of compulsory direction control and other signs
- state the different type of arms traffic signal.







Traffic signs











Traffic signs are divided into 3 main categories














- Mandatory/Regulatory signs
- Cautionary signs
- Information signs

	Red circle instructs what should not be done.
	Blue circle instructs what should be done
	Triangle cautions
	Blue rectangle informs
	Restriction ends sign This sign indicated the point at which all prohibitions notified by prohibitory signs for moving of vehicles cease to apply.

Typical cautionary sign






	
Right/Left hand curve: This sign is used where the direction of curve changes. The sign warns the driver to reduce the speed and proceed caution along the road.	
	
Right/Left hair pin bend: This sign is used where the change in direction is so considerable that it amounts to reversal of direction. The symbol bends to right or left depending upon the road alignment.	
	
Right/Left reverse bend: This sign is used where the nature of the reverse bend is not obvious to approaching traffic and constitutes a hazard. If the first curve is to the right, a right reverse bend shall be used. If the first curve is to the left, a left reverse bend is used.	

	Narrow bridge: This sign is erected on roads in advance of bridges where the clear width between the kerbs or wheel guards is less than normal width or carriageway.
	Gap in Median: This sign is installed ahead of a gap in the median of a divided carriageway, other than an intersection.
	Narrow road: This sign is normally found in rural areas where a sudden reduction in width of pavement causes a danger to traffic.
	Road widens: This sign is normally found in rural areas where a sudden widening of road causes a danger to traffic, such as, a two-lane road suddenly widening to a dual carriageway.
	Cycle crossing: This sign is erected in advance of all uncontrolled cycle crossings.
	Pedestrian crossing: This sign is erected in advance of both approaches to uncontrolled pedestrian crossings.
	School: This sign is erected where school buildings or grounds are adjacent to the road where the traffic creates a hazard to children.
	Men at work: This sign is displayed only when men and machines are working on the road or adjacent to it or on overhead lines or poles. This sign is removed when the work is completed.
	Side road left/right: This sign is displayed in advance of the side road intersections where a large volume of entering traffic together with restricted sight distance is likely to constitute a hazard. The driver is warned of the existence of a junction.
	








		
Y-Intersection: These signs are displayed on the approach to a bifurcation on any road. This sign warns of the existence of a junction and no other indication given.		
		
Major road: These signs are displayed in advance of crossing with the major road, where a sufficiently large volume of traffic together with a sufficiently large volume of traffic together with restricted sight is likely to cause a hazard.		
		
Staggered Intersection: This sign is used to indicate junctions where the distance between two junctions is not more than 60 meters.		
	T Intersection: This sign is displayed in advance of T-junctions where the nature of inter-section is not obvious to approaching traffic. This sign is used to warn the driver of the existence of a junction.	
	Roundabout: This sign is used where it is necessary to indicate the approach to a roundabout.	
	Start of dual carriageway: This sign is displayed when a single carriageway ends into a dual carriageway.	
	End of dual carriageway: This sign is displayed when a dual carriageway is ending and a single carriageway is starting.	
		
Reduced carriageway: These signs caution the driver of the reduction in the width of the carriageway ahead. This is displayed on undivided carriageways when some portion of the carriageway is closed or reduced for repairs.		

	Two way operation: This sign is used to caution the driver of a changed pattern of traffic operation of the carriageway expected to carry traffic in one direction only.
	Cross Road: This sign is displayed in advance of the cross road where a sufficiently large volume of crossing or entering traffic with restricted sight distance is likely to constitute a hazard.
	Cattle: This sign is used where there is danger due to farm animals or cattle crossing on the road.
	Traffic diversion on dual carriageway: This sign warns the driver of the diversion of traffic from one carriageway to the other. It is used on dual carriageway when one carriageway is closed.
	Falling rocks: This sign is used wherever rocks are liable to fall on the road seasonally or throughout the year. The symbol may be reversed to show the side from which rockfall is expected.
	Ferry: This sign is used to warn the drivers about the existence of a ferry crossing across a river.
Lane closure: This sign cautions the driver of the closure of a portion of the carriageway on multilane highways.	
	Barrier: This sign is erected in advance of a gate controlling entry into a road. A definition plate with words "Slow barrier ahead" or "Toll Barrier Ahead" is also displayed on the sign.
	Loose gravel: This sign is used on section of a road on which gravel may be thrown up by fast moving vehicles.
	Overhead cable: This sign cautions driver of the presence of overhead power transmission lines.







	Quarry side or river bank: This sign is used to caution the driver of the presence of water by the side of the road and the impending danger.
	Rough Road: This sign is posted where the road is rough and the drivers are required to slow down their vehicles for safe travel.
	Runway: This sign is used to warn the drivers of the presence of runway ahead and possible movement of the aircrafts.
	Series of bends: This sign is used to installed to caution the driver of the presence of zig-zag for a long distance over the section of road ahead.
	Slippery road: This sign is used to installed to caution the driver of the presence of zig-zag for a long distance over the section of road ahead.
	Sudden side wind: This sign is used to caution the driver of the danger of side winds which endangers the lives of travelers. This sign is posted at places where such weather conditions exist.
	Traffic signals: This sign is used to caution the drivers of the presence of traffic signals.
Unguarded railway crossing: This sign is used on the approaches of level crossings where there are no gates or other barriers. An advance warning sign (with two bars) is installed at a distance of 200 meters and second sign (with one bar) is installed near the crossing.	
Guarded railway crossing: This sign is used to warn traffic on the approaches to guarded railway crossing. An advance warning sign (with two bars) is installed at a distance of 200 meters and second sign (with one bar) is installed near the crossing.	

	
<p>Steep ascent/Steep descent: This sign is displayed before a steep upgrade/downgrade that may constitute a hazard to traffic. A gradient of 10 percent and above is considered steep gradient.</p>	
	<p>Rumble strip: This sign is installed in advance of the rumble strips provided on the road to control the speed of the vehicle.</p>
	<p>Dangerous dip: This sign is used where a sharp dip in the profile of the road or a causeway is likely to cause considerable discomfort to traffic.</p>
	<p>Speed breaker: This sign warns the drivers of the presence of a speed breaker.</p>





Parking signs












	Parking Arrow mark side
	Parking both sides
	Scooter & motor cycle stand
	Cycle stand
	Taxi stand
	Auto rickshaw stand
	Cycle rickshaw stand




Speed limit and vehicle control signs

	<p>Speed limit: This sign is erected at the beginning of the section of the road or area covered by a speed restriction, with numerals indicating the speed limit in kilometers per hour.</p>
	<p>Width limit: This sign is used where entry of vehicles exceeding a particular width is prohibited.</p>
	<p>Height limit: This sign is erected in advance of an overhead structure where entry is prohibited for vehicles whose height exceeds a certain limit.</p>
	<p>Length limit: This sign is used where entry of vehicles is prohibited for vehicles whose laden weight exceeds a certain limits.</p>
	<p>Load limit: This is used where entry of vehicles is prohibited for vehicles whose laden weight exceeds a certain limits.</p>
	<p>Axle load limit: This sign is used where entry of vehicle is prohibited for vehicles whose gross load exceeds a certain limits.</p>



Prohibitory signs

	
<p>Straight prohibited or no entry: These signs are located at places where the vehicles are not allowed to enter. It is generally erected at the end of one-way-road to prohibit traffic entering the roadway in the wrong direction and also at each intersection along the one way road.</p>	
	
<p>One way sign: These signs are located at the entry to the one-way street and repeated at intermediate intersection on that street.</p>	






	Vehicles prohibited in both directions: This sign is used at the approach end of the roads where entry to all types of vehicular traffic is prohibited, especially in areas which have been designed as pedestrian malls.
	Horn prohibited: This sign is used on stretches of the road where sounding of horn is not allowed, near hospitals and in silence zones.
	Cycle prohibited: This sign is erected on each entry to the road where cycles are to be prohibited.
	Pedestrian prohibited: This sign is erected on each entry to the road where pedestrians are to be prohibited
	
Right/Left turn prohibited: These signs are used at places where vehicles are not allowed to make a turn to the right or left. The signs are also used at the intersections of one-way street to supplement the one-way sign.	
	U-U-turn prohibited: This sign is used at places where vehicles are forbidden to make a turn to the reverse direction of travel between the sign and next inter-section beyond it.
	Overtaking prohibited: This sign is erected at the beginning of such sections of highways where sight distance is restricted and overtaking will be dangerous.
	All motor vehicles prohibited: This sign is used at places where entry to all types of motor vehicles is prohibited.
	Trucks prohibited: This sign is erected on each entry to the road where hand carts are to be prohibited.
	Hand Card Prohibited: This sign is erected on each entry to the road where hand carts are to be prohibited.








	Bullock cart prohibited: This sign is erected on each entry to the road where bullock carts are to be prohibited.
	Tonga prohibited: This sign is erected on each entry to the road where tongas are to be prohibited.
	Bullock carts & hand carts prohibited: This sign is erected on each entry to the road where all types of slow moving vehicles except cycles are to be prohibited.

Stop and give way signs

	Stop sign: This sign is used on roadways where traffic is required to stop before entering a major road. The vehicle shall proceed past the stop before entering a major road. The vehicle shall proceed past the stop line only after ascertaining that this will not cause any damage to traffic on the main road.
	Give way sign: This sign is used to assign right-of-way to traffic on certain roadways and intersections, the intention being that the vehicles controlled by the sign must give way to the other traffic having the right of way.

Compulsory direction control and other signs

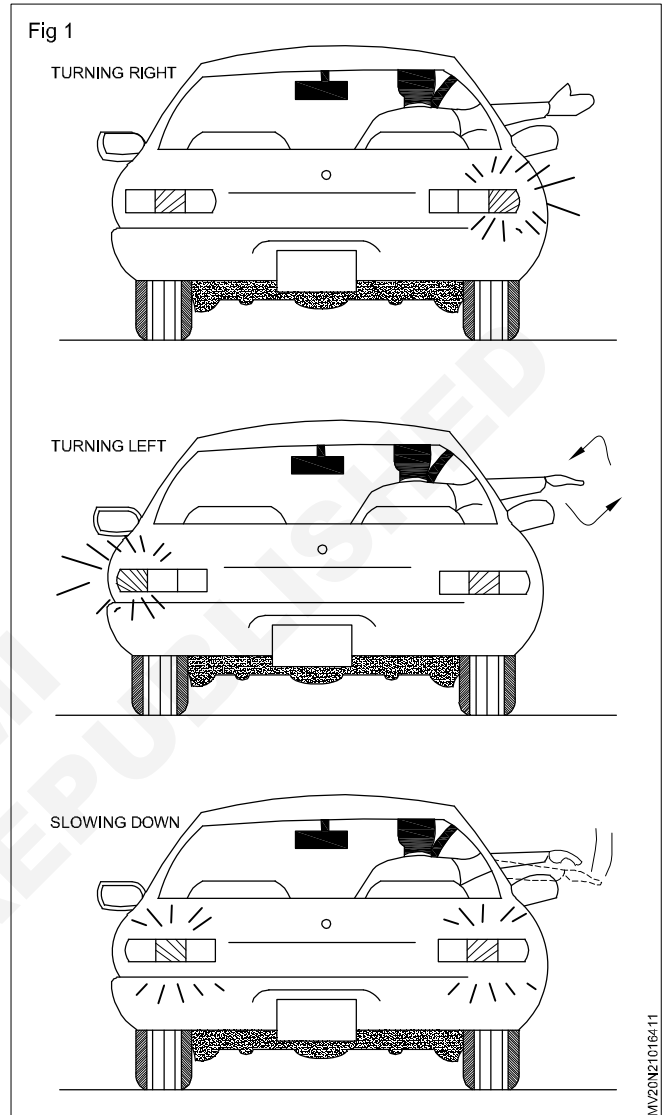
	
Compulsory turn left/right: These signs indicate the appropriate direction in which the vehicles are permitted to proceed.	
	
Compulsory ahead or turn left/right: These signs indicate the appropriate directions in which the vehicles are permitted to proceed. Vehicles are supposed to move either of the given two directions.	
	Compulsory ahead: This sign indicates that the vehicle is only permitted to proceed ahead.

	Compulsory keep left: This sign is most frequently used on bollards or islands and refuges in the middle of the carriageway and at the beginning of central reserves of dual carriageway. The vehicles are obliged to keep left only.
	Compulsory cycle rickshaw track: This sign means only cycles and rickshaws are allowed on this road / carriageway.
	Compulsory sound horn: This sign means the motor vehicles shall compulsorily sound horn at the location where the sign is place. This sign in mostly put at sharp curves on hill roads.
	Main road ahead: This sign means the vehicles can either go straight or turn left.
	Main road ahead: This sign means the vehicles can either go straight or turn right.
	Pedestrians only: This sign means only pedestrians are allowed and the traffic is not allowed on this road carriageway.
	Buses only: This sign means that only buses are allowed and other traffic is not allowed on this road/carriageway.

Arm signals

Arm signals may sometimes be needed, for example.

- When your direction indicators have stopped working
- when you want to make it clear to drivers of vehicles coming up fast behind you that you are slowing down or turning. (Fig 2)



Vehicle service informations

Objectives: At the end of this lesson you shall be able to

- **Vehicle information report**
 - **use scan tool data**
 - **use a shop manual**
 - **refer a labour guide**
 - **use a service information program.**
-

Vehicle Information Report

A Vehicle Information Report (VIR) provides information about a vehicle's registration history in Alberta only. The report is produced using the Vehicle Identification Number (VIN). A VIN is the unique serial number assigned to every vehicle by the manufacturer. An accurate and complete VIN must be provided to complete a VIR request.

The information contained in the VIR includes:

- The date and time of the report
- Vehicle description - year, make, model, style, colour, fuel type, odometer reading if available
- Vehicle status - active, salvage, non-repairable, unsafe, rebuilt, etc.
- Vehicle registration - date vehicle first entered on system, license plate classification, registration history date and location.
- Lien information - provides the number of liens and other related instruments which are registered in the province of Alberta and associated with the serial number (detailed information, such as the secured party and the party to whom the money is owed, can be determined by purchasing a separate Personal Property lien search)
- The VIR ONLY shows information from the Alberta Motor Vehicle System.

Locating vehicle information

RTO vehicle information about car or bike with owner's and vehicle details verify the vehicle registration details, on which person's name it is registered, it is not on your name change it immediately with VAHAN RTO INDIA anytime.

All RTO registration number verification at one place. This APP works for all vehicle types such as cars, M/C, trucks, autos etc.,

How to use this APP?

Type your name vehicles first 6 letters (e.g GJ01RM) in box.

Now type vehicle number in seen box (e.g 4321)

Click on "Check RC status" and get details.

Details available

- RTO vehicle registration data
- Vehicle owner name
- Vehicle age
- Vehicle registration authority
- Vehicle engine number
- Vehicle chassis number
- Vehicle maker model
- Vehicle class
- Vehicle fuel type
- Vehicle state and city
- Vehicle age and fitness certificate expiry date of Vahan.
- Insurance information of Vahan.
- Motor vehicle tax details

This APP is not affiliated, associated, sponsored, endorsed or approved by VAHAAN or RTO.

Obtaining and interpreting scan tool data

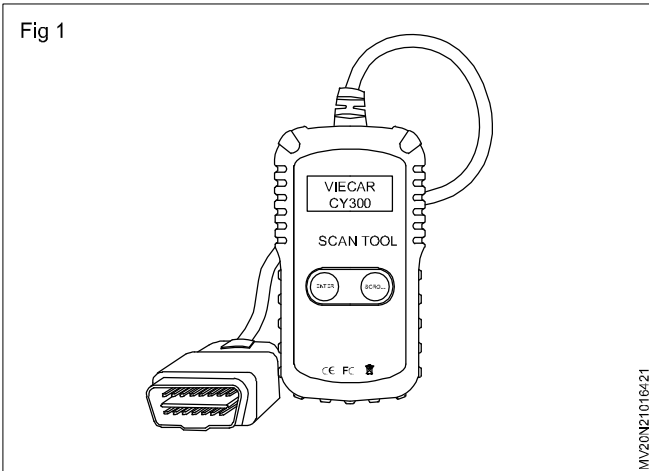
OBD I & II stands for on board diagnostics second generation superstanding that of OBD I, OBD II is a system that was mandated by the federal EPA and was developed by the society of automotive electronic diagnostics, so technicians can use the scan tool to test all makes and model of automobiles with our special adoptors or factory seamers. When the EPA mandated OBD II computer systems, they also mandated that all manufacturers would also mandated that anybody. Scanner could have access to the computer system with the proper software and adoptors. The information would have the same code terminology data parameters, freeze frame data and system monitors updated scanner software will usually have OBD II genericmode and allow you to retrieve codes, data, monitor information and freeze frame data without having to buy specific software for that manufacturer.

Standardisation of OBD computer system

- Universal diagnostic test connector or data link connector (OBD - II)
- Standard location for the DLC (dash board)
- Standardised list of generic diagnostic trouble code (DTC)

- The ability to clear all hard and pending codes with a scan tool
- The ability of the computer system to record a frame of data as a fault occurs within the computer system known as freeze, frame data

Obtain an OBD II scan tool (Fig 1)



- Locate the diagnostic link connector in your vehicle.
- Insert the scan tool connector or code reader into the DLC
- Enter your vehicle information
- Find the menu

Malfunction Indicator lamp (MIL)

The MIL is that terrible little light in the dash that indicates a problem with the car. There are a few variations, but they all indicate an error found by the OBD-II protocol.

Scan tool letter codes

First unit identifies the type of error code:

- **Pxxxx** for power train
- **Bxxxx** for body
- **Cxxxx** for chassis
- **Uxxxx** for class 2 network

Second digit shows whether the code is manufacturer unique or not:

- **x0xxx** for government - required code
- **x1xxx** for manufacturer - specific code

Third digit shows us what system the trouble code references:

- **xx1xx/xx2xx** show air and fuel measurements
- **xx3xx** shows ignition systems
- **xx4xx** shows emissions systems
- **xx5xx** references speed / idle control
- **xx6xx** deals with computer systems
- **xx7xx/xx8xx** involve the transmission
- **xx9xx** notates input/ output signals and controls

Digits four and five show the specific failure code:

- xxx00 to xxx99 - these are based on the systems defined in the third digit.

Learn the letter with code number

For example

- P 0XXX - Models
- P1XXX - Manufacturer
- P07XX - Transmission

Read engine fault code - P0301 - Misfire on No.1 cylinder.

Terminology

Before we get too much farther, let's make sure we understand all the keywords used in these protocols.

Engine/Electronic Control Unit (ECU)

The ECU can refer to a single module or a collection of modules. These are the brains of the vehicle. They monitor and control many functions of the car. These can be standard from the manufacturer, reprogrammable, or have the capability of being daisy-chained for multiple features. Tuning features on the ECU can allow the user to make the engine function at various performance levels and various economy levels. On new cars, these are all typically microcontrollers.

Some of the more common ECU types include:

- Engine Control Module (ECM) - This controls the actuators of the engine, affecting things like ignition timing, air to fuel ratios, and idle speeds.
- Vehicle Control Module (VCM) - Another module name that controls the engine and vehicle performance.
- Transmission Control Module (TCM) - This handles the transmission, including items like transmission fluid temperature, throttle position, and wheel speed.
- Powertrain Control Module (PCM) - Typically, a combination of an ECM and a TCM. This controls your powertrain.
- Electronic Brake Control Module (EBCM) - This controls and reads data from the anti-lock braking system (ABS).
- Body Control Module (BCM) - The module that controls vehicle body features, such as power windows, power seats, etc.

Diagnostic Trouble Code (DTC)

These codes are used to describe where an issue is occurring on the vehicle and are defined by SAE. These codes, can either be generic or unique to the vehicle manufacturer.

Using a Diagnostic Car Code Reader

Diagnose car problems with an auto code reader. Simply plug it into the car's computer system, then interpret the trouble code readout.

Plug your car code reader into the diagnostic link connector under the dash (engine off). Then start the vehicle and follow the auto code reading procedure in the instruction manual.

An engine code reader/scanner can help you make the drive/no drive decision and even help you fix the problem. It works by plugging into the car's computer system and displaying a "trouble code."

An engine code reader/scanner is worth buying if you're a fairly competent amateur mechanic who understands how an engine works. But it's not a silver bullet that will always tell you exactly what's wrong. An auto code reader give you a head start, but you'll still have to do some detective work before you start pulling and replacing parts (more on this later).

The least expensive auto code reader units are simple car code readers that burp up an alphanumeric trouble code but no information about what it means. You'll have to look up the code in a reference book or search the Internet. Midpriced units actually display the problem on the screen, like "P0115 Engine Coolant Temperature Circuit Malfunction." One model even accesses the Internet, so you can upload the trouble code to a Web site that has information on the most likely cause of the problem.

Here are three ways to get to the root of a problem without replacing good parts.

- 1 Go to the car code reader/scan tool manufacturer's Web site to see if it has information on your trouble code.
- 2 Take advantage of Internet forums. Just search for your car's model and add "forum" to the search term. Register for the site (usually free) and post your question, including your vehicle's year, mileage, code number and what you've done so far. You'll be surprised by the number and quality of responses you get.
- 3 Subscribe to an online shop manual. It will have not only all the carmaker's technical service bulletins listed but also the complete diagnostic procedure for your particular code. It will walk you through the testing procedure, telling you which wires to check and what voltages you should see. The services also include component locators to help you find the part in your vehicle, and wiring diagrams showing the connector position for each wire.

Required Tools for this Project

You'll need a code reader or scanner, along with a computer with internet access for interpreting the trouble codes.

Interpreting generic scan data

Generic scan data provides an excellent foundation for OBD II diagnostics. Recent enhancements have increased the value of this information when servicing newer vehicles.

One of the best places to start is with a factory scan tool.

Example:

The Mass Airflow (MAF) Sensor, if the system includes one, measures the amount of air flowing into the engine. The PCM uses this information to calculate the amount of fuel that should be delivered, to achieve the desired air/fuel mixture. The MAF sensor should be checked for accuracy in various rpm ranges, including wide-open throttle (WOT), and compared with the manufacturer's recommendations, volumetric efficiency and help with MAF diagnostics.

When checking MAF sensor readings, be sure to identify the unit of measurement. The scan tool may report the information in grams per second (gm/S) or pounds per minute (lb/min). For example, if the MAF sensor specification is 4 to 6 gm/S and your scan tool is reporting .6 lb/min, change from English units to metric units to obtain accurate readings. Some technicians replace the sensor, only to realize later that the scan tool was not set correctly. The scan tool manufacturer might display the parameter in both gm/S and lb/min to help avoid this confusion.

Oxygen Sensor Output Voltage B1S1, B2S1, B1S2, etc., are used by the PCM to control fuel mixture. Another use for the oxygen sensors is to detect catalytic converter degradation. The scan tool can be used to check basic sensor operation. Another way to test oxygen sensors is with a graphing scan tool, but you can still use the data grid if graphing is not available on your scanner. Most scan tools on the market now have some form of graphing capability.

The process for testing the sensors is simple: The sensor needs to exceed .8 volt and drop below .2 volt, and the transition from low to high and high to low should be quick. In most cases, a good snap throttle test will verify the sensor's ability to achieve the .8 and .2 voltage limits. If this method does not work, use a bottle of propane to manually richen the fuel mixture to check the oxygen sensor's maximum output. To check the low oxygen sensor range, simply create a lean condition and check the voltage. Checking oxygen sensor speed is where a graphing scan tool helps.

Note:The sensor should be tested with a lab scope to verify the diagnosis before you replace it.

Repair manuals

The automobile manufacturer are supplying workshop repair manuals for each type of vehicle produced them. The workshop manual gives more basic informations to skilled/ unskilled technicians to improve their technical knowledge.

Workshop repair manuals give details about the sequence operation of the vehicles each part it gives part number and dismantling and assembling procedures in details. Every one can understand it easily.

Shop manual

Workshop manual is used to refer to the individual vehicles and each component's part number reference.

Owner's manual

The owner's manual gives more information about a particular vehicle owner like vehicle service particulars, engine number, chassis number, vehicle model, year of manufacturing, vehicle class, vehicle fuel type, engine capacity.

Labour guide

Matters related to employment in India, primarily governed by the constitution of India, specific laws framed by the central and state governments, municipal laws, collective and individual agreements as well as judicial precedents. Some key legislation has been classified in the table below.

Key labour Acts	Details
Factories Act 1948	Provide for the health, safety, welfare, working hours and leave of workers in factories.
Shops of establishment Acts	To regulate payment of wages, terms of service, holidays, leaves, work conditions, hours of work, overtime etc.
Contract labour regulation Act - 1970	To regulate the engagement of contract labour by the principal employer
Industrial employment standing order	Where more than 100 employees in industry is required to regulate and codify conditions of service and obtain certification from the concerned regulator authority.
Trade union Act - 1926	To establish the rights, duties and obligations of trade unions and facilities their registration
Payment of wages Act - 1936	It regulates the payment of wages to certain classes of persons employed in the industry and provides for the responsibility for payment of wages, fixation of wage period, time and mode of payment of wages and permissible wage deduction.
Minimum wages Act - 1948	To stipulate minimum rates of wages that must be paid to skilled and unskilled labourers factors such as the industry, location and nature of work to be undertaken
Payment of bonus Act-1965	To obligate employers to pay bonus to employees and provide the principle and formula for the calculation of bonus
Equal remuneration Act - 1976	To provide for the payment of equal remuneration to men and women workers
Payment of gratuity Act - 1972	To provide for the payment of gratuity a retirement benefit paid upon classification employment
Workers compensation Act - 1923	To provide workmen and/ or their dependents some relief in case of accidents arising out of or during employment and causing either death or disablement
Employees provident fund and miscellaneous provisions Act - 1952	To provide for a scheme where in both the employer and the employee make an equal contribution into national fund.
Employees state insurance Act - 1948	To provide for a scheme where in the employer and employee must contribute a certain percentage of the monthly wages to the insurance corporation.

Introduction to electric vehicle technology

Objectives: At the end of this lesson you shall be able to

- state the electric vehicle technology.
- describe the comparison of electric vehicle with I.C Engine
- state the types of electric vehicle BEV, HEV, PHEV and FCEV
- state the architecture and working principle of electric vehicle.

Introduction to electric vehicle

In recent years, green house gas problem increases and also the gasoline fuel rate also increases days by day in India and global wide so that public also suffer financially due to this reason, automobile manufacture and new companies put their effort to convert the conventional vehicle into electric vehicle that provide reliable solution.

Electric vehicle is propelled with electric motors and draw power from on board electric source in an electric vehicle, it is more durable and mechanically simpler than gasoline vehicle. It gives more fuel efficiency that gasoline because it does not produce emission like internal combustion engine However, automobile industry is not completely moving towards pure electric vehicle production, because there is in herenk problem of existing batteries technology for storing the electric energy.

However now a days increasing the usage of hybrid and electric vehicle in our country and globalize.

Internal combustion engine vehicle : This type of vehicle uses Internal combustion engine and it has use fuel like petrol, gas, diesel which fuel combusts inside a combustion chamber with the help of an oxidizer and ignition by spark plug or compressed air heat.

Electric vehicle : This type of vehicle uses one or more electric motor for propulsion. Electric vehicles are the automobiles that are propelled by one or more electric motors using the energy stores in batteries.

Comparison between IC engine vehicle and electric vehicle. The following table highlights the points that differentiate and IC Engine vehicle from an electric vehicle

Point of comparison	Internal combustion engine vehicle	Electric vehicle
Source of power	The source of power for ICEV is different types of fuels such as diesel or petrol	Electricity obtained from charged batteries, ultra-capacitors, etc. is the source of power in electric vehicles.
Prime mover	Internal combustion engine (ICE) is the prime mover or powertrain.	Electric motor is the prime mover in the electric vehicles.
Specific energy	There is high specific energy of fuel	In electric vehicles, low specific energy of battery.
Power density	Fuels used in ICEV have high power density.	In power density of power source is low.
Impact on Environment	ICEV emits green-house gases which have adverse effect on environment.	EV does not have adverse effect on environment.
Travelling distance	ICEV can travel more than around 300 miles per fill.	EV travels less than around 100 miles per charge.
Refilling time	ICEV requires less refilling time (approx. less than 5 min)	EV has long charging time, about 0.5 to 8 hours.
Space & weight fuel tank	In ICEV, fuel tank takes less space and the weight of fuel is very less.	In EV, batter bank takes large. Also, the batteries are very heavy.
Maintenance & running costs	The maintenance and running costs of internal combustion engine vehicles are high.	The electric vehicles requires low running and maintenance costs.
Efficiency	The efficiency of IC engines is about 30%.	The electric motors used in electric vehicles have approximately 80% efficiency.

Point of comparison	Internal combustion engine vehicle	Electric vehicle
Noise production	IC engine vehicles produces noise	Electric vehicles have noise free operation
Recovery of braking energy	In case of IC engine vehicles, the braking energy cannot be recovered.	In case of EVs, the braking energy can be recovered by using regenerative braking.
Time required for maximum torque	IC engine vehicles require to pick up some speed to deliver maximum torque	Electric vehicles produce maximum torque instantly after starting of motor
Capital cost	IC engine vehicle have average initial cost	The initial cost of electric vehicles is high.
Power transmission	In IC engine vehicles, the system of power transmission from source to load is mechanical only.	Electric vehicles have both mechanical as well as electrical power transmission system.

Types of electric car : An Electric car is a vehicle that is fully or partially propelled by electric motors using energy stored in rechargeable batteries. Some electric vehicles run solely on battery power, others known as hybrids combine an electric motor with an internal combustion engine in various ways. Then there are fuel cell electric vehicles and even solar electric cars. There are different types of electric cars changed and developed continuously giving users and potential users choice. Now a days the world is increasingly familiar with the terms BEV, HEV PHEV and FCEV.

Electric cars common method. When pedal of the Electric car is pressed then the controller takes and regulates electrical energy from batteries and then inverts with the controller set tot the inverter then sends a certain amounts of electrical energy to the motor (according to the depth of pressure on the pedal)

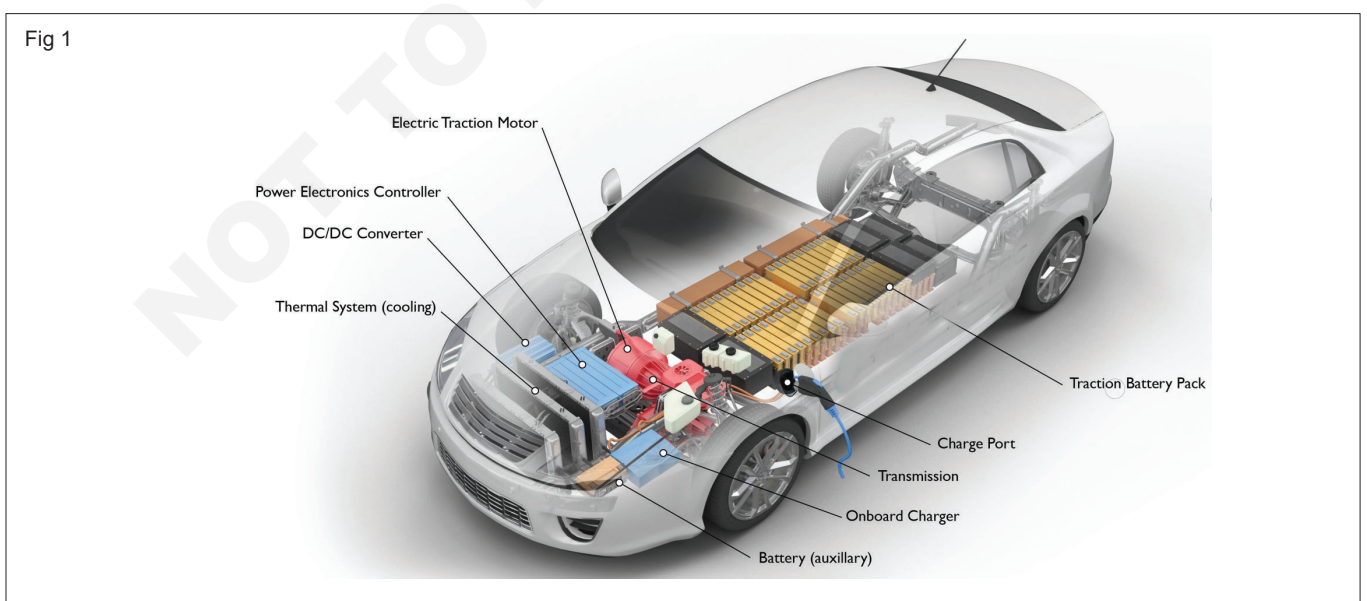
Types of electric cars : There are 4 types of electric car mainly used by card users. They are as follows :-

- Battery Electric Vehicle (BEV).

- Hybrid Electric Vehicle (GEV).
- Plug in Hybrid Electric Vehicle (PHEV).
- Fuel Cell Electric Vehicle (FCEV).

Battery Electric Vehicle (BEVs). The battery electric vehicles (BEVs) also referred to as all electric vehicles pure electric vehicle. It is run entirely on battery electricity only and have no gasoline engine. BEVs are moved by one or more electric motors powered by rechargeable batteries. Most of the BEV auto manufactures choose lithium due to their high power to weight ratio resulting in a more extended range in a smaller physical foot print the battery packs are charged using electricity delivered through an Electric vehicle charger. (Fig 1)

Unlike gasoline powered vehicles, BEVs are Zero emission vehicle that do not produce any harmful emission or air pollution. This vehicle driving range per battery charge of between 50 to 350 miles although new models with longer ranges being released over 500 to 900 miles.



Architecture and main components of BEVs

- Electric motor
- Inverter
- Battery
- Controller

Working principles of BEV

- Power is converted from the DC battery to AC for the electric motor
- The acceleration pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor
- The motor connects and turns the wheels through a cog.
- When the brakes are pressed or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery.

Hybrid Electric Vehicles (HEVs):

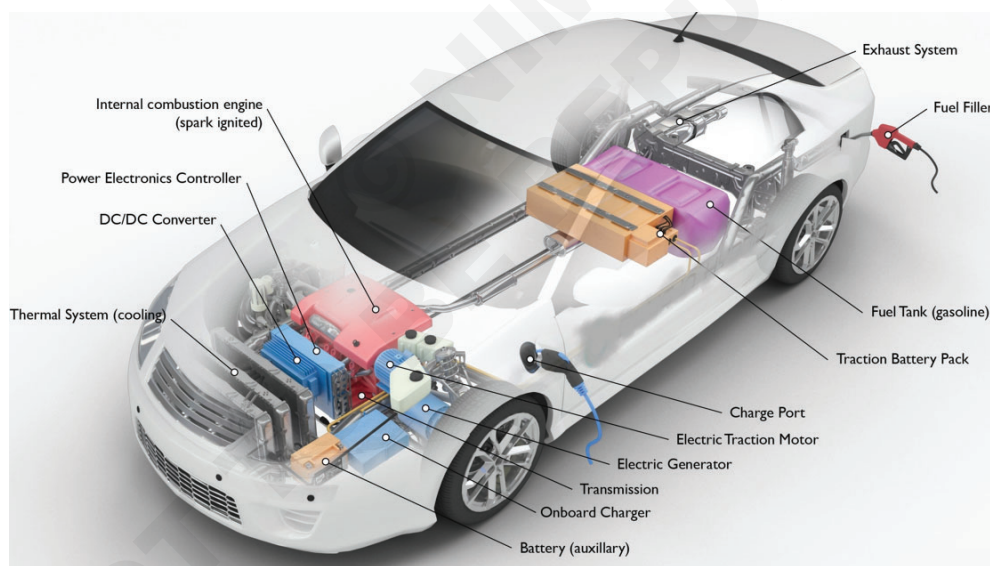
Hybrid Electric Vehicles (HEVs), sometimes referred to as 'self-charging hybrids', use both an internal combustion engine and an electric motor, which uses electricity stored in a battery pack. The main difference

between a PHEV and an HEV is that you cannot plug an HEV into an EV charger to charge the battery. Instead, the onboard battery pack is charged via the engine and regenerative braking. The additional power generated by the electric motor may allow for the vehicle to have a smaller engine. The battery pack can work as an auxiliary battery for the car, helping to reduce idling when stopped; this results in better fuel economy and lower emissions when compared to a conventional engine car. Toyota was one of the pioneers in introducing and popularizing Hybrid Electric Vehicles with the Toyota Prius.

There are different types of HEVs, they include :

- **Mild Hybrid Electric Vehicles (MHEVs)** - Also referred to as 'Micro Hybrids,' 'Power Assist Hybrids' and 'Battery Assisted Hybrid Electric Vehicles (BAHEVs)'. It uses the battery pack and electric motor to help power the vehicle and enables the engine to be shut off when the car has stopped. MHEVs cannot drive the vehicle on electricity alone and are not as fuel-efficient as a full hybrid.
- **Full Hybrid Electric Vehicles (FHEVs)** - Full Hybrids have larger capacity battery packs and more powerful electric motors than mild hybrids and can travel short distances at low speeds on battery power. (Fig 2)

Fig 2



Architecture and Main Components of HEV

Components of HEV

- Engine
- Electric motor
- Battery pack with controller & inverter
- Fuel Tank
- Control module

Working Principles of HEV

- Has a fuel tank that supplies gas to the engine like a regular car

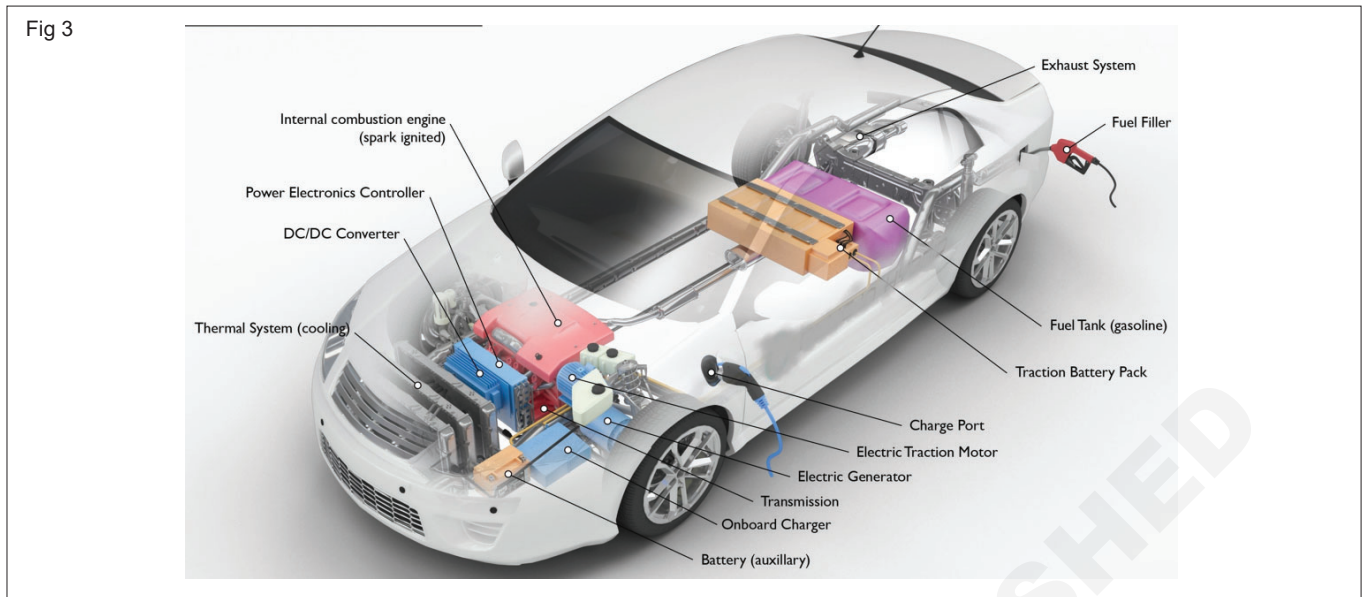
- It also has a set of batteries that run an electric motor
- Both the engine and electric motor can turn the transmission at the same time.

Plug-in Hybrid Electric Vehicle (PHEVs):

Plug-in hybrids Electric Vehicles (PHEVs) use batteries to power an electric motor and incorporate an Internal Combustion Engine (ICE) that can recharge the batteries to enable longer driving ranges. A PHEV typically runs on electricity stored in the battery until nearly depleted generally around 50-90 Kms depending on the vehicle model and battery size and capacity. Then the car automatically switches over to use the ICE and can travel

several hundred Kms on a tank of fuel. This can dramatically reduce fuel use and emissions especially on short journeys. When no electricity is available, a plug-

in hybrid can run on fuel alone all types of PHEV batteries can be charged by a level-1 and level-2 type Electric Vehicle charger. (Fig 3)



Architecture and main components of PHEV

Components of PHEV

- Electric motor
- Engine
- Inverter
- Battery
- Fuel tank
- Control module
- Battery Charger (if onboard model)

Working Principles of PHEV

PHEVs typically start up in all electric mode and operate on electricity until their battery pack is depleted. Some models shift to hybrid mode when they reach highway cruising speed, generally above 60 or 70 miles per hour. Once the battery is empty, the engine takes over and the vehicle operates as a conventional, non-plug-in hybrid.

In addition to plugging into an outside electric power source, PHEV batteries can be charged by an internal combustion engine or regenerative braking. During braking, the electric motor acts as a generator, using the energy to charge battery. The electric motor supplements the engine's power; as a result smaller engines can be used, increasing the car's fuel efficiency without compromising performance.

Fuel Cell Electric Vehicles (FCEVs)

Fuel Cell Electric Vehicles (FCEVs) create zero tailpipe emissions powered by hydrogen. An FCEV uses a similar system as a Battery Electric Vehicle to run the vehicle. In the case of an FCEV, the energy is stored as hydrogen

and then converted into electricity by the fuel cell to propel the vehicle. Fuel Cell Electric Vehicles have a gas tank used to store the pure hydrogen; the tank can be fuelled up in just a few minutes, similar to how conventional ICE vehicles are filled up today.

FCEVs can reach around 450 Kms on one tank of pure hydrogen. They also utilize regenerative braking technology and capture energy lost during braking, which is stored in a battery pack. There are a limited number of production FCEVs available to the public, and as of today, the refueling infrastructure isn't anywhere near where it needs to be to support a mass rollout of FCEVs.

Architecture and Main Components of FCEV

Components of FCEV

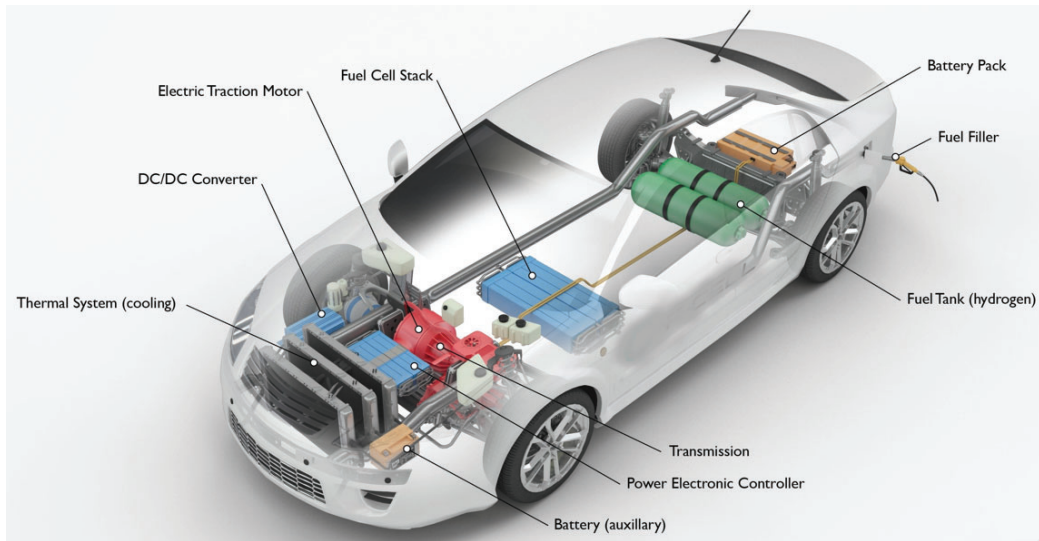
- Electric motor
- Fuel-Cell Stack
- Hydrogen storage tank
- Battery with converter and controller

Working principles of FCEV (Fig 4)

Fuel cell cars are powered by compressed hydrogen gas tank feeds into an onboard fuel cell stack that does not burn the gas, but instead transforms the fuels chemical energy into electrical energy. This electricity then power the cars electric motors. Tailpipe emissions are zero, and the only waste produced is pure water the construction of the fuel cell is similar to a battery.

A fuel, such as hydrogen is fed to the anode and air is fed to the cathode in a hydrogen fuel cell a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through and external circuits creating a flow of electricity.

Fig 4



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Electric Vehicle of major components and their functions

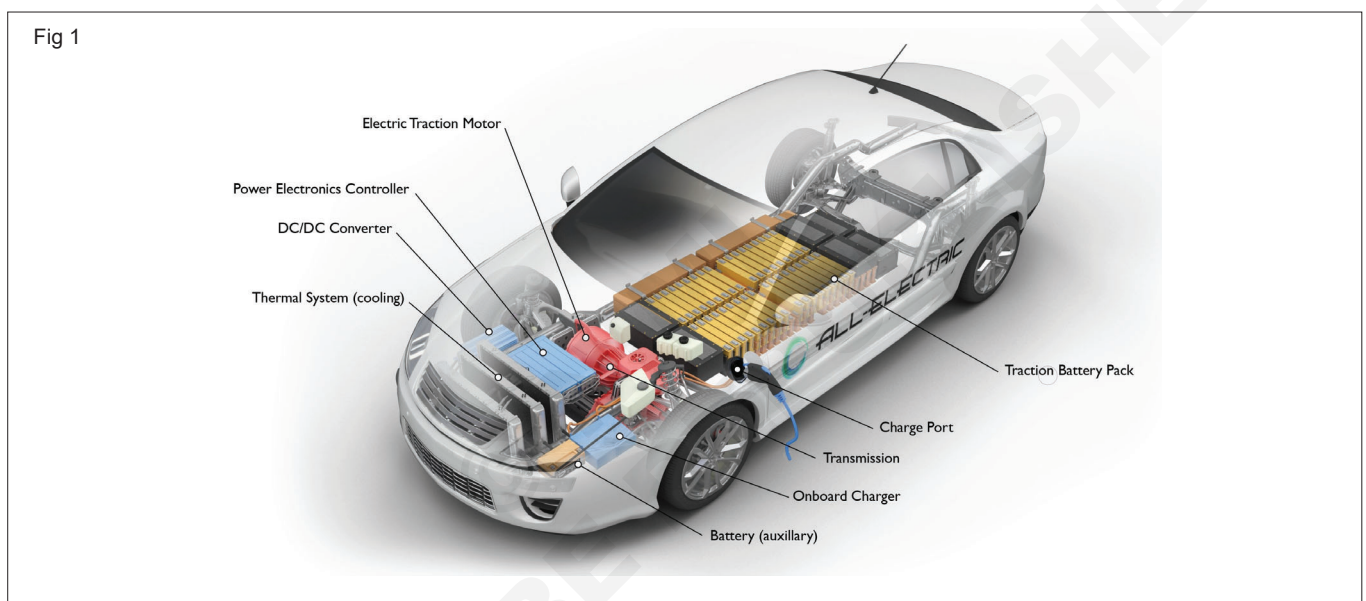
Objectives: At the end of this lesson you shall be able to

- state the major components of electric vehicle and their functions
- state the Basic motors of electric vehicle
- describe the EV motor selection, sizing and electric transmission
- state the EV motor characteristic of motor and calculation for motor effort
- state the electric vehicle drive systems,
- state the EV battery management systems.

Introduction

Electric vehicle consists of many components. This lesson will discuss various common main electric vehicle components or parts and their functions. (such as traction

batteries, inverters, traction motors on board chargers and controllers. The different types of electric vehicle components determines how the components are consist and work in a electric vehicle. (Fig 1)



Method of electric vehicles move

EV's are like an automatic car. They have a forward and reverse mode. When you place the vehicle in gear and press on the accelerator pedal these things happen:

- Power is converted from the DC battery to AC for the electric motor
- The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor
- The motor connects and turns the wheels through a cog
- When the brakes are pressed or the car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery

Main components of electric vehicle

- Traction battery pack
- DC-DC Converter

- Electric Motor
- Power Inverter
- Charge Port
- On board charger
- Controller
- Auxiliary batteries
- Thermal System (cooling sys for battery)
- Power transmission motor to wheel

Traction battery pack (Fig 2)

Traction battery pack is also known as Electric Vehicle Battery (EVB). Electric vehicle batteries undergo cycles of discharge that occur when electric vehicle is driving and charge when the car's plugged in repeating this process over time affects the amount of charge the battery can hold. This decrease the range and time heeded between each journey to charge. EVs don't use a single battery like a phone, use instead of a pack battery cells working together, whether cars charging up

electricity is used to make chemical changes inside its batteries. When its on order these changes reversed to produce electricity the battery connects to one or more electric motors which they drive the vehicle wheels. When the accelerator the car instantly feeds power to the motor which consume the energy stores in the batteries. The battery acts as an electrical storage system. it stores energy in the form DC current. The range will be higher with increasing KW of the battery. The life and operation of the battery depends on its

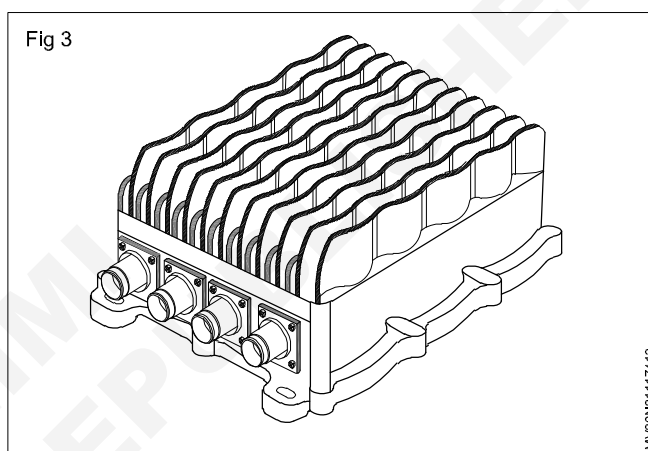
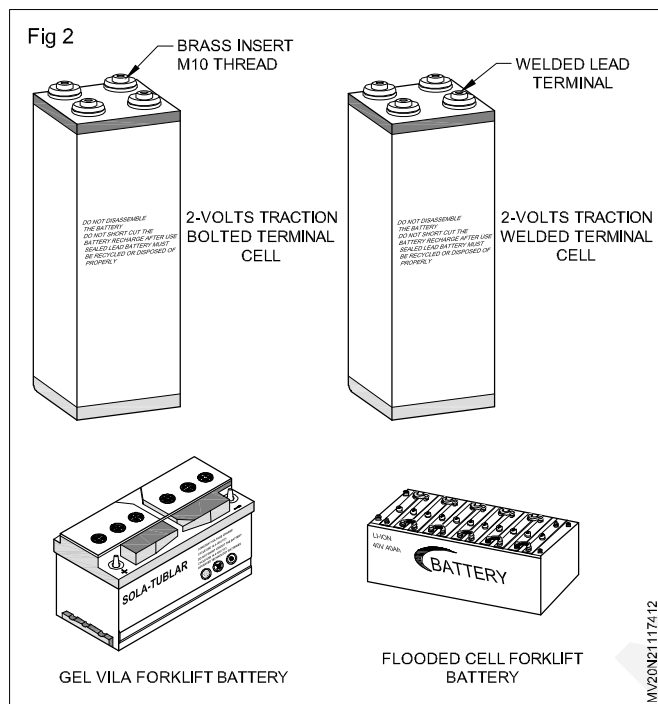
designs. The life time of a traction battery pack is estimated to be around 3,50,000 Kms. Most manufactures have a 5 to 15 years warranty on their battery. The current prediction is that an electric car battery will last 10-20 years before they need to be replaced.

There are different types of batteries too. Let's compare the types on some basic parameters related to batteries.

Lithium-ion batteries are used commonly used because they are reliable, easy to use, cheaper, energy-efficient.

DC-DC converter (Fig 3)

The traction battery pack delivers a constant voltage. The DC-DC converter distributes the power that comes from battery to the lower voltage DC power needed to run the electric vehicle accessories and it also provides the voltage required to recharge the auxiliary battery.



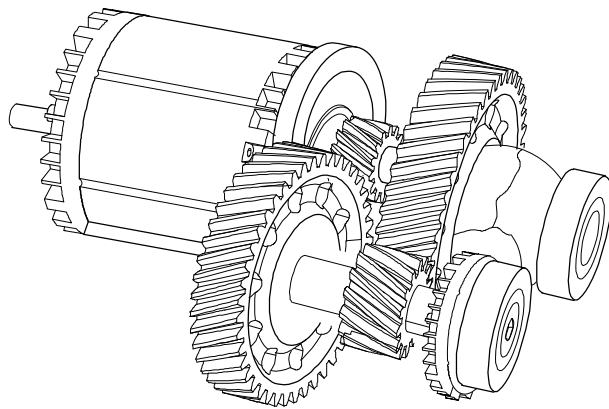
Parameters	Lithium-ion	Nickel-metal	Lead-acid	Ultra capacitors
Low Cost	√	X	√	X
Energy efficient	√	√	√	√
Temp Performance	√	X	X	√
Low Weight	√	√	√	√
Life Cycle	√	X	√	X

Electric motor (Fig 4): Electric traction motor is the main component of an electric vehicle. The motor converts the electrical energy into kinetic energy. This energy rotates the wheels. Electric motor is the main component that differentiates and electric vehicle from conventional vehicle. An important feature of an electric motor is the regenerative braking mechanism. This mechanism slows down the vehicle by converting its kinetic energy into another form and storing it for future use. There are basically two types of motors DC and AC motors. In general the BLDC electric motor is used

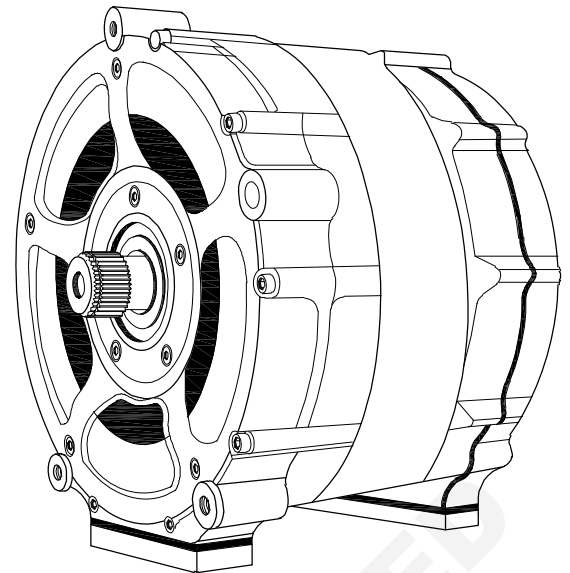
(brush less motor). Some hybrid electric vehicle use a type of generator motor that performs the function of propulsion and regeneration.

Power inverter (Fig 5): The power inverter converts DC power from the batteries to AC power. it also converts the AC current generated during regeneration braking into DC current. Power inverter further used to recharge the batteries. This type of inverter used in some electric vehicle models is the bi-directional.

Fig 4



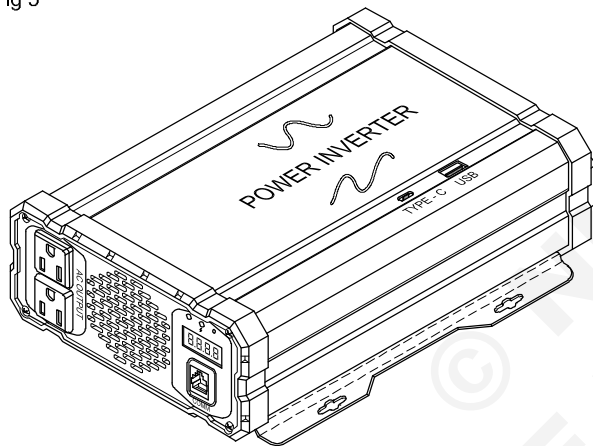
(a)



(b)

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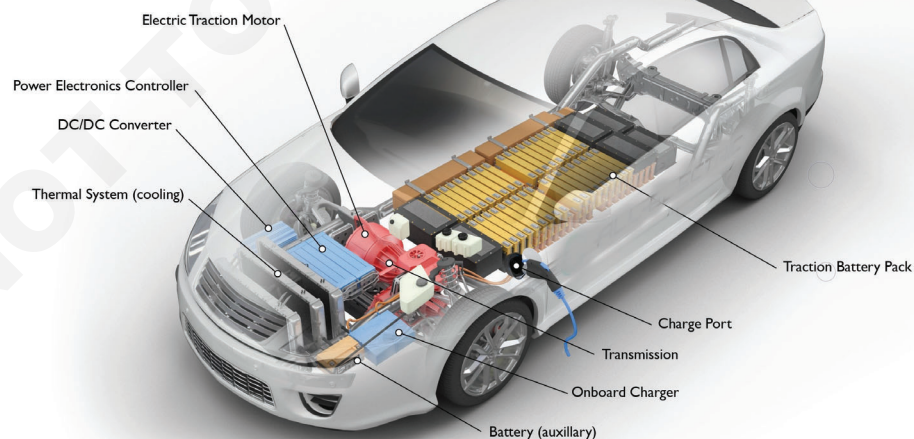
Fig 5



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Charge port (Fig 6): Electric vehicle charge port connects the electric vehicle to an external incoming AC electricity supplies via vehicle charge port and converts it to DC power for charging the traction battery pack it also communicates with the charging equipment and monitors battery characteristics such as voltage current temperature and state of charge while charging the battery pack. The charge port is sometimes located in the front or rear park of the vehicle

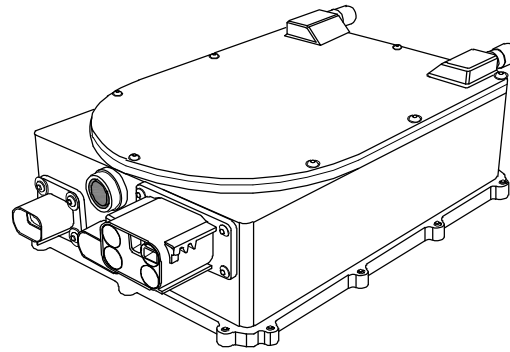
Fig 6



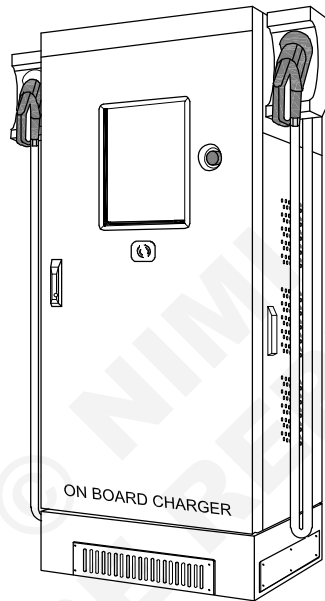
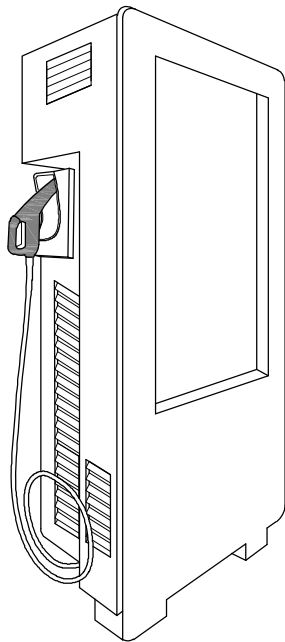
ON board charger (Fig 7): ON board charger takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery pack it also communicates with the charging equipment

and monitors battery characteristics such as voltage, current, temperature and state of battery charge which charging the battery pack. The on board charger is located and installed inside the car.

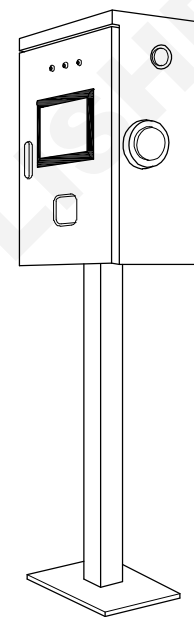
Fig 7



(a)



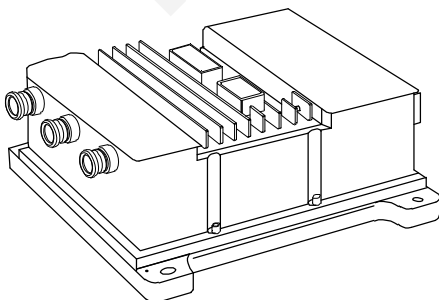
(b)



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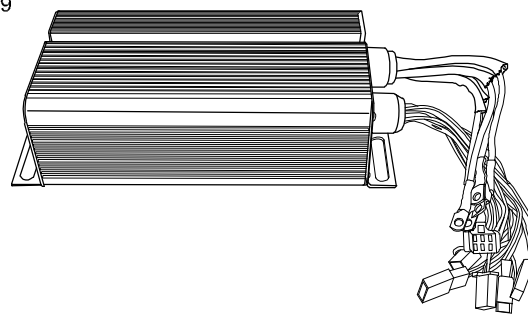
Controller (Figure 8&9): This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and torque it production. While the controller itself gets the main input from the car pedal . The pedal getting will determine the frequency variation or voltage variation that will enter the motor and at the same time determine the car's speed. Controller is determine how electric car work.

Fig 8



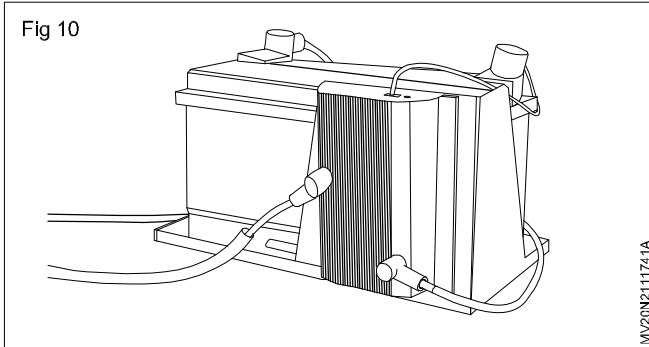
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Fig 9



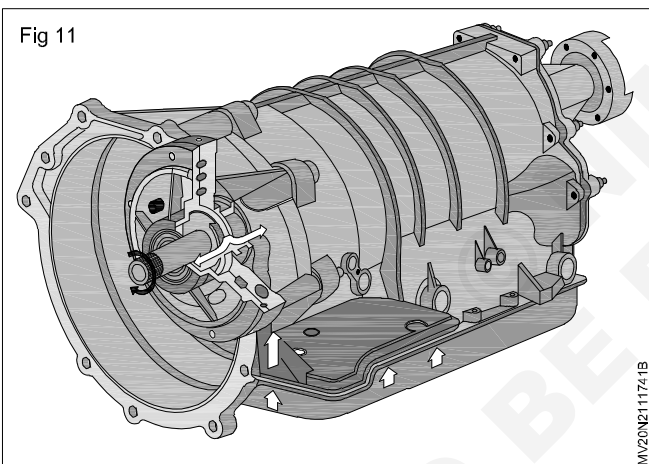
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Auxiliary batteries (Fig 10): Auxiliary batteries are the source of electrical energy for the accessories in electric vehicles. In the absence of the main battery, the auxiliary batteries will continue to charge the car. It prevents the voltage drop, produced during engine start from affecting the electrical system.



Thermal system (Cooling): This system maintains a power operating temperature range of an electric vehicle such as electric motor, power electronics and other components it functions during charging as well as obtain maximum performance it uses a combination of thermo electric cooling forces air cooling and liquid cooling.

Electric vehicle transmission (Fig 11): This vehicle transmission used to transfer the mechanical power from the electric traction motor to the drive wheels, through gear box. The advantage of electric vehicle is that they do not require multi-speed transmissions. The transmissions efficiency should be high to avoid power loss.



Basic function of electric motor: The main function of motor is to convert supplied electric energy current into mechanical energy. Brushless DC motor is much focused for many motor manufactures this type of motor is more effective to term of system cost, size higher in efficiency, excellent controllability and also power savings than other motors. AEV is propelled with electric motors and draw power from on board electric source is an electric vehicle.

Motor selection for electric vehicle: Selecting the right electric motor to fit a particular vehicle is not always straight forward. There are so many variables to consider that it can be difficult to know where to start given the price of batteries and electric motors in order to find the most economical solutions and power train that will full required vehicle performance as close as possible. Basically you need to determine the most demanding requirements of a vehicle as well as evaluate how various road conditions will in pack performance of the power train.

Keep in mind the following points before select the electric vehicle motor.

- **Vehicle characteristics:** The properties of the vehicle such as size, weight, overload and aerodynamic are curial vehicle characteristics that will determine the vehicle speed, torque and power requirements of the electric motor.
- **Driving cycles:** How is the vehicle being used is also very important vehicle will be driven as long distance with many stops or few stops.
- **Vehicle Configuration** is the vehicle hybrid or full electric
- **Maximum speed of the vehicle:** The electric vehicle is the targeted maximum speed of the vehicle. The electric vehicle speed is depend on gear box ration available and differential ration and rolling radius of the wheel.
- **Maximum torque:** Maximum torque enables the vehicle to start in given slope, highest grade the vehicle will need to ascend.
- **Maximum power:** Select the motor to full fill the need of your electrical vehicle carrying the load, road condition, torque and maximum power need to perform the vehicle function.

Battery capacity: The battery capacity is typically calculated using a simulator to go through a reference cycle typical of the usage of the vehicle. The simulator can output the consumption of the vehicle in Kwh/Km from that value, the capacity of the battery can be calculated by multiplying it with the desired range.

Battery voltage: The battery voltage is dependent on the size of the vehicle. As the battery voltage increases the current output is lowered. so in the cases where the vehicle continuous power is high like in bigger vehicles. To keep the size of the conductors at a manageable level by increasing the battery voltage.

Gearbox: The high torque/low speed of the motor allows it to directly interface with standard axis differentials with out the need for an intermediate gearbox. While improving system reliability and reducing overall maintenance costs, removing the transmission in an electric vehicle also increases the power trains efficiency considerably, allowing optimal use of the energy stored in the battery pack.

Cost:Select the motor by cost and their pros and cons and their relative usage in electric vehicles.

Signing and characteristic of EV Motor. The electric motor has only two basic main parts rotor and stator. The rotor is rotating part, which carry permanent magnet and their stator is stationary part and containing stator winding the structure of stator is similar to the induction motor it is made up of steel lamination with axially cut for winding.

Motor size: Motor sizing refers to the process of picking the correct motor for a given load. It is important to size a motor correctly because if a motor is too small for an application it may not have sufficient torque to start the load and run it up to the correct vehicle speed.

Motor coil burns, higher current will also lead to higher alternate current and smaller volume. Motor speed unit an increase in motor speed the required torque to get the same output power reduces and hence the volume and weight of the motor will reduce, power the torque required is reduced by 50%. There are three factors to calculate when sizing a motor moments of inertia, torque and speed.

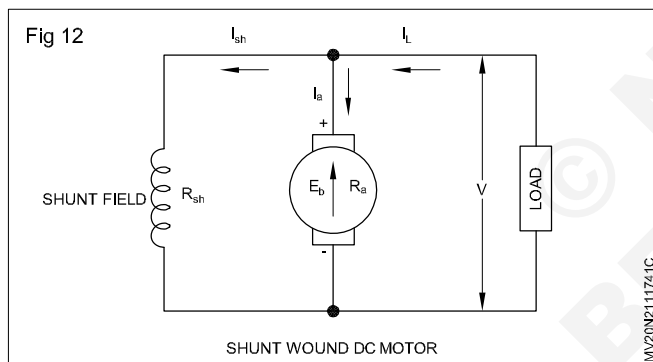
Types of DC motor: There are two types of DC motors

- separately excited DC motor.
- self excited DC motor.

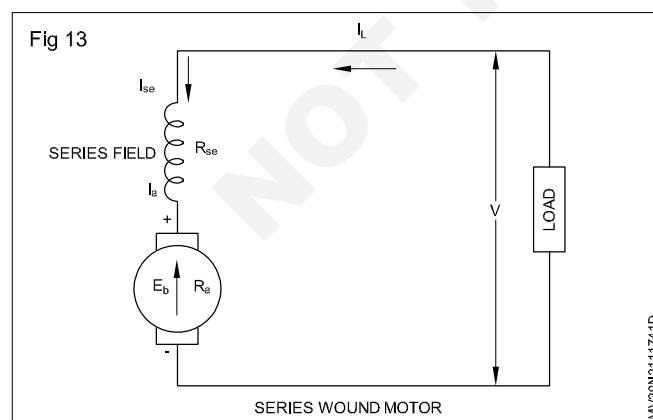
Separately excited DC motor has two voltage sources to supply the armature and field windings separately

The self excited DC motor the other way only has one voltage source to supply both armatures and field windings this type can be divided further into three types.

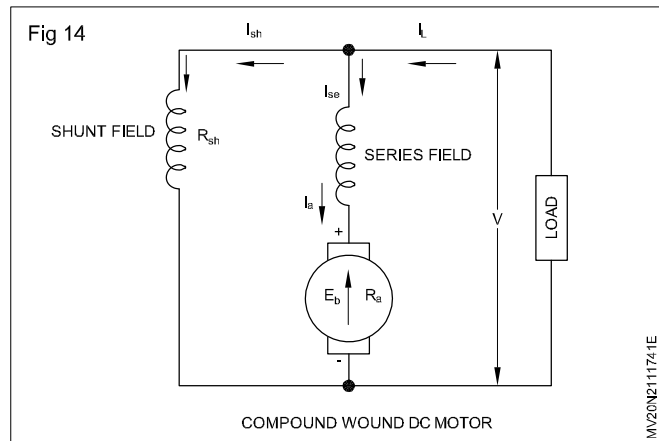
- **Shunt winding DC motor:** In a shunt wound motor the field winding is connected parallel to the armature (Fig 12)



- **Series winding DC motor (Fig 13):** In a series wound DC motor, the field winding is connected in series with the armature winding.



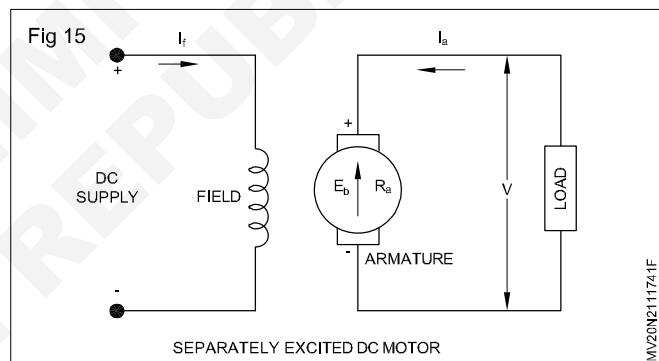
- **Compound winding DC motor (Fig 14):** DC motors having both shunt and series field winding is known as Compound DC motor, as shown in the figure. The compound motor is further divided into:



- Cumulative Compound Motor
- Differential Compound Motor

In a cumulative compound motor, the magnetic flux produced by both the windings is in the same direction. In a differential compound motor, the flux produced by the series field windings is opposite to the flux produced by the shunt field winding.

Separately excited DC motor (Fig 15): In a separately excited DC motor, the field coils are energised from an external source of DC supply as shown in the figure.



Characteristic of DC motor (Separately excited)

This motor has characteristic of

- The armature (rotor) and field (stator) windings have to be supplied by voltage separately, thus we need two DC voltage sources electrically separated from each other.
- The armature and field windings are separated electrically.
- The torque is inversely proportional to the speed of the rotor.
- Stall torque is the maximum torque but the rotor is not rotating.
- No load speed is the maximum speed of the rotor when there is no torque applied to the rotor.

Characteristic of DC motor (Shunt): This type of motor has the following characteristic of

- The armature and field windings are connected in parallel

- Only one voltage source is needed to supply both armature and field windings.
- This motor relatively has constant torque in a wide range of speed.
- The torque speed characteristic and equation for shunt DC motor is the same with the separately excited DC motor.

Characteristic of DC motor (series)

- The armature and field windings are connected in series.
- Only one voltage source is needed to supply both armature and field windings.
- The current in the field winding is the same as the current in the armature winding
- Series motor has a special trail that we can apply AC or DC voltage to it.
- Even if we reverse the supply polarity the motor will always rotate in the same direction

Characteristic of DC motor (Compound)

- Compound DC motor use both series and shunt field windings
- One field windings is connected in series to the armature and other one field windings is connected in parallel to the armature.

Factors affecting motor performance:

Electric motor performance depends on three elements such as voltage across terminals, resistance across terminals and magnetic force, various factors that affect these elements and change motor performance way of giving some specific examples

- Voltage of power supply
- Type of power supply
- winding specifications
- Environmental Temperature
- Type of magnet
- Flux yoke
- Phase of current

Calculation of motor effort: Calculating the motor effects force F is force in Newton (N) B is magnetic flux density (magnetic field strength), I is current is an pers also referred to as amps- A is length in meters (m).

A wire carrying a current creates a magnetic field this can interact with another magnetic field, causing a force that pushes the wire at right angles.

Calculating the motor effect force: To calculate the force on a wire carrying a current at right angles to magnetic field use the equation

Force = magnetic flux density x current x length

F= BIL this is when

F is force is Newton (N)

B is magnetic flux density (magnetic field strength)

I is current in amperes - also referred to as amps (A)

L is length in meters (M)

Calculating the strength of force: To calculate the size of the force acting on a current carrying wire, at a right angle to the directions of magnetic field use the following equation

$$F = BIL$$

Definition of the motor effect:The motor effect describes how electricity and magnets can work together to create a magnetic force. This magnetic force is the basis of all electric motors hence name motor effect.

The motor effect is the phenomenon of a force being generated on a current carrying wire in the presence of an external magnetic field. The motor effect use Fleming's left hand rule shows the directions of the force on a conductor carrying a current in an external magnetic field.

Electric Transmission: When the electric motor RPM gets too high, the automatic transmission shifts gears allowing the motor to operate at a lower RPM wheel providing steady power to the wheels. The process continues as you accelerate and works in reverse as you slowdown.

The electric vehicle uses single speed transmission because the motor is efficient in wide range of condition. The output speed of motor is reduced in two steps that is speed reduction and torque multiplication.

Working and operation of electric vehicle propulation system

The electric vehicle transmission systems consists of a motor, inverter controller, power controller and battery and these play a major role in the overall working mechanism.

- When a battery power input is given to starter, it creates rotating magnetic field and hence induces a current in rotor and it starts rotating. The speed of induction motor depends on the frequency of power supply, the speed of drive can be changed.
- Electric vehicle can work on any speed, it does not require a speed varying transmission.
- The power generated in the electric vehicle motor is transferred to a drive wheel via gear box. The EV uses single speed transmission because the motor is efficient in wide range of condition.
- The output speed of motor is reduced in two steps that is speed reduction and torque multiplication.
- Open differential can control torque rather than slip differential the arrangement of differential is another important feature of electric vehicle.

- The traction control of differential can be overcome by two methods that is selective braking and cutting the power supply.
- EV can be run by first pedal, it saves huge kinetic energy in the form of electrical as soon as acceleration pedal is applied and hence regenerative braking is introduced in electric vehicle
- During regenerative braking, motor acts as generator so wheels drive the motor.
- Motor rotor speed less than rms speed.
- Generator rotor speed greater than rms speed.
- The generated electric energy can be stored in battery after conversion
- opposing electromagnetic field acts on the rotor, so drive wheel and car will slow down so that vehicle stopped can be controlled using single speed.
- Electric vehicle has planetary gear set and torque converter instead of clutch pack.
- Most of electric cars have just one electric motor found on either the rear axle or front axle wheel drive. On an all wheel drive electric car, there will be two motors - one for each axle. There are four types of transmission used in all types of vehicles. They are as follows;
- Automatic transmission (AT)
- Manual Transmission (MT)
- Automated Manual Transmission (AMT)
- Continuously Variable Transmission (CVT)

Components of electric vehicle propulsion system :-
There are many components are used in electric vehicle propulsion system. Thus are as follows :-

- Software DTC- SVM control system
- Energy storage - Power Battery
- Two level inverter
- PMSM - Traction motor
- Transmission - differential wheels

Types of electric vehicle drive systems: There are three types of electric vehicle drive systems followed. They are as follows

- Electric drive system with a clutch (Fig 16a)
- Electric drive system without the clutch (Fig 16b)
- Integrated electric drive system (Fig 16c)

The propulsion system in an EV consists of an energy storage system, the power converter and the propulsion motor and related controllers differential are used in EV propulsion system. The battery is unduly used as energy storage system and its charging is an integral part of the EV systems. Each part's function is explained in above mentioned main components of Electric Vehicle.

EV power systems (motor and controllers): The power system of an electric vehicle consists of two components such as the motor that provides the power and the controller that controls the application of this power. The electrical drive system is defined as the system which is used for controlling the speed, torque and direction of electrical motor.

Electric motor: Electric Motor convert electrical energy into mechanical energy. Two types of electric motors are used in electric vehicles to provide power to the wheels: the direct current (DC) motor and the alternating current (AC) motor.

DC motor (Brushed) (Fig 17 (a)): DC Current from the battery is delivered to the rotor windings via spring-loaded "brushes" of carbon or lead that energize spinning contacts connected to wire windings. Every few degrees of rotations, the brushes energize a new set of contacts; this continually reverses the polarity of the electromagnet on the rotor as the motor shaft turns. (This ring of contacts is known as the commutator).

The housing surrounding the rotor's electromagnetic windings typically features permanent magnets. (A "series DC" or so-called "universal motor" may use an electromagnetic stator). Advantages are low initial cost, high reliability, and ease of motor control. Varying the voltage regulates the motor's speed, while changing the current controls its torque. Disadvantages include a lower lifespan and the cost of maintaining the brushes and contacts. The motor is seldom used in transportation today, save for some Indian railway locomotives.

Brushless DC motor (BLDC) (Fig 17 (b)): The brushes and their maintenance are eliminated by moving the permanent magnets to the rotor, placing the electromagnets on the stator (housing), and using an external motor controller to alternately switch the various field windings from plus to minus, thereby generating the rotating magnetic field.

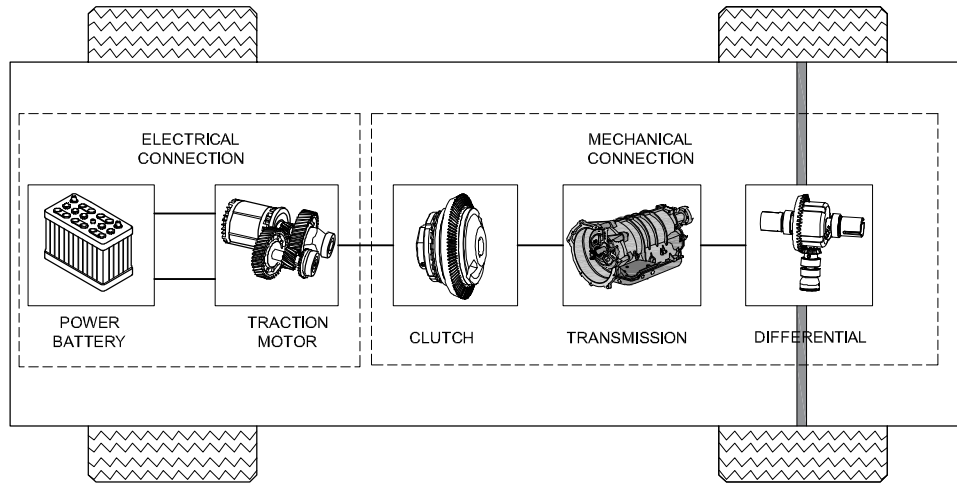
Advantages are a long lifespan, low maintenance, and high efficiency. Disadvantages are higher initial cost and more complicated motor speed controllers that typically require three hall-effect sensors to get the stator-winding current phases correctly. That switching of the stator windings can result in "torque ripple"-periodic increases and decreases in the delivered torque. This type of EV motor is popular for smaller vehicles like electric bikes and scooters, and it's used in some ancillary automotive applications like electric power steering assist.

Different types of electric vehicle drive electric motors

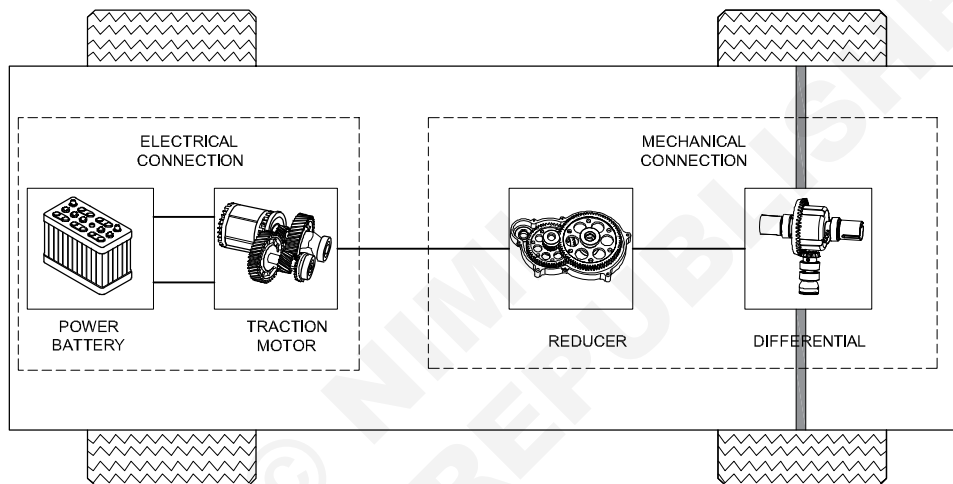
There are many types electric motors are used in electric vehicle, but mainly six different types of electric motors which are being used in current and upcoming EVs BLDC motors. They are as follows

- DC series motor.
- Brushless DC motor (BLDCM).
- AC Induction Motor (ACIM)

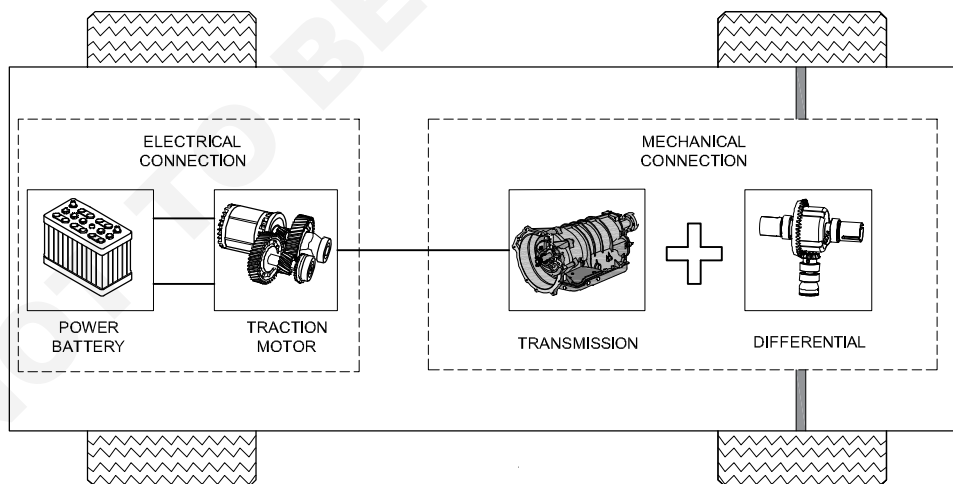
Fig 16



(a) ELECTRIC DRIVE SYSTEM WITH A CLUTCH

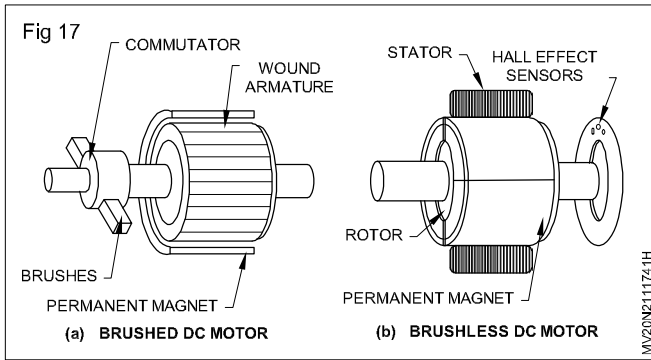


(b) ELECTRIC DRIVE SYSTEM WITHOUT THE CLUTCH



(c) INTEGRATED ELECTRIC DRIVE SYSTEM

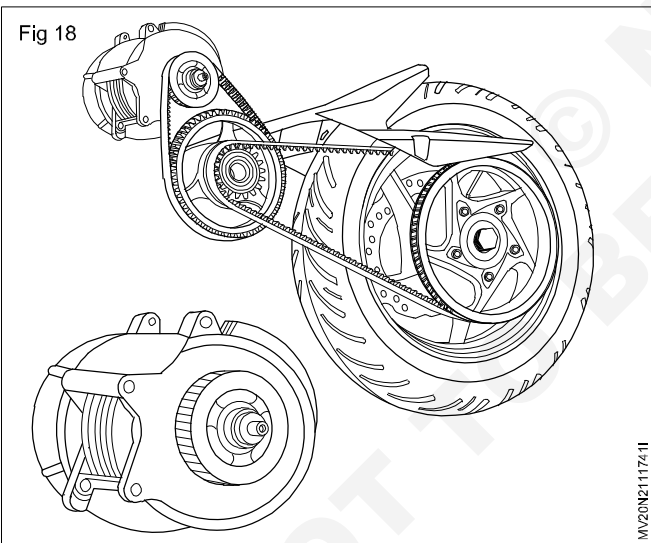
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- Interior Permanent Magnet Motor (IPMM).
- Permanent Magnet Switched Reluctance Motor (PMSRM).

1 DC series motor: It was a widely used motor back in the 1990s. This motor is capable of producing high initial torque. The easy speed control and sudden load increase bearing capacity make these motors a good choice. But the high maintenance due to the brushed and commutators is a major drawback in the DC series motor which are also known as brushed DC motors. These motors are still in use by the Indian Railways.

2 Brushless DC motor (BLDC) (Fig 18): Brushless DC Motor (BLDCM) are being used in most of the lightweight 2 wheeler & Wheeler EVs like electric scooters and electric motorcycles.



For examples in electric scooters

- Ather energy scooters.
- Upcoming TVS creon.
- 22 Motors, Hero Electric.
- Niu Electric Scooters.
- Yamaha EC-03, etc.

For examples in electric motorcycles

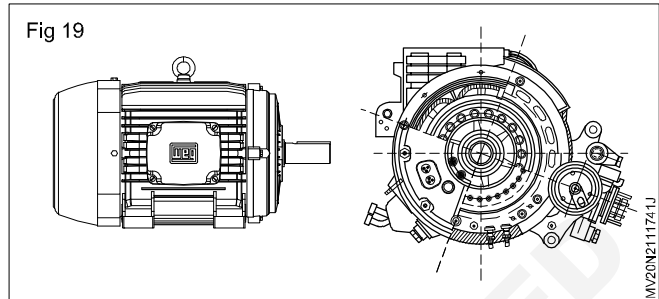
- Tork Motors,
- eMotion Motors,
- Menza Motors,

- Chinese Evoke Motorcycles etc.

And in all e-rickshaws & eAuto rickshaws.

3 PMSMs (Fig 19)

Permanent magnet synchronous motor (PMSM) are also being used by many RV manufactures for their high-performance electric motorcycle, electric cars, electric buses.



For examples in electric motorcycles:

- Energica motors.
- Brammo empulse R

For examples in electric cars:

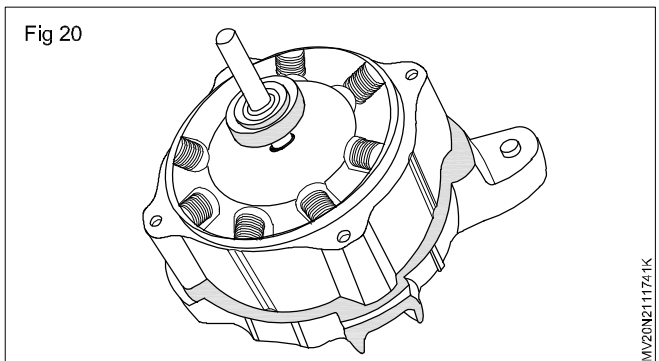
- Chevy bolt EV
- Nissan leaf EV
- Upcoming hypercar pininfarina battista 0-100 kmph in <2 Sec

For examples in electric buses

- TATA Ultra Urban 6/9 & 6/12

4 IPM Motors (IPMM) (Fig 20)

Interior Permanent Magnet Motor (IPMM) are also being used by some 2 Wheeler EV Manufacturer for their High-Performance Electric Motorcycle.

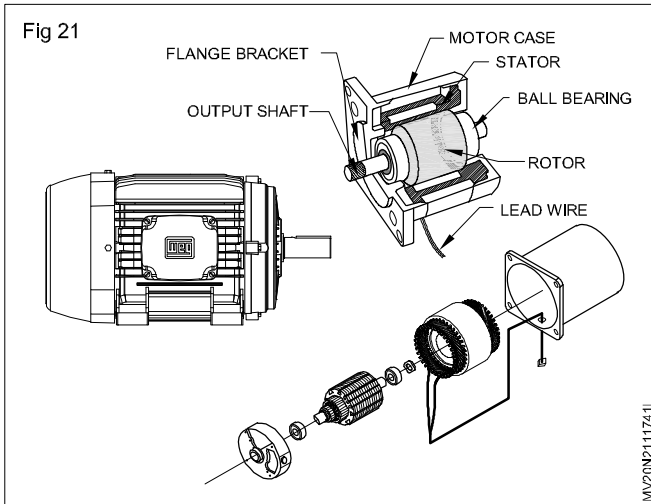


For Example:

- Zero motorcycles (Model S/SR, DS/DSR, FX, FXS, 'SR/F')
- Lightning motorcycles (Model LS-218).

5 ACI Motors (ACIM) (Fig 21)

AC Induction motor (ACIM) is also being used by some EV manufactures in 2 wheeler and 4 wheeler.



For examples in 2 wheeler:

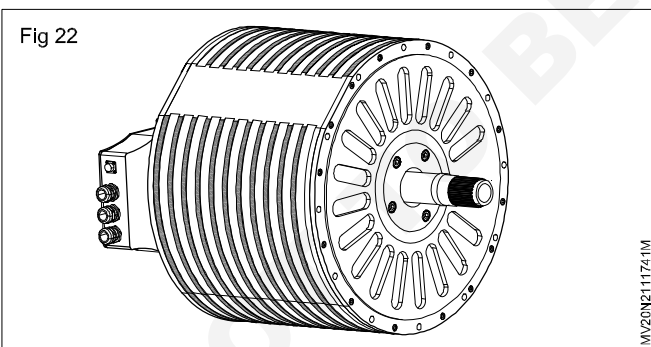
- Emflux Motors-Emflux One,

For examples in 4 wheeler:

- Tesla roadstar 2008,
- Tesla model S,
- Tesla model X,
- Mahindra e-verito,
- Mahindra e2o,
- Mahindra e-supro,
- TATA Tigor,
- TATA Tiago

6 PMSRM (Fig 22)

Permanent magnet switched reluctance motor (PMSRM) is used in tesla model 3.



DC electric motors have three main components

- A set of coils (field) that creates the magnetic forces which provide torque.
- A rotor or armature mounted on bearings that turns inside the field.
- Commutating device that reverses the magnetic forces and makes the armature turn, thereby providing horse power.

As in the DC motor, an AC motor also has a set of coils (field) and a rotor or armature, however, since there is a continuous current reversal, a commutating device is not needed.

Both types of electric motors are used in electric vehicles and have advantages and disadvantages, as shown here.

While the AC motor is less expensive and lighter weight, the DC motor has a simpler controller, making the DC motor/controller combination less expensive. The main disadvantages of the AC motor is the cost of the electronics package needed to convert (invert) the battery's direct current to alternating current for the motor.

Past generations of electric vehicles used the DC motor/controller system because they operate off the battery current without complex electronics. The DC motor/controller system is still used today on some electric vehicles to keep the cost down.

However, with the advent of better and less expensive electronics, a large number of today's electric vehicles are using AC motor/controller systems because of their improved motor efficiency and lighter weight.

Different types of electric vehicle drive electric motor

EV DC motor drives: Motor drive system is one of the core components of electric vehicle, which requires high torque at low speed, high power at high speed wide speed control range to meet the EV performance requirements. Electric vehicle's use both alternating current and direct current motors.

DC motor armature drive voltage: When pedal of the EV is pressed, then the controller take and regulates electrical energy from batteries and inverters. With the controller set, the inverter then sends a certain amount of electrical energy to the motor (according to the depth of pressure on the pedal).

EVs DC motor required high voltage to power the motor, voltage levels of 400 to 800 V or more are needed to generate sufficient power to run the vehicle.

The flow of current measured in amps, multiplying volts times amps gives power to motor. Its power that makes a car move. The normal unit of power in electricity is watts.

Watts = Volts x Amps. Tesla batteries are 375 Volts, Nissan Leaf batteries are 360 Volts.

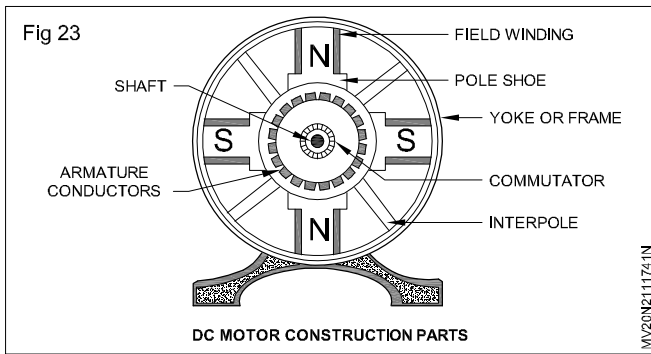
A simple DC controller connected to the batteries and DC motor if the driver press the accelerator pedal, the controller delivers the 96 volts from the batteries to the motor.

DC motor construction parts (Fig 23)

EV DC motor is an electrical machine that converts electrical energy into mechanical energy. In a DC motor the input electrical energy is the direct current which is transformed into the mechanical rotation. DC motor construction parts shown in figure:

Different parts of a DC motor

A DC motor is composed of the following main parts :



Armature or Rotor

The armature of a DC motor is cylinder of magnetic laminations that are insulated from one another. The armature is perpendicular to the axis of the cylinder. The armature is a rotating part that rotates on its axis and is separated from the field coil by an air gap.

Field coil or stator

A DC motor field coil is a non-moving part on which winding is wound to produce a magnetic field. This elector-magnet has a cylindrical cavity between its poles.

Commutator and brushes

Commutator

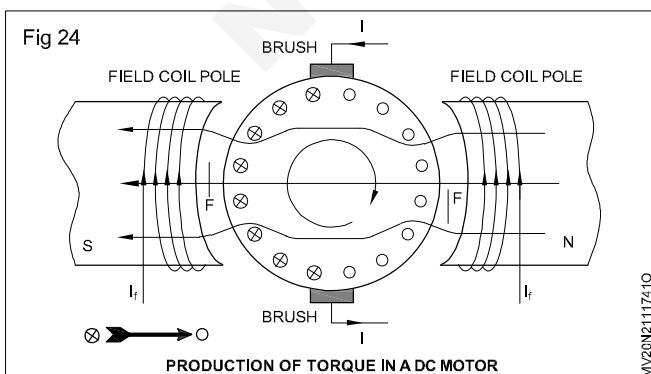
The commutator of a DC motor is a cylindrical structure that is made of copper segments stacked together but insulated from each other using mica. The primary function of a commutator is to supply electrical current to the armature winding.

Brushes

The Brushes of a DC motor are made with graphite and carbon structure. These brushes conduct electric current from the external circuit to the rotating commutator. Hence, we come to understand that the commutator and the brush unit are concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.

DC motor working (Fig 24)

A magnetic field arises in the air gap when the field coil of the DC motor is energized. The created magnetic field is in the direction of the radii of the armature. The magnetic field enters the armature from the North pole side of the field coil and "exits" the armature from the field coil's South Pole side.



Production of torque in a DC motor

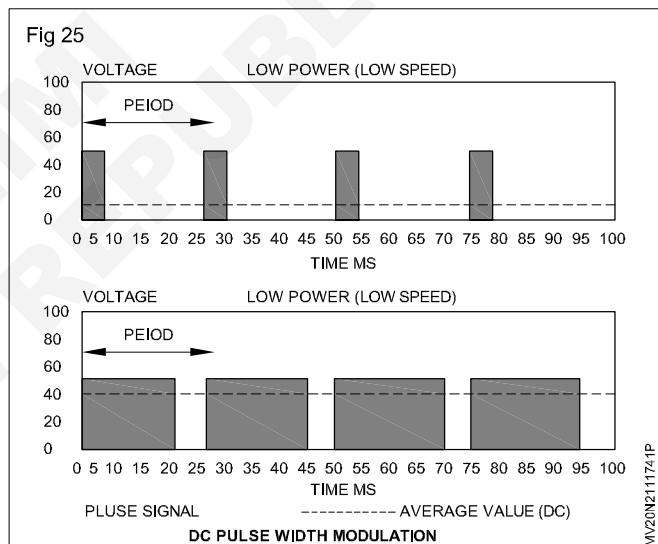
The conductors located on the other pole are subjected to a force of the same intensity but in the opposite direction. These two opposing forces create a torque that causes the motor armature to rotate.

Working principle of DC motor

When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work.

Controllers (Fig 25)

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle's speed and acceleration. The controller transforms the battery's direct current into alternating current (for AC motors only) and regulates the energy flow from the battery. The controller will also reverse the motor rotation (so the vehicle can go in reverse), and convert the motor to a generator (so that the kinetic energy of motion can be used to recharge the battery when the brake is applied).



In the early electric vehicles with DC motors, a simple variable-resistor-type controller controlled the acceleration and speed of the vehicle. With this type of controller, full current and power was drawn from the battery all of the time. At slow speeds, when full power was not needed, a high resistance was used to reduce the current to the motor. With this type of system, a large percentage of the energy from the battery was wasted as an energy loss in the resistor. The only time that all of the available power was used was at high speeds.

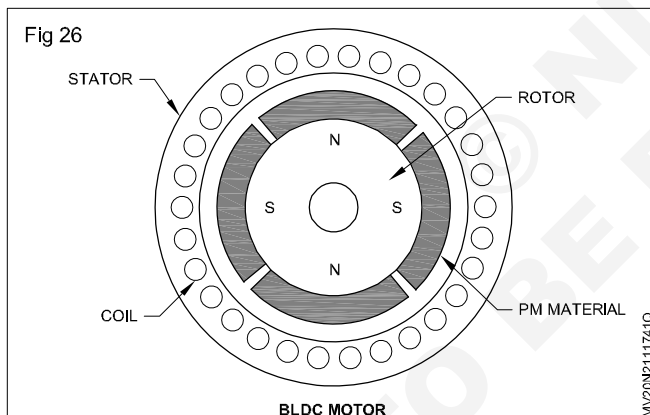
Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation. Switching devices such as silicone-controlled rectifiers rapidly interrupt (turn on and turn off) the electricity flow to the motor. High power (high speed and/or acceleration) is achieved when the intervals (when the current is turned off) are short. Low power (low speed and/or acceleration) occurs when the intervals are longer.

The controllers on most vehicles also have a system for regeneration braking. Regenerative braking is a process by which the motor is used as a generator to recharge the batteries when the vehicle is slowing down. During regenerative braking, some of the kinetic energy normally absorbed by the brakes and turned into heat is converted to electricity by the motor/controller and is used to recharge the batteries. Regenerative braking not only increases the range of an electric vehicle by 5-10%, it also decreases brake wear and reduces maintenance cost.

Brushless DC motor (Fig 26)

A vehicle is propelled with electric motors and draw power from battery source is an electric vehicle. The electric vehicle is used the battery for storing the electric energy it can store large amount of energy in a small volume and weight.

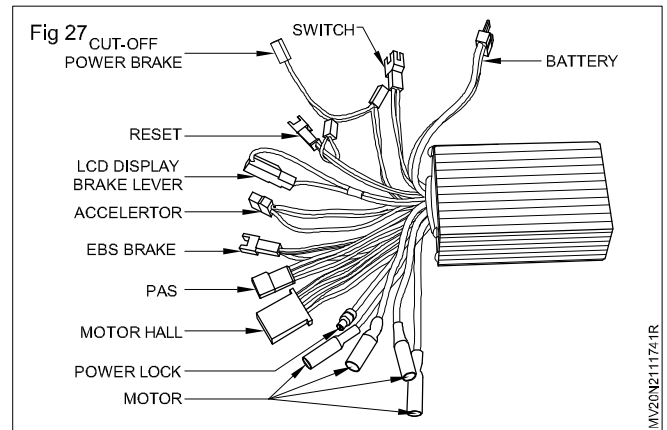
The main function of motor is to convert supplied electric energy current into mechanical energy. The brushless DC motor have been much focused for many motor manufactures. These are more effective in terms of system cost, size, higher in efficiency, excellent controllability and also power saving than other motor it has only two basic main parts rotor and stator. The rotor is rotating part which carry permanent magnet and stator winding. Stator is made up of steel lamination with vocally cut for winding,



Motor controller and vehicle speed controller (Fig 27)

In most of the electric vehicle, brushless DC motor is used which is better than brushed DC motor, permanent magnet DC motor. Brushless DC motor does not have brush and commutator, the electric vehicle which uses brushless DC motor has to use motor controller which helps to control various properties of motor to take sufficient current and voltage applied to motor. When accelerating pedal is pressed, this linked variable resistor type controller gives signal to the motor controller to adjust speed as per our needs. The motor controller has no power when vehicle is at rest position.

Working principle of brushless DC motor: BLDC motor works on the principle similar to that of a brushed DC motor. When current carrying conductor placed in a magnetic field it experiences a force. As a consequence



of reaction force, the magnetic will experience an equal and opposite force in the BLDC motor, the current carrying conduct stationary and the permanent magnetic is moving.

When the stator coils get a supply from source, it becomes electromagnetic and starts producing the uniform fields in the air gap. Though the source of supply is DC, switching makes a generate an AC voltage wave form with trapezoidal shape. Due to the force of interaction between electromagnetic stator and permanent magnet rotor continues to rotate.

With the switching of windings as high and low signals, corresponding winding energized as north and south poles. The permanent magnet rotor with north and south poles align with stator poles which causes the BLDC motor to rotate.

Features of brushless DC motor

- Less maintenance due to absence of brushes.
- Reduce the size with far superior thermal characteristics
- Higher speed range and lower electric noise generation
- It has no mechanical commutator and associated problems
- High efficiency and high output power to size ratio due to use of permanent magnetic rotor.
- High speed operation even in loaded and unloaded condition due to the absence of brushes that limits the speeds.
- Smaller size and lighter in weight than others.
- Long life as no inspection and maintenance is required for commutator system
- Less electromagnetic interferences and low noise and higher dynamic response.

Brushless direct current motor power and efficiency:

There are two main efficiencies to consider in a brushless system; motor efficiency and propeller efficiency. There are several key formulas used for brushless motor performance. The formula will help to know how motor power and efficiency are closely related and dependent on factors such as torque, RPM, current and voltage.

Motor efficiency = Mechanical power

Electrical power

Mechanical power = Torque * RPM

Electrical power = Current * Voltage

Electrical power = Mechanical power + heat losses

Heat Losses = R * current

Mechanical power is the product of torque and RPM, so when there is either no torque or no rotation, no power is produced

Electrical power can be determined experimentally or theoretically and it can be a fun exercise to compare your task results to your theoretical calculation.

The efficiency of a motor is determined by dividing the mechanical power outputs by the electrical power inputs. A goal for vehicle design is therefore to maximize the overall system efficiency by using the biggest propeller possible without over loading the motor. By using a giant propeller would drastically increase the propeller efficiency but the motor would struggle so much to make it spin, that its efficiency would be ridiculously low. During the opposite is not great either as making a tiny propeller spin very fast would lower both the motor and the propeller efficiency. The best solution is to balance both efficiencies to get the highest overall performance and system efficiency.

To achieve the highest efficiency the motor has to operate where there is a balance between torque and RPM. Testing various motors can help you, which size, KV and brand of motor will get you for best operation.

Brushless direct current motor efficiency calculation formula

Electrical motor efficiency is often denoted by the greek letter η and is calculated by using the following formula.

$$\eta = 0.7457 \times \frac{hp \times load}{P_1}$$

P_1

Here hp = motor horse power

load = out put power as a percentage of rated power

P_1 = input power is KW

The constant factor 0.7457 is used to convert horse power to kilowatts. This is because 1 HP = 745.7 KW or 0.7457 KW

Battery Management Systems: The Electric vehicle constructed with various types batteries for storing electrical energy to operate the electric motor provided in Electric vehicle.

Battery management system is a full featured battery, Battery management system is specifically designed to meet the high requirements of protecting and managing battery packs for electric vehicles, plug-in hybrid electric

vehicle and hybrid E-vehicle with automotive grade quality. Battery management system ensures safeguard both user and battery by ensuring safe operating parameters.

- **Current and voltage protection:** Protects the battery pack from overcharge and over discharge there by extending battery life cycle.
- **Thermal management:** Over temperature and under temperature protection with fan controls for cooling or heating
- **Digital & analog output controls:** Provides multiple methods of controlling chargers, motor controllers and other external device.
- **Intelligent cell balancing:** Efficient passive balancing is used to maximize the usable capacity of battery packs
- **Health monitoring:** Monitor internal resistance of individual cells and measure capacity of the battery pack.
- **State of charge monitoring with drift:** Coulomb counting and dynamic drift correction are used to monitor the state of charge
- Compatible with almost all lithium-ion batteries : **A wide** cell voltage range supports almost all lithium-ion batteries and even some NiMH batteries
- **Field Programmable:** Parameters such as voltage ranges current limits and many other settings are easily field chargeable

Need of battery management systems:

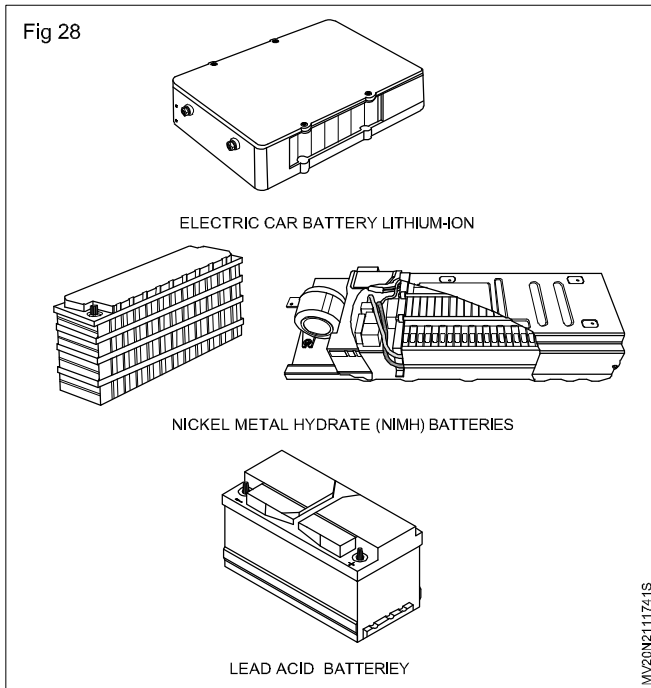
Electric vehicles operates on high voltage battery packs, hence we need to ensure the safe operation of these batteries. The BMS monitors parameters such as temperature input, output current voltage across the battery packs to ensure the safe operation of the battery

Main components of BMS: Electric power control and monitor core electrical and mechanical equipment, heating schedule the system on and off, maintain a set temperature point, ventilation- adjust based on occupancy controls. Security and observation access control, surveillance and intrusion detection

Advantages of BMS (Battery management systems)

- Maintains battery in a state in which it can fulfill its functional design requirements
- Protects the safety of the battery operated devices and detects unsafe operating conditions and responds.
- Protects cells of battery
- BMS is to keep track of the state of charge of battery
- Simple coulomb counting
- Simple and easy to predict capacity fade, and internal resistance increment of batteries.

Electric car battery lithium-ion (Fig 28)



Nickel-metal-hydrate (NiMH) batteries

Super capacitor 48V 165F Graphene Energy Storage Battery

Lead acid battery

Induction power transfer for EV by using Diodes and Transistors: Now a days silicon insulated - gate bipolar transistors (IGBTs) are dominates in automotive power electronics but a rapid transition is underway to a sixth generation of wide band gap semiconductors, silicon carbide (SiC) metal oxide field effect transistors (MOSFETS) and gallium nitride high electron mobility transistors (HEMTs)

WBG semiconductors does are a step change, making power electronic devices vastly more efficient power dense and capable of high temperature operation. As the semiconductor does are no longer the bottle neck for high temperature operation and life time, new opportunities are created in the packaging materials.

Wide bandgap semiconductor switches are enabling more efficient high voltage operation (800V-1000V) which brings advantages such 350 KW DC fast battery charging. The move to 800V is not as simple as rewiring battery to the cells, thermal management system, inverter motor and high voltage cabling is required.

Electric vehicle power electronics package: The power electronic package contains models to describe switching electronic devices required in the context of electric drive modeling, it contains the semiconductor switches at the heart of the power electronic device as well as power electronic devices such as inverters and converters.

Inductive Power Transfer (IPT) (Fig 29): Development of battery technology and advancement of power electronics has allowed EVs to gain popularity in the recent years, with strong boost to greener environment. Inductive Power Transfer (IPT) is the method of wirelessly transferring power. The system for static wireless charging. AC power is drawn from the grid into the system. This power is rectified by using a diode bridge to supply a DC voltage. This is followed by a Power Factor Correction (PFC) stage to improve the power factor and step up the voltage to 380 V. The DC input voltage is supplied into an inverter, which converts it in high frequency AC so that power can be transmitted by primary coil to the secondary coil using IPT. The secondary coil will take in the HF AC power and rectify it using the SiC diode bridge into a DC voltage for vehicle charging. IPT for EVs provide a convenience and safety for the user [,]. This system is weatherproof and difficult to vandalism like a plug-in station [].

Static wireless charging: However, there are challenges facing wireless charging, such as low efficiency compared to plug-in chargers. This is overcome by using wide bandgap semiconductor materials such as GaN, which is attracting attention for enabling high efficiency, high power density converters , rectifiers and inverters. The materials properties of GaN such as high critical field, electron mobility and saturation velocity push the boundaries of power electronics performance such as efficiency, power density, reliability and cost.

