INVESTIGATION OF BRAKING SYSTEM (EFFICIENCY) OF CONVERTED MERCEDES BENZ BUSES (207)

By

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DECLARATION

I hereby declare that this thesis is my own original work undertaken at the Department of Mechanical Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, under the supervision of Dr. Y.A.K. Fiagbe and Mr. S. Abu Frimpong.

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ABSTRACT

Road accidents as a major cause of misery, morbidity and mortality in Africa particularly in Ghana have been of considerable concern to the general public. More worrying is the accidents involving Benz 207 buses. This is attributed to the fact that the Mercedes Benz 207 bus is originally made as a van for conveying goods. When brought into the country it is converted to passengers' bus by artisans in 'fitting workshops' in and around the country. This conversion increases the gross weight, affects the suspension and the stability of the vehicle. Also, a serious effect is that the performance of the braking system may be affected. This research highlights various modifications done to the Mercedes-Benz 207 van at the Suame magazine. The braking efficiency of the converted Mercedes Benz 207 bus as against that of the original and compared to the safest degree of efficiency required for these buses.

It was observed that the alteration of suspension (leaf spring) and chassis frame, brake adjustments, body and spraying works, construction of seats and fixing of glass were the major modifications that are done on the buses. Average ground height of the bus was increased and was found to be between 60.9 cm to 76.2 cm (2 to 2.5 feet) due to suspension alteration.

The gross weight of the original bus was increased by an average of 20% after conversion. The results show that 60% of the buses have no parking brakes and between 20% were having defective or no rear brakes. Also, 70% of the converted buses have their braking efficiencies decreased whilst 20% had increased braking efficiency with the rest remaining unaffected.

It was again observed that 60% of the original buses tested fell within the standard value required for the front imbalance and 50% of the converted buses exceeded the maximum value for the front imbalance.

It is recommended among others that the Driver, Vehicle and Licensing Authority (DVLA) should stop licensing the converted Mercedes Benz 207 buses or at best license those that are tested to have the required braking efficiency. Any future research should consider analyzing a bigger sample size for more information to be obtained on 207 buses regarding their braking system and failures.

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ABBREVIATIONS

LCV	Light commercial vehicle
GVM	Gross vehicle mass
HCV	Heavy commercial vehicle
BE	Braking efficiency
BF	Braking force
GVWR	Gross vehicle weight rating
CW	Curb weight
UW	Unladen weight
NW	Net weight
FB	Front brake
RB	Rear brake
NS	Near side
OS	Off side
BM	Brake imbalance

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My appreciation will be incomplete if I did not give special thanks to all the lecturers in the Mechanical Engineering Department, KNUST for their support during this project work.

DEDICATION

This work is dedicated to my children Judith and Eugene Amedorme.

CHAPTER ONE

INTRODUCTION

This chapter discusses the background information, the objective of the research, the significance of the research and the scope of the research.

1.1 Background

In Ghana it is common to see Mercedes Benz buses referred to as “207 buses” in use for passenger transportation. Also, most fatal accidents reported involved these buses which are very worrying to authorities and with the Ashanti Region recording the highest in the road traffic crash fatalities (NRSC, 2007). According to the Ashanti Regional Commander of the Motor Traffic and Transport Unit (MTTU) of the Ghana Police Service, the police vigilance over the “207 buses” has increased in the wake of numerous accidents involving these buses in recent times. Again, statistics indicates that 1,988 accidents occurred in the Ashanti Region alone in 2003, with majority of the accidents involving 207 buses (MTTU, 2008).

The origin of the “207 bus” is by Mercedes Benz vehicle manufacturing company based in Germany. It is interesting to note that they are designed as load carrying vehicles or vans. The model series included 207 D, 208, 307 D and 308. They debuted in April 1977. The original line was composed of two engines and four weight classes, as follows:

- 207 D, 208 - gross weight 2,550 kg (5,622 lb) or 2,800 kg (6,173 lb)
- 307 D, 308 - gross weight 3,200 kg (7,055 lb) or 3,500 kg (7,716 lb)
- 207 D, 307 D - four cylinder Diesel engine with 2404 cc and 48 kW (65 hp)
- 208, 308 - four cylinder petrol engine with 2307 cc and 63 kW (85 hp)

In September 1981, the 407 D and 409 D were added with a gross weight of 4,600 kg (10,141 lb), The 409 D had a bigger and more powerful Diesel engine with five cylinders, 3005 cc and 65 kW (88 hp). It was the OM 617 engine which was used in all these models of the Mercedes Benz cars. Other revisions throughout the vans production were minor, the OM616 engine having a modified cylinder head with slightly more power 54 kW (72 hp) and then later on to 58 kW (78 hp) and the van thus redesignated as 208D, 308D and 408D. The 5 cylinder variant was also changed from 3005 cc to 2898 cc, producing slightly more power and the models re-designated 210D, 310D and 410D.

Some features of the Mercedes-Benz cargos imported into the country are as follows. The vehicle has the engine capacity of 2.3 litre, 4 or 6 cylinder vertical in – line engine and can generate about 59 kW (79 hp). Most of them used overhead valve (OHV) arrangement. Majority has 5- speed manual transmission gearbox. The chassis dimensions are 2997 mm and 1880 mm for wheel base and wheel track respectively and used leaf spring suspension system. The overall length of the vehicle is about 4978 mm and the average height for most of the vehicles is 2362 mm. The fuel tank capacity is 300 litres. The braking system used on the vehicle is ether disc or drum brake. Some used disc brake at the front and drum brake at the rear. For some the disc brakes are used at both axles. The foot brake is hydraulically operated and the hand brake operated mechanically.

The Mercedes-Benz van is converted to the passenger bus in order to satisfy the domestic transport needs. During the conversion, one of the objectives is to increase the occupancy space of the vehicle. To achieve this, the chassis is extended in between the wheels. The act of extending the chassis of the vehicle calls for discarding of some of the original components like propeller shaft and replacing it with another one. Seats are also produced and fixed into the vehicle without any anthropometric consideration and the number of leaf springs in the suspension of the vehicle is increased arbitrarily. All these components add to the gross weight of the vehicle. This in turn affects the suspension and the stability of the vehicle since the centre of gravity is altered. Also, the modifications may render the brakes ineffective and performance of the braking system (efficiency) compromised. According to Hillier et al (1972) an increase in weight of a vehicle has a direct bearing on the power required for the vehicle and braking efficiency. Theoretically, brake efficiency is defined as ratio of the braking force to the weight of the vehicle. The efficient braking of vehicle is one of the principal factors in securing the safe operation of the brakes (Lateef et al 2008). It is therefore clear that the braking efficiency is compromised with changes in gross weight.

A number of researchers have studied on Mercedes-Benz buses regarding seat arrangement and the need for seat belt in the vehicle in relation to road accidents, but not much has been done to assess the performance of the braking system in the vehicle.

1.2 Goal and Objectives

The goal of this thesis is to investigate the effectiveness of braking system of converted “207 buses”

The goal would be achieved with the following specific objectives:

1. To investigate the processes involved in the conversion of the cargo and their influence on the brake system.

2. To determine the braking effectiveness/efficiency of the converted bus and compare it with that of the original van.

1.3 Justification

Road accidents as a major cause of misery, morbidity and mortality in Africa particularly in Ghana have been of considerable concern to the general public. More worrying is the accidents involving Benz 207 buses. This is attributed to the fact that the Mercedes Benz 207 bus is originally made as a van for conveying goods. But when brought into the country, it is converted to passenger bus by artisans in 'fitting workshops' in and around the country. This conversion may increase the gross weight of the vehicle, affects the suspension and the stability of the bus which in turn alters its centre of gravity. One serious effect is that the performance of the braking system may be affected and may lead to malfunction resulting in road accident. Statistics from the Driver Vehicle and License Authority (DVLA) quarterly report, 2011 indicated that between September 2011 and December 2011 finding from Private Vehicle Testing Stations (PVST) shown that total of 18,128 vehicles were tested. Out of this number 15,278 vehicles representing 84.3% passed the test with about 2,853 vehicles representing 15.7% failing the test. Analysis of the defects found in vehicles that failed the test revealed that the commonest defect observed in most vehicle tested was defective lights and this represents about 61.9%. The second highest defect found in vehicle tested that failed the test was defective brakes with about 22.2%. Other defects observed were worn-out tyres (6.3%), suspension defects (3.2%), power steering defect (3.2%), defective horn (1.6%) and hydraulic leak (1.6%). It would, therefore, be prudent to investigate the effectiveness of the braking system after conversion process since the braking system is one of the essential systems of a vehicle (Lateef et al, 2008).

1.4 Methodology and Scope of Research

A study of the conversion processes will be undertaken at the various workshops involved in the act of conversion of the van to passenger bus in Suame magazine. The braking system (efficiency) testing will be undertaken with appropriate and available testing facilities in Kumasi Technical Institute (KTI). The roller brake tester at (KTI) and National Vocational and Training Institute (NVTI) workshop will be used to test ten (10) original 207 vans and for the braking force, weight of the bus and braking efficiency. The same testing will be done on the converted buses for the same parameter.

1.5 Organization of the Thesis

This thesis is organized into five chapters. The introduction, which is the subject of chapter one, consists of the background, the specific objectives, justification, methodology and the scope of the study and the organization of the work. Chapter two contains the review of the various modifications done to vehicles, types of braking systems and various methods of determining the braking efficiency of a vehicle. Chapter three describes the processes that were carried out on the 207 buses. Chapter four discusses the experimental results and analyses of the results. Chapter five gives the conclusions and recommendations from the research.

CHAPTER TWO

LITERATURE REVIEW

This chapter discusses Mercedes Benz buses, various modifications done to vehicles, types of braking systems and various methods of determining the braking efficiency of a vehicle.

2.1 Mercedes Benz Buses

Mercedes Benz buses popularly called '207 buses' in Ghana are commercial vehicles used for carrying commuters. Originally, the buses were made as cargos trucks for conveying goods before they are converted to passenger bus. These buses which fall under the category of light commercial vehicles carry passengers not exceeding twenty-three (23) persons and have gross and net weights not exceeding 5720 and 900 kg respectively. They come in various sizes and shapes depending on the model. The models include 207D, 208, 307D, 308, 410 etc. depending on the gross weight, engine capacity and the power output. The bus employs either the chassis less (integral) or separate chassis and body construction but majority of the 207 buses use separate chassis construction. The dimensions of the wheel base and vehicle length vary according to the type of model. The following components are attached to the chassis. Front suspension, steering mechanisms, radiator, engine, clutch, gearbox, propeller shaft, rear suspension to which is attached the real axle. Road wheels, shock absorbers, fuel tank, fuel and hydraulic pipes, brake shaft and cables and some means of mounting these components.

Mercedes-Benz has been making these buses since 1895 in Mannheim in Germany. Since 1995, the brand of Mercedes-Benz buses and coaches is under the umbrella of EvoBus GmbH, belonging 100 % to the Daimler AG.

2.2 Classification of Vehicles

There are three vehicle classifications by the Driver Vehicle and Licensing Authority (DVLA).

- **Car**: includes cars towing a trailer or caravan
- **Light commercial vehicle (LCV)**: any cab chassis 1.5-4.5 tonne gross vehicle mass (GVM), two axles.
- **Heavy commercial vehicle (HCV)**: includes rigid trucks with three or more axles over 4.5 tonnes GVM and buses with 13 or more seats including driver and articulated trucks.

Light commercial vehicle (LCV) sometimes called Light goods vehicle (LGV) is a commercial carrier vehicle with a gross vehicle weight (GVW) of up to 4.5 tonnes. Vehicles which qualify in this category are pickup trucks, vans and 3 wheelers and all commercially based goods or passenger carrier.

2.3 Classification of Vehicle Modifications

Modification according to Advanced Longman dictionary is a small change made in something such as a design, plan, or system. According to Adewale (2009) vehicle modification is synonymous to vehicle conversion and that there are two types of modification.

Slight change: This is when a part of the vehicle is modified to achieve the desired purpose. For example, lengthening of chassis frame of 207 buses to carry more passengers.

Complete change: This is when the whole vehicle is converted from its present form to an entirely new form. For example, conversion of a cargo truck to a tipper truck.

Apart from these, there is also an operational change or modification that is done to the vehicle. This is experienced when the means of providing power or moving the vehicle is changed. For example when the petrol engine vehicle is changed to using Liquefied Petroleum Gas (LPG) and vice-versa or automatic transmission is changed to manual transmission. Again, according to the Vehicle Standard Information (2007) vehicle modifications also fall into three categories. There are owner certified minor modifications which can be accepted for registration purposes without formal certification. Engineering signatory certified modified production vehicles and engineering signatory certified individually constructed vehicles.

These modifications by themselves are legitimate. However, the manner and the way in which they are carried out may not conform to the laid down regulations established by the various international and national transport authorities in charge of registration, licensing and the manufacturing of the vehicles (Adewale, 2009).

According to Donkor (1990), some of these modifications have been linked to casualties on the road due to the fact that they are built on poor design principles.

2.4 Modifications that do not Need Approval

Minor modifications are accepted if and only if they do not :-

- Reduce the vehicle strength structurally
- Affect vehicle control and stability
- Hinder vehicle safety
- Affect the braking system (efficiency) and
- Cause nuisance to other road users (Vehicle Standard Information, 2007)

The following minor modifications are allowed so long as they do not contravene the Road Traffic and Vehicle Safety standard rules.

- Door modification (changing of door handles, glass winding mechanism etc)
- Tyre size and aspect ratio
- Air conditioners
- Alarm (security) systems
- Additional lighting
- Roof racks
- External carriers
- Wind screen and lamp shields
- Seat belts
- Radio and stereo systems
- Blinds and other internal screening systems (Queensland Transport, 2008)

2.5 Modifications that Need Approval

Complex modifications such as engine upgrades, gearbox and rear axle changes, vehicle body modifications and steering and brake replacements require approval from an Approved Agency.

The following modifications also need approval:

- Additional axle or axles
- Chassis extension
- Wheelbase alterations
- Increase in gross vehicle mass or gross vehicle weight
- Brake modifications
- Change of vehicle type
- Engine changes (Queensland Transport, 2008)

2.6 International Motor Vehicle Modifications and Alteration Regulations

To establish standards for the alteration and modification of vehicles the International Motor Vehicle Safety Standards has regulations concerning parts or components of the vehicle. For example vehicles which have had original engines replaced with engines of greater horsepower or of significant difference respecting physical size and shape shall have the following:

a. Power ratio compatibility with the remainder of the drive train (transmission, U-joints, drive shaft, differential, axles) b. Must have adequate engine mounting to frame c. Must have sufficient space to accept normal engine torque movement without contacting the frame or other adjacent components or body structure d. No part of the motor shall interfere with any steering component e. No frame shall be cut or notched without being boxed, fish plated, or otherwise modified so as to retain its original strength f. No part of the engine shall be at a height which intrudes the forward viewing area of the driver. The full regulations for the various parts or components below are in Appendix B.

i) Body requirements.

(a) Defroster and defogging device

(b) Door latches

(c) Floor pan

(d) Glazing

(e) Driver visibility

(f) Hood latches

(g) Instrumentation and controls

(h) Rear view mirror

(i) Seat belts

(j) Seat securement

(k) Windshield wipers

ii) Chassis requirements

(a) Accelerator control system

(b) Brakes

(c) Bumpers

(d) Exhaust system

(e) Fenders

(f) Frame

(g) Fuel system

(h) Steering and suspension

iii) Electrical system requirements

(a) Dimmer switch

(b) Headlamp system

(c) Headlamp system

(d) High beam indicator

(e) Horn

(f) License plate lamp

(g) Parking lamp

(h) Stop lamp

(i) Tail lamp system

(j) Turn signal indicator

(k) Turn signal lamp

(l) Turn signal switch

(m) Position of controls

2.7 Ghana Vehicle Alteration and Regulatory Body

The Driver and Vehicle Licensing Authority (DVLA) is a semi-autonomous public sector organization under the Ministry of Transportation. It was established by Act 569 of 1999 to be responsible for ensuring safety on roads. Before the enactment of the DVLA Act, the Department was called Vehicle Examination and Licensing Division (VELD). The mandate of the Authority as provided in the DVLA Act is to promote good driving standards in the country, and ensuring safety of vehicles on roads and to provide for related matters.

2.7.1 Functions of the Authority

The functions of DVLA as spelt out by the Act are as follows:

- Establish standards and methods for the training and testing of driving instructors and drivers of motor vehicles and riders of motor cycles
- Establish standards and methods for the training and testing of vehicle examiners
- Provide syllabi for driver training and the training of instructors
- Issue driving licenses
- Register and license driving schools
- License driving instructors
- Inspect, test and register motor vehicles
- Issue vehicle registration certificates
- Issue vehicle examination certificates
- License and regulate private garages to undertake vehicle testing
- Maintain registers containing particulars of licensed motor vehicles, driving instructors, driving schools and drivers of motor vehicles.

  (Parliament of the Republic of Ghana Act 569, 1999)

The Driver Vehicle and Licensing Authority (DVLA), however, has limited requirements for physical conversion of a motor vehicle in Ghana. The procedure for physical conversion involves the transformation for the make of a motor vehicle. For instance, conversion of a van into a bus, or conversion of an articulated truck into a tanker.

Requirements:

i) Vehicle owner must submit to DVLA a formal request for physical conversion.

ii) The requested application must contain the vehicle owner's name and address, chassis and engine numbers of the vehicle.

iii) The vehicle must be brought to the premises of DVLA for inspection after conversion to ensure that the physical conversion has been done and the vehicle is in good condition.

iv) A fee is charged for the processing.

v) Copies of the processed documents are given to the vehicle owner with the Authority retaining original copies on the vehicle file (DVLA, 2010).

2.8 Braking System

A moving vehicle possesses kinetic energy whose value depends on the weight and the speed of the vehicle. The engine provides this energy in order to accelerate the vehicle from a standstill to a given speed, but this energy must be partially or totally dissipated when the vehicle is slowed down or brought to rest. It is the function of the braking system to convert the kinetic energy possessed by the vehicle at any time into heat energy by means of friction and eventually bring the vehicle to a stop.

2.8.1 Types of Braking System

There are two main types of friction brakes which are in common use today. They are the drum brake and the disc brake. The disc brakes are more favoured by most car manufacturers because it offers a number of advantages over the drum brake. The chief among the advantages is the fact that the disc friction surface on which the heat is generated is exposed to the air. This makes heat dissipation easier and provides a greater resistance to fade. Brake fade is the loss of retardation or stopping power which occurs during the application of the brake and it is caused by the overheating of the brake assemblies. This high temperature reduces the coefficient of friction of the brake lining, a fact clearly demonstrated when the vehicle is fitted with drum brakes.

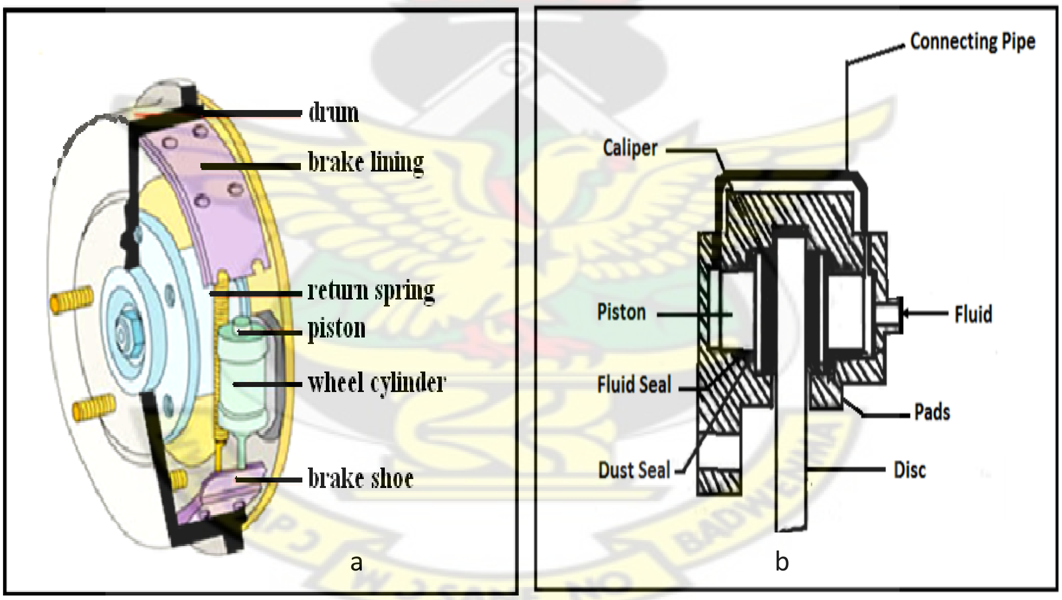


Figure 2.1. The Brake System (a) Drum and (b) Disc brake assembly

2.8.2 Brake Operating Systems and their Layouts

Until the mid-1930s most braking systems were mechanically operated using rods and cables (similar to brakes on a bicycle). Today most foot brakes systems are operated hydraulically, although the handbrake is still usually operated by mechanical linkages.

Some heavy commercial buses and heavy duty trucks are also operated pneumatically (Hitler et al, 2004).

2.8.3 Mechanically Operated System

A mechanically operated system uses a series of push rods or cables together with levers to push the brake linings against the friction surface. Fig 2.2 shows the layout of a simple mechanical system.

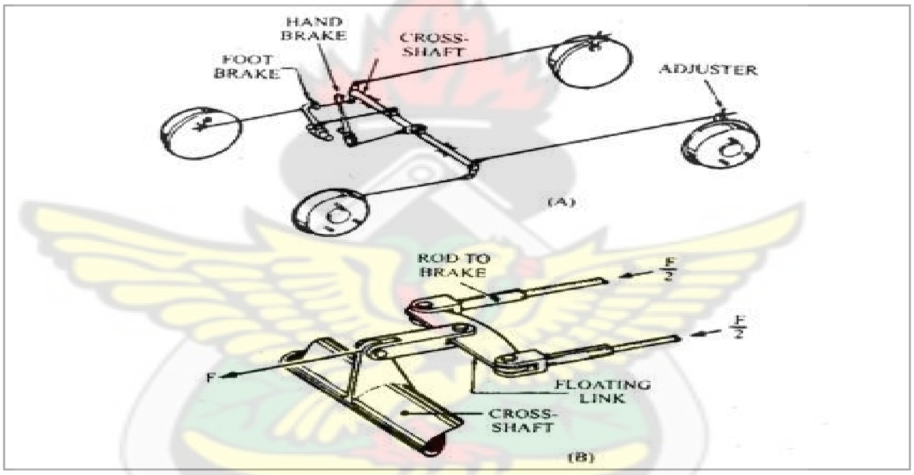


Figure 2.2 Mechanical brake layout. (A) Brake layout. (B) Brake compensator to balance two brakes

2.8.4 Mechanically Operated Handbrake

To comply with legislation, a vehicle must have a handbrake (parking brake) to hold the car stationary when the vehicle is left unattended. The handbrake also functions as an emergency brake should there be any major failure with the main braking system. Legal requirement insist that hydraulically operated brake systems must be fitted with mechanical handbrake that acts on at least two wheels.

The handbrake mechanism is usually operated by a hand lever, the lever is held in the "on" position by a ratchet and paw mechanism. When the handbrake is disengaged, the pawl is released from the ratchet allowing the brakes to be released

2.8. 5 Hydraulically Operated Systems

A hydraulic system has a much higher efficiency than a mechanical system and is fully compensated, (i.e. brake pressure is balanced to all the brake wheel cylinders).

The system consists of a fluid tank or reservoir, a master cylinder, a system of rigid and flexible pipes, pipe junctions and wheel cylinder assemblies. The reservoir may be combined with the master cylinder. The wheel cylinder may operate shoes and linings or disc pads. The layout of the system is shown in fig 2.3

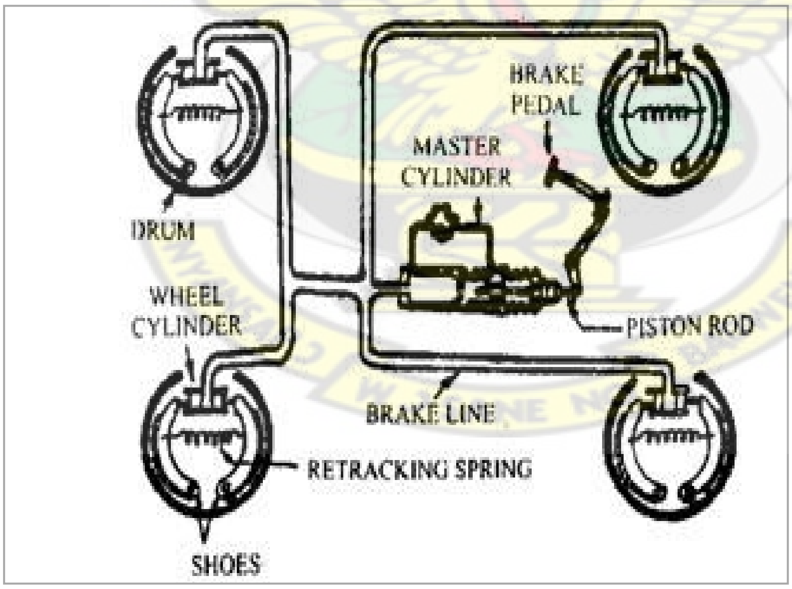
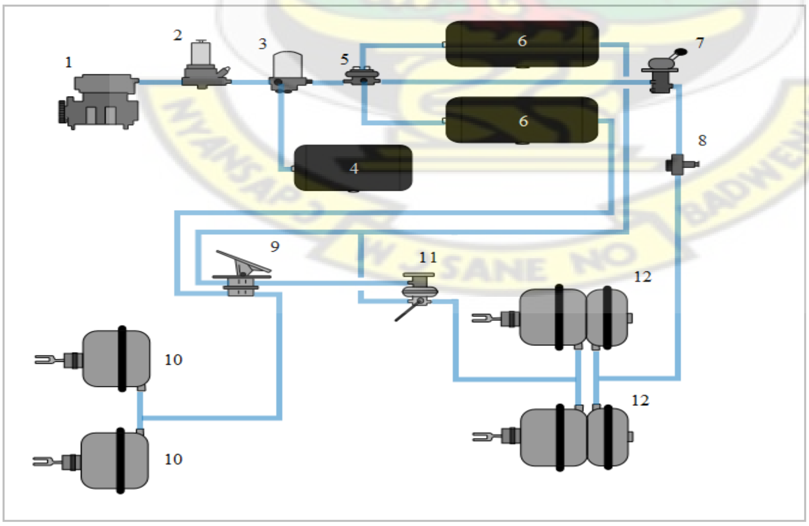


Figure 2.3 Hydraulic brake layout

When the foot brake pedal is operated, a piston in the master cylinder pumps fluid through the lines into the wheel cylinders. This causes the pistons in the wheel cylinders to move outwards so that the shoe or pad is brought into contact with the drum or disc. The pressure on the master cylinder piston is transmitted through the fluid in the system to apply a force to each brake. The greater the force applied to the pedal, the higher is the pressure produced in the system.

2.8.6 Pneumatic Operating Systems

Air brakes are used in trucks, buses, trailers, and semi-trailers. Compressed air brake systems are typically used on heavy trucks and buses. The system consists of service brakes, parking brakes, a control pedal, an engine-driven air compressor and a compressed air storage tank. For the parking brake, there is a disc or drum brake arrangement which is designed to be held in the 'applied' position by spring pressure. Air pressure must be produced to release these "spring brake" parking brakes. For the service brakes (the ones used while driving for slowing or stopping) to be applied, the brake pedal is pushed, routing the air under pressure to the brake chamber, causing the brake to reduce wheel rotation speed.



1. Air compressor
2. Pressure regulator
3. Air dryer
4. Regeneration reservoir
5. Four way protection valve
6. Compressed air reservoirs
7. Park brake hand control
8. Park brake safety release valve
9. Brake foot valve
10. Front air brake chambers
11. Brake relay valve + load sensing valve
12. Rear spring brake chambers

Figure 2.4 Pneumatic brake layout

2.9 Braking Efficiency

Vehicle braking efficiency is the ratio between the retardation or deceleration of the vehicle and the acceleration due to gravity, expressed as a percentage. Retardation and acceleration due to gravity, g are both measured in units of metre per square second (m/s^2) and braking efficiency may be calculated from the formula:

Braking efficiency (BE) =

The GVWR is normally shown on the manufacturers' name plate or in the manual.

Curb or kerb weight (CW) is the total weight of a vehicle with standard equipment, all necessary operating consumables e.g., motor oil and coolant, a full tank of fuel, while not loaded with either passengers or cargo.

Unladen weight (UW) is the weight of an empty vehicle or container.

2.11.1 Stopping Distance method of Determining Braking Efficiency

In this method the vehicle is driven at a steady speed on a level road. The brakes are applied and the distances covered between applying the brakes and stopping the vehicle is measured. The test is repeated in opposite directions and at the same speed to reduce possible inaccuracies resulting from the effects of wind and slight variation in road gradient. Tyre pressures must of course be set to the manufacturer's specification. When the stopping distance for a given speed is known, the braking efficiency may be determined from tables such as those published by brake manufacturers and the motoring organization as shown in table 2.2 or from calculations using Newton's equations of motion.

Table 2.1 Braking efficiency and stopping distance

Efficiency (%)	**DISTANCE TO STOP**									
	From		From		From		From		From	
	20 miles/h	32.2 km/h	30 miles/h	48.3 km/h	40 miles/h	64.4 km/h	50 miles/h	80.5 km/h	60 miles/h	96.6 km/h
	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres
30	44.7	13.6	100	30.5	178	54.3	278	84.7	400	121.9
50	26.8	8.2	60.2	18.4	107	32.6	167	50.9	240	73.2
60	22.4	6.8	50.2	15.3	89.3	27.2	139	39.9	200	61
70	19.2	5.9	43	13.1	76.6	23.3	119	36.3	171	52
80	16.8	5.1	37.7	11.5	67	20.4	104	31.7	150	45.7
100	13.4	4.1	30.2	9.2	53.6	16.3	83	25.3	120	36.6

Source: Dolan, 1976

The efficiency can be interpreted using the tables 2.3 and 2.4.

Table 2.2 Percentage efficiency corresponding to brake conditions

EFFICIENCY %	BRAKES CONDITION
30	Minimum allowable for any vehicle
50	Four wheel brakes in good condition
60	Four wheel brakes in very good condition
70	Four excellent brakes in excellent condition
80	Safest degree of efficiency
100	Theoretical limit for brakes on all wheels

Source: Mudd, 1972

Table 2.3 Efficiency interpretation table

EFFICIENCY (%)	QUALITY
30	very poor (dangerous)
40	Poor
50	Fair
60	Good
70	Very
80	Excellent

Source: Dolan, 1976

2.11.2 Decelerometer Method of Determining Braking Efficiency

In this method the braking efficiency is indicated directly by the tapler meter. The Tapley meter records the effect of the retardation upon a pendulum, i.e. it records how far a pendulum is forced from the vertical. Higher the retardation, greater the swing of the pendulum and vice versa. The pendulum swing is hydraulically damped to enable the instrument to be used in a vehicle subjected to vibration and road shocks, and it must carefully zeroed while the vehicle is on a level ground, i.e. the pendulum must be vertical before the test is carried out. The motion of the pendulum is transfered by a magnet pivoting about the same point, the magnet rotating a circular scale by the action of a gear and quadrant.

2.11.3 Using Test Instrument to Determine Braking Efficiency

Tests of braking efficiency may also be carried out by means of much larger, more elaborate, and more expensive machines. These instrument can test not only the overall efficiency but the retardation torque exerted by each brake and wheel assembly it is possible to therefore check and correct unequal braking efforts between the near and off-side assemblies, and proportioning of the braking effort between the front and rear wheels. There are two main types of instrument available, the platform and the roller type.

2.11.3.1 Platform Type instrument

In this type, the vehicle is driven on to four platforms at a speed of between 6 km and 13 km/h and the brakes applied. As the brakes operate, the wheels move the platforms against a fixed resistance, the extent of the movement of the individual platforms being indicated upon dial gauges or columns of liquid. The four indicators are calibrated in hundreds of newtons and are automatically cancelled as the vehicle is driven off the plat forms.

2.11.3.2 Roller Type instrument

In this type, the rollers are of steel and have a diamond tread pattern. They are arranged in pairs at each side of the machine and each pair is driven by an electric motor in such a way that their torque reaction can be measured. The reactions are transmitted to gauges by a hydraulic system and the gauges are calibrated in hundreds of newtons. These instruments test front and rear wheel brake separately. The motors are set running and the gauges are zeroed. The vehicle is driven on to the machine in such a way that the front wheels contact the rollers and brakes are then applied. The resistance the wheels offer to the rotation of the rollers results in a torque reaction which is indicated on the dials. The two gauge readings are recorded and the gauges zeroed again ready for the rear brake test, the vehicle being driven forward to bring the rear wheels on to the rollers.

The total retardation force is the sum of the separate braking force in hundreds of newtons. The braking efficiency may then be calculated from formula or determined from the manufacturers' charts. The vehicle weight must be known.

CHAPTER THREE

CONVERSION PROCESS AND EXPERIMENTAL SET UP

This chapter looks at how the research was conducted and describes the conversion processes, tests conducted to determine the efficiency of converted 207 buses.

3.1 Suame Magazine

Suame magazine is a suburb in Kumasi, the Ashanti Region of Ghana and a local vehicle modification site where automobile services, repairs, fabrication of metal works, spare parts and scraps are carried out. The magazine has about 4000 artisans with excellent practical skills and high level ingenuity. Apart from artisans involve in automobile services and repairs other workers are spare part dealers, scrap dealers, black smiths, tools dealers, oil and lubricant dealers, electronic dealers, vehicles and vehicle accessories sales, vulcanizers, machine tool shop operators, casting experts to food vendors. In Kumasi, for that matter Ghana, Suame Magazine stands out as the site where all vehicle repair works can be done.

3.2 Overview of Modifications done to Vehicle in Suame Magazine

The following modifications are undertaken in Suame magazine:

i. Chassis extension or wheel base alteration
ii. Conversion of petrol injection to carburetor system
iii. Propeller shaft extension
iv. Increase in vehicle capacity so as to carry more passengers or goods
v. Radiator change and thermostat removal

vi. Complete conversion of one vehicle type to another (cargo truck to tipper truck)

vii. Conversion of 207 van to commercial vehicle

viii. Building or mounting of bodies on naked chassis (as it is done to get the Metro mass vehicle)

ix. Conversion of automatic transmission to manual transmission

x. Changing of motor cycle to tricycle

xi. Changing of left hand drive vehicle to right hand drive vehicle

xii. Conversion of transistorized ignition system to the coil ignition system

xiii. Conversion of one door car to multiple door cars

xiv. Various structural cosmetic changes such as modifying of body styles, fixing of glasses, painting or spraying works, coloured head lamp and tinted glass

xv. Conversion of petrol engine vehicle to gas (LPG) engine vehicle or vice versa

3.3 Conversion Process of Mercedes- Benz '207'cargo to Bus at Suame Magazine

The Conversion of Mercedes Benz 207 van is transformed to the passenger's bus in Suame Magazine in order to solve the domestic transport needs and to reduce the cost of buying a brand new Mercedes Benz bus. The Mercedes Benz van is converted to the bus through the following processes. Suspension (leaf spring) alteration, chassis frame alteration, brake adjustments, body and spraying works, making of seat and fixing of glass.

3.3.1 Suspension System (Leaf Spring) Alteration

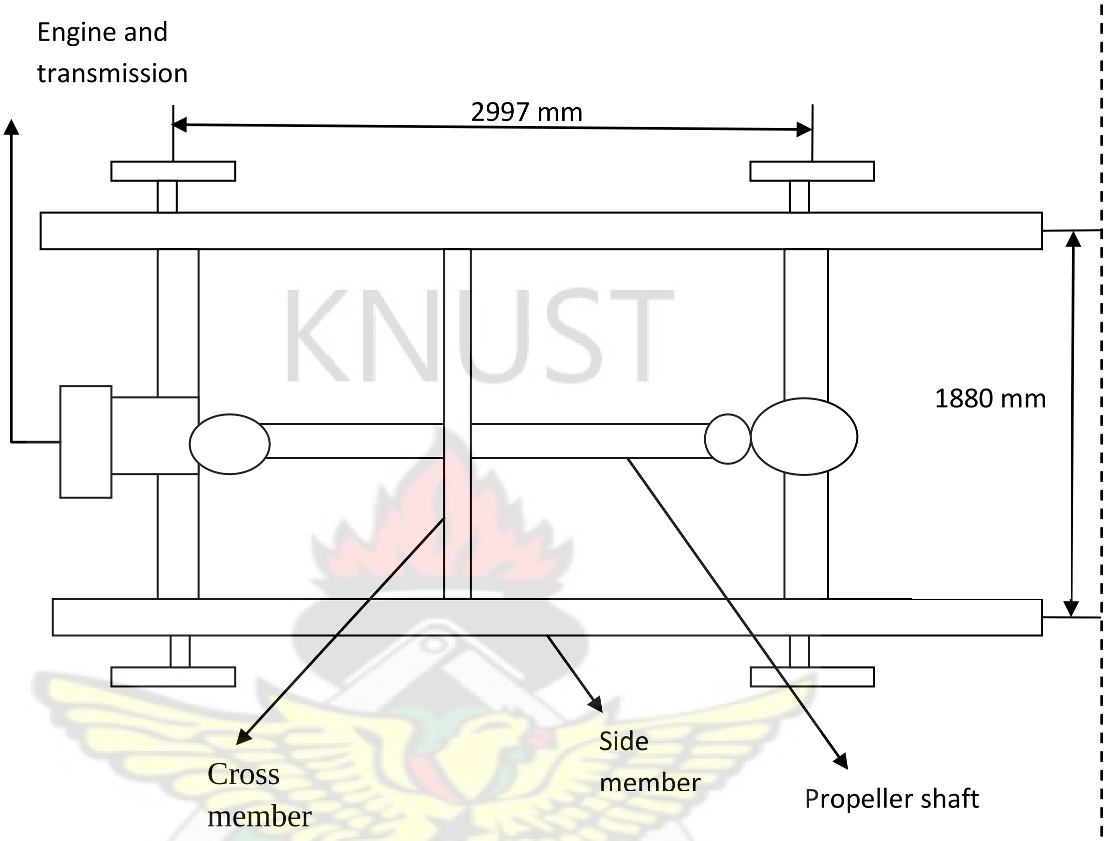
In order to give more ground clearance beneath the body and chassis for the bus to sustain more loads and to reduce shock and vibration due to too many irregularities on the road surface being transmitted to the occupants of the bus, the leaf springs are altered. This alteration affects or impairs the stability and the general handling qualities of the bus. The original bus comes with one leaf or more at the front and two or more leaves at the rear. Since these springs will not withstand the weight of the passengers and the load, they are increased by adding two or more leaves to the master or the longest leaf and in addition put another leaf in between the spring and the axle. The procedure for increasing the number of leaves of the bus is quite simple. The vehicle is jacked and supported with no axle stand. Tyres are either removed or left in position. The movable and fixed shackle pins are unscrewed, centre bolt or U-bolt removed and the spring is taken out. The clips are removed and individual leaves are inspected and changed. For the front beam and from the U-bolt position 23/26 cm leaf is added and in the back axle (rear axle) 28/30 cm leaf is added to the master leaves. More supports leaves are added from the experience of the artisan or the interest of the customer based on the load to be carried and the ground height the customer wants. Since the leaves are increased the old clips are replaced and' human tension' is used to press the leaves together while fixing the clips with no friction materials in between the leaves. Original rubber or plastic bushes are replaced by rubber bushes made from tyre by another artisan whose job is to cut and produce rubber bushes from tyre for vehicles. In fixing it, the spring is set in position with rubber (tyre) bushes push inside the eyes of the longest or master leaves. The centre bolt and its supports are positioned to hold the spring and axles together. The ground clearance for the original cargo was 20 inches (51 cm).When the two leaves are added the average ground clearance was found to be between 60.9 cm to 76.2 cm (2 to 2.5 feet).

Figure 3.1 Artisan fixing leaf spring of Benz 207

3.3.2 Chassis Frame Alteration

To increase occupancy, chassis are extended in between wheels. The following components propeller shaft, rear brake pipes, cables for hand brake and other auxiliary components and parts are removed. The chassis frame is measured and a cut is made at two points where the extension plate is to be fixed with power grinding and cutting machine. Two metal plates of length 40 cm are welded to the side members. Two or more reinforcement bars are welded in between the cross members. Body is built on the new portion. Depending on the extension the propeller shaft is replaced by a longer one or extended using two propeller shafts joined together by universal joint. The rear and handbrakes are discarded and adjustment is done on the front brake to concentrate the total braking force on the front. However, in theory the front brake is designed to accommodate 60% of the braking force and the rear brake 40%. This is to prevent the vehicle toppling or overturning during braking. The figures 3.2 to and

3.3 show the dimensions of chassis frame of Mercedes-Benz 207 van before and after conversion respectively.



Dimensions of wheel base and wheel track of 207 bus before conversion

Figure 3.2 Dimensions of wheel base and wheel track of 207 bus before conversion

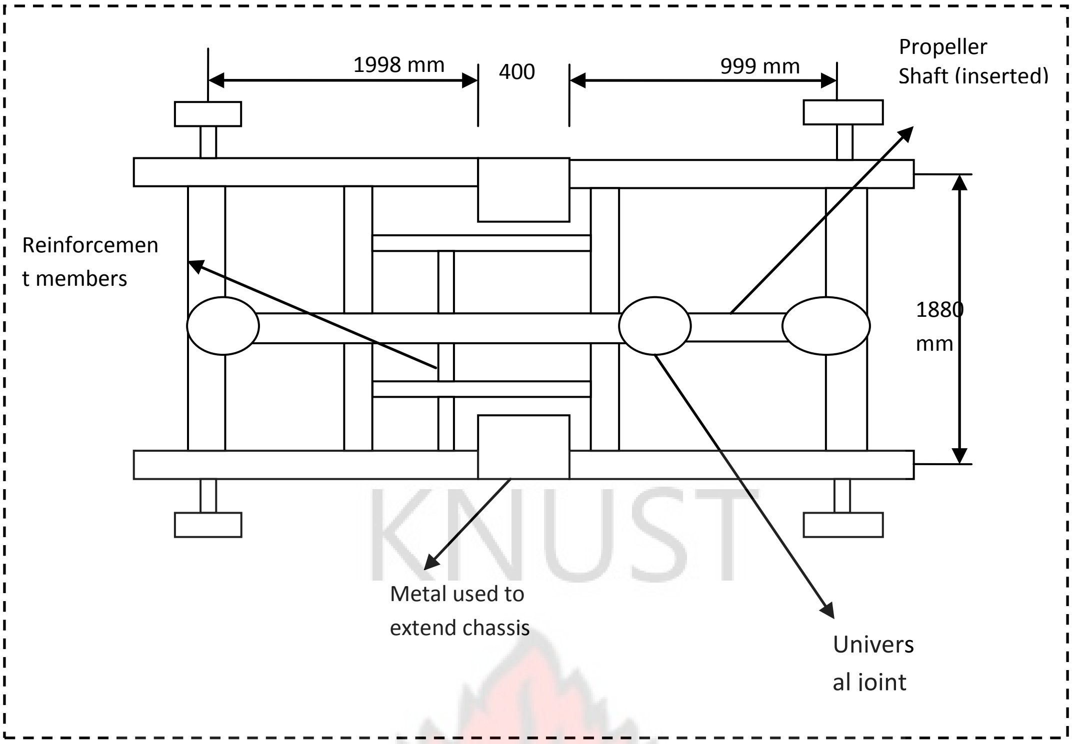


Figure 3.3 The lengths of the wheel base and track of 207 bus after conversion

3.3.3 Braking System Alteration

Apart from the sprinter which uses both disc brakes at the front and the rear, the other models (208D, 410D etc) use disc brake at the front and drum brake at the rear. In adjusting these brakes, the hand brake which operates the rear brake mechanically is discarded in some of the buses during the conversion process. In some other 207 buses, the rear brake itself is removed and the maximum braking force is concentrated in the front only. According to the mechanics, this is done to ensure that the vehicle can stop as fast as possible and have a high braking efficiency at the front only. But this rather results in rapid wear at the front brake lining and tyres, discomfort to passengers and the risk of losing control of the bus during braking. Also, in theory the front brake is designed to accommodate 60% of the braking force and the rear brake 40%. This is to prevent the vehicle toppling or overturning during braking. In the brake adjustment, try and error or ‘feel’ the brake pedal method is used. This adjustment is done to ensure that the brake shoe or pad clearance is within the correct limit. In doing the adjustment, the bus is jacked up and the wheels turn until the hole corresponds with the adjusting screw. A flat screwdriver is inserted in hole drilled through the wheel and the brake drum. When the screw driver touches or ‘feels’ the shoe adjusting screw, it is then turned until the correct clearance is obtained. The drum is rotated to ensure free movement while the assistant depressed the brake pedal to feel the brake and to achieve the correct clearance between the shoes and the drum for efficient brake action to be achieved.

Master cylinder seal replacement

The master cylinder seals are replaced or changed through the conversion process of the 207 buses with a locally manufactured seal made from tyre which any data than the ‘original’ seal. Generally, the seals are replaced whenever a sign of crack or damage is shown to avoid leakage of brake fluid passing by the master cylinder and also maintain the brake fluid pressure in the system. The seal is replaced with its piston and spring in the master cylinder. The master cylinder is removed from its position before getting access to overhaul and replaced the spring, piston together with the seal.

Other maintenance and replacements carried out on the braking system of the bus were.

a) Replacement of brake shoes or pads
b) Renewal of rubber horse.
c) Replacement of hand brake cable when damaged
d) Renewal of drum or disc when they become excessively worn out.
e) Replacement of brake caliper and its parts

Tools and materials for servicing and maintenance of braking system of the bus were:

a. Brake fluid, master cylinder, wheel cylinder repair kits
b. Sand paper used for cleaning the brake shoes disc or drum
c. Wrenches, screw drivers and spanners for loosing and tightening bolts and nuts
d. Pliers for removing and replacing brake shoes and retaining clips and other parts

3.3.4 Spraying

The 207 bus goes through the following stages during the spraying processes.

Surface preparation. The high and low spots of the body are hammered to the level of the surrounding contour of the panel by the use of pick hammer, mallet and dolly block. This is done to ensure that the surface on which the filler is to be applied is straight. The wire brush or sand paper is used to clean the rust and dirt from the surface on which the filler is to be applied if necessary.

Application of the body filler

The plastic filler is first stirred thoroughly. After the filler is properly stirred, a small quantity is put onto a missing board and then a small amount of hardener is added and missed with it together. The filler which has been missed with the hardener is applied onto the required area.

Sanding the filler

After the filler is dried, the filler is sand smoothly by using sand paper with sanding block or disc sander operated by pneumatic power. After this, the wet sand paper (P300 or 320) is used to finish the sanding with the water.

Application of undercoat

The putty is now applied over the filler or primer to fill minor imperfections. And sand paper with grit size of (P400 or 500) is used to smooth the area with water. Before applying the paint the bus is masked with a masking paper and masking type. This is done to prevent spraying unwanted portion of the bus.

Application of paint

After mixing the paint with the thinner or petrol to the correct manner, the paint is strained with a well designed sieve (strainer). The first coat paint is matched first onto an old panel which is not part of the vehicle body panel, purposely to see if it conforms to the original colour or type required. The paint is then applied onto the surface with the correct stroke and speed. The distance between the position of the spraying gun and the body surface is maintained to achieve a correct spraying. Sometimes the second coat is applied before the top coat or final coat is applied. This final stage requires a skill to obtain a better final refinishing. After the final finishing the paint is well dried and the surface polished with number four (4) or 7 polish material.

The following are tools, equipment and materials for the spraying works

a. Mallet(Rubber mallet, bumping hammer), sanding machine (disc sander), body filler file (hacksaw brade), sanding, abrasive material(sand paper), safety glass, noose mask, wire brush, dolly block, putty knife, masking tape, air compressor, air transformer, spraying gun with air hose, bucket with soap and water, sieve(strainer), cleaning cloth(washing mitt and brush), spraying booth, hand glove

b. Materials: Masking papers, body filling materials (plastic filler, fiber filler), undercoat materials (putty, primer, sealers), paint

3.3.5 Seat Production

To convert Mercedes Benz ‘207’ to a passenger bus seats are designed and fixed in position for the occupants. The following are the processes through which the seat are designed and fixed. Depending on the model the seat ranges from four (4) to six (6) seater buses .The most common one is the five (5) seater ‘207’ bus which has twenty (20) seats excluding the three front seats. The seats are arranged five rows with the rear seat having the dimension of 35 cm x 158 cm which accommodates four people. This rear seat has no adjustable part. The rest of the seats have the specification 35 cm by 112 cm and four of them are required and each accommodates three passengers. To complete the row, one small seat about 35 cm by 40 cm which can be adjusted for passengers to move to and fro in the vehicle is required. The height is 36 cm. The rest of the seats have a height of 48 cm and all the seats are mounted on a support that is 40 cm from the floor of the bus.

In forming the seat a half- inch galvanized pipe is measured to the recommended dimension (158 cm by 35 cm) and cut by a hacksaw. The round galvanized pipe or square pipe is preferred to solid steel because it can last longer, it does not corrode easily and can withstand high pressure according to the artisans. The pipes are joined to a rectangular form by arc welding. The backrest is formed through the same process and welded to the side of the rectangular frame. The unwanted portions are removed and the joints smoothened using grinding machine. The upholstery works is done on the seat with the following materials plywood, foam and leader. The supports are welded under the seat and fixed to the floor with bolts and nuts. A tyre rubber is placed between the base of the seat support and a flat plate welded on the floor to enhance friction. The side of the seat is fitted to an angle bar which is bolted and run through the side of the vehicle. The space between the seats is 31cm and the space between the rear seat and the inside of the bus is 22 cm. Fixing of the seats starts from the rear of the vehicle. The space between the seats is measured from the end of the seat to the back of the next seat without any anthropometric considerations. The total weight of these seats is 450 kg. The tools used in this process are hammer, chisel, electrode, steel tape measure, hack saw and combine grinding/cutting machine. Designing and fixing of seats in Benz 207 bus can last for a week and cost Gh 700.00.

Figure 3.4 207 Benz bus seat under construction

Schematic of Mercedes- Benz 207 bus seat

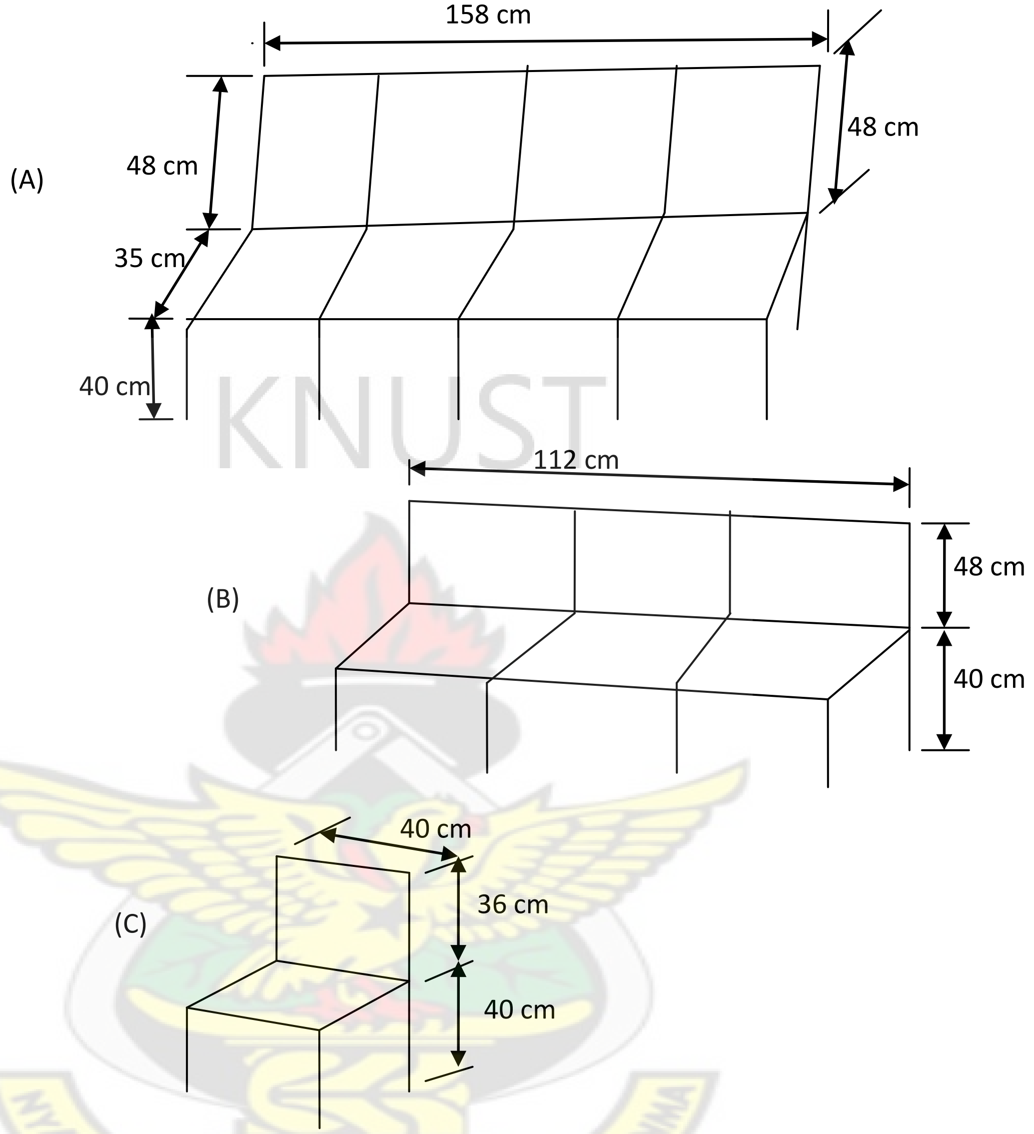


Figure 3.5 Schematic of Vehicle seat (A) Back seat (B) Middle seat (C) Adjustable

3.3.6 Fixing of Glass

The following are the tools and materials used in the process of fixing the glass. The grinding and cutting machine, chisel, heavy duty sledge hammer, steel tape measure, a sharp metal (scriber), flat sheet of metal (steel rule), bostic shooter (bostic gun), bostic, rivets , dolly block and straighten hammer.

The following are the processes by which the glass is fixed. When the cargo or 'container' as the artisans called it is brought to the shop the first thing that is done is measurement and marking out. This is done by a sharp piece of metal to serve as a scriber and a flat metal sheet in place of a steel rule to do the marking out. For the measurement, steel tape measure is used.

Cutting is the next process. This is done by the use of cutting machine (power chisel) which is powered by either pneumatic or electricity and sometimes by powered stand by generator plant if there is a power outage. The cutting machine is held by the artisan and put on the marked line and the cutting is done with much accuracy. A lot of skills and physical energy are expended in this operation. To make the edge of the cut edge accommodating for the glass, the cut edge is straightened and grinded using a straighten hammer, dolly block and disc grinder. An adhesive caulking compound (bostic) is applied at the cutting edge where the glass would be fixed and around the glass frame. The glass frame is then installed in the cutting edge and hold in position by clips or rivets. On some Mercedes Benz bus (207) where there are no glass portion, a thin sheet of metal is bent in a square form and fix round the cut edge using rivets or spot welding. Any small space left between these two parts is sealed using 'bostic' and a body filler. This square sheet metal formed is smoothened with the grinding machine to ensure that the square plate is in line with the window and the body of the car.

The fixing of the glass itself requires some expert knowledge and the hands-on experience and it is mostly handled by the 'master' of the garage. They are standard sizes of glasses available in the market. The cost depends on the specifications and the quality and to some extent the number of glasses to be fixed. Most of these glasses are sold with already fix rubber lining at the perimeter of the glass. When it is a naked glass then the rubber (weather strips) must be bought separately and fix it on the glass using glue. The following are the specifications of the glasses fixed on 208D Mercedes Benz ‘container’ undergoing conversion. The side glass has a dimension of 55.5 cm by 115.5 cm and four of these were required, two at each side. A small glass of the size 55.5 cm by 46 cm to complete the side glass is also fixed and two of them were used. The back glass (rear windscreen or shield) has each specification of 71 cm by 54 cm and two were fixed. The glass fixing is done manually by two people (a master and a senior apprentice). During the installation of the glass, the master holds the glass whilst the apprentice guides the glass inside the car with the two hands until the glass is in position. After the glass is set in position, for a rear windscreen and side quarter glasses, a rubber robe is used to fasten the glass together with the frame and the body until the bostic is dried enough. The robe is then removed and some ‘bostic’ is applied around to prevent water leaking around the glass into the interior of the car. Because of the hazards associated with this work leather glove, Wellington boot (safety boot), over coat, minimum use of safety glasses and maximum care needed to handle the glasses. During the mixing of hardener and a body filler and application of bostic the nose is protected with a cover (respirator). The whole process of fixing the glass which consists of measurement and marking out, cutting, straightening the edges, forming the base plate and fixing of the glass itself required four (4) days.

Figure 3.6 Fixing of glass

3.4 Experimental set up for Brake Testing

The roller brake testing instrument is instrument used to determine the braking efficiency of a vehicle. The brake roller tester at Kumasi Technical Institute (KTI) was used to conduct the test.

The most important parts of this instrument are the roller and the display cabinet. The size of the roller is 7000 mm long. The display cabinet indicates the values of the braking force. It is calibrated to read from (0- 8 kN) and has two sets of value, one for near (right) side braking force and the off (left) side braking for either the front brakes or the rear brakes.

Fig. 3.7 Brake Testing machine and rollers

Factors considered or checked before using roller brake testing instrument are:

(a) All tyres checked for their correct pressure (b) Types of tyres used and tread depth were inspected and checked. (c) The footbrake checked for sideways movements. (d) The spring and the stability of the vehicle were checked.

The table 3.1 shows the specifications of a roller brake testing instrument.

Table 3.1 Specifications of Roller Brake Testing Instrument

Name	**Unit**	**Comar 4070 brake Tester**
Model		4070RRT20
Max. axle weight	T	5
Measuring range	kN	0 – 8
Roller coefficient-wet		0.9-0.5
Temperature range	^{0}C	0 up to +70
Idle running speed	km/h	5.4
Roller length	Mm	1000
Roller diameter	Mm	216
Test width min.- max	Mm	800/2800
Dimension mechanics	Mm	670 x2905 x 255
Motor power	kW	2x3.7
Dimension display cabinet	Mm	600x800x200
Power supply	V	400V /3Ph
Fuse rating slow-blow	A	2x 25

3.5 Description of Experiment

After gauging or visually examining the tyres of the bus to ensure that they were not obviously under inflated, the instrument was switched on and waited for the right signal from the instrument. The instrument was programmed by setting the weight, direction of rotation of the roller, date, time and the year. The bus was driven forward with the front wheels positioned in the rollers. With the engine running and the bus or gears in the neutral position, the roller was started and with a signal from the monitor the brake was applied gradually until the rollers stopped rotating. The front braking force was displayed on the monitor or display cabinet. The bus was driven forward for the rear wheels to be positioned in the rollers and the same procedure was repeated and rear braking force for the near and off side recorded. The same procedure was followed when the braking force for the hand brake was checked.

Figure 3.8 207 Buses on Weighbridge

Factors considered or checked before using roller brake testing instrument

a. All tyres must be check for their correct pressure

b. Types of tyre used and tread depth

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter discuses the results obtained from the tests conducted on Benz 207 buses, the presentation and the analysis of the data collected.

4.1 Results of braking forces for original 207 buses

The table 4.1 shows the results of the testing done on the various original 207 buses to determined the braking force exerted by each brake. It can be seen from the table that the braking force concentrated in the front brakes is higher than those in rear brakes. The hand brake recorded the least braking force. That is, about 60% of the braking force was applied on the front wheels only. The total braking force was achieved by adding the braking force at the front and the rear when the service and hand brakes were applied. From the table, the total braking force varied from model to model with an average braking force of 23.4 kN.

Table 4.I Results of braking forces for original '207' buses

Vehicle	**Service Brake**				**Hand brake**		**Total Braking Force (kN)**
	Front brakes (kN)		**Rear brakes (kN)**		**Rear brakes (kN)**		
	Near side (NS)	**Off side (OS)**	**Near side**	**Off side**	**Near side**	**Off side**	
310D	6.8	5.8	4.5	4.0	3.2	3.1	27.4
208D	5.5	5.0	3.3	3.5	1.2	1.4	19.9
308D	6.1	6.4	5.0	4.4	2.0	2.2	26.1
210D	5.0	5.9	2.5	2.0	1.4	1.6	18.4
207D	3.6	3.2	2.4	2.6	1.0	0.8	13.6
310D	6.6	6.2	5.6	5.2	4.0	4.1	31.7
307D	5.8	5.0	3.5	3.8	1.5	1.3	20.9
Sprinter	6.1	6.5	4.2	4.5	2.5	2.2	26.0
410D	7.0	6.8	5.2	5.6	4.2	4.5	33.3
207D	4.5	5.1	2.0	2.2	1.4	1.5	16.7

4.2 Results of braking force, gross weight and braking efficiency (original)

The table 4.2 shows the total braking force measured using the roller brake testing machine tabulated in table 4.3, the gross weight from manufacturers manual and with appropriate formula the braking efficiency was calculated. The average gross weight for the original bus was found to be about 3340kg. The maximum efficiency of about 82.33% was obtained and close to 60.44% was found to be the least braking efficiency for the original buses. The average efficiency of 70% was obtained for the buses.

Table 4.2 Results of braking force, gross weight and braking efficiency (original)

Vehicle	**Total Braking force (N)**	**Gross weight (N)**	**Braking Efficiency (%)**
310D	27400	38000	72.10
208D	19900	25400	78.35
308D	26100	35000	74.57
210D	18400	28000	65.71
207D	13600	22500	60.44
310D	32700	38500	82.33
307D	20900	32000	65.31
Sprinter	26000	42500	61.18
410D	33300	47500	70.10
207D	16700	24500	68.16

4.3 The results of percentage imbalance at front and rear brakes (original)

The table 4.3 shows that the average percentage front imbalance was lower than the average percentage rear imbalance with the lowest being 2.8% for the front brakes while 5.7% was found for the rear brakes. 15.2 % was the highest imbalance obtained for the front brakes and 20% represented the maximum imbalance calculated for the rear brakes of the original bus.

Table 4.3 The results of percentage imbalance at front and rear brakes (original)

Vehicle	Service Brake		Front Percentage imbalance	Rear Percentage imbalance
	Front brake out balance (kN)	Rear brake out of balance(kN)		
310D	1.0	0.5	14.7	11.1
208D	0.5	0.2	9.1	5.7
308D	0.3	0.6	4.7	12.0
210D	0.9	0.5	15.2	20
207D	0.4	0.2	11.1	7.7
310D	0.4	0.4	6.1	7.1
307D	0.2	0.3	3.4	7.9
Sprinter	0.4	0.3	6.2	6.7
410D	0.2	0.4	2.8	7.1
207D	0.6	0.2	11.7	9.1

4.4 The results of total braking forces (converted 207 buses)

The table 4.4 shows the total braking force applied for the converted buses. Out of the ten vehicles tested, six was found to be without a hand brake which represented about 60% of the buses without effective hand brake. About 20% of the buses were found to be without rear brakes. 70% of the braking force was applied to the front brakes. The highest braking force was found to be 28.8 and the least found to be 14.

Table 4.4 The results of total braking forces (converted 207 buses)

Vehicle	**Service brake**				**Hand brake**		**Total Braking force (kN)**
	Front brakes (kN)		**Rear Brakes (kN)**		**Rear brake (kN)**		
	Near side	**Off side**	**Near Side**	**Off side**	**Near off**	**Off side**	
310D	6.4	7.1	5.6	6.2			25.3
208D	6.8	7.2	-	-			14.0
308D	6.0	5.5	5.0	4.0	2.5	2.0	27.5
210D	6.0	5.2	5.0	4.2			20.4
207D	6.3	5.2	4.0	3.0	2.5	2.0	24.5
310D	6.5	5.5	5.0	4.2	3.0	2.5	28.8
307D	7.0	6.3	5.5	5.0			23.8
Sprinter	5.2	6.5	4.8	3.8			20.3
410D	6.8	5.2	4.0	4.5	3.2	2.8	26.5
207D	7.3	7.8	-	-			15.1

4.5 Results of braking force, gross weight and braking efficiency (converted)

The table 4.5 shows the total braking force determined using the roller brake testing machine tabulated in table 4.4, the gross weight determined using weight bridge together with the relevant relation and with appropriate formula the braking efficiency was calculated. The average gross weight for the converted bus was found to be about 4122.6kg. The maximum efficiency of 69.01% was obtained and 41.86% was found to be the least braking efficiency for the converted buses.

Table 4.5 Results of braking force, gross weight and braking efficiency (converted)

Vehicle	Braking force (N)	Gross weight(N)	Efficiency (%)
310D	25100	47260	53.11
208D	14000	30500	45.90
308D	27500	48000	57.29
210D	20400	32250	63.26
207D	24500	35500	69.01
310D	28800	47500	60.63
307D	23800	37750	63.05
Sprinter	20300	48500	41.86
410D	26500	52500	50.48
207D	15100	32500	46.32

4.6 Results of percentage imbalance at front and rear brakes (converted)

The table 4.6 shows, the average percentage front imbalance was lower than the average percentage rear imbalance with the lowest being 5.5% for the front brakes while 9.1% was found for the rear brakes. 23.5 % was the highest imbalance obtained for the front brakes and 20.8% was found to be the maximum imbalance calculated for the rear brakes of the converted bus. There was no percentage imbalance for two rear brakes since there were no rear brakes.

Table 4.6 Results of percentage imbalance at front and rear brakes (converted)

Vehicle	Service Brake		Front Percentage imbalance	Rear Percentage imbalance
	Front brake out balance (kN)	Rear brake out of balance(kN)		
310D	0.7	0.6	9.9	9.7
208D	0.4	-	5.5	-
308D	0.5	1.0	8.3	20
210D	0.8	0.8	13.3	16.0
207D	1.1	1.0	17.9	25
310D	1.0	0.8	15.3	16
307D	0.7	0.5	10	9.1
Sprinter	1.3	1.0	20	20.8
410D	1.6	0.5	23.5	11.1
207D	0.5	-	6.4	-

4.7 Results of comparison of gross weight of original and converted 207 buses

The graph of figure 4.I shows that the gross weight of the original bus was increased when the bus was converted. The average percentage increase on the original bus was found to be 20%. The least and the highest percentage increases were found to be 9.52 % and 36.61% respectively.

Table 4.7 Results of comparison of gross weight of original and converted 207 buses

Vehicle	Gross weight original(N)	Gross weight converted(N)	% Increase
310D	38000	47260	19.59
208D	25400	30500	16.72
308D	35000	48000	27.08
210D	28000	32250	13.18
207D	22500	35500	36.61
310D	38500	47500	18.95
307D	32000	37750	15.23
Sprinter	42500	48500	12.37
410D	47500	52500	9.52
207D	24500	32500	24.62

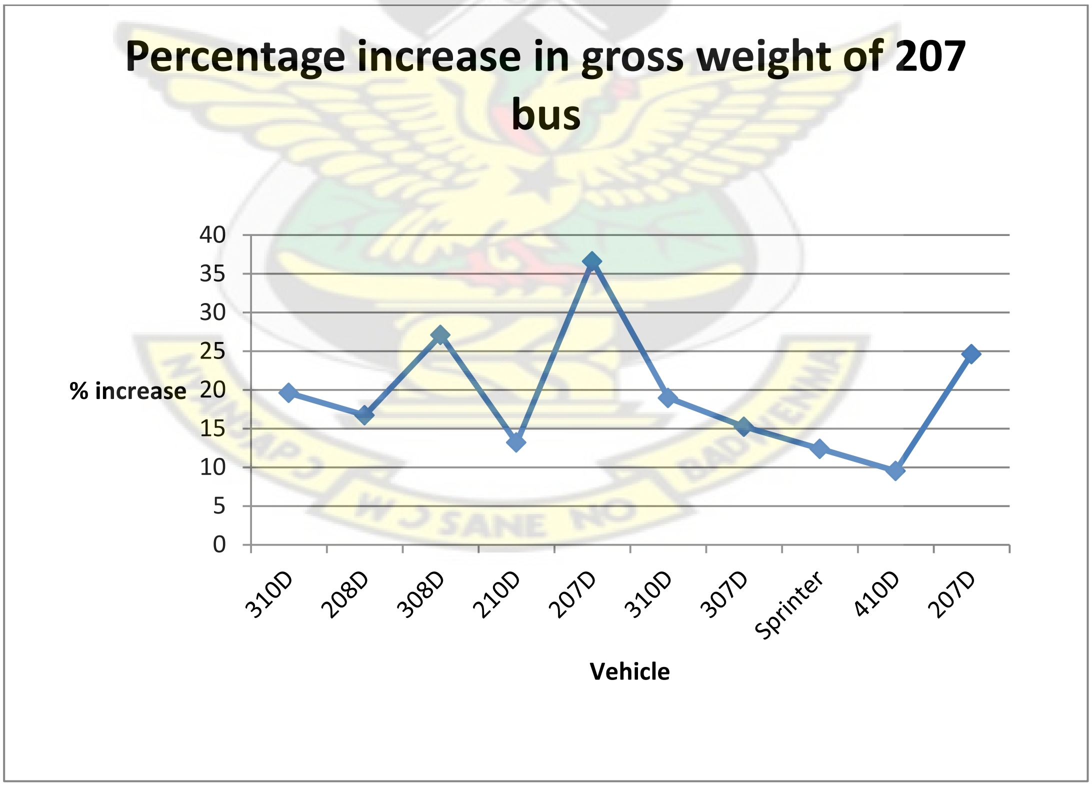


Figure 4.I Graph of percentage increase in gross weight of 207 bus

4.8 Comparison of front imbalances of original and converted 207 buses

The graph of figure 4.4 shows the front imbalances of the converted, original buses and compares it with the maximum standard front imbalance allowed. It can be seen from the graph that, out of the ten original buses tested six (6) of them fell within the standard value required for the front imbalance and for the converted five (5) of them exceeded the maximum value for the standard front imbalance.

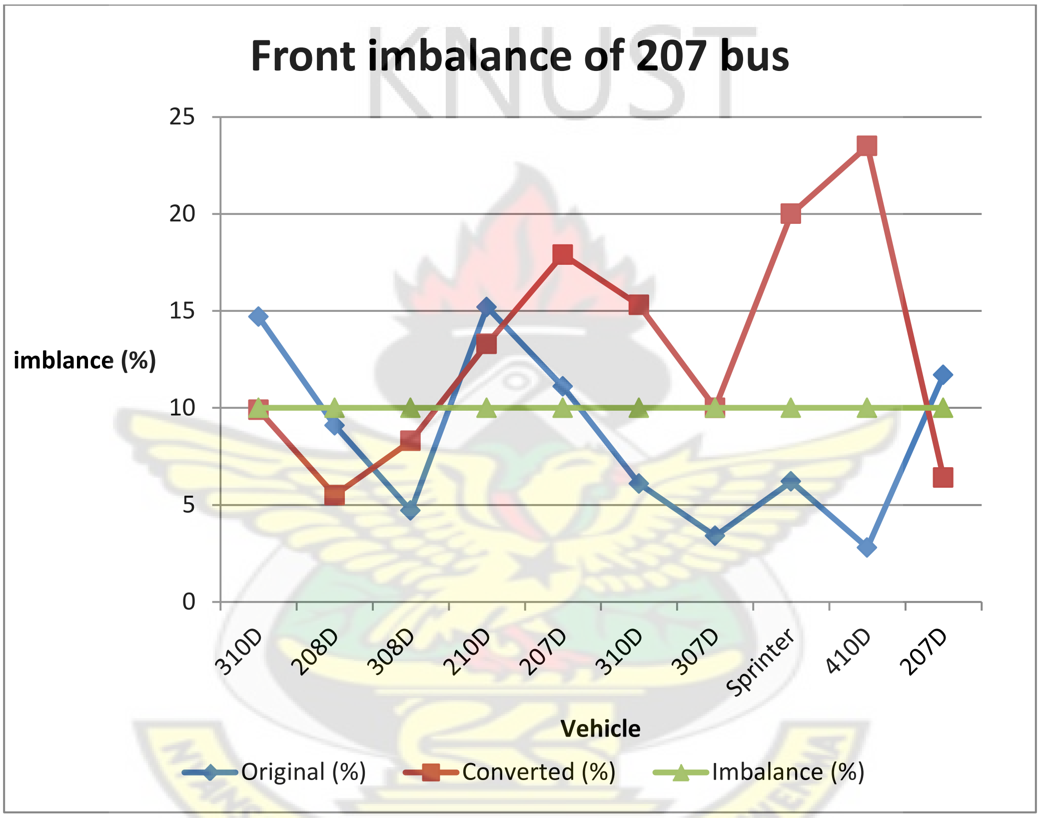


Figure 4.2 Graph of front imbalances of original and converted 207 bus

4.9 Comparison of rear imbalances of original and converted 207 buses

The graph of figure 4.3 reveals that out of the total original bus tested almost all of them were within range except 210D.This is because some of these buses are not brought fresh from the factory. And out of the ten buses tested when the buses were converted, five of them were above the maximum standard value required for rear imbalance and no value was showed for buses 208D and 207D since there were no rear brakes.

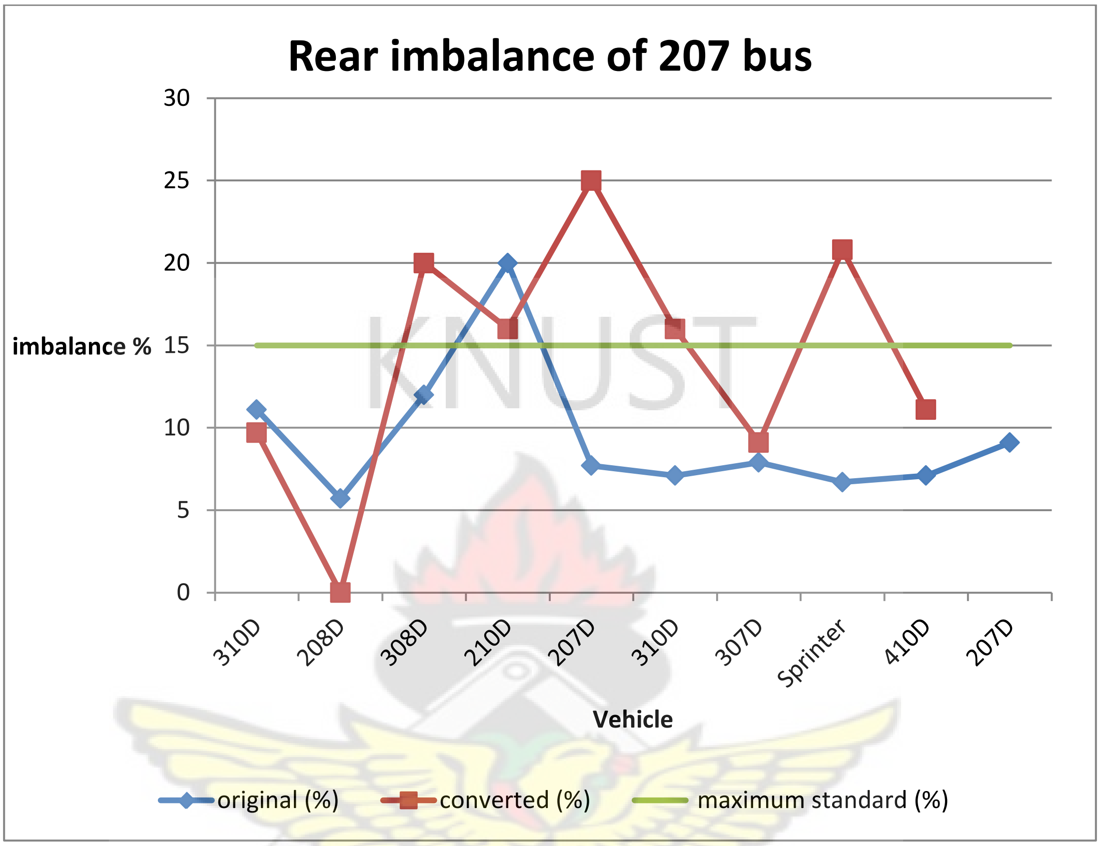


Figure 4.3 A graph of rear imbalances of original and converted 207 bus

4.10 Comparison of efficiency of original and converted 207 buses

The graph of figure 4.4 compares the efficiency of the original bus and the converted bus. It can be deduced from the graph that out of the ten buses tested the efficiency has decreased for seven of them when the bus was transformed from cargo to the passengers' bus. Only one bus showed an increase in efficiency when the bus was converted and two buses showed slight change in efficiency when the bus went through the conversion process.

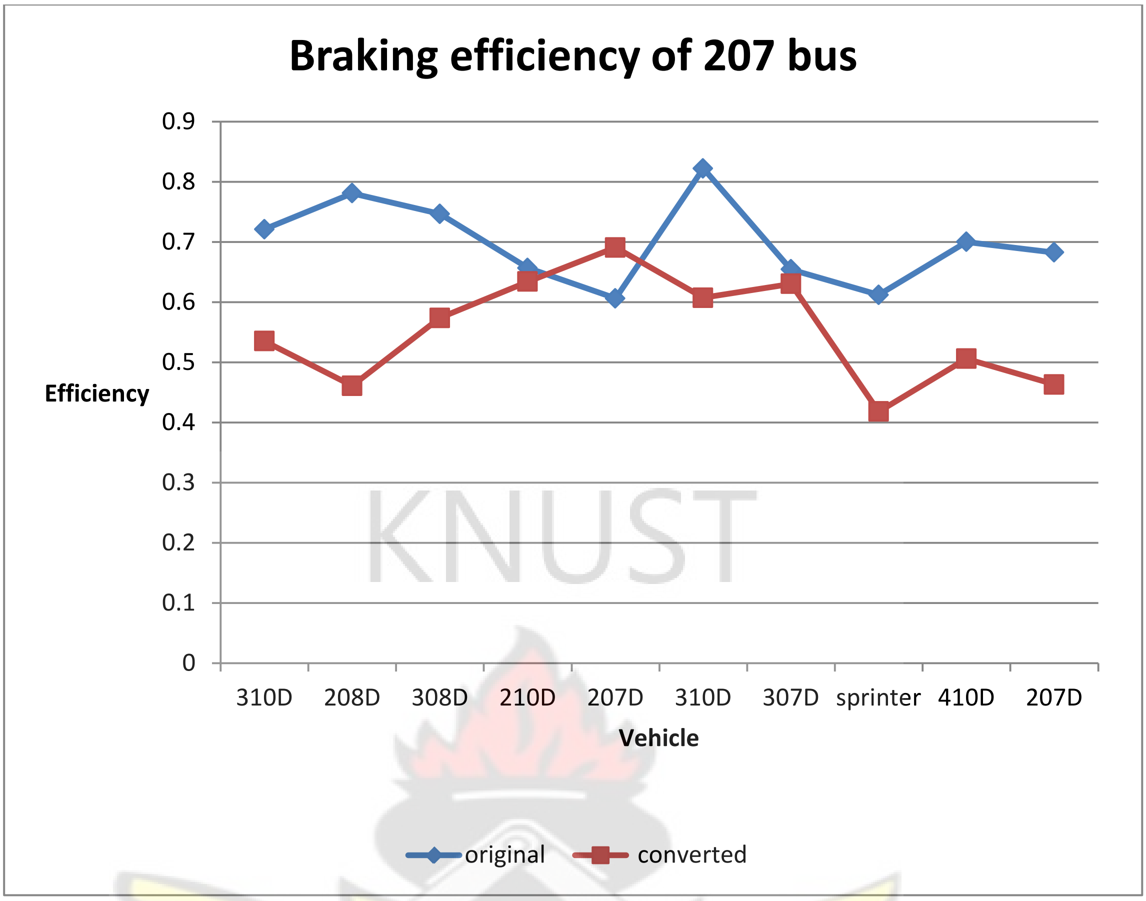


Figure 4.4 A graph of efficiency of original and converted 207 bus

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This research sought to find out the efficiency of converted Mercedes-Benz 207 buses and compared it with the original 207 van, the modification processes carried out on the 207 van and converting it to the passenger's bus. It was observed that the bus went through the following modifications before it was transformed to the passenger bus. Suspension (leaf spring) alteration, chassis frame alteration, brake adjustments, body and spraying works, seat construction and fixing of glass. The average ground height of the bus was increased and it was found to be between 60.9 cm to 76.2 cm (2 to 2.5 feet) when the suspension (leaf spring) of the bus was altered. It was again observed that most of the conversion processes done to the vehicle in Suame magazine were done from the experience the artisans acquired over the years. The artisans do not follow the laid down procedure in engineering design during the conversion process. The right or required machine, tools, materials and methods were not used when the artisans at the Suame magazine were undertaking the modifications.

During the conversion process, it was found that the gross weight of the original bus was increased by an average of 20% and out of the buses tested 70% of them were having no hand brakes and between 20-30% were having defective or no rear brakes. When the efficiency of the original and converted was compared it was observed that seven out of the ten buses tested had their braking efficiencies decreased, one had no change in braking efficiency and two converted buses had their braking efficiencies higher than the original when they were not converted.

5.2 RECOMMENDATIONS

The following recommendations have been arrived at to enable further research work to be carried out:

- Informal training should be given to the artisans in the Suame magazine by Non-Formal Education and NVTI so they can read and write, express themselves in English language, do and interpret basic engineering drawing or sketches etc.
- The government should supply the required machine, tools and materials and safety aids to the artisans in the magazine and subsidize the prices for them since they used their own manufactured or improvised tools most of which are dangerous to work with.
- The DVLA should stop licensing the converted 207 buses or at best license those that are tested and are within the braking efficiency recommended by the vehicle manufacturer.
- The DVLA in Kumasi as a matter of urgency install a new roller brake testing machine which will be used to test the 207 buses before licensing and during road worthy. The brake testing should not be delegated to any private garage since there is no mechanism to monitor and check if the vehicles really pass the braking efficiency test.
- Small sample size was used however it is recommended that any future research should consider analyzing a bigger sample size. This will help obtain more information on the 207 buses regarding their brake system

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APPENDICES

Appendix A

Interview Guide for mechanics at Suame Magazine

For a particular process …………………………..

1. Tool(s) used and how it is used in doing the work

……………………………………………………………………………………………..

……………………………………………………………………………………………..

2. What types of materials are used and sources of the materials?

……………………………………………………………………………………………..

3. What heat treatment techniques are applied to the material?

……………………………………………………………………………………………..

4. The specifications or sizes of the materials

……………………………………………………………………………………………..

……………………………………………………………………………………………..

5. Quantity of parts/components required

……………………………………………………………………………………………..

6. Number of days used in discharging this process

……………………………………………………………………………………………..

7. The skills/expertise of the artisans/name of artisan/garage

……………………………………………………………………………………………..

8. Hazards associated/ with this process/safety measures

……………………………………………………………………………………………..

9. Description of the process

……………………………………………………………………………………………..

……………………………………………………………………………………………..

Name of the garage and the master

……………………………………………………………………………………………..

……………………………………………………………………………………………..

Appendix B

International Motor Vehicle Modifications and Alteration Regulations

General objective

1. To establish standards for the alteration and modification of vehicles and to ensure that the vehicle meets standards described in the Highway Traffic Act and its regulations and the Canadian Motor Vehicle Safety Standards.

Definitions

2 Special Motor Vehicles -passenger vehicles, trucks and buses which are intended for the use on public highways, the term "Special Motor Vehicle" shall include the following types:

TYPE I Vehicles which retain their original body configuration with changes made to the steering, brakes, and power train or suspension systems.

TYPE II Vehicles changed from the recognized vehicle manufacturer's original body configuration or a reproduction thereof but which retains the general appearance, including changes to the body, chassis or engine of the original vehicle. This type may also include changes and modifications to engine, chassis, brake system, power train, steering and suspension systems.

TYPE III All special vehicles which are custom built with fabricated parts, or parts taken from existing vehicles excluding Type I and Type II vehicles.

3 Recognized Manufacturer - Manufacturer means a person engaged in the manufacturing, assembly or importation of a Special Motor Vehicle intended for use on the Public Highways, or for distribution and sale in the Province.

4. S.A.E.-Societies of Automotive Engineers.

5. C.M.V.S.S.-Canada Motor Vehicle Safety Standards.

6. Certification of Compliance - The alterations and modifications done to a motor vehicle shall be certified for compliance by a Qualified Mechanic (Automotive).

Body Requirements

Defroster and defogging device

7. Every closed Special Motor Vehicle shall be equipped with a defrosting or defogging system capable of maintaining clear windshield area.

Door latches

8. The doors on a Special Motor Vehicle leading directly into a compartment that contains one or more seating accommodations shall be equipped with mechanically actuated door latches which firmly and automatically secure the door when pushed closed and which allow each door to be opened from the inside by the actuation on a convenient lever, handle or other suitable device.

Floor pan

9. Every special vehicle shall be equipped with a floor pan under the entire passenger carrying compartment. The floor pan shall support the weight of the number of occupants that the vehicle is designed to carry. The floor pan shall be so constructed that it prevents the entry of exhaust fumes.

Glazing

10. Windshields - every special vehicle shall be equipped with a laminated safety glass windshield that complies with the provisions appearing in the ANSI Z 26.1 standard. The vertical height of the unobstructed windshield glass shall be not less than 2540 mm. (10in.) or as originally equipped by a recognized manufacturer

11. Side and Rear Glass - these items are not required, but if they are present they must comply with the provisions of the ANSI Z 26.1 standard..

Driver visibility

12. The vehicle shall be provided with a windshield, and side windows or openings which allow the driver a clear unobstructed forward view 180 degrees measured from the line of the back of the driver's seat. This range of vision may be interrupted by window framing not exceeding two inches in width each, and windshield door post support areas not exceeding four inches in width at each side location, or as originally equipped by a recognized manufacturer.

13. A special motor vehicle shall have no obstruction forward of the windshield which extends more than two inches upward into the horizontally forward projected vision area of the windshield as measured from the rearmost part of the hood or bottom edge of the windshield glass whichever is the highest with the exception of windshield wiper components.

Hood latches

14. A front opening hood shall be equipped with a primary and secondary latching system to hold the hood in a closed position.

Instrumentation and controls

15. Speedometer - every special vehicle shall be equipped with an operating speedometer calibrated to indicate as accurately as possible the speed being travelled.

16. Odometer - every special vehicle shall be equipped with an operating odometer calibrated to indicate total distance traveled.

17. Steering Wheel - every special vehicle shall be equipped with a steering wheel with an outside diameter of not less than 330 mm. (13in.).

Rear view mirror

18. Every special motor vehicle shall be equipped with a rear view mirror. It shall be mounted in such a way that it affords the driver a clear view of the roadway and of any vehicle approaching from the rear. The mirror mounting shall provide for minor adjustment by tilting in both horizontal and vertical directions. Each mirror shall have a minimum of 645 mm^2 (10 $in.^2$) of mirror glass and any one of its diameters may not be less than two inches.

Seat belts

19. Seat belt requirements for the three types of special motor vehicles defined under section 1 are as follows:

All Special Motor Vehicles shall be equipped with at least a Type 1 (lap belt) seat belt, in compliance with the Canadian Motor Vehicle Safety Standard number 209, for the driver and each passenger seating position for trucks and buses.

20. All seat belts shall be securely anchored.

Seat securement

Seat securements for the three types of special motor vehicles defined under section 2.5.1 are as follows:

21. An adequate seat shall be provided for the driver. The driver's seat shall be positioned to allow easy access to switches, and controls when the driver is seated in the normal driving position and restrained by a Type 1 seat belt.

22. The driver's seat shall be adequately secured.

23. Provision for the driver's seat adjustment is required if originally equipped. The seat adjusting device shall be securely locked into the desired driving position when the driver is seated.

24. An adequate seat shall be provided for each allowable passenger and it must be securely attached to the vehicle.

Windshield wipers

25. Every windshield on a motor vehicle being driven on a highway shall be equipped with a windshield wiper in good working order for clearing rain, snow or other moisture there from and the device shall be such so that its operation shall not require any manual effort on the part of the driver for its control operation other than to activate the controls of the unit. The controls shall be in easy reach of the driver when in the driver's normal seating position and restrained by a Type 1 seat belt.

26. Special Motor Vehicles originally equipped with two windshield wipers, must retain two wipers. Type III Special Motor Vehicles shall have two windshield wipers.

Chassis Requirements

Accelerator control system

27. Every special motor vehicle shall be equipped with an accelerator control system that returns the engine throttle to an idle position when the driver removes the actuating force from the accelerator control and the geometry of the throttle linkage shall be so designed that the throttle will not lock in an open position.

Brakes

28. Service Brakes - every special motor vehicle shall be equipped with brakes acting on all wheels and shall be at all times in compliance with Section 41(Code of the Highway Traffic Act Manitoba, Power of Brakes).

29. Parking Brake - every special motor vehicle shall be equipped with parking brakes capable of effectively applying the brakes to wheels on the same axle.

Bumpers

30. Every special motor vehicle of the passenger type shall be equipped with a bumper both on the front and rear of the vehicle.

31. The bumper width must cover the full track width of the vehicle.

32. The horizontal bumper of customized bumper or grill bar structure shall be at least 76mm.(3in.) in vertical height and centered on the vehicles center line and securely fixed to the vehicle and designed to minimize damage.

33. The bumper shall have no sharp ends and the ends shall angle towards the body.

34. The bumper shall be constructed of non-splintering material.

35. Original Car Manufacturers designs are acceptable.

36. Bumper Height Measurement Procedure - measure on a level surface the height of both front and rear bumpers to both the top and bottom of the horizontal bumper bars.

37. Bumper Height Requirement some part of the horizontal bumper must fall within 350mm.(13.7in.) and 560mm.(22in.) above the ground level surface.

38. Every modified vehicle that is a truck or multi-purpose passenger vehicle having a gross vehicle weight rating of 4500kg or less, the following shall apply:

a) There shall be a front bumper of at least 100mm.(4 in.) in vertical height and extending to the width of the vehicle manufacturer's track width.

b) The bumper shall be of non-splintering material with no sharp ends.

c) Bumpers shall be of sufficient strength and so attached to the vehicle frame so as to effectively transfer impact loads to the frame.

d) Dropped bumpers shall be horizontal, at least 100 mm. (4 in.) in vertical height and continuous across its normal width or shall consists of separated sections. Separated sections shall not be less than 100 mm (4 in.) high and 100 mm (4 in.) wide and shall not be more than 300 mm. (12 in.) apart.

e) All bumpers shall have a foremost contact point at the bottom of the bumper not to exceed a maximum height of 740 mm. (29 in.) above a flat surface upon which the vehicle stands at curb weight, unless originally equipped.

Exhaust system

39. Every special motor vehicle shall be equipped with a complete exhaust system to limit sound. The exhaust system shall not interfere with the operational components of the vehicle.

40. Exhaust systems on truck type vehicles may discharge the exhaust fumes to the midpoint but must discharge fumes beyond the rear of the passenger compartment.

41. Exhaust systems on passenger type vehicles shall discharge at a location to the rear of the vehicle body or at a car manufacturer's side exit design and it must not exit in a vertical alignment to an operable window unless the exhaust is deflected downward.

42. No part of the exhaust system shall pass through any area of the vehicle that is used as a passenger carrying compartment.

43. Exhaust piping of a flexible type shall be that type which is approved for use in automotive systems.

Fenders

44. Every special motor vehicle shall be equipped with fenders and/or adequate body coverage designed to cover the entire tread width that comes in contact with the road surface. Coverage of the tire tread circumference shall be from at least 15 degrees in front to at least 90 degrees to the rear of the vertical center line at each wheel measured from the center of wheel rotation. At no time shall the fender or adequate body coverage contact the tire.

A **Frame**

45. Special motor vehicle shall be equipped with a frame. If an existing frame from a recognized car manufacturer is not used and a special frame is fabricated, it shall be constructed of wall box tubing, wall channel or unitized construction capable of supporting the vehicle, it's load and the torque produced by the power source under all conditions of operation. Sub frames of modular suspension assemblies manufactured by a recognized manufacturer may be attached to dissimilar existing or special frame providing that the sub frame was originally designed to accommodate a similar load and that it be attached in a similar manner to which it was originally installed.

Fuel System

46. Every special motor vehicle shall have all fuel system components such as tank, tubing, hoses clamps, etc., securely fastened with fasteners designed for this purpose, to the vehicle so as to not interfere with the vehicle operation, and shall be leak proof.

47. Fuel lines shall be positioned so as not to be in contact with high temperature surfaces or moving components.

48. Every fuel tank shall have air vent.

49. Every fuel tank shall be installed in a location to afford maximum body protection.

50. Every fuel tank shall be constructed of materials which will meet the safety performance requirement as outlined in the Canada Motor Vehicle Safety Standard, Part IV, Section 301.

Steering and Suspension

51. A special motor vehicle shall have no parts extending below the wheel rims in their lowest position, excepting tires and electric grounding devices designed for that purpose.

52. The steering system shall remain unobstructed when turned from lock to lock.

53. The steering wheel shall have not less than two turns or more than six turns when turning the road wheels from lock to lock.

53. While the vehicle is in a sharp turn at a speed between 8 km.(5mph) and 24 km.(15 mph) release of the steering wheel shall result in a distinct tendency for the vehicle to increase its turning radius.

54. No special motor vehicle shall be constructed or loaded so that the weight on the wheels of any axle is less than 30% of the gross weight of the vehicle.

55. Special motor vehicles shall be equipped with a shock absorber at each wheel location allowing a minimum relative motion between the unsprung axle and wheel and the chassis body of plus and minus two inches. When each corner of the vehicle is depressed and released the shock absorber shall stop vertical body motion within two cycles.

56. The steering wheel shall have an outside diameter of not less than 330mm.(13 in.). Any enlargement of the outer perimeter to gain compliance respecting the required minimal diameter is acceptable only if the enlargement become an integral part of the steering wheel and is easily grasped.

57. The steering box shall be securely bolted to the vehicle frame.

58. The spring mounts and shackles shall be properly aligned and of sufficient strength so as to support the gross weight of the vehicle and provide free travel in an up and down movement under all condition.

59. A special motor vehicle shall have a suspension system that allows movement between the unsprung axles and wheels and the chassis body and shall be equipped with a shock absorber at each wheel location. The suspension system shall provide a minimum relative motion of plus and minus two inches. When any corner of the vehicle is depressed and released the shock absorber shall stop vertical body motion within two cycles.

60. There shall be no heating or welding of coil springs, leaf springs or torsion bars.

61. A special motor vehicle shall be capable of stable, controlled operation while traversing a slalom-type path passing alternately to the left and right of at least four cones or markers arranged in a straight line and spaced 18m (59ft.) apart at a minimum velocity of 40 km (25mph).

62. In the case of any truck or multi-purpose passenger vehicle with a gross vehicle weight of 4500 k. or less, the following shall apply:

Raised Vehicle: The front tread width divided by the sum of the frame height at its highest point, and anybody lift shall not be less than 1.80 for vehicles with wheelbase of 254 cm. (100 in.) or more and not less than 2.00 for vehicles with a wheelbase of less than 254 cm. (100 in.).

Lowered Vehicle: No part of the chassis or the steering components of the vehicle shall extend below the rim of the wheel or come in contact with the road surface if all four tires are flat.

Tires

63. The tires on special motor vehicles shall comply with current Canadian Motor Vehicle Tire Safety Regulations, and Manitoba Highway Traffic Act and Regulations.

64. All tires when installed on the rear and at the recommended P.S.I. air pressure shall, when the vehicle at maximum loaded weight is jacked up at the rear at one wheel, have a minimum lateral clearance each side of 2.5 cm.(1in.) from the nearest component and a minimum fore and after clearance of 3.5 cm.(1.4 in.). The same shall apply to front tires and that the tires while in full contact with ground and at maximum vehicle weight shall not make contact with any component when the wheels are turning from stop to stop.

65. Every special motor vehicle shall have tires that are rated to carry that vehicle weight.

66. Front tire to rear tire section width variances if other than car manufacturers allowance shall be not less than 60% of the section width of the rear tires.

67. No vehicle shall be equipped with a tire having a section width less than the vehicle manufacturer's recommended specification.

Electrical System Requirements

Dimmer switch

68. The headlamp circuit shall be equipped with a driver controlled switch used to select the high or low beam.

Headlamp switch

69. The headlamp switch must activate the headlamps, tail lamps, license plate lamp, parking lamps and the speedometer illumination lamp(s).

Headlamp system

70. The headlamps shall be mounted not less than 560 mm.(22 in.) nor more than 1370 mm.(54 in.) above the road surface when measured to the headlamp center. Lamp shall be constructed with adequate adjustment to afford proper aiming of the headlamp(s).

High beam indicator

71. An indicator shall be provided to show the driver when the upper beam of the headlamp system is energized. The indicator shall emit a light without glare and be plainly visible to the driver under normal driving conditions.

Horn

72. The horn must be capable of emitting sound audible from a distance of not less than 60 meters (197 ft.). The switch used to activate the horn shall be easily accessible to the driver when seated in the normal driving position and restrained by a Type 1 seat belt.

Licence plate lamp

73. At least one white lamp shall be provided at the license plate to illuminate the plate.

Parking lamps

74. Two amber or white parking lamps in compliance with SAE Standard J222 may be mounted on the front of the vehicle, one on each side and equidistant from the vertical center line of the vehicle, at the same height, and as far apart as practicable. The parking lamps shall be mounted not less than 380 mm.(15 in.) nor more than 1830 mm.(72 in.) above the roadway.

Stop lamps

75. Two red stop lamps in compliance with SAE Standard J586B shall be mounted on the rear, one on each side equidistant from the vertical centerline of the vehicle, at the same height, and as far apart as practicable. Type I vehicles which were originally equipped with only one stop lamp need not be equipped with two stop lamps providing the original lamp is located in accordance with the original design configuration. The stop lamps shall be mounted no less than 380 mm.(15 in.) nor more than 1830 mm.(72 in.) above the roadway.

Tail lamp system

76. Two red stop lamps in compliance with SAE Standard J586B shall be mounted on the rear, one on each side equidistant from the vertical centerline of the vehicle, at the same height, and as far apart as practicable. The stop lamps shall be mounted no less than 380 mm.(15 in.) nor more than 1830 mm.(72 in.) above the roadway. Type I vehicles which were originally equipped with only one tail lamp, need not be equipped with two tail lamps providing the original lamp is located in accordance with the original design configuration.

Turn signal indicator

77. If the operation of the signal lights are not visible to the driver there shall be an illuminating indicator to indicate to the driver that the signal lights are operating. The indicator may be of a one lamp or a two lamp design. If of the two lamp design, only the lamp which indicates the signal being made shall flash in unison with the signal.

Turn signal lamps

78. Two Class A turn signal lamps in compliance with approved standards shall be mounted as follows:

At the front of the vehicle, one white or amber lamp on each side equidistant from the vertical centerline of the vehicle, at the same height, and as far apart as practicable. At the rear of the vehicle, one red or amber lamp on each side equidistant from the vertical centerline of the vehicle, at the same height, and as far apart as practicable. All turn signal lamps shall be mounted no less than 380 mm. (15 in.) nor more than 1830 mm. (72 in.) above the roadway

Turn signal switch

79. Every special motor vehicle shall be equipped with a turn signal switch controlled by the operator of the vehicle that shall cause the turn signal lamps to function. All originally manufactured vehicles from 1971 on shall have a self canceling turn signal switch

Position of the controls

80. Every switch and control in a special motor vehicle necessary for the safe operation of that motor vehicle, shall be easily accessible to the driver when seated in the normal driving position and restrained by a Type I seat belt.

81. Neutral Safety Switch - A special motor vehicle if equipped with an automatic transmission shall be equipped with a neutral safety switch that prevents the starter motor from being actuated except when the gear selector is in the neutral or parked position.

Engine replacement

Vehicles which have had original engines replaced with engines of greater horsepower or of significant difference respecting physical size and shape shall have the following:

82. Power ratio compatibility with the remainder of the drive train (transmission, U-joints, drive shaft, differential, axles).

83. Must have adequate engine mounting to frame.

84. Must have sufficient space to accept normal engine torque movement without contacting the frame or other adjacent components or body structure.

85. No part of the motor shall interfere with any steering component.

86. No frame shall be cut or notched without being boxed, fish plated, or otherwise modified so as to retain its original strength.

87. No part of the engine shall be at a height which intrudes the forward viewing area of the driver.