CHAPTER 1

ESSENTIAL COMPONENTS OF EV'S

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CHAPTER 1

1.1 Essential Components of EVs

Essential components of EV's can be grouped into 5 systems:

- **Energy System --** Instead of using a gasoline tank to store energy, EVs store electricity in batteries until it's needed to power the motor. A battery controller monitors and governs the operation of the battery pack. In a "series" hybrid EV, a small internal combustion engine generates electricity on board to recharge the battery. Another technology being developed for EVs – fuel cells - does not store electricity, but instead generates it through a chemical process on board the vehicle, as it is needed.

- **Power System –** The flow of electricity from the batteries to the motor is regulated by the motor controller, which is the "brain" of the vehicle drive system and the main component of the power system. The Motor Controller acts like a typical "Fan Regulator" - allows varying the speed of the Motor. If the EV has an AC motor, the power system also includes an inverter to convert the DC electricity from the batteries to AC current for the motor.

- **Drive Train –** This is the muscle of the EV, an electric motor that converts electric power into rotational, mechanical power, which is delivered to the wheels through a transaxle, propelling the vehicle. A "parallel" hybrid electric vehicle uses both a small internal combustion engine and an electric motor to power the wheels.

- **Charger System –** The charger converts AC electricity from utility power lines to DC current that can be accepted by the EV batteries to restore their power after being depleted. Some EVs carry the charger onboard, while other EVs use chargers located off-board at recharging sites. Electric current is transmitted to the vehicle via the charger inlet.

- **Auxiliary Systems –** Like gasoline- powered cars, EVs have heat and air conditioning, power brakes and steering, radios and CD players and other familiar features. In an EV, these auxiliary systems run primarily from battery-stored electricity. EV's generally have a DC-DC Converter that converts the high voltage of the battery pack to 12 Volts required for standard automotive accessories.

1.2 Some general specifications of Evs.

Components	Specifications
Power Source	Single phase 220 V AC, 15 A, 50 to 60 Hz is normally used for regular Charging.
Charger	Converts alternative current to direct current to charge batteries. Regular charging and rapid charging is used.
Time required for regular Charging.	Approximately 8 - 9 hours.
Time required for rapid Charging.	60 minutes (50% of Full Charge)
Battery Controller	Energy (electricity) is charged and discharged for driving and other purposes. Lead acid, nickel – metal hydride, lithium ion and other batteries are available. Controls the current to operate the motor as per the throttle demand
Motor	Operated by commands sent from the controller, the motor converts electric energy into mechanical energy, which rotates the wheels. AC motor is used.

1.3 How do EVs differ from IC Engine Vehicles?

The main difference is in how the two types of cars are powered. A conventional car typically uses an internal combustion engine fueled by petrol/diesel, whereas a motor powered by batteries drives an electric car. Because electric vehicles (EVs) don't use an internal combustion engine, they are much quieter, making virtually no noise while idling. Since they also don't use petrol and there are fewer moving parts, they are typically a third the annual operating costs of conventional vehicle. This means no stopping for petrol, no dependence on foreign imported oil. Though today's new internal combustion engine (ICE) vehicles are quite clean initially, the effectiveness of their emission control systems decreases significantly throughout the life of the vehicle. So, while conventional automobiles are leading cause of air pollution, EVs do not generate noxious emissions, and thus are far better for our environment.

Feature	Electric vehicles	Conventional engines
Number of parts	Less than 10 moving parts	More than100 moving components
Ease	Absence of clutch and gears	Applicable
Braking	Regenerative braking	No Regen feature
Cooling/heating system Body	State-of-the-art Patented CCS system ABS - Strongest polymer known to man	Regular HVAC Sheet Metal body
Operating cost	0.40 Paisa per kilometer	Minimum available Rs. 2.53 per kilometer (as per Jan 2006 petrol prices)
Environmental benefit/ hazard	Smoke free and Zero-pollution	Toxic wastes like CO, NO_2 and other harmful wastes
Prime mover	AC or DC motor	IC engine
Maintenance cost	Less	Relatively higher
Noise pollution	Nil	Relatively higher
Condition at idling	No power used	Inefficient at low speeds

1.4 EV Market Worldwide

Europe remains to be a most fertile market for electric vehicles. Stringent emissions laws, crowded streets and mid-day traffic plus the popularity of subcompacts and micro cars make electric vehicles the logical choice. The major automakers like Renault, Peugeot, Fiat, Citroen and the like have introduced their Evs. Volkswagen, which is well known for making zippy compact vehicles as well as its concern for the environment, has come up with Volks Electric - Wagon. Even though, the current VW petrol engines have been refined to such an extent that Golfs and Passats can actually be sold without catalytic converters to countries where exhaust emissions standards are not too strict, they could not resist making an EV.

It is a fact that Japanese car makers are known to spend millions of dollars on research and development for technologies that may not even hit the streets. This is why they have the uncanny ability to literally leapfrog into the market even while a process or technology is still evolving. This attitude brought the electric vehicle out of the laboratory and onto the streets as early as 1956 when Mitsubishi introduced a commercially viable, battery-powered Fuso light truck. These days Honda with its EV +, Toyota with its Prius & Nissan with its Hypermini & Renaissance are making their foothold in the EV market worldwide.

The Big 3 in America - Ford, GM & Chrysler has their own EVs. Infact, in California, today you can visit a car dealer and drive home in a brand-new, road-ready electric vehicle (EV). General Motors EV-1 went on the market in a lease-only ($300 a month) arrangement in California and Arizona. The EV-1, which would retail for $33,995 if it was actually for sale, is an impressive, built-from-scratch AC electric that cost GM $350 million in development outlay. In its initial form, it used lead-acid batteries and a special ultra-safe, no-shock charger. The EV-1 has made many friends among car testers for its quick acceleration (0-60 mph in less than eight seconds) and almost-sports car handling. Attitudes have changed towards electric vehicles**.** Volumes of market studies conducted by Volkswagen, BMW and Daimler- Chrysler reveal how appetizing EVs are to the market.

1.5 Benefits of driving an EV

Driving an EV has many benefits:

- **Quiet, Clean Driving Experience -** On a personal level, EVs offer a quiet, fume-free, smooth driving experience. Since the motor does not operate when the vehicle is at a stop, an EV has no "idle" noises. When an EV is under power, the only sounds are the soft humming of the motor and the tyres whirring over the roadway.

- **High Performance –** First-time EV drivers are consistently surprised by the quality of the EV driving experience. EVs provide fast acceleration by delivering power instantly to the wheels. By providing high torque at low speeds, they give a feel of smooth and quick responsiveness. Well-designed EVs, like those produced by major auto companies, travel at speeds equivalent to conventional vehicles and offer all the same safety and high-performance features.

- **Lower Operating Costs –** The per-mile fuel cost of operating an EV can be less than $1/3^{rd}$ that of petrol –powered car. The exact amount of savings depends on the local electricity rate, which varies from utility to utility. In addition, EV owners say goodbye to much familiar maintenance costs – no more tune-ups, oil changes or muffler replacements.

- **No Gas Stations –** One of the conveniences EV drivers like the most is that " refueling" can be done easily and safety at home overnight, at work, or at public locations like shopping centers , where electric charging units have been installed.

- **Environmentally friendly -** Electric vehicles are today's only zero-emission vehicles. They have no tailpipes and emit no pollutants. Instead of petrol from oil refineries, EVs get their fuel from electric power stations. Although power plants using fossil fuels do have emissions, power plant emissions generated for EV use are typically much lower than emissions from the comparable use of petrol-powered cars. For power plants using renewable energy sources like wind, solar and hydropower, no air pollution is at all created.

- **Energy Security –** Electric vehicles help lessen the country's dependence on imported petroleum and reduce the national security concerns associated with that growing dependency.

1.6 Electric Cars are practical, economical, and fun to drive!

The EVs are designed for daily commuting and local trips, with overnight recharging when electricity rates are lowest.

Consider all the single-passenger gigantic cars stuck in traffic every day. Perhaps you drive one yourself? Imagine what would happen if the rest of the world were so profligate with resources. Yet initiatives to encourage car-pooling, commuter busses or trains have not significantly reduced the number of single-passenger commuters. Experiences with the EVs prove that Electric Vehicles are an exciting, efficient solution to the single-occupant commuter problem.

EVs are truly "Driving the Future!

- **Recharging off peak** -- An EV starts out every morning completely full. EVs conveniently recharge each night at home, when electricity is cheapest -- about 40 paisa per Km.
- **Quick and fast –** The electric motor delivers high torque from a standing start for quick acceleration. Maximum speed of Reva is electronically limited to about 80 Km/hr.
- **Ample Range --** About 80 Km per charge... or up to 100 Km per day if you "plug-in" at work for a few hours.
- **Take it anywhere ---** A car that you can safely turn on indoors. No offensive odour when you back into the garage. No more smog checks, oil changes or leaks.
- **Quiet ---** There's no ignition, an EV "starts up" every time. There is no engine to warm up or wake the neighbors.
- **Reliable ---** The EVs powered by new batteries like Nickel Metal Hydride ("Ni-MH"), Nickel Cadmium etc. are very reliable.
- **Regenerative braking** – When you take your foot off the accelerator, the motor becomes a generator, slowing the car and returning energy to the battery. Hydraulic brakes are only applied for hard stops. Energy spent climbing uphill is recovered on the way down, rather than wasted burning up brakes! In an EV, regenerative braking makes driving in stop-and-go rush hour traffic smooth and effortless.
- **Motor uses no power when stopped! ---** Gas engines are inefficient at low speeds, but a motor has no need to idle.
- **Zero smog ---** Modern hi-tech natural gas power plants are about 97% cleaner than the cleanest conventional car (Cal AQMD, Cal Energy Commission).
- **Easy to drive ---** No clutch, no gearshift, full power is available as soon as you step on the pedal. People, who take a test drive, just start driving! You just concentrate on steering and stopping, there is no engine to start, no clutch to engage, no difficult hill-side starts, no problem with stalling, no tense parallel parking episodes. All Driver Training courses should use EVs.

➲ **There's no reason to drive anything else for commuting, errands, and local trips!**

CHAPTER 2

INTRODUCTION TO PROJECT REVA

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INTRODUCTION TO REVA PROJECT

2.1 Overview

The REVA is a ground-up electric vehicle designed for Indian urban driving conditions. The vehicle has passed homologation requirements for India and has been approved for commercial sales and use on roads in India. Over 20 vehicles have been under test in the US and India for up to 3 years. Vehicles have been used in several Indian cities, and have been exposed to typical winter, summer and monsoon rain conditions. Shaker life cycle tests, home charging test and analysis have been conducted. The vehicle's design allows it to be manufactured and tooled at low cost and done indigenously. It incorporates advanced battery management, HVAC and power control systems. ARAI Pune has certified REVA for its roadworthiness.

2.2 Background

India is country with a population of more than a billion. Cites are growing at an alarming rate resulting in an increase in noise pollution, air pollution and congestion. The requirement of small cost effective urban transportation is on the rise. Typical average speeds in cities are less than 35 km/h and average distances traveled daily are less than 30 km. The combination of low speeds, short distances, high pollution, high gasoline prices and congestion in the cities makes electric vehicles ideal for such a country.

The REVA was designed from information received in surveying over 3000 people in India. Requirements included low operation cost, low purchase price, ease in parking and driving in congested city traffic. The REVA was designed to meet these requirements and will be sold as the least expensive vehicle in India.

2.3 Reva: Unique Indo-American Collaboration

US companies have been involved in the Reva project right from product inception to the current stage of execution.

Amerigon Inc. of Monrovia, California, which has collaborated with the Maini group for the Project, has developed 4 key patented technologies exclusively for use in Reva. These are:

(a) Running Chassis
(b) Integrated Power System (IPS)
(c) Energy Management System (EMS)
(d) Climate Control Seats (CCS)

The batteries forming the Power Pack for Reva have been developed by Trojan in the US.

The Charger for Reva was developed in conjunction with Modular Power System (MPS) of USA. MPS, a division of TDI, is a leader in charger and power supplies. Maini Materials Movement, a Maini Group Company, has recently signed a technical collaboration agreement with TDI for making Chargers for Reva in India.

Curtis PMC in USA manufactures the Controller for Reva, the world leaders in Motor Controllers for EV application. Curtis has been involved in the project for five years and has developed a Motor Controller specifically for the Reva.

Within two years of starting production, all components and sub assemblies for Reva are being made in India as a result of a strategic collaboration between Amerigon and Maini and the involvement of the other US companies.

The US Government has been extremely supportive of the Reva EV Project. Amerigon has received US funding support through agencies such as SCAMD, CEC and FTA for EV development activities.

In 1995, President Bill Clinton inaugurated the Alameda Naval Air Station and commended Amerigon on its development efforts for EVs. It was at this facility that the kits for Reva were manufactured earlier and sent to India for final assembly.

US AID has also extended substantial help and has played a major role in the road tests for Reva.

2.4 REVA – Product Description

Reva is a stylish compact 2-door hatch back that carries 2 adults and 2 children or a payload of 227 Kg. It has a top speed of 80 km/h and a range of 80 km, ideally suited for city driving conditions in India as well as other developing nations.

The Power Pack used in Reva consists of eight 6 Volt EV type lead acid batteries that can be charged "anywhere, anytime" using 220V (15 Amp) power supply. Reva has an "on-board" Charger that is computer controlled and has a built-in stabilizer and auto shut-off mechanism. The charge time is 8-9 hours, though 80% of the full charge can be attained in 3 hours.

The dent proof body panels are made of high impact ABS that is colour impregnated to eliminate the paint process and ease recycling. The suspension consists of McPherson single A-arm in the front and coil spring at the rear, which allows for good road handling and a smooth drive.

Reva's state-of-the-art electronics translates into an efficient energy management system and advanced computerised vehicle diagnostics. Side impact beams, a specially developed steel frame and electronic regenerative braking lead to a high level of reliability and safety.

Reva is ideal for "stop and start" city driving, with its absence of an engine, gears or clutch. The high motor power (12kw@2400rpm) enables quick acceleration. Its compact size and small turning radius (3800 mm) makes it easy to maneuver and park. With Reva, engine tuning, change of engine oils and filters, replacement of spark plugs and mufflers are all things of the past.

2.5 Technical Specifications

Key Technical Specifications of Commercial REVA

PARTICULARS	SPECIFICATION
• Length	2638 mm
• Width	1324 mm
• Height	1510 mm
• Ground Clearance	118 mm
• Turning Radius	3800 mm
• Maximum Grade ability	18%
• Charge Time	80% in under 3 hours, balance 20% in 6 hours
• Body Type	2 door hatch back
• Body Panel material	High impact ABS vacuum formed panels.
• Frame Type/Material	Welded tubular Steel Space Frame 1020 cold rolled steel IS 3074.
• Suspension	McPherson Strut (front) Solid axle with coil over springs (rear)
• Tyres	Tubeless
• Wheels	3.5” 5 13” Steel wheels (Alloy wheels optional)
• Brakes	Four – wheel dual circuit hydraulic disc/drum brakes Integrated with regenerative breaking.
• Motor	3 Phase Induction Motor (6kw nominal and 12kw peak power)
• Controller	Microprocessor based with regenerative braking for AC Induction Motors.
• Charger	220 V, 2.2 kW, High frequency switch mode type.
• DC – DC converter	13.8 V, 400 W
• Energy Management System	Microprocessor based battery management system with an intelligent fuel gauge.
• Transmission	9:1 single gear reduction directly coupled to motor drives rear wheel.

2.6 KEY TECHNOLOGIES IN REVA

Reva deploys the following 4 key patent protected technologies that have been imported from AEVT:

1. Running Chassis
2. Batteries and Charger
3. Motor and Motor Controller
4. Energy Management System (EMS)
5. Climate Control Seats (CCS)

A brief description of each of these key technologies is given below:
1)The **Running Chassis** consists of a very strong, self supporting, light weight space frame and includes the motor, integrated power system, drive- train, steering, suspension, brakes, wheels, tyres and high voltage systems. ABS body panels are directly attached to the space frame of the running chassis.
Vehicles built using this technology require only a fraction of the capital costs of conventional stamped, sheet steel, auto assembly techniques. Use of this technology will enable RECC to produce Reva at a comparatively low-cost compared to traditional automobiles, even at relatively low levels of production.

2) Energy Management System (EMS) - It is a computer based system that optimises charging and energy output of batteries to maximise operating range and improve performance of Reva.
The EMS performs five key functions that collectively improve performance and reduce cost. These are:

- Charger control
- State-of-Charge (SOC) estimation
- Vehicle diagnostics
- Battery warranty verification
- Vehicle data acquisition (DAQ).

The EMS also controls the outputs on the Reva instrument panel, such as the SOC meter, charge indicator and other diagnostic indicators. The EMS communicates with a handheld diagnostic unit (palm computer or a laptop) for data acquisition and service diagnostics.

4) Climate Control Seats (CCS):
Another critical system protected by Amerigon patents to be used in Reva is the cooling, heating and ventilating system called CCS™. The system cools / heats / ventilates the seat to increase occupant comfort in different weather conditions.

The CCS has a solid state heat pump and is extremely efficient; typically energy consumption is less than 10% of that of conventional automobile air-conditioners. As a result, driving is more comfortable and the range is not compromised under very hot or cold conditions (as is the case with other electric vehicles).

2.7 VEHICLE SUBSYSTEM

The REVA was designed to be a cost effective, efficient Electric Vehicle for urban commuting. An explanation of vehicles key subsystems is given below:

2.7.1 Drive System

The REVA uses a 3 Phase Induction motor and controller that have been optimized for efficiency under the Indian driving cycle. The motor is directly linked to a transmission that drives the rear wheels. The single speed transmission consists of a 2-stage reduction gear set with ground gears to reduce noise. The drive system is rated at 6 kW continuous and 12 kW peak. Vehicle performance under congested traffic conditions has been improved by 20% through the use of a forward mode switch. This was achieved by controlling acceleration parameters as a function of speed and optimizing field maps for efficiency. The controller is also equipped with regenerative braking that has been optimized with the hydraulic brakes and results in a range increase of 17-22%. To protect the power electronics from dust and humidity, they are housed under the rear seats with cutouts for thermal management.

2.7.2 Power Pack

The REVA uses eight 6-volt tubular lead acid batteries with a single point watering system. The battery pack is located under the front seats to lower the vehicle's center of gravity. Individual battery voltages are monitored along with battery pack temperature and water level. The vehicle is charged via plugging it into a 220V-15A-plug point. A special socket along with an energy meter is provided at the charge point. The charger is a high frequency onboard type that charges the vehicle to 80% in about 3 hrs. A 400W DC-DC converter is also integrated in the charger. The charger has been design to operate over an input voltage region of 160V-260V and handle frequent blackouts and brownouts, typically encountered in India. The key specifications of the power pack are given in the Table.

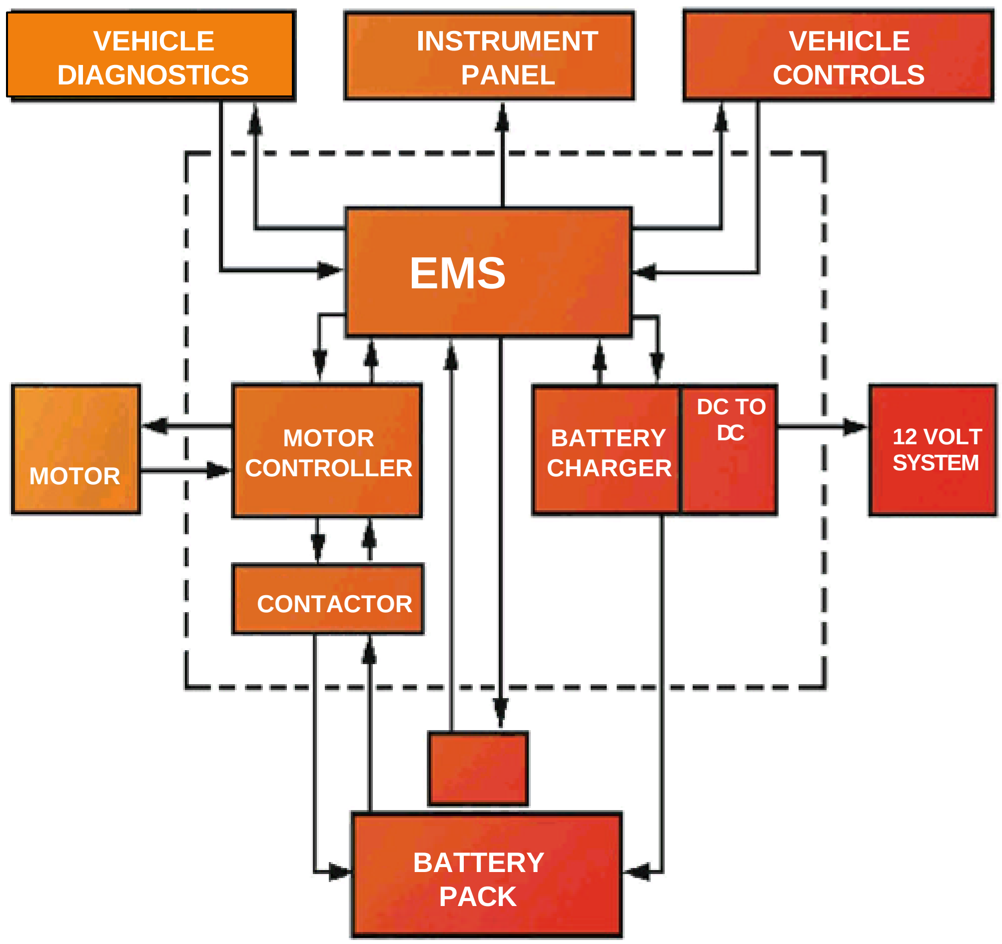
Battery Weight	**265 kg**
Battery Capacity (C-5) **Battery Pack Voltage**	**200 AH** **48V nominal**
Charger output	**2.2 kW**
Charger Weight	**7 kg**

2.7.3 Energy Management System

To date, EVs have been commercially viable mainly in the industrial arena, where frequent professional maintenance is possible. The proprietary Reva Energy Management System (EMS) was developed to allow consumers to benefit from the cost, performance and environmental advantages of EVs for urban transport. The EMS has been developed and tested over the last seven years to address two major problems consumers have had with production electric vehicles in the past: poor battery life and poor State of Charge (SOC) estimation.

The EMS performs five key functions that collectively improve performance and reduce cost: charger control, SOC estimation, vehicle diagnostics, battery warranty verification and vehicle data acquisition (DAQ). The EMS also controls the outputs on the instrument panel, such as the SOC meter, an efficiency gage, and the diagnostic indicators. The EMS communicates with a handheld diagnostic unit (or laptop computer) for data acquisition and service diagnostics.

INTERACTION OF THE EMS WITH THE VARIOUS SUBSYSTEMS



2.7.4 Diagnostics in Reva

One of the key functions of the EMS is Vehicle diagnostics. The EMS Diagnostics can provide a wealth of information to speed diagnosis and repair. The EMS not only communicates with the handheld diagnostic unit for data acquisition and service diagnostics but it also controls the outputs on the instrument panel which help the consumer to know the exact health of the car.
The EMS controls the following five indicator lamps on the instrument cluster: Service, Brake, Motor temperature, water level light, Charge and Low battery.

Battery Pack Over Temperature Light
This light indicates if the temperature of the battery pack exceeds the safe temperature.

Charge indicator light

While the battery is being charged, this light flashes green and is made ON & OFF for every 2 second.

State of Charge gauge / Fuel gauge

This gauge shows the actual level of SOC in the batteries so that the customer can plan his journey. This shows the amount of charge available in the batteries.
When key is turned on the needle goes to maximum and comes back to the actual value.

Low Battery Light

This light starts flashing if the SOC is < 35% and turns solid if the SOC falls below 25%. Car will be forced to move in economy mode if SOC becomes 25% and car will move in limp home mode if the SOC falls below 15%.

Low Water level Light

This light comes on when the batteries need water. Periodically batteries need to be watered, as there will be evaporation during charging and drive cycles. Initially when the batteries need water this light flashes for 5 minutes in first and second cycle. If the customer ignores the light, then light will be continuously on for the next two consecutive cycles. If the customer doesn't water even after that, the light will be flashing continuously.

Service Light
When the service light comes ON, it could be to warn the user of the following:

- Battery Over temperature
- Charger Over temperature
- Motor Over temperature
- Battery Fan not working
- Controller Over Temperature
- SOC less than 5% etc.

Chime Output
The EMS shall control a chime under the instrument panel to warn the driver in the event of a serious fault. Also, a single chime sound will be used to indicate when the battery is approaching empty.

The chime will sound in the following conditions:

KEY	Parking Brake (BPS)	Door (TAP)	Throttle	Chime (BEL)
ON	Pulled	Open		ON
ON	Pulled	Closed	> 5%	ON
ON	Released	Open		ON
ON	Released	Closed		OFF
OFF	Pulled	Open		OFF
OFF	Pulled	Closed		OFF
OFF	Released	Open		ON
OFF	Released	Closed		OFF

Brake Light on IP cluster

This light comes on when

- Parking brake is pulled when key is ON
- When the brake fluid level in the master cylinder falls below the minimum level (flashes)

2.7.5 Regenerative Braking

Regenerative braking recovers useful electricity by putting it back into the batteries. A stronger, controlled braking effect in an EV occurs when regenerative braking circuit is added to the control circuits. All electric motors have the potential of being a generator. Regenerative braking lets the motor act as a generator, converting the vehicle's momentum into electricity. As the batteries absorb this electricity, the vehicle is slowed down.

So, when you take your foot off the accelerator, the motor becomes a generator, slowing the car and returning energy to the battery. Since it takes the kinetic energy of the vehicle to generate electric energy, the vehicle's momentum is consumed and the vehicle slows.

The immediate benefit of this process is that it simulates the comprehensive braking (slowdown effect) feature of gas engines, reducing the brake wear normal to most cars. ABS brakes are only applied for hard stops.

Energy spent climbing uphill is recovered on the way down, rather than wasted burning up brakes! In an EV, regenerative braking makes driving in stop-and-go rush hour traffic smooth and effortless.
Regenerative braking often touted as a "range extending "or" energy recovery technique" also has the virtue of saving brake jobs.

CHAPTER 03
BATTERIES IN REVA

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3.1 Lead Acid Battery:

Lead acid batteries are the most widely used batteries in automotive field. Their advantages are low cost, high voltage per cell, and good capacity life. The disadvantages are – relatively heavy and cannot be left in discharged state for long. The lead acid battery has electrodes of lead and lead dioxide. These are dipped in dilute H_2SO_4 (electrolyte) and separated by an inert porous material. Potential difference (pd.) is above 2V approx. with respect to lead electrode. The negative plates have a spongy lead material while the positive plate has active material of brown lead dioxide. The plates are immersed in an electrolyte of dilute sulfuric acid. Tubular positive plates are used in Europe while in USA, a flat plate is preferred.

Many factors have to be considered when battery selection is considered for traction i.e. motive power for road transport, fork lift etc. eg: For fork lift, lifting 2 tons may require a discharge current of 200A for 0.25 min or 50 A min. This fork lift travels 6m at 1 m/s during which discharge current is 80A or 80 x (6sec)/60 i.e. 8A min. These calculations are required to find the total number of AH consumed by the motor. It must be remembered that shorter the time of discharge, lower is the available capacity.

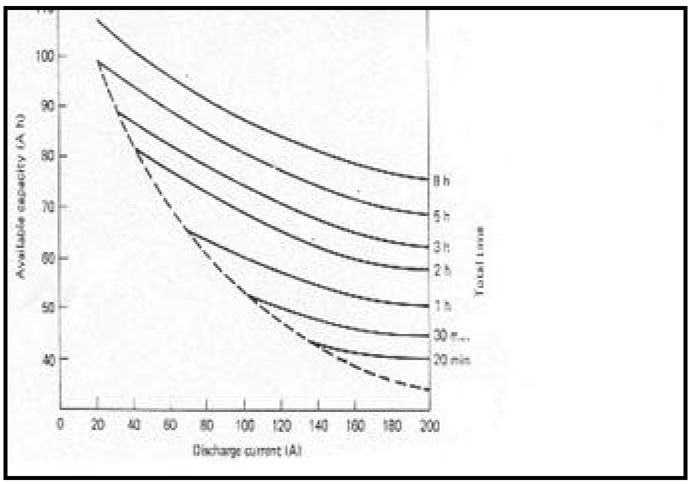


Fig 1

The curve shows the typical capacity available at various discharge currents and for discharge spread over various times.

E.g. a 100 AH battery is discharged continuously at 100A, the available capacity is 54% of nominal capacity and it will last 0.54h. The same capacity when spread over 1h. Will result in available capacity of 64%. Finally when spread over 8h, it is almost 88%. It is so because the required battery capacity depends on the percentage current, and the percentage current itself is dependent on the chosen battery capacity. Due to various factors, battery efficiency may be taken as 0.7 or 70%. This is to cater for the various load conditions, terrain of the road, discharge and braking etc, duty

of vehicle may be heavier than what was assumed earlier, and also because the battery is getting old, its ability to give full rated capacity reduces.
To take into account these factors, the battery should not be discharged to more than 80% of its rated value.

3.2 Chemical Process and discharge curves

The chemical actions on the negative plates and the positive plates during discharge and while charging is given below:

Discharge:
Negative plate (lead)

$$Pb + SO_{4}^{--} \rightarrow Pb\ SO_4 + 2e$$

Positive Plate (lead dioxide)

$$Pb0_2 + Pb + 2H_2\ SO_4 + 2e \rightarrow 2Pb\ SO_4 + 2H_2O$$

During discharge – both electrodes are thus covered with lead sulphate and hence show minimum Potential difference between two electrodes when the process is complete i.e. when cell is fully discharged. In practice, negative plate is covered with lead sulphate and positive plate with compounds of lead sulphate ($Pb0.PbSO_4$).

Charging:
Here, the current is passed through the cell so that original lead electrode is reconverted to lead.

$$PbSO_4 + 2H + 2e^- \rightarrow H_2SO_4 + Pb$$

And lead peroxide is re-formed.

$$Pb\ SO_4 + 2H_2O \rightarrow Pb0_2 + H_2SO_4 + 2e^- + 2H^+$$

Full Equation on Discharge:
$Pb0_2 + Pb + H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$ (water is formed so SG is lowered).

Full Equation on Charge:
$2PbSO_4 + 2H_2O \rightarrow Pb + Pb0_2 + 2H_2SO_4$ (now the acid concentration increases).

The SG (specific gravity) dictates the condition of the battery and not the emf.

Discharge Curves:

During the charging, the emf rises rapidly to 2.1V and then remains constant, increasing very slowly as charging proceeds. At 2.2V, 0_2 begin to liberate and at 2.3V, H_2 at negative plate begins to liberate. This is called gassing.

During discharge – a kink is seen in the curve. This is due to the $PbSO_4$ layer, which is formed while the battery is idle – and it soon disappears. When it has reached 1.8V, it should be recharged.

Difference between charge and discharge curves is due to the changes of concentration of the acid. It is greater during charge and lesser during discharge.

$$\text{Current efficiency} = \frac{\text{Amount of current taken out during discharge}}{\text{Amount of current put in during charge}} = \frac{\text{AH Drive}}{\text{AH Charge}}$$

For nominal capacity the discharge is at 20 hrs at 20ºC .20AH means 20 hours rate. We may discharge at higher current rating for a shorter duration or we may discharge at low current rating for a longer duration i.e.

Higher the current – lower the capacity or shorter the time of discharge.

Discharge Time	**Approx % Capacity**	**End Voltage per Cell**	**Capacity (AH)**
10	106	1.73	212
9	105	1.73	210
8	104	1.72	207
7	102	1.72	205
6	101	1.71	202
5 4	100 96	1.70 1.69	200 192
3	89	1.67	178
2	81	1.66	162
1	67	1.62	134
Min 30	54	1.61	108

3.3 Some Definitions :

Capacity: Expressed for a battery in terms of Amp hours (AH) i.e. total **AH** available from a fully charged cell or battery. Total capacity that may be obtained at defined charge and discharge rates at their associated environmental conditions are called the available capacity. The rated capacity is the value given by the manufacturer eg. 6V, 200AH.

Gassing: During charge the emf rises rapidly to a little over 2.1v and remains steady, increasing very slowly as the charge proceeds. At 2.2v oxygen begins to be liberated at the positive plate and at 2.3v, hydrogen is liberated at the negative plate. This liberation of gases at fully charged condition is known as gassing. Three states is achieved during a charging and discharge cycles and are known as the End of Charge (eoc), End of discharge (eod) and Overcharge – In the charging cycle, the battery emf reaches 2.03V at 25ºC. Further passing of current would lead to free evolution of gases. This would amount to overcharge and lead to wasteful charging current since this current is now entirely devoted to gas production only, rather than charging of the plates. The gassing is likely to cause mechanical damage to the battery plates.

During discharge, the emf drops rapidly to just below 2v. The emf falls steadily during the discharge and when it has reached 1.8V, the battery should be recharged. The further withdrawal of current would cause the voltage to drop rapidly; electrolyte concentration would also go down to such limits that the recharging may not be possible to bring up the battery by re-charging.

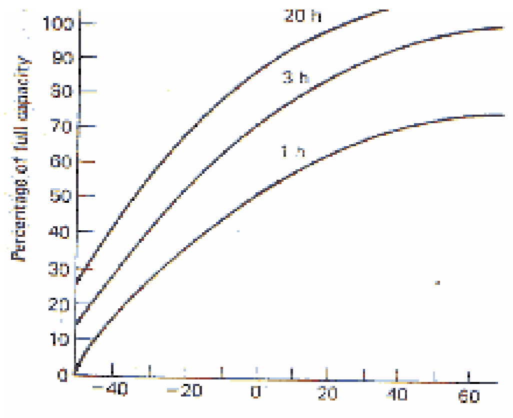
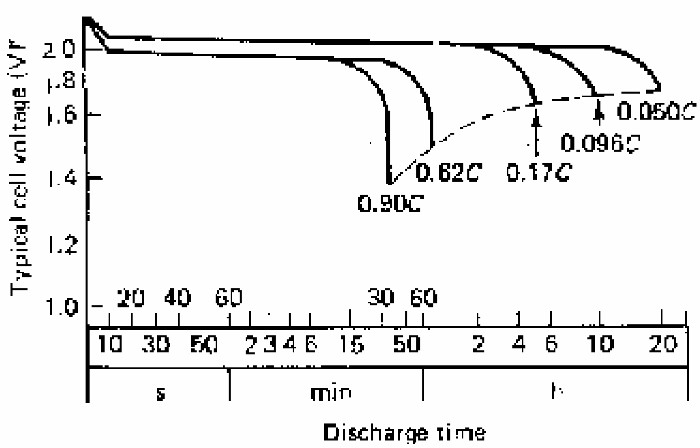


Fig 2 **Temperature ºC**

Capacity versus temperature at various rates of discharge. Carefree Rechargeable lead-acid battery (courtesy of Eagle Picher).

The above graph shows that at higher temperature, an increased capacity is obtainable with a corresponding increase in self-discharge rate.
Battery behavior during discharge (at various conditions).

Fig 3



The plot (discharge time Vs cell voltage) shows that several hundred complete charge / discharge cycles can be obtained when subjected to less than 100% depth of discharge, cycle life will improve considerably. Hence we restrict to 80% discharge. Similar conclusion can be drawn from the table below:

Discharge Rate	Approx % of rated	End Voltage / Cell
20	100	1.75
10	97	1.70
5	88	1.65
1	62	1.50
0.5	52	1.00

The effect of discharge on voltage is reverse of that on charge. The internal resistance of the cell creates a voltage drop when a current is passing; causing the voltage during discharge to be less than what it is on open circuit. This is expressed as voltage on discharge = open circuit voltage (current & internal resistance). The plot below shows the effect on voltage of a discharge at the 5 hours rate for a typical battery.
It can be seen that slower is the discharge rate, greater is the capacity returned.

3.4 Charging Curves:

Constant current charging is recommended for Ni–Cd batteries. However for lead acid batteries, tapering charge is recommended, charging can be at:

- Normal rate
- Accelerated rate
- Controlled rapid charges and timed with voltage time control or voltage temperature control.
- Low temp charge
- Permanent or floating charge
- Uncontrolled rapid charge

A typical charging curve is plotted below for a constant potential charging. The curve shows a plot against charging time of charging current, terminal voltage and charging volume. The charged capacity indicated as % against discharged capacity.

3.5 Taper Charging of Lead Acid Batteries:

As the charging progresses and the battery voltage rises during charge, output current of charger reduces. This charging characteristic is known as taper – we refer to by the current obtained at beginning and at the end of the charging e.g.

If output is 100A at 2.1V / Cell and in second case, the output is 50A at 2.6V / Cell, then the taper characteristics will be 2:1.

Steepness of charger taper is dependent on voltage fluctuation, the charging time required and temperature rise in battery. These parameters must be controlled during charging process.

A battery will accept higher current at the start of charge than at the end. Higher the starting rate, more expensive is the charger to make. In practice, the steepness of the "Taper Charge" is usually a compromise between the economy and the battery's charging current requirements. Finishing current is kept low for reasons enumerated below:

- To restrict temp rise in battery. Temperature rise would cause damage to the battery.
- When the battery is 75 –80% charged O_2 and H_2 gases are released. If the finishing current is too high, these gases may dislodge the particles of active materials from the positive plate – resulting in reduced battery life.
- Gassing also mixes the electrolyte – hence the finishing current should be high enough to allow this process and not so high so as to damage the plates as described above.

3.6 Equalizing Charge:

Each cell in a battery has its own characteristics hence each cell requires a different amount of charge. Self-compensating charges cater for this during the normal charge function; hence a separate equalizing facility is not required.

However, with pre-programmed chargers, an "equalizing charge" is available via a switch, which provides a continuous low current, which is used to stabilize the voltage and sp.gr. of the cells. If periodically, equalizing charge is not given with the pre-programmed chargers, the battery life could be reduced. Battery manufacturer can advise on the frequency and duration of 'equalizing charge'.

For a 36 cell 500AH battery, if the charging time were 12 hours with charger output of 70A; then for 8 hours the charger output would be 95A.

A battery that is continuously worked for 8 hours, charged for next 8 hours and immediately worked again will have its life reduced. Batteries must be given rest between charging and being discharged – to cool down.

3.7 Power pack

The Power Pack comprises of eight 6V batteries to provide 48V, 162 AH (C2) i.e. 7.7 Kwh. Each battery is lead acid, tubular type. Total weight of the pack is 260 kg. The specific energy is 30 wh/kg. The batteries are connected to each other in series. The pack has sensors for battery temperature, sensors for water level and individual block level sense line, water topping is done centrally. The inter connection and layout of the battery pack is shown in the figure.

3.8 Battery Maintenance

1) Check Battery Voltages at Pin numbers as shown below : (C.N 66 Connector)

Block Number	**Pin Number**	**Standard Value**	**Maximum Deviation**
1.	1-2	6.2 to 6.3	< 0.1 Volts
2.	2-3	6.2 to 6.3	< 0.1 Volts
3.	3-4	6.2 to 6.3	< 0.1 Volts
4.	4-5	6.2 to 6.3	< 0.1 Volts
5.	5-6	6.2 to 6.3	< 0.1 Volts
6.	6-7	6.2 to 6.3	< 0.1 Volts
7.	7-8	6.2 to 6.3	< 0.1 Volts
8. **Pack Voltage**	8-9 1-9	6.2 to 6.3 48 to 52V	< 0.1 Volts

2) For Water level Sensor, check voltage between Pin 1and 13 of CN66. It should be 7.5 to 8.5 V.

3) For Temperature Sensor, check voltage between Pin 11 and 12 of CN 66. It should be 2.93 to 3.08 V for temperature between 20 to 35^0 C.

At 30^{0}C, voltage output from the temperature sensor will be 3.03V. For every 1^{0}C rise in temperature, voltage raises by 0.01V.

1) While charging, running sound of battery ventilation fan can be heard. If the fan is not working, check the following

- 12V supply between red wire and ground
- Ground signal from EMS to fan (black wire) and 12 V signal in 12 versions EMS.
- F2 fuse in the fuse box, replace the fuse if blown
- TTL signal from fan to EMS (2.5V between yellow and black wire)

5) Check if there is any Leakage of Electrolyte. In case of Leakage from the sidewalls, the battery block will have to be changed. In case of leakage from top cover, M-seal can be used to prevent spillage. Refer service manual for replacement of the battery block or battery pack.

6) Fully charge the battery (i.e. upto100% SOC). Put it on equalization charge through PET or turn on and off the key switch three times if there is an error recorded due to requirement of equalization.

7). Watering is to be done only after the battery is fully charged. The indication would be on the IP cluster. Use only dimineralised water for watering the batteries. Ordinary tap water would damage the health of the batteries.

8). In case of low Battery Voltage, (below 40V) the on board Charger will not work. The battery block voltage has to be individually brought up by Charging externally with an external charger. After the Battery pack voltage reaches 40V or above, the car can be connected to the mains for normal charging.

9). Do not blow air on the battery, the traces of Electrolyte may splash and damage other electronic parts or may cause human Injury (especially eyes).

10). For replacing a Battery Bbck or removing the complete Battery pack, refer service manual.

3.9 Requirements of EV batteries / Parameters to be considered before choosing a battery for Electric Vehicle

- High voltage per cell.
- Low operating and maintenance cost
- Ability to withstand and sustain deep discharges.
- High rate capacity for climbing hills.
- Quick recharge.
- Compact and easy to replace.
- Protection during normal operation and accidents .

3.10 Frequently asked Questions

1). what is self-Discharge rate?

Self-Discharge rate of Battery is 1.6 AH per day.

2). Why the SOC gauge registers increases after some time?

The S.G (specific gravity, ratio of electrolyte to water) is not uniform throughout the electrolyte. Near the plates, it is low and away from the plate, it is high. Measure of SOC is by way of measuring the SG of Electrolyte. After the lapse of 2-3 hours, the S.G of entire electrolyte becomes uniform. Thus, the SOC based on lower SG measure gave low SOC indication, whereas, after the SG settled and became uniform, the SOC gauge registers a rise in value.

3). Why the capacity is high when temp is high?

Speed with which electrolyte reacts with active material are much higher when electrolyte temp is high. Conversely, when electrolyte is cold, reaction is slow. At higher temperature, faster chemical action permits more active material to take part i.e. more active material is available to take part. Since battery capacity is dependent on availability of active material to react, increasing temperature will amount to in creasing capacity.

4). Why do we charge for 3-4 hours at high current and then taper it down?

Time required for SG to stabilize can be 3 to 4 hours, depending on depth of discharge and duration of discharge. At a moderate load of 200A, it is seen that voltage stays constant for nearly 4 hours. Up to this point, the battery has delivered 80% of its capacity. During charging the same logic is followed. For approximately 3 to 4 Hours, charging is at 40 A and then tapers to 5 A. when it reaches 99% Charge, it is further continues with 5 A for 15 to 20 minute to provide equalization charge.
Also as per the manufacturers specification, Lead Acid batteries prefer taper charging as the chemical reaction is more vigorous in the initial stages of charging and the batteries will not be able the accept high current when the voltage builds up. Hence the current needs to be reduced.

5). What is maximum charge rate?

Maximum charge rate is set by maximum allowable temperatures rise in the battery and necessity not to produce excessive gassing. A practical temperature limit is 29.4 to 46.1 C. For a battery that is fully discharged, 1A per AH of battery capacity can be the initial charging current. For REVA batteries this is 40A if the ambient temperature is 30 C.

Finish rate is also determined in the same manner so that excessive gassing and excessive Temperature rise is avoided.

Finish rate is approx. 5A per 100AH of rated capacity, a rate low enough to avoid over charging but high enough to complete 100% charging in 8 to 9 hours.

6). What is gassing?

Once the batteries are fully charged, the current supplied will result in production of Hydrogen bubbles at the negative plates and Oxygen at the positive plates. This happens when the cells are fully charged (normally after 2.3V). Hence the charging current does not contribute for any voltage rise. This is called gassing.

During charging it is advisable the charge the car in a properly ventilated place. If the customer is charging the car in a closed garage, it is advisable to use an exhaust fan, as the gasses emitted during charging will be pushed out.

7). Why is ventilation necessary?

4% of Hydrogen concentration in atmosphere is explosive; therefore, ventilation of battery is necessary. It also keeps the battery temperature low.

8). How Battery efficiency affects energy efficiency?

=> Input Energy = [Charger] => [Battery] => Output for Discharge say 32 kWh
220V A.C.

Charger out put is 42 KW for the input of 50 KW from the 220V AC mains. The battery input is 42KW from the charger for the output of 32KW.
Battery Efficiency = 32/42 KW *100 = 76%
Charger Efficiency = 42/50 KW *100 = 84%
Overall efficiency in energy Conversion = 76 * 84 = 64%

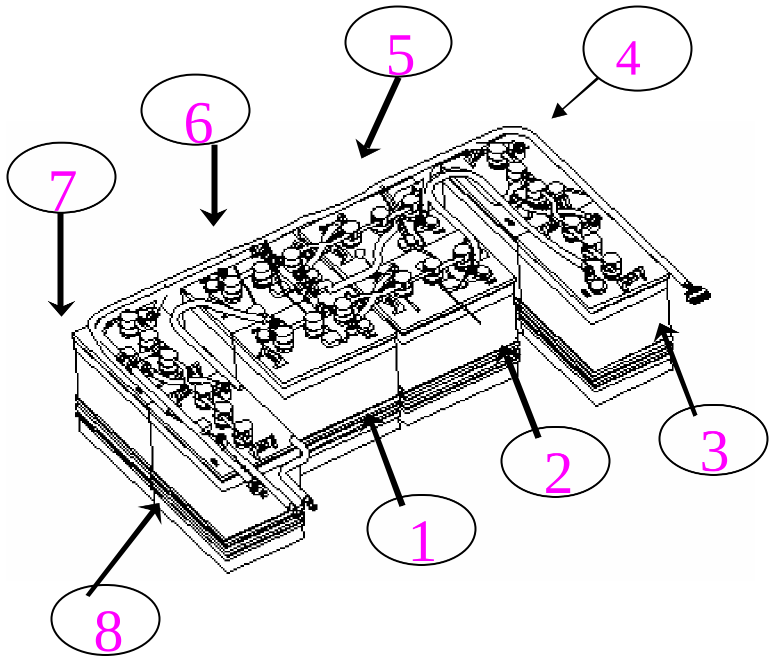
9). How depth of Discharge affects system efficiency?

% Discharge at start of Charge	Charger efficiency	Battery efficiency	Overall efficiency
80	84	76	64
40	77	63	49
20	71	50	36

We see that optimum efficiency is achieved for 80% discharge .For say 20% discharge, when the battery is again put for charge, the system efficiency is only 36%. So the Customers need to be advised to charge to 100% and discharge down to 20% before recharging.

3.11 Points to ponder:

- Battery is a device, which stores energy in the form of electric charges.
- There are two types of batteries, Primary and Secondary. REVA uses **lead acid traction type batteries**, which belong to secondary batteries.
- In REVA, there are 8 batteries of 6V each connected in series to give a total pack voltage of 48V.
- A 250A fuse protects the pack. And each block has 3A fuse and block 3 has 5A fuse at their negative terminals.
- There are **dedicated sensors** to monitor the water level and the temperature of the blocks.
- Water level sensor is located in cell 2 of block 2. If the water level in the batteries is below the limit, **low battery water light** will flash on the IP cluster
- Temperature sensor is located in the cell 3 of block 5 (semiconductor device). If the battery temperature is higher than the specified value, **temperature light** glows on IP cluster.
- Voltages from all the blocks, water level sensor (8V), temperature sensor (2V) and TTL fan signal (2.5V) will be given to EMS through **CN66**.
- An On-board charger charges batteries. The **capacity** of the pack is **200AH.**
- Watering of batteries has to be done once in 2 weeks OR 300 Km, whichever is earlier.
- Equalization is done after every 750 Km (1500AH) to maintain equal charge levels in all the blocks.

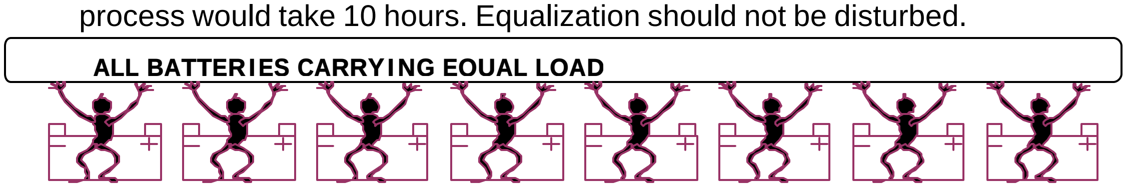


Battery life and performance:

- Heart of REVA is the power pack. Performance of Reva depends entirely on the state of these batteries.
- To enhance the life of batteries, REVA incorporates an on board computer called EMS which optimizes the performance.
- EMS senses the voltage level, temperature and water level of the battery and gives an alarm to the user if the level is low.
- As the performance of the pack depends on the temperature, exposure of the pack to very hot and cold climates should be avoided.
- Life of the batteries can be enhanced if maintained properly in terms of SG, water level and SOC.
- Batteries carry a full warranty of one year and second year of Pro rata.

Equalization:

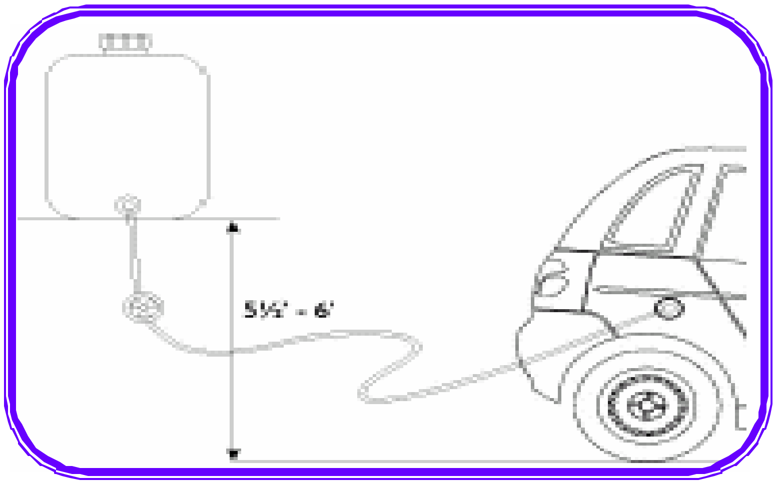
- Power pack consists of 8 identical batteries to share the load. During the course of time batteries develop inequalities in terms of block voltage and SG. This would overload some blocks and affect the life of the pack if not corrected.
- **Equalization in REVA is automatic**. EMS will calculate the AH internally and does the equalization after every 1500 AH. However equalization command can also be given through the PET.
- During Equalization, charge light and Low battery light will blink alternatively. This process would take 10 hours. Equalization should not be disturbed.



Pack Care:

a) Watering: Batteries lose water during course of time due to evaporation. Hence watering has to be done to overcome this. Watering is done once in 300 Kms or 2 weeks (whichever is earlier). Quantity of water varies with climate. If watering is needed, then low water level light will come on in the IP Cluster for duration of 5 minutes. If ignored for 2 consecutive cycles, low water light will be on throughout the drive. Low water level light will flash if ignored for 5 successive cycles.

Watering should be done only after full charge.



Note: Use only **demineralised water** available at the authorized outlets. Ordinary tap water will damage the battery blocks.

b) Charging: At the end of every drive, car should be put for charging. If batteries are kept idle, they lose the capacity due to self-discharge (approximately 2 AH per day). If the car is kept idle for more time, trickle charge error will be recorded in the EMS.

Precautions:

- Avoid charging the car in hot sun.
- During summer it is advisable to charge the car during evening.
- If the temperature is too low, pack capacity will be reduced and the range will come down.
- Avoid parking of the car outside when it is snowing.
- Keep the car plugged to mains whenever it is idle.

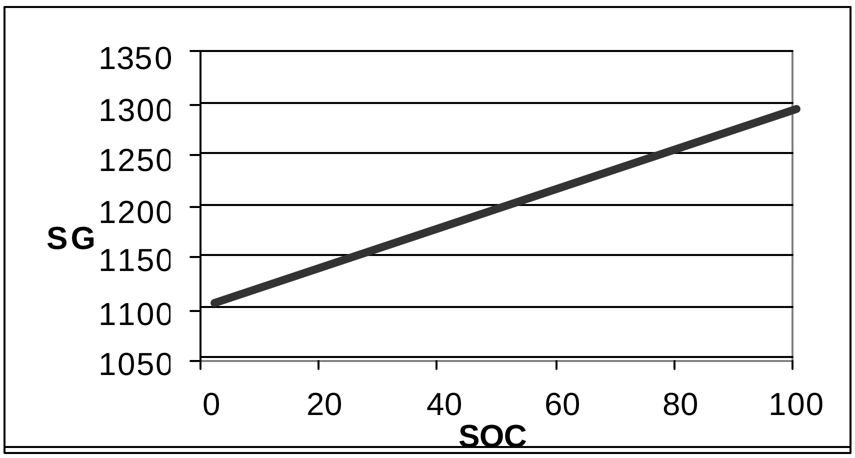
Important:

- Electrolyte should always cover the electrodes.
- Watering should be done only after the full charge.
- DOD should be limited only to 80% to avoid damage to the pack.
- Avoid driving in RED band.
- Ensure that fan is running and Vprog and Iprog are followed during charging.
- Keep an eye on acid leakage from the blocks.
- Ensure Avg.DV and Max.DV are within the specified limits.

A note on Specific Gravity:

Specific gravity is an important factor, which contributes for the capacity of the battery pack. In a fully charged battery, SG will be 1.28 and in a fully discharged battery, SG will be 1.18 (depends on the voltage level)

- Specific gravity is an indication of the battery health.
- Specific gravity to be measured only after full charge.
- Specific gravity increases with increase in SOC and decreases with increase in temperature.
- SG correction/acid correction can be done to bring the specific gravity to the specified level.
- If the SG is higher than the normal, demineralised water can be added and if the SG is below normal, electrolyte can be added to compensate for the deviation. However, the quantity of electrolyte to be added / removed depends on the deviation from the normalized value of SG.
- For every 0.01 unit deviation of SG approximately 40 ml of electrolyte of will be added or removed.



CHECK LIST FOR BATTERY PACK

REVA The electriCity Car	CHECK LIST FOR BATTERY PACK	REPORT NO:	
		REPORT DATE:	

DEALERS NAME			LOCATION	
VIN NO	BATTERY PACK NO	CYCLE NO	BATTERY PACK INSTALLATION DATE	FAILURE DATE
TOTAL KMS COVERED BY CAR			KMS COVERED BY BATTERY PACK	
SYMPTOMS				

CHECK BATTERY VOLTAGES

DETAILS	STANDARD	ACTUAL		REMARKS
		PALM	MULTIMETER	
BATT PACK VOLT	48V			
INDL. BATT VOLT BV1	6V			
INDL. BATT VOLT BV2	6V			
INDL. BATT VOLT BV3	6V			
INDL. BATT VOLT BV4	6V			
INDL. BATT VOLT BV5	6V			
INDL. BATT VOLT BV6	6V			
INDL. BATT VOLT BV7	6V			
INDL. BATT VOLT BV8	6V			

CHECK SPECIFIC GRAVITY (1.28@FULL CHARGE IN IDLE CONDITION)

CELL	BV-1	BV-2	BV-3	BV-4	BV-5	BV-6	BV-7	BV-8	REMARKS
C1									
C2									
C3									

CHECK POINTS	REMARKS
1. CHECK VOLTAGE (8.6V) B/W PIN NO.13 OF CN66 W.R.T B-VE FOR WATER LEVEL SENSOR.	
2. CHECK VOLTAGE (3V) B/W PIN NO.11&12 OF CN66 FOR TEMPERATURE SENSOR.	
3. CHECK ALL PACK SENSE FUSES (3AMPS).	
4. CHECK CONTINUITY OF EACH CABLE FROM BATTERY TO CN66.	
5. CHECK THE PHYSICAL CONDITION OF THE BATTERY.	
6. ATTACH SUMMARY AND ERROR DATA.	

PREVIOUS HISTORY OF BATTERY:

CHECKED BY (NAME & SIGN)	DEALERS STAMP AND SIGNATURE

CHAPTER – 04

AC MOTORS

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AC MOTORS

4.1 INTRODUCTION:

A motor is a device which electrical energy into mechanical energy.

The combination of a motor, converter and controller is frequently referred to as a “drive train OR power train”. IEEE standard dictionary describes converter as “a device that changes electrical energy from one form to the other”; and a controller as “a device that regulates the state of a system by comparing a signal from a sensor located in the system with a pre-determined value”. The converter can act as a rectifier (ac-dc conversion), an inverter (dc-ac conversion), or as a chopper (dc-dc conversion). Of all the motors, the 3-phase induction motor is the one extensively used for various kinds of drives. By definition, a chopper drive consists of a power electronic device such as MOSFET, which acts as a controllable switch to convert the constant voltage to a desired average level (V_{avg}). To be ON time, T is the period and 1/ T is the chopper frequency (f) (Fig.1). If MOSFET are used, a forced zero current is required during turn off. This is referred to as “forced commutation” and imposes minimum ON time (To) to charge the capacitors used for the commutation process (Fig.2)
to obtain min average voltage,

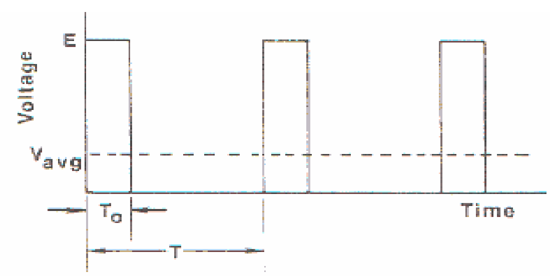


Fig.1 Output voltage of the controller for a chopper drive $\bar{V}_{avg}$ = E (To/T)

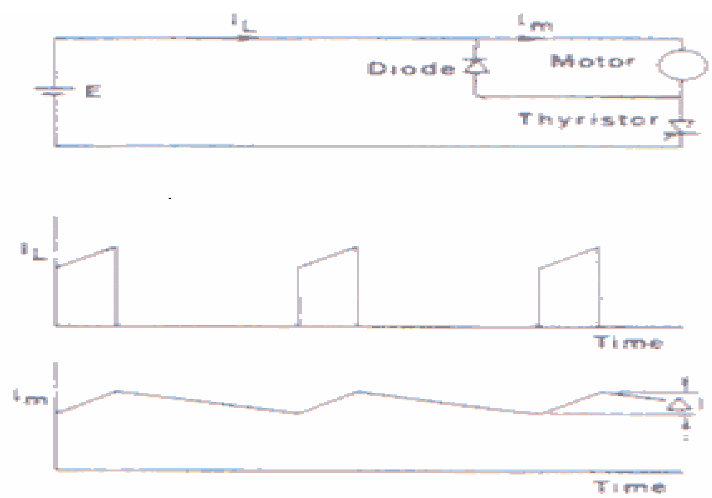
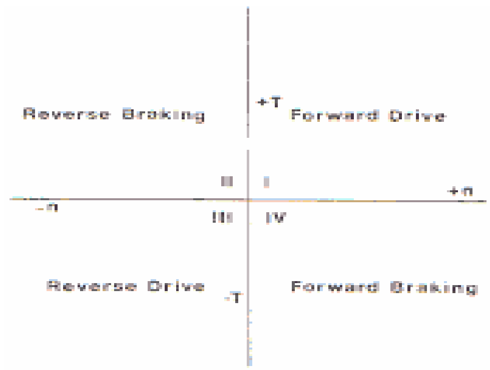


Fig.2 Basic chopper circuit, source current is and motor current Im as a function of time.

Large value of T is required i.e. the frequency must be low e.g. if min required voltage is 10% of source voltage and min ON time is 0.01s, frequency is $10H_z$. However, tests indicate that motor efficiency increases with increase in frequency because of reduced harmonics content in the current at higher frequency. Many converter are one quadrant type i.e. they provide energy to the motor in one direction only (I quadrant) i.e. they can move forward only. Other

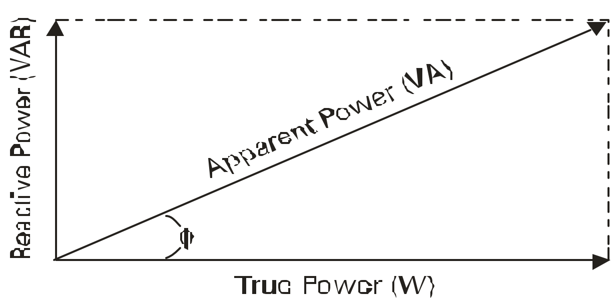


converters can operate in I & II quadrant. More complex converters can operate in all four quadrants i.e. they supply power from the combination (regenerative braking) in the normal forward direction, and they can also operate in the reverse direction in either a motoring mode or in a braking mode.

Fig.3 The four possible quadrants of motor operation; n=speed, T=torque.

4.2 Power in an AC Circuit:

Resistance is not only circuit property that affects power in an AC circuit. Power consumed by a resistor is dissipated in heat and not returned to the source. This power used to do work is called as true power. True power is the rate at which energy is used and measured in watts (W). Current in an AC circuit rises to peak values and diminishes to zero many times a second. The energy stored in the magnetic field of an inductor or plates of a capacitor is returned to source when current changes direction. This power not consumed is called reactive power. Power in the AC circuit is the vector sum of true power and reactive power. This is called as apparent power measured in volt-amps.



The formula for apparent power is

$$P = EI$$

True power is calculated from a trigonomic function, the cosine of the Phase angle.

$$P = EI \cos F$$

Power Factor:

Power factor is the ratio of true power to apparent power, or a Measurement of how much power is consumed and how much power Is returned to the source. Power factor is equal to cosine of phase angle.

PF = cos F

All the energy delivered by the source is consumed by the circuit and dissipated in the form of heat.

Horse power and Kilowatts:

AC drives and motors generally rated in horse power (HP). Horse power can be converted to kilowatts with the below formula.

KW = 0.746 X HP

Kilowatts can be converted to horse power as below.

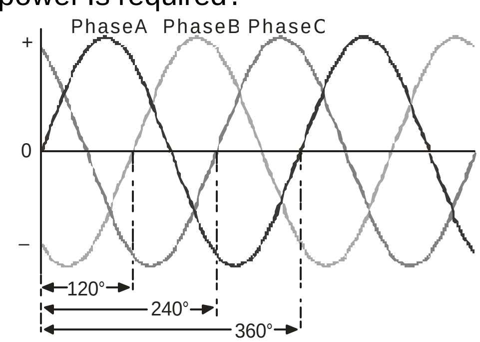
HP = 1.341 X KW

The power formula for 3-phase power is

KW = (V X I X PF X 1.732) / 1000

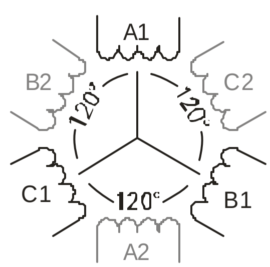
Three Phase Power:

Three phase power is produced by three voltage sources. These are Continuous series of three overlapping AC voltages. Each voltage wave represents a phase and is offset by 120 electrical degrees. Three phase power is used where a large quantity of electrical power Is required.



4.3 AC MOTORS

A rotating magnetic field must be developed in the stator of an AC motor In order to produce mechanical rotation of the rotor. Wire is coiled into loops



2-PoleStatorWinding

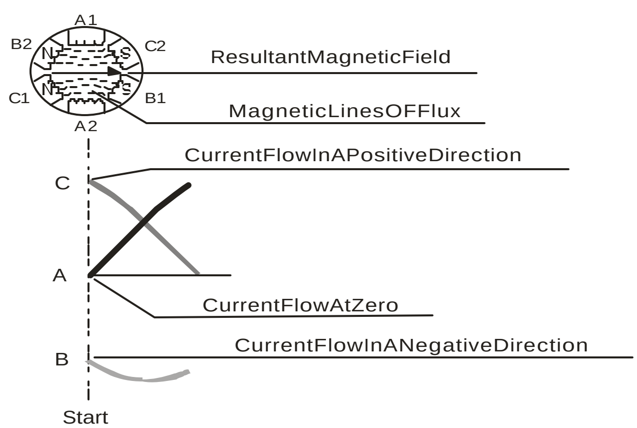
and placed in slots in the motor housing. These are called as stator windings. The following drawing illustrates the 3– phase stator. The number of poles is determined by how many times a phase winding appears.

When AC voltage is applied to the stator, current flows through the

Windings. The magnetic field developed in a phase windings depends on the direction of current flow through that winding. The following Chart is shown for explanation. It assumes that a positive current flow in the A1 , B1 and C1 windings result in a north pole.

Winding	Current Flow Direction	
	Positive	Negative
A1	North	South
A2	South	North
B1	North	South
B2	South	North
C1	North	South
C2	South	North

It is easier to visualize a magnetic field if a time is picked when no current is flowing through one phase. In the following illustrations, for example, a time has been selected during which phase A has no current flow, phase B has current flow in a negative direction and phase C has current flow in positive direction. Based on the above chart, B1 and C2 are south poles and B2 and C1 are north poles. Magnetic lines of flux leave the B2 north pole and enter the nearest south pole, C2. Magnetic lines of flux also leave the C1 north pole and enter the nearest south pole, B1. A magnetic field results indicated by the arrow.



The amount of flux lines (F) the magnetic field produces is proportional to the voltage (E) divided by the frequency (F). Increasing the supply voltage increases the flux of the magnetic field. Decreasing the frequency increases the flux.

$$F = E / F$$

If the field is evaluated at 60° intervals from the starting point, at point 1, it can be seen that the field will rotate 60°. At point 1 phase C has no current flow, phase A has current flow in a negative direction. Following the same logicas used for the starting point, windings A1 and B2 are north poles and windings A2 and B1 are south poles. At the end of six such intervals the magnetic field will have rotated one full revolution or 360°.

Rotation of a Squirrel cage Rotor:

The squirrel cage rotor of an AC motor acts essentially the same as the

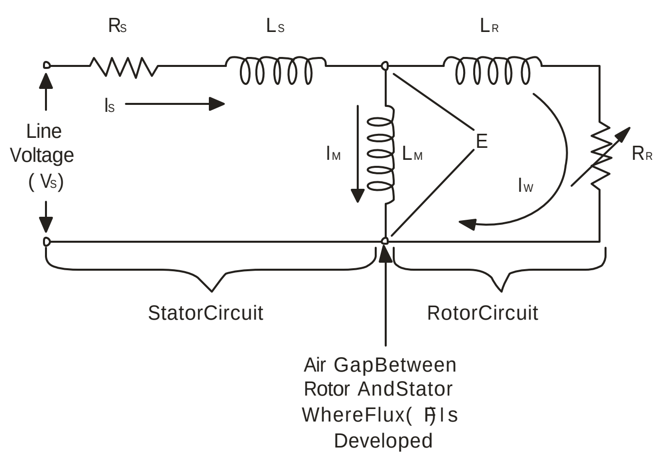
Magnet. When a conductor, such as the conductor bars of the rotor, passes through a magnetic field a voltage (emf) is induced in the conductor. The induced voltage causes current flow in the conductor. The amount of induced voltage (E) depends on the amount of flux (F) and the speed (N) at which the conductor cuts through the lines of flux. The more lines of flux, or the faster they are cut, the more voltage is induced. Certain motor constants (K), determined by construction also affect induced voltage. These constants, such as rotor bar shape and construction, do not change with speed or load

$$E = KFN$$

4.4 Electrical Components of a Motor

The following diagram represents a simplified equivalent circuit of an AC Motor. An understanding of this diagram is important in the application of AC Motor to an AC drive.

Vs : Line voltage applied to stator power leads
Rs : Stator resistance
Ls : Stator leakage inductance
Is : Stator current
E : Air gap or magnetizing voltage
Lm : Magnetizing inductance
Im : Magnetizing current
Rr : Rotor resistance (varies with temperature)
Lr : Rotor leakage inductance
Lw : Working or torque producing current



Line Voltage:

Voltage (Vs) is applied to the stator power leads from the AC power supply. Voltage drops occur due to stator resistance (Rs). The resultant voltage (E) represents force (cemf) available to produce magnetizing flux and torque.

Magnetizing Current:

Magnetizing current (Im) is responsible for producing magnetic lines of flux which magnetically link with the rotor circuit. Magnetizing current is typically about 30% of rated current. Magnetizing current, like flux (F), is proportional to voltage(E) and frequency(F).

$$Im = E / (2pFLm)$$

Working Current:

The current that flows in the rotor circuit and produces torque is referred to as working current (Iw). Working current is a function of the load. An increase in load causes the rotor circuit to work harder increasing working current (Iw). A decrease in load decreases the work, the rotor circuit does decreasing working current (Iw).

Stator Current:

Stator current (Is) is the current that flows in the stator circuit. Stator current can be measured on the supply line and is also referred to as line current. A clamp-on ammeter, for example, is frequency used to measure stator current. The full-load ampere rating on the name plate refers to stator current at rated voltage, frequency and load. It is the maximum current the motor can carry without damage. Stator current is the Vector sum of working current (Iw) and magnetizing current (Im). Typically magnetizing current (Im) remains constant. Working current (Iw) will vary with the applied load which causes a corresponding change in stator current (Is).

$$Is = \sqrt{(Im^2 + Iw^2)}$$

4.5 REVA AC MOTOR:

The drive to the transmission is through an ac motor. An AC motor has basically two components as shown in figure.

- Stator.
- Rotor.

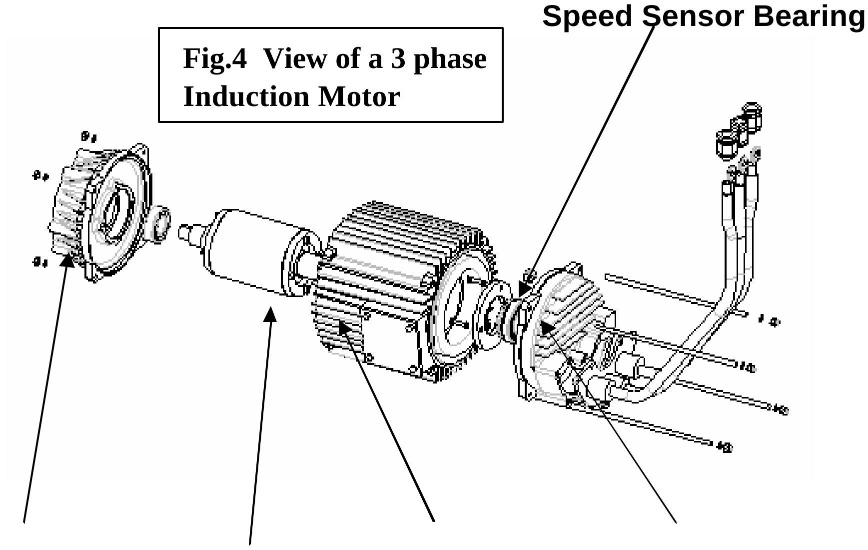


Fig.4 View of a 3 phase Induction Motor

4.6 SQUIRREL CAGE INDUCTION MOTORS :

Almost 90% of induction motors are of this type, since in this type of motors, the rotors has the simplest and most rugged construction. The rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor conductors that are not wires but heavy bars of copper, aluminum or alloys. One bar is placed in each slot; rather the bars are inserted from the end when semi-closed slots are used. The rotor bars are brazed or electrically welded to two heavy and slot short –circuiting end rings, thus looks like a squirrel cage construction.

It should be noted that the rotor bars are permanently short circuited on themselves; hence it is not possible to add any external resistance in series with the rotor circuit for starting purposes. There are no brushes in this motor which is one of the reasons for its ruggedness. The below figures shows torque Vs Speed regulation and power Vs speed.

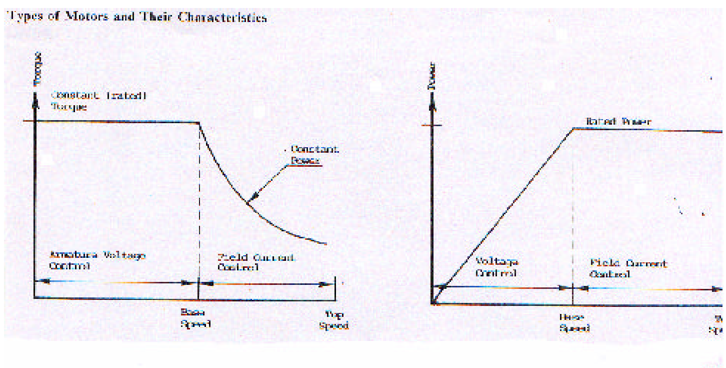


Fig.7 Torque Vs Speed Regulation **Fig.8 Power Vs Speed Regulation**

4.7 BRAKING: REGENERATIVE

Every rotating machine and connected load contains the stored (KE) Kinetic Energy. In addition, the electrically driven vehicles will also have varying amount of potential energy (PE), depending on the route traversed and elevations encountered. The objective of every method is to take stored energy and convert into another form with the help of mechanical brakes. This energy is converted into thermal energy, which is seldom utilized.

To brake a dc motor electrically, we shift its operation from the motor to a generator action. A small increase in I_f will cause the internally generated voltage E_a to exceed the line voltage V. I_a will then reverse direction, as will the power flow. Braking action changes during the braking period. At the beginning, maximum braking torque is developed because the armature current is high. As the motor slows, generated voltage becomes smaller, being directly proportional to speed and the I_a falls in the same proportion. As the motor approaches zero speed, braking torque is approaching asymptotically. It is sometimes necessary to initiate mechanical braking action towards end of braking period and a mechanical brake is required if motor and load are to be held stationery after stopping.

Dynamic braking transforms KE and PE into thermal energy (TE). Regenerative braking on the other hand transfers energy from the rotating system back into supply. The motor thus 'regenerates' power back into the line. Regenerative braking becomes less effective as the speed is reduced and there is a lower limit to the speed at which it has any effect on the braking. In such cases dynamic or mechanical braking would be necessary.

Check sheet for Motor Failure

Customer Name:		Location:	
Dealers Name:		Location:	
VIN No.		Date of Motor installation (If Replaced earlier)	Failure Date
Motor No.			
Total Kms covered by car		Kms covered by failed motor	
Symptoms			

Checks by Customer

Check points	Standard	Observed	Remarks
Any abnormal noise from the motor?	No Abnormal Noise	Yes / No	
Check for motor temp indication in the IP?	Temp indication coming ON during running and reduction in speed	**Yes / No**	
Is car moving when accelerator is pressed?	Car should move.	**Yes / No**	
Any burning smell from the motor?	No burning smell from the motor during running	**Yes / No**	

Checks by Service Personnel

Check in Hand held for any Motor related errors	No motor errors to be seen	Yes / No	
Check for U, V and W	All the terminals should be tight and no burning sign.	Yes / No	
Remove the EMS connection and Battery –ve or +ve cable. Remove the motor terminals and check for the following	EMS connections as per sequence	Yes / No	
Check IR value for 1. U, V and W cables with rotor	Min 2 Mega Ohms	OK / Not OK	
Check the continuity by Multimeter 1. between U, V and W cables and motor stator body	Should not have continuity(>20 mega ohms)	**Yes / No** **Yes / No**	If No open motor
Note: Follow the procedure as per service manual for removing the motor from the car and dismantling.			

Checked By Dealer Stamp & Signature	

4.9 Motor Maintenance

1.
    - Check for continuity of U, V and W phases. It should be continuous i.e. 0 Ohms when measured by Megger or Multimeter.
    - Check for no Continuity of all three phases with rotor and motor body. It should be >20 mega Ohms when measured by Megger or Multimeter.
    - Insulation resistance between filed and armature should be above 2 Mega ohms.
2. In case of poor insulation resistance or coil resistance, refer service manual to dismantle, then check and clean the motor.
3. Check the state of motor bearing and replace if required.
4. Check for the rigid connections of motor U, V and W phase cables. If the connections are not rigid, it may lead to motor short circuit.
5. Check for any fouling of shield mesh of motor cables with terminal lugs.
6. Do not drive the car with parking brake engaged as it leads to overheating of motor.
7. While parking on the slopes engage parking brake and do not use accelerator or brake to hold the car (example in traffic signals). This again leads to overheating of motor.
8. Check for the spider position and wear for flexible coupling.
9. Clean the dust deposited on the connectors of temperature sensor and speed sensor bearings.

CHAPTER 05

ENERGY MANAGEMENT SYSTEM

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CHAPTER 05

ENERGY MANAGEMENT SYSTEM (EMS)

5.1.1 INTRODUCTION:

Efficient battery management is necessary in a cost-effective consumer EV. Experience with electric vehicles reveals consumer dissatisfaction with operating costs, especially those incurred through battery replacement. While a battery lifetime of three years is often quoted, customers have frequently found replacement necessary after every 12 to 18 months. Primary causes of this early mortality are over discharge and overcharging of individual batteries in the battery pack due to differences in the condition of individual batteries. These problems are difficult to solve in practice, because high battery variability requires accurate tracking of individual battery SOC (state of charge).

The Reva Energy Management System (EMS) provides the following features critical to maximizing battery performance and life in a consumer EV.

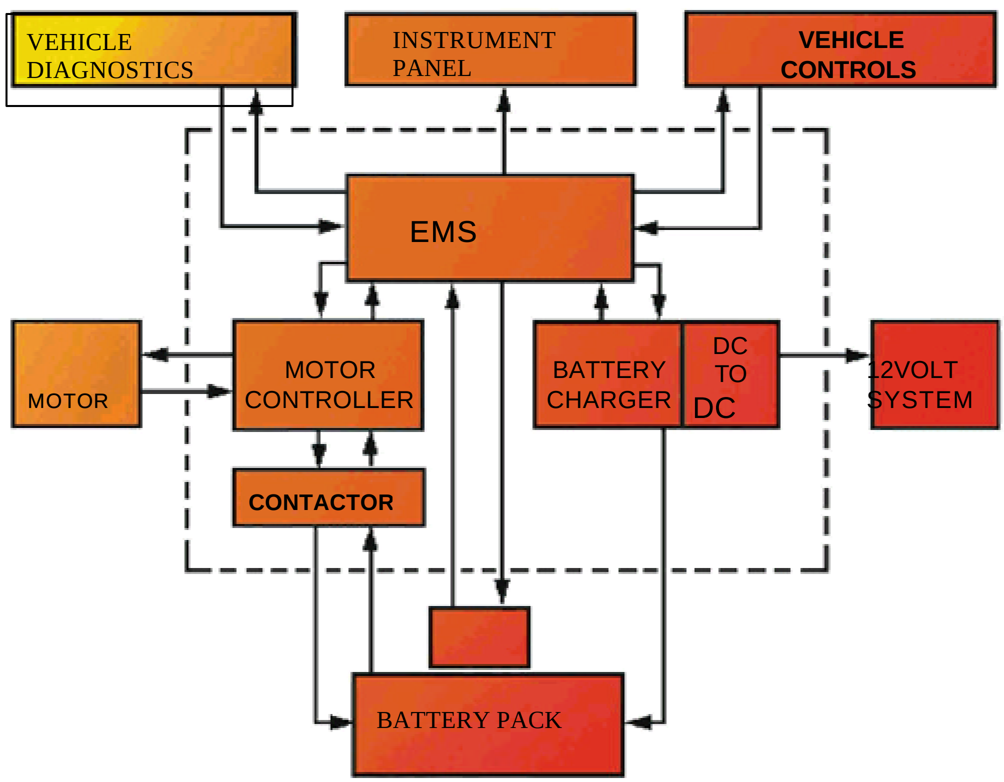
- **Monitors the status of each battery in the battery pack –** Patented sensing hardware provides reliable tracking of individual battery characteristics.
- **Advanced charge control –** EMS controls charge current and voltage to provide safe charging. Employs temperature compensation and thermal fold back to prevent charger electronics damage.
- **Reliable state of charge (SOC) estimation –** Provided by a highly rugged and reliable SOC meter that allows consumers to drive with greater confidence and security. The SOC signal is on a dash-mounted SOC meter. The EMS is set to reduce vehicle acceleration when the SOC is low.
- **System diagnostics –** A “Service” indicator light on the instrument panel instructs drivers to take their vehicles in for service. A palmtop computer interface allows service personal to rapidly pinpoint weak batteries for replacement before vehicle performance suffers noticeably. The diagnostic system also displays warranty-related information that can help verify that the consumer has met warranty requirements.
- **Data acquisition –** The EMS stores data for later retrieval.
  eg. W-hr/km, total km, total Ahr, charge times, charge termination criteria, charge phase times, average battery voltage differentials, etc.

5.2 EMS BENEFITS:

- **Longer battery life –** By automatically sensing and controlling individual battery voltages during charging, the EMS is able to reduce pack damage due to over charging.

- **Greater effective pack range –** By performing automatic charge, equalization of batteries of a pack, effective storage capacity is maximized without subjecting individual units to excessive discharge.
- **Automatic warranty verification and diagnostics –** The EMS speeds up service personnel by providing them with accurate summaries of pack life histories and by identifying which batteries are experiencing problems.
- **Reduced cost –** EMS reduces maintenance, battery replacement and battery service costs.
- **Improved State of charge estimation –** This feature enables customers to drive with greater confidence while reducing the chance of over-discharge. Effective SOC estimation helps in getting good battery life by reducing over discharge conditions that are often the result of inaccurate SOC displays.
- **Reduced charging time –** Because the EMS is able to sense each battery voltage, it can safely charge the pack more quickly than the systems that do not use battery feedback.

The EMS is located in the rear tub / electronics tub under the back seat. It is part of the “Tub Electronics”.



5.3 EMS communicates with the various electronic units as follows:

- Motor controller through RS 232 (Tmot, Tctr).
- IP Cluster through output signals SOC (FG), SRL, BPL, MTL, WLL, LBL, CHL and chime and input signal from the key.

- Power pack through input signals BV_0 to BV_8, water level sensor (WSS), Battery temp (T.Bat).
- Charger through input signals CUV, COT, Tchr (CT) Fchg (CS) and output of Iprog (CIS) V prog (CVS), PEM (CCE). 48V DC is available for the pack and through DC-DC converter; 12V is available for IP Cluster, chime, lights etc.
- Bat fan through output (BFP) and input (FTO).
- EMS has RS232 at CN67 (4 pin) for connecting PET or PC. The micro chip is PIC 17C 756A with an E^2 PROM. It has CN64 (24 pin – main harness and motor controller) CN66 (18pin from battery pack) and CN63 (16 pin from charger). Block diagram is at Fig.1.

5.4 ANALOG INPUTS:

- Battery voltage inputs – eight individual battery voltages and over all pack voltage is sensed. Each battery is 6V and sensing range is 3 to 8V. Accuracy is 50mv per battery. EMS will detect open or short. All batteries are connected in series.

- Battery Current Input is sensed from (-) 400 to (+) 400A. Reading accuracy is 1A.
- Battery Temp. Input is sensed through 3 pin IC temperature sensor at accuracy ± 3ºC 27ºC = 3.00V and voltage will raise by 0.01V for 1ºC rise in temperature
- Charger Current is sensed from (-) 50 to (+) 50A with accuracy of 0º2A. EMS is able to detect open or short circuit faults.
- Charger temp input is similar to battery temp input.
- Charger Voltage Control is (0 to 5V, fault range < 0V and > 5V)
- Charger Current Control is (0 to 5V fault range < 0V and > 5V)

Parameters	**Description**	**Dig input 0V to 5V**	**Nominal Range**
Batt. amp	Batt. Current input	-50mv to +50mv	-50mv to +50mv
Batt.temp	Batt.temp input		2.7v to 4v
Ch – amp	Charger current	-50mv to +50mv	-50mv to +50mv
Ch – temp	Charger temp	0 to 100ºC/2.73-3.7v	-50mv to +50mv

.

5.5 ANALOG OUTPUTS:

The location of EMS in relation to other components in “Tub Electronics”
SOC display on instrument panel is 8 – 16V with ± 0.25V accuracy. Charger current control output is 0 – 5V on I _prog and corresponds to 0 – 40A. Charger minimum output is 2A hence charger will not respond to values below 2A.
Charger voltage control output is 0 – 5V on V-prog and corresponds to 40 - 66.5V. Charger maximum output current is 42A.

Particulars	**Nominal Range**
SOC Display	8 – 16V
Gauge	- do -
Ch. current	0 – 5V
Ch. volt	0 – 5V

5.6 DIGITAL INPUT / OUTPUT:

Key on input – 48v input signal, limiting to 5 – 6v. Input state is 5v – 48v = 5v and 0v = 0v. Threshold level is 2 to 3.5v. It has four protections i.e 48v short circuit, 12v short circuit, ground short and (-) 12v short protection (internal EMS hardware protections)
Charger control output. TTL contact closure type is referenced to (-) $V_{o.}$ TTL low or short circuit disables internal charging profile. TTL high or open circuit also disables internal charging profile. Memory location is PEN and controller output is RC2. It is off for logical low (0V) and it is on for logical high (5V). Threshold is 2 – 3.5V.
Low AC input from mains – charger can handle 160V ac. Charger will not be damaged when operated between 145 to 158V. Charger will shut down at least 5V below its startup point.
Battery Fan Power Output is switched to 12V with power handling capability of 6w. Memory location is BFP, controller output at RG4. Logical low (0V) is off and logical high (5V) is on. Threshold is 2 – 3.5V.

	Input State 5-48v=5v	**0v = 0v**	**Threshold**	**Memory Location**
Brake fluid	On	Off	2-3.5v	BFS
Brake parking	-do	-do-	-do-	BPS
Ch.over temp.	-do	-do-	-do-	COT
Ch.status in.	-do	-do-	-do-	CSS
Ch. Interlock	-do	-do-	-do-	CIL
Water level sensor	-do	-do-	-do-	WSS
Tacho pulses	-do	-do-	-do-	TAP

	Memory	**Controller**	**Log low 0v**	**Log high 5v**	**Remarks**
Charge indicator	CHL	RC5	Off	On	Battery charging – On/Off every 01sec.
Brake light	BPL	RC6	Off	On	Brake is on or low brake fluid.
Low battery light	LBL	RC7	Off	On	On if soc is between 25-35% and flashes when soc is below 25%.

Chime is a friendly alarm given by the EMS to the user. It alerts the user on following events. Chime is located inside the instrument panel.

Chime On condition				
KEY	**Parking Brake (BPS)**	**Door (TAP)**	**Throttle**	**Chime (BEL)**
ON	Pulled	Open		ON
ON	Pulled	Closed	> 5%	ON
ON	Release	Open		ON
ON	Release	Closed		OFF
OFF	Pulled	Open		OFF
OFF	Pulled	Closed		OFF
OFF	Release	Open		ON
OFF	Release	Closed		OFF

Connecting the PET (palm computer) to the EMS and going through the various menus engineers can do **Service Diagnostic**. (refer service manual).

5.7 Diagnostic Output

EMS controls the five indicator lamps on instrument cluster

- Service Light – This indicates an attention from service personnel as per error code.
- Brakes – parking or foot brake 'ON' state and brake fluid indicator.
- Battery water level indicator.
- Over temperature indicator – for battery, or motor, or charger temperature.
- Head light on indicator.

During charging, charge LED blinks green and at 100% charge (after full charge) LED turns solid green.

If SOC is 25-35%, the low battery light turns on blinking and if soc is less than 25% then it becomes solid.
Alternate blinking of charge LED and low battery light will be seen during equalization charge.

If EMS does not have micro controller chip inside then colour of LED on the IP cluster will be amber (Yellow + Red)
Auto Equalization – Say the does 80Km or 150Ahr per day. In 10 days the car has done say 800km and has logged 1500 Ahr. At 1500 Ahr, auto equalization takes place after c_f phase. It is automatic and should not be disturbed.

Charging Phases:

Phase 1 – This is also called as C1 phase. This phase is characterised by constant current, max current 40A while V<50.4v or until time out. In this phase, charging current is maintained at 40A or the taper current which ever is less. Taper current is calculated from battery voltage, on the line from 40A, 49.6v to 69.6v as I = [69.6 – v] *2. The transition from constant current to taper current is at 49.6v. During taper charging, battery voltage increases while charging current reduces. Generally it continues to about 62.5v and 14A. V_prog os setup, ax and I_prog are controlled via closed loop circuits.

The termination criteria for taper charge are:

- dv / dt < 60mv / 10min when V_a > 58v @ 30ºC
- battery voltage > 66.5v
- Charge timeout > 12 hrs.

After the charge phase (Phase I to Phase 3) has terminated, the charger switches to the final phase C_f.

Phase 2 – This is also called as C2 phase. Here charger current tapers from 40A (50.4v) to 5A (57.6v) until dv / dt < 60mv / 10min.

Phase 3 – This is also called as C3 phase, again charging current continues at 5A.

Final phase – This is also called as Cf phase, after the termination of the above three phase taper curve is followed for 20 minutes and then it goes to the float phase. Purpose of final phase is to ensure that the batteries are equalized after dv/dt criteria is detected in the charge phase.

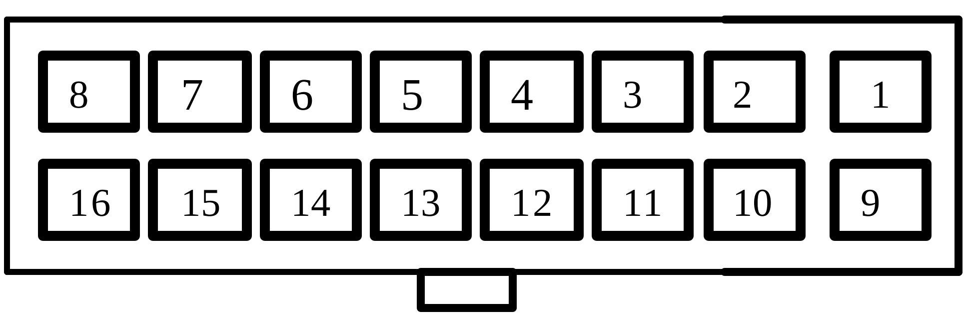
5.8 PIN CONNECTIONS AND EMS CONNECTORS:

EMS has four connectors for communication. CN 67 for external communication, CN 66 for sensing battery voltages, temperature and water level, CN 64 for user interface and other commands and CN 63 for charger communication. There is a particular sequence for removing and reconnecting EMS connectors.

Following is the procedure for removing EMS connection

- Note down the SOC before removing the EMS connections
- **Remove** EMS connectors in sequence **(CN66, CN 64, CN 63 and CN 67)**
- Remove the battery postive terminal and insulate.
- Carryout the repairs / service
- Reconnect the battery positive cable.
- **Connect** the EMS as per the sequence **(CN 67, CN 63, CN 64 and CN 66)**
- Set the SOC to its original value

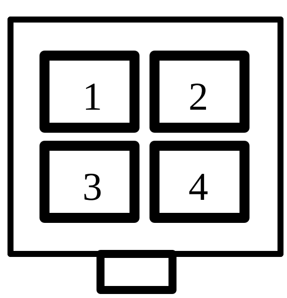
Note: If the sequence is not followed while connecting or disconnecting, OR if battery positive terminal is removed prior to the removal of EMS connectors would lead to EMS malfunctioning. (Calibration parameter may get erased)



CN 63 Charger to EMS

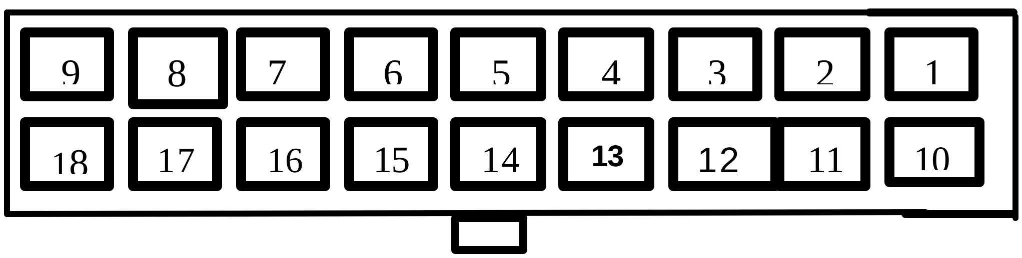
Note: To number the connector, hold it in such a way that you are facing the wire entry side and lock is upwards.
If the connector is female, number it from right to left
If the connector is male, number it from left to right.

Pin No.	Description	Function
1	12V to EMS	12 V supply to EMS
2	GND	Ground to EMS
3	COT	Charger Over Temp. Shuts down the charging if the temperature is more than 75^{0}C.
4	CSS	NA
5	CUV	Charger Under Voltage: This is the signal from the charger to EMS, which indicates that charger is ready to charge the pack.(while charging :0V & Idle: 5V)
6	PEN	Charger Control Enable: EMS enables the charger to charge the pack.(while charging :0V & Idle: 5V)
7	CSG	Charger control ground
8	CVS	Charge Voltage Control: This is nothing but Vprog. This voltage should always follow the battery voltage. Voltage measured is (0V-5V) increases with states of charging.
9	CIS	Charger Current Control: This is nothing but Iprog. This should always follow the battery current. Voltage measured will decrease with different states of charging.
10	CS-	Charger shunt low: Reference pin to read the charger current
11	CS+	Charger shunt High: Shunt pin to read the charger current
12	CT-	Charger temp. Low: Reference pin to read charger temp.
13	CTA	**Not Used**
14	CT+	Charger temp. High: Pin to measure the temp. of charger
15	NC	**Not used**
16	NC	**Not used**



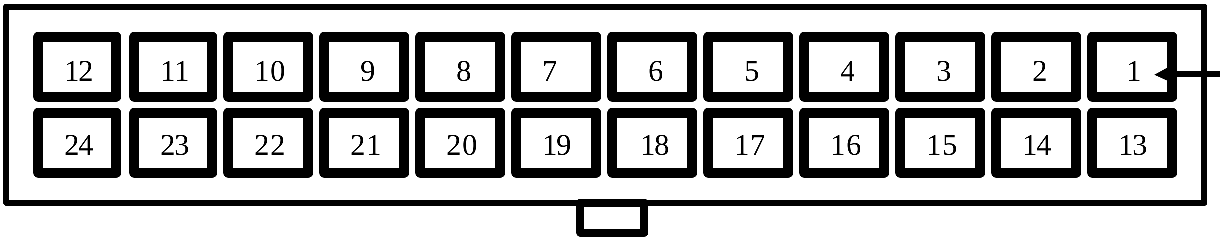
CN 67- EMS diagnostic port

Pin No.	Description	Function
1	STX	Serial Transmit: Data is transmitted serially through this pin. (RS232)
2	SRX	Serial Receive Data: Serial data is received through this pin. (RS232)
3	GND	Ground Signal
4	GND	Ground Signal



CN 66 Connector and Pin details (Pack sensor harness)

Pin No.	Pin description	Function
1-2	BV1	Voltage of block1
2-3	BV2	Voltage of block2
3-4	BV3	Voltage of block3
4-5	BV4	Voltage of block4
5-6	BV5	Voltage of block5
6-7	BV6	Voltage of block6
7-8	BV7	Voltage of block7
8-9	BV8	Voltage of block 8
0-9	V Pack	Voltage of the pack
10	**No Connection**	-
11	BTS	Output voltage from the bat. Temp sensor. It should be 2 to 2.5V or 650 ohms resistance
12	BTG	Ground for the bat. Temp sensor
13	WLS	Output from the water level sensor. It should be 8 to 9V.
14	**No Connection**	-
15	**No Connection**	-
16	Ground signal or12 V	Ground or 12 V for the battery fan.
17	**No Connection**	
18	TTL signal from fan to EMS	TTL fan output from fan to EMS. It should be 2 to 2.5V.



CN 64 Connector diagram and pin description

Pin	Signal	Description	Pin	Signal	Description
1	0 / 48 V	Limp Home signal to controller (48)	13	0 / 48V	Key ON signal (Input to EMS-48 V for ON)
2	15V	Power supply from Controller	14	0/48V	Economy mode' signal to controller (48)
3	Data	Controller Transmit data (To Handheld / EMS)	15	NC	No Connection
4	NC	No Connection	16	0 / 12V	Water level light (EMS to IP-Gnd for ON)
5	0 V	Ground' signal from controller	17	8 - 16 V	Fuel gauge +ve (EMS to IP)
6	0 / 12V	Brake light signal - EMS to controller	18	0V	Fuel gauge return
7	0 / 12V	Door switch input to EMS (0V when door open)	19	0V / 12V	Chime (EMS to Chime- 'Gnd' for ON
8	0V	Ground'	20	0 / 48V	Brake Fluid sensor input to EMS
9	0 / 12V	Over temperature light (EMS to IP-Gnd for ON)	21	0 / 48V	Parking Brake sensor (Input to EMS)
10	0 / 12V	Service light (EMS to IP - Gnd for ON)	22	Gnd	Battery Shunt shield
11	0 / 12V	Low Battery light (EMS to IP - High for ON)	23	0 - 75 mV	Battery Shunt Hi (input to EMS)
12	0 / 12V	Charge Indicator light (EMS to IP-High for ON)	24		Battery Shunt Low (input to EMS)

5.9 SUMMARY DATA TERMS EXPLAINED:

(See summary data and Error data)

TYPE

- eod – end of discharge
- eoc – end of charge
- 1 cycle = (eoc + eod)

CYCLE

One completion of charge and discharge is called cycle. One cycle means the time when connected for charging to the time disconnected and key switch is put on to drive. Discharge cycle would be from switch on for drive to drive and put on again for charge.

TIME

It is the time taken to charge /discharge in one cycle during charging / discharging cycle.

(T Batt- Avg) Average Temperature

It defines the average temperature of the battery at the end of charge (eoc) and discharge eod, 27º = 3V or 1ºC = 0.01V. While charging if the temperature of the battery exceeds 45ºC, then temperature light blinking will be turned on by the EMS on the IP cluster.

(T Batt - Max) Maximum Temperature

It defines the maximum temperature of the battery has reached during charging or driving.

(Amp_Hr) Ampere per Hour

It is the amount of current the battery has taken while under charge. This is measured in AH. If the battery has taken a current of 40A for duration of 2 hours then, it amounts to 80AH (40 amperes * 2 hours).

(AH_Dr) Ampere Hour Drive

It is the ampere discharge from battery per hour during the drive. It would be shown as zero during the charging cycle (refer to summary data).

(AH _ Reg) Ampere Hour Regeneration

It is the ampere hour regenerated back to the battery during drive on braking. Current is zero during the charge cycle.

(Kwhr) Kilowatt per hour

It is the product of current and voltage. It defines the kilowatt hour given to the battery at the end of charge, eoc and taken from the battery at the end of discharge eod. AMP HR x V-pack ÷ 1000; should be < 8Kw.

(SOC) State of Charge

It gives the percentage amount of charge in the battery in the end of charge (eoc) and discharge ie eod. t should be 100% at eoc. C1 = 76% C2 = 90% C3 = 99 % and Cf = 100%.

(Avg DV) Average Differential Voltage

It is the average voltage differences between the individual battery voltages should be less than 15% deviation in drive (dv value) and 20% in charge.

(@V_ Batt) Battery Voltage

This defines the battery voltage at the end of charge or discharge at run time when Dv_max occurred > 59.8.

(@I_Batt) Battery Current

This defines the battery current at the end of charge or discharge, at run time when Dv_max occurred.

(@SOC) State of Charge

This defines the state of charge when the dv_max occurs in the power pack. Full charge 100% at 16v and at 8v, 0% charge is indicated on the gauge.

(Tchg/Tmot) Charger Temperature & Motor Temperature

This defines the charger temperature at the end of charge and defines the motor temperature at the end of discharge. < 75 (Tchg) and < 150 (Tmot). However motor temperature is considered only while driving.

(T_Cont) Controller Temperature

It defines the controller temperature at the end of discharge (only in drive) < 82. It is zero during charge cycle.

% Over Charge – Indicates the over charging that has been done. For 145 Ahr (drive), 10-12% over charge ie in charge cycle it can go up to 160AH. Beyond this value will be overcharge when 160 Ahr is pumped in, we should be able to get at least 145 Ahr ie 10% overcharge. (160-145) ÷ 145 x 100 = 10.3% overcharge.

DV Fault – Is the fault due to difference between DV-Avg (average voltage difference) and DV-max (max voltage difference).

% Fault – Compared with % overcharge and % regen. And then % fault is calculated. Compare % overcharge and % regen and calculate % fault.

Whr / Km - (Ahr * Av Vpack) ÷ Km recorded; should be < 100.

Iprog, Vprog – programming current and programming voltage by the EMS. These two are the analog signals and vary from 0 to 5V

TTL - Counts by the fan – indicating that the fan is working.

Negative / Positive Values – In charging, negative value is shown since current is being pumped in. During discharge – positive value is shown for drive. Some values would be negative in drive cycle. This is due to “regen”.

Idle Mode (Im) – During this period, there is neither charging or discharging. Critical parameters are voltage, temp and current.

Co – over voltage shut down when V-pack > 66.5v for 3 consecutive cycles.
Ce - indicates equalization charge.
Ct - time out or over time shut down when charging continues for > 43,200sec.
Cq - end of equalization.
Cp - over temp shut down when T-batt > 50ºC.
Ci - end of charge after the idle mode, after dv / dv shut down.

Step voltage is shown due to special algorithm, a continuous plot is seen.

Points to Ponder

1. The service person should ensure for the harness connections with the EMS. And he should make sure that all the lights on the IP cluster should glow when the key is ON (Except High Beam indicator).
2. Sequence should be followed to connect and remove the harnesses from EMS.
3. Data should be checked with the PALM computer. If there is a problem with the EMS and can not be solved at that instant of time EMS has to be replaced.
4. Before removing the EMS connections, SOC has to be noted down.
5. Once we remove EMS supply and put back, the state of charge will get set to 28% (default value) and bw battery light comes on. So the engineer has to set to the previous value and the error code 513 has to be erased. (If there is).
6. All the EMS connections and removal has to be done in idle mode (neither charging nor discharging) only after taking eoc and eod of 2 AH.
7. When communication error occurs in Palm, check for the wire disconnection or reset EMS once or the car has to be put for charge if it is in drive and vice–versa.
8. Never put the Multimeter probes to harnesses connectors as it may damage wire crimping. Use always the bypass connectors to measure voltages.
9. The summary and error data should be recorded whenever there is a problem.

5.10 Check sheet for EMS Failure

Customer Name:		Location:				
Dealers Name:		Location:				
VIN No. / Cycle No.	EMS No.		Date of EMS installation (If Replaced earlier)		Failure Date	
Total Kms covered by car		Kms covered by failed EMS				
Symptoms						

Checks by Customer

Check points	**Standard**	**Observed**	**Remarks**
Key switch on	All the IP lights should flash for 2 Sec's.	Yes/ No	
Charge LED blinking during charging	Green Led should blink during charging	Yes/ No	
Checks by Service Personnel			
Check for Head lights, horn etc	All 12V in the Car should work	Yes/ No	If No, check 12 V o/p from charger
If 12V is not working then check for 40 Amps fuse F1 in the rear tub.	40 A fuse Blown	Yes/ No	If yes, refer motor failure checklist
Check for service light ON.	Record the error code	Yes/ No	If yes, refer service manual for appropriate action.

Check for fuel gauge when key ON.	Fuel gauge should show SOC	Yes/ No	If No, refer service manual for SOC Gauge.
Check for Chime	Chime should work as per owners manual	Yes /No	If No, refer service manual for Chime not working
Not Communicating to the Palm. Solid green light ON during idle & drive mode.	Should communicate to palm	Yes/ No	If No, put the car for charge once. If again found not communicating, change the EMS.
Fan not working during charging	Fan should work during charging	Yes/ No	If No, refer service manual for battery fan not working
Car not charging with EMS connections/No Charge LED (Green) blinking and charging in internal profile.	Car should charge with EMS connection	Yes / No	If No, change the EMS
Battery current in idle mode	Should show zero	Yes/ No	If No, Change the EMS

Check Battery voltages in Idle mode		Calibration param eters	
Palm	Multimeter at CN64		
Battery voltage 1		C_fact BV1	
Battery voltage 2 Battery voltage 3		C_fact BV2 C_fact BV3	
Battery voltage 4		C_fact BV4	
Battery voltage 5		C_fact BV5	
Battery voltage 6		C_fact BV6	
Battery voltage 7		C_fa ct BV7	
Battery voltage 8		C_fact BV8	
Battery Pack Voltage		Cs_factor	
REMARKS:		Csos_factor	
		Bs_factor	
		Bsos_factor	
		Chg_factor I_prog factor	
		V_prog factor	
		Soc_factor	
		Speed factor	
Checked By		**Dealer Stamp & Signature**	

5.11 Analysis of most likely EMS problems

1. Improper charging.
2. Less range.
3. Over temperature.
4. When to equalize.
5. Fuel gauge going to zero.
6. Gauge dropping fast.
7. Charging not ending even after nine hours.
8. Fuel gauge always struck at 100% SOC.
9. Erasing of calibration parameters.

Additional (In general)

1. Problems with respect to battery voltages.
2. Problems with respect to battery current.
3. Problems with respect to state of charge.
4. Problems with respect to charging.

Causes for Improper Charging

1. High Battery Temperature

It occurs during Charge, when the temperature of the Battery is more than 50 °C.

SL No.	Causes	Action to be taken
1. 2.	Due to erratic readings of the Sensor. After Drive, if the car is put for Charge immediately.	Check for Battery temperature sensor with Multimeter. The voltage equivalent of temperature will be 3V @ 27 °C and increases by 0.01V for every 1 °C rise thereafter. For e.g., at 40°C the voltage is equal to 3.13V. Allow the battery to be cooled and then put for charge.
3.	If actual temperature of the Battery is more than 50 °C.	Allow Battery for Cooling.

2. If there is a fan failure

During Charge, Fan is not working (0 Counts) and v_prog reading is 54.50V.

SL No.	Causes	Action to be taken
1. 2.	If 12Volts to the Fan is disconnected. If EMS is not giving Ground to the Fan.	Check for Fan connections and check for 12V supply for the fan If the EMS is not giving the ground, the EMS has to be replaced.
3.	If no TTL is coming from Fan.	Check the voltage between Pin 16 & 18 of CN66 & Ground and it should read between 2 to 2.5V. If the required voltage is not coming, fan has to be replaced.

3. High Charger Temperature

During Charge, the temperature of the Charger is more than 78 °C

SL No.	Causes	Action to be taken
1.	If cooling Fans are not working.	Check for the fan failures.
2.	If the actual temperature of charger is more than 78°C.	Allow charger for Cooling.

4. If the CUV signal is not coming from the charger

SL No.	Causes	Action to be taken
1.	If the charger is failed in sending the CUV (Charger under voltage) signal, then the charging won't take place.	The CUV signal should be checked. When the car is put on charge it should read 0V. Other wise it is 5V .If the CUV reads 5V even when the AC is on, the charger has to be replaced.

5. If there is a MOSFET Failure in the Charger

SL No.	Causes	Action to be taken
1.	When the harness connections to the EMS is not given in the correct order, the spike on the Iprog line will kill the MOSFET in the charger causing no control of the EMS on charging and allowing the charging control to charger to go on it's internal profile. That's why we don't get the required range, as the EMS doesn't have the control of charging and charger won't charge the batteries fully.	Connect the I_PROG and V_PROG test jig to check the charging. If the current is not matching with the I_PROG replace the charger. The jig test should be carried out only for a pack voltage greater than 58V. The detailed procedure to check the charger with the Iprog and Vprog test jig is given in Additional. (The charging related things)

6. If I_PROG crimp has been damaged in the Charger to EMS harness connector

SL No.	Causes	Action to be taken
1.	If the crimp has come out in the charger to EMS harness connector.	Re crimping has to be done for the I_PROG line in the charger to EMS connector.

Equalisation

When the car is put on charge automatically equalization will happen (after full charge). Equalization is an automatic process, once in 1500 AH, EMS will flag equalization command and it will last for 10 hours. The total process will last for about 18 hours (8-9 hrs normal charging and 10 hrs equalization). Equalization should be completed in 5 cycles. If not an error will be recorded in error data. Then equalization has to be done manually.

Manual equalization command can be given using palm computer (refer service manual) or by **turning ON and OFF the key switch three times** till all the lights appear on the IP cluster, and putting car on charge.

SL No.	Causes	Action to be taken
1.	Stopping of charging, when it is equalizing. (Indication of equalizing, with charge light & low battery light blinking)	Checking for the alternate blinking of charge light & low battery light whenever the charging cable is removed from the charge port. Leaving for equalization charge in installments for 10 hours in 5 consecutive cycles.
2.	No clear instructions about the start of equalization to customers.	The customer should be clearly instructed about the next start of equalization charge.
3.	If the average deviation between battery voltages is more than 15%	Equalize for the remaining period till we get 'cq' on the terminal and solid green light.

Fuel Gauge going to Zero

SOC coming down to zero when the KEY is TURNED ON, low battery light start flashing.

What Customer should do!

If the fault occurred when the customer is away from his house (Charging point) and if customer is sure that SOC was > 35% at the time of fault, then the car can be driven in E mode for about 15 kms. Obs erve that SOC needle showing increase in charge. Call the service person to clear the service light.

What Service Person should do!

1. Put for Charging.
2. Down load the summery data -using palm.
3. Check for previous drive AH.
4. If previous drive Ahr. Is less than 100 and previous charge SOC is > 92% then it confirms that this is a false alarm from EMS.
5. Set the SOC and reset the service light.

SOC Gauge Dropping Fast

If the SOC gauge is dropping fast, check the voltage between pin 17 and 18 of CN 64 on EMS, It should be 8 to 16V, if it is fluctuating, replace the EMS. If batteries are dipping then also SOC gauge fluctuates, engineer has to check the battery health.

Charging not ending for even Nine Hours

While charging, if Charge Time is more than 43200 sec, then there will be Time Out Shutdown.

SL No.	Causes	Action to be taken
1.	If Battery Current is not read by EMS correctly.	Check Battery Shunt Readings & check EMS for Calibration of battery current.
2.	If there is a Fan Failure	Check Fan for its working. The 12V supply for the FAN ,GND from EMS to run the fan and fan TTL output (2 .5 to 3V)
3.	If Temperature sensor is reading erratically more than 50 °C .	Check for Sensor with Multimeter.
5	Car put on charge immediately after the drive	Allow the batteries to cool and then put for charge
6	High ambient temperature, hot summers	Prefer evening charging or charge the car during nights

Fuel gauge always struck at 100% SOC

While charging, if Charge Time is more than 43200 sec, then there will be Time Out Shutdown.

SL No.	Causes	Action to be taken
1.	If Battery Current is not read by EMS correctly. i.e. when the crimping of battery shunt wires Pin No.23 and Pin No.24 of the Main harness connector (CN 64) is damaged. When the current reading in drive will always be negative leading the SOC gauge not to go down.	Check for the crimping of battery shunt wires Pin No.23 and Pin No.24 of the Main harness connector (CN 64) for any damage. And also the shunt wires at the shunt end to be checked.

Erasing of Calibration Parameters

SL No.	Causes	Action to be taken
1.	Removal and connecting of battery negative with all EMS connections intact. I,e without removing the EMS connection when the battery negative is removed and put back there are chances of disturbing the calibration parameters	The connection and removal of battery negative should be done only after the EMS connections are removed.
2.	Not following the order of connections of harnesses to EMS may disturb the calibration parameters.	The connection to be made as per recommended sequence (refer service manual)

Additional Problems

Battery Voltage not being read by EMS

1. Use bypass connectors to see the voltage readings.
2. Check for the calibration parameters.
3. See the crimping and any loose connection in the battery pack harness.

Battery Current

1. Check for the shunt wires both at the shunt end and the EMS end.
2. Crimping and loose connection in the main harness of pin no.23 and pin no.24.

Charging Related

Check for fan functioning properly and fan T TL output.

1. Check for the CUV signal from charger when the mains put on and it should be 0V. When there no power it should be 5V with respect to ground.
2. Check Iprog and Vprog from EMS going to charger.

CHAPTER 06

AC Motor Controller

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6.1 INTRODUCTION:

These are used to control the speed of 3 Phase Induction motors and used in light electric vehicles. These are programmable controllers to control the speed and torque of motor. These controllers do not require additional relays and contacts as they have solid state electronic devices like MOSFETS, diodes etc. With the help of the solid state circuitry. They provide reversing and regenerative braking power for the motor. The controller (1236) is programmable by a hand held programmer (Curtis – 1311). This programmer also provides diagnostics and test capability.

FEATURES:

- Regenerative braking to near zero speeds– adjustable.
- Compression (regenerative) braking upon throttle release.
- Brake pedal variable regenerative braking utilizing the same input type as throttle.
- Standard throttle, 3-wire (0 – 5 K ohms or 0-5V) potentiometer. Throttle fault detects (open pot, signals out of range).
- Responsive acceleration - adjustable
- Programmable parameters like acceleration, deceleration, battery current limit, motor current, regenerating current (compression and braking) and maximum speed / Torque.
- Vehicle speed limiting (closed loop limiting with speed sensor).
- Programming diagnostic and test interface capability with the handheld programmer.
- Faults detect output LED (on controller) flashes error code information.
- High Pedal Disable (HPD) feature prevents vehicle run-away on startup.
- Fault detection such as Contactor weld check and Motor fault check.
- Brake / Drive interlock.
- Low EMI emission design.
- Low side, voltage independent, fault driver with inductive spike protection.
- Low side, voltage independent, main contactor driver with inductive spike protection.
- Low side, multifunctional auxiliary driver with inductive spike protection, which may be configured for several functions such as brake light driver or battery current limit indicator.
- Battery current limit to enforce economical vehicle operation.
- Multi mode operation allows the independent selection of several operating parameters in four modes of operation. Vehicles feel and performance can be tailored in each mode of operation.
- Rugged environmentally protected housing to IP64/IP67 standard.
- Over-voltage causes smooth reduction of regenerative braking if battery charge is excessive. Controller will allow as much regenerative braking as possible without exceeding over voltage level.
- Linear over-temperature fold-back. Power is reduced gradually, without sudden loss, to allow as much drive current as possible under these conditions.

- KSI off action initiates compression braking.
- Resistant to on-road vehicle shock and vibration.
- Active Power on Self Test (POST).
- Hardware and Software watchdogs to ensure proper operation.
- Ambient operating temperature range: -25ºC to 50ºC.
- Controller temperature cutback points: -25ºC to 85ºC.
- Programmable to match individual motor characteristics.

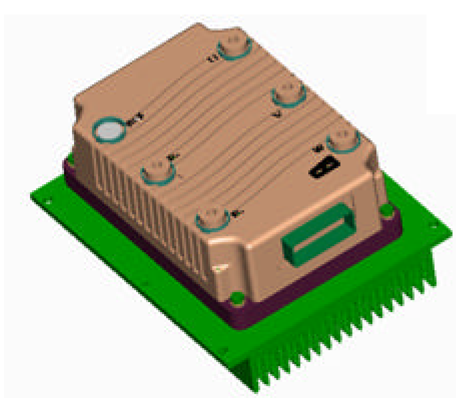
CONNECTIONS:

LOW CURRENT:

Only one low current connection is available. This is 35 Pin, which is located in rear side of the controller.

A 4-pin low power Molex connector is provided for connecting to EMS, 2-pin to temperature sensor and 4-pin to Encoder bearing (speed sensor).

4-Pin low power connector is used for hand held programmer (1311)

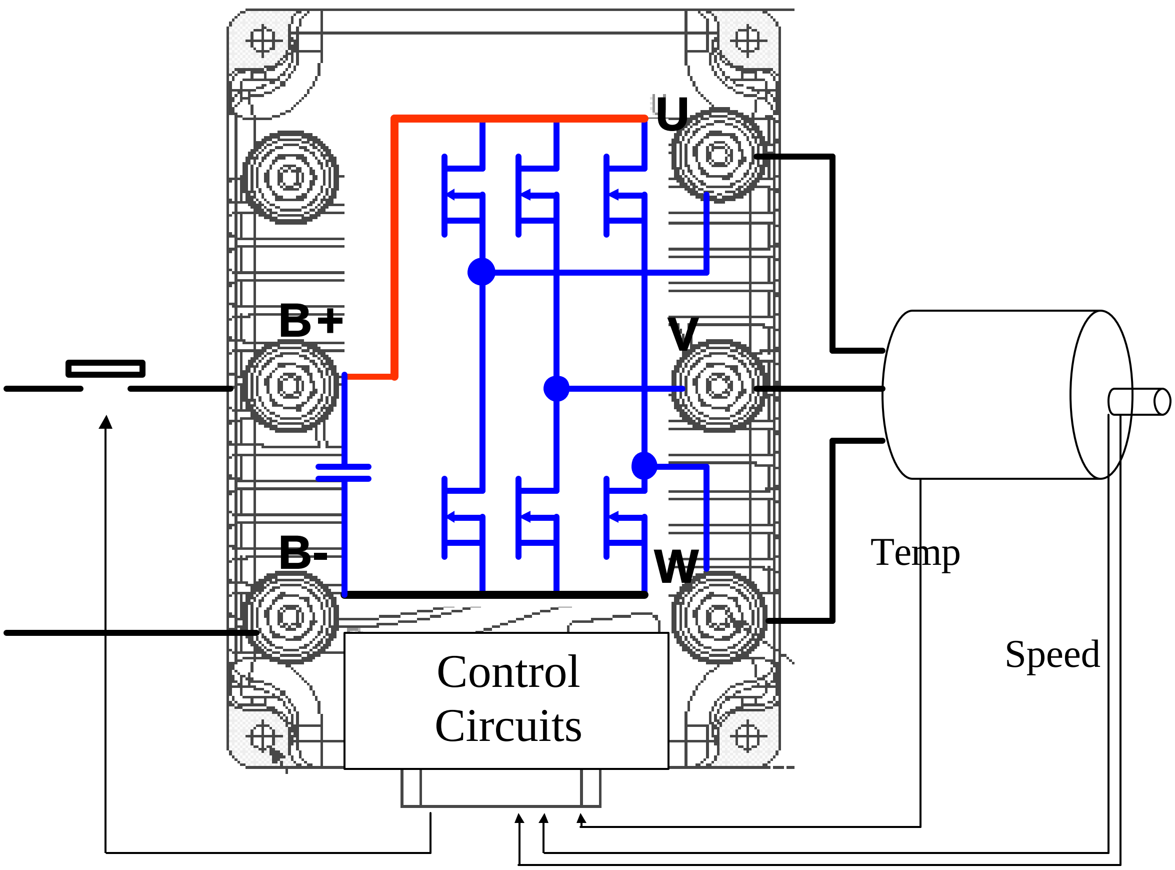


HIGH CURRENT:

The terminals on Controller are (B+ and B-) for battery, Motor U, V and W cables.
The M8 bolts (5/8”, 19mm) are used for mounting the cables. Torque value should not exceed 20NM for M8 bolts.

6. 2. WIRING:

The Control switch inputs are connected to 12V control wire through DC-DC converter. The controller can be programmed to check for welded or missing main contactor fault. It uses the main contactor coil driver to remove power from the controller and motor in the event of various faults.



Pin No	Designation	Connected to
J1-24	Switch 1/ Analog input 1	Charger Temperature
J1-8	Switch 2/ Analog input 2	Motor temperature
J-9	Switch 3 (Dig input)	Interlock
J1-10	Switch 4 (Dig input)	
J1-11	Switch 5 (Dig input)	
J1-12	Switch 6 (Dig input)	Economy
J1-22	Switch 7 (Dig input)	Forward
J1-33	Switch 8 (Dig input)	Reverse
J1-14	Program	Program
J1-30	Analog output (0-10V)	Fuel gauge
J1-25	+12V (100 mA)	
J1-26	+5V (100 mA)	
J1-19	Digital output 1	
J1-20	Digital output 2	
J1-15	Throttle pot high	
J1-16	Throttle pot wiper	
J1-27	Brake pot high	
J1-17	Brake pot wiper	
J1-18	Pot low	Throttle/Brake pot
J1-1	Key switch input (KSI)	Power on 1236
J1-13	KSI coil return	
J1-6	Driver 1 (output)	
J1-5	Driver 2 (output)	
J1-4	Driver 3 (input)	
J1-3	Driver 4 (output)	cooling fan for controller
J1-2	Prop. Driver (output)	
J1-26	+5V	
J1-31	Phase A	
J1-32	Phase B	
J1-7	I/O GND	Encoder
J1-21	Can term H	
J1-34	Can term L	
J1-23	Can H	
J1-35	Can L	CAN Communication
J1-25	+12V	
J1-28	TX	
J1-29	RX	
J1-7	I/O Ground	Serial Communication

The Pin Details of the Controller is as shown above.

6.3 BRAKE / THROTTLE Potentiometers.

Brake and throttle potentiometer share a common pot low (Pin 18), Where as brake has pot wiper on (Pin 17) and pot high on (pin 27) and Throttle has pot hi (pin 15) and pot wiper (pin 16) conditions.
Total travel of potentiometer is 270 degrees (mechanical) or 45° (135 to 180, electrical) for the range of 0-5K, 3 wire design.

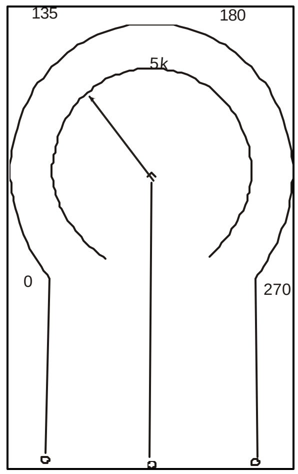


Fig 5

Features:

- Both low and high dead bands are adjustable over the full range.
- Open connections are sensed as faults.
- Adjustable mapping is available for both – throttle and brake.
- Additional set points are available to over come backlash.

FAULT OUTPUT :

The 1236 displays the faults by the status LED or by hooking the Hand held and Palm.
WIRING: MAIN CONTACTOR DRIVER
Pin 1 is for the main contactor driver. The driver is rated for 2A max to avoid damage to the controller. The coil return is connected to the driver return (pin 13) through a coil for controller protection.

6.4 CONTACTOR, KEY SWITCH AND FNRE SWITCH

Main Contactor:
Main contactor allows the controller and motor to be connected and disconnected from the battery. This provides significant safety to disconnect battery power to motor in case of wiring faults .It has a single pole, single throw (SPST), and continuously rated contactor with silver alloy contact. The coil voltage is rated to 48V.
Key Switch:

The vehicle has a master switch (key switch) to turn off when the vehicle is not in use. The key switch input provides logic power to the controller.

FORWARD, REVERSE, ECONOMY AND AUXILIARY MODE SWITCH (RNFB SW.):

This is a SPST (single pole, single throw) switch.

Mode	B	R	F	Aux.
Neutral	Off	Off	Off	Off
Neutral	On	On	Ignore	Ignore
Forward	On	Off	Off	Off
Reverse	Off	On	Ignore	Ignore
Economy	On	Off	On	Off
Auxiliary	On	Ignore	Ignore	On

6.5 PROGRAMMABLE PARAMETER:

1236 controller has a number of parameters that can be programmed by means of a hand held programmer (Curtis 1311). The multimode feature of the controller allows operation in four distinct modes. These modes can be programmed to provide four different sets of operating conditions. Such as:

Open and high way cruising (forward).

Stop start city traffic and uphill, (Boost).

Low battery reserve (Limp home).

Reversing (Reverse)

Parameters can be configured independently for the four modes. There are

Drive Current Limit

Regen Current Limit

Battery Current Limit

Acceleration Rate

De-acceleration Rate

DRIVE CURRENT LIMIT :

Defines the max current the controller can supply to the motor during drive operation. This parameter can be used to reduce the max torque applied to the motor

REGEN BRAKE CURRENT LIMIT:

Brake current limit defines the max current the controller can supply to the motor during regenerative braking operation. During regenerative braking, this controls the armature regenerative current back to battery. (Drive Current limit can be varied from 0A to full rated current – incremented in steps of 10A).

BATTERY CURRENT LIMIT:

Max current the motor can supply to battery during regenerative action. This can be set to lower limit than the motor armature current. Due to AC ‘transformer effect’ of controller, high motor current will still be available at low voltage levels (eg. at start up). As the motor voltage and speed increase the motor current becomes limited so that battery current is not limited. This battery current will reduce the main drive current to the motor to keep within set parameters. Battery current limit is adjustable from 25A to controller’s full rated value in steps of 10A.

ACCELERATION RATE:

Time taken by controller to increase motor current from 0% to 100% during acceleration. A larger value represents a longer deacceleration time and a gentle start. Faster starts can be achieved by reducing acceleration value time in 0 to 5 sec, with 0.2 sec increments step.

DE-ACCELERATION MODE:

Time taken by controller to decrease motor current from 100% to 0% during de-acceleration. A larger value represents a longer acceleration time and a gentle start. Faster starts can be achieved by reducing acceleration value time in 0 to 5 sec, with 0.2 sec increments step.

MAX BRAKE:

Brake parameters define a brake map (fig.7). The brake map is used to scale the brake potentiometer input to normalized brake demand. Decreasing the value of this parameter will decrease the max brake demand.

BRAKE MAP:

Brake parameters* define a brake map. The brake map is used to scale the brake pot meter input to the normalized brake demand. The normalized brake demand is scaled to the brake demand by the Maximum brake (Max brake) of the multimode.

6.5.1 Brake Parameters –

Brake Pedal Enable

Brake Type

Brake Dead Band

Brake Map

Brake Max

Brake Offset

BRAKE PEDAL ENABLE:

Defines the brake pedal enable, which is off and minimum value is Zero and maximum value is 1.

BRAKE TYPE:

In the controller brake type value is kept 2 and its minimum is 1 and maximum is 5 Volts.

BRAKE DEAD BAND:

Brake to dead band defines the brake pot wiper voltage that controller interprets as min. Due to mechanical arrangements within the brake and pot linkage, the pot may not actually return to zero. The controller through the use of brake dead band function can automatically compensate for this deficiency. With brake pedal set to zero and pot meter reading 7% on hand held programmer the brake low dead band parameter can be set to read 10% to compensate for the 7% pot output. This also gives 3% of extra dead band to allow for wear. The value is 0.3 Volts and its minimum is zero and maximum is 5 volts.

BRAKE MAP:

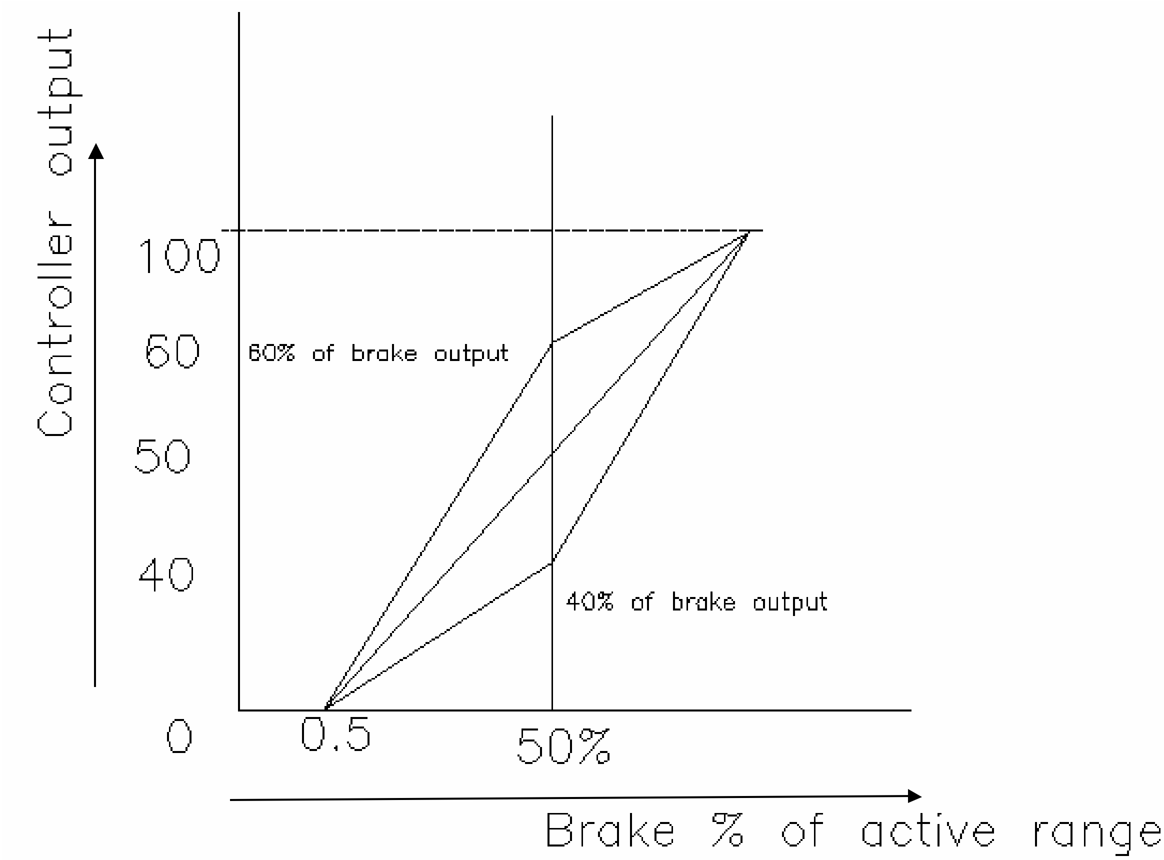
This defines the profile of Brake applied which can be set based on the requirement. Normally this is set with linearity. The value is 50% and its minimum and maximum are zero & 100%.

BRAKE MAX:

Defines the maximum brake pot wiper voltage that controller interprets as max. Due to mechanical arrangements within the brake and pot linkage, the pot may not actually read 100%. The controller through the use of brake max can automatically compensate for this deficiency. Usually the value is 1.2 Volts and its minimum and maximum values are zero and 5 volts.

BRAKE OFFSET:

This Parameter defines the % of offset of the brakes due to mechanical arrangements. This should always be read zero. As the % of brake is read, the speed of the car decreases in the reverse profile. This can be adjusted by adjusting the brake dead band.



6.5.2 ACCELERATION PARAMETERS:

There are mainly three parameters in this group.

- Forward Dead Band
- Forward Map
- Forward Max

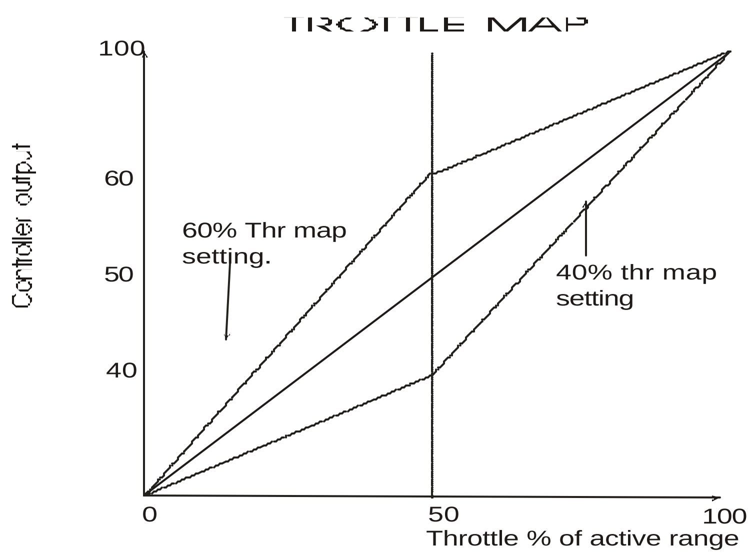
FORWARD DEAD BAND:

Parameter defines the % of throttle pot meter input where throttle demand is 0%. Due to mechanical linkages, the pot meter may not return to zero. The controller, through the use of this parameter can automatically compensate for this deficiency. If, with throttle pedal set to zero, the actual pot meter reads 7% on the hand held programmer, the throttle min parameter can be set to read 10%. This will allow compensation of 3% to allow for wear.

Any throttle input below this % will produce a throttle demand of 9%.

THROTTLE MAP:

The throttle map parameters define the throttle ramp profile. The throttle ramp profile consists of two slopes. The two slopes meet where the throttle input is at the mid point between the throttle high dead band and the throttle low dead band. The value of this parameter can be set with hand held programmer (Curtis 1307) between 20-80% adjustable in steps of 5% increment. 50% is the default setting. The throttle ramp has the characteristic of a straight line when this parameter is set to 50%. As the throttle map parameter value is increased, the throttle demand



is increased at the mid points and if the Value is decreased; the throttle demand is also decreased at the mid point. The other two throttle parameters are Throttle High Dead Band and Throttle Low Dead Band.

THROTTLE MAX :

Parameter defines the percentage of throttle pot input where throttle demand is 100%. Any throttle input above this % will produce a throttle demand of 100%. Due to mechanical linkages, the pot may not reach full travel. The controller, by use of throttle dead band can automatically compensate for this deficiency. e.g. Throttle pedal reaches end of its travel with throttle pot reading 87%. The controller throttle high dead band parameter can then be set to 85% which will allow the controller to give full output once 85% travel is attained.

Same values should be put for Reverse Dead Band, Reverse Map and Reverse Max as in Forward parameters.

MOTOR Parameters:

Motor Temperature Hot Cutback

Motor Temperature Sensor Fault

Over Voltage Cutback

Under Voltage Cutback

Motor Temperature Hot Cutback:

This parameter defines the field temperature at which the controller will stop driving the motor. This parameter protects the motor when over heated. Temperature is in degrees (°C). Set at 150°C.

Motor Temperature Sensor Fault:

This parameter defines the temperature at which the controller will reduce the current to the motor. As the temperature of motor is at or above the Max setting or the sensor bearing failure reads the temperature of motor as max.

Over Voltage Cutback:

This parameter defines the regen brake current limit. It indicates the elevation of battery voltages more than the setting in controller (115% of nominal voltage ie, 48V) =55.2 Volts.

Under Voltage Cutback:

This parameter defines the allowable minimum voltage of batteries while driving. It indicates drop in battery voltages during drive (80% of nominal voltage ie, 48V) = 38.4 Volts.

FAULT PARAMETERS:

HPD (High pedal disable) – Prevents the motor to drive if throttle demand is greater than 25% when the controller is on.

Fault Output Parameter - This parameter allows the LED fault driver to provide a flashing error code when turned on.

SPEED:

The speed is sensed by an encoder mounted in the motor. The controller Accepts 32/64 pulses per rotation (selected by program).

6.6. VEHICLE PERFORMANCE ADJUSTMENTS:

The controller has the following characteristics, which is adjusted in the factory:

- Tuning the active throttle and brake parameters.

MAINTENANCE:

- Remove power by disconnecting battery.
- Clean the controller carefully when removed for servicing. Do not use water to clean controller, wipe it gently with a moist clean cloth
- Ensure rigid connections and tighten the bolts as per the torque settings prescribed for motor and controller.
- Ensure that controller-mounting bolts are tight and heat sink compound is applied properly to controller.

Controller Checklist is as below

Customer Name:		Location:			
Dealers Name :		Location:			
VIN No :		Date of Controller installation (If Replaced earlier)		Failure Date:	
Controller No :					
Total Kms covered by car		Kms covered by failed Controller			

Symptoms			
Checks by Customer			
Check points	**Standard**	**Observed**	**Remarks**
1. Is Car moving when accelerator is pressed?	Car should move.	**Yes / No**	
Checks by Service Personnel			
2. Is Contactor is coming ON when Key switch ON.	Contactor should come ON	**Yes / No**	If yes check point No. 3. If No check point No 4 & 5.
3. Is car moving when accelerator is pressed in forward, Boost & reverse mode.	Car should move.	**Yes / No**	If yes there is no problem with car, check for sequence fault and HPD Fault. If No check bad crimps, dirty connector pins, faulty wiring and check point No 4, 5 & 6
4. Connect Palm to the EMS and check for error.	Read the error code and fault in the service manual	**Yes / No**	Refer the service manual for appropriate code and take action accordingly
5. Connect the Curtis Hand Held Programmer & Check the diagnostic fault	Should show error	**Yes / No**	If yes refer service manual for further action
6. Go to Test Menu in the Hand held and check for Forward, Boost& Reverse input when FBNR knob is selected.	Should show ON (Test Menu) in the Hand held when selected the appropriate mode	**Yes / No**	If yes there is No problem with FBNR switch. If No check for FBNR switch
7. If NO Error in the Palm & Diagnostic mode, check for any % Acc in the test mode of Hand held	Should not show any accelerator % when Acc pedal in normal position (un- pressed condition)	**Yes / No**	If Accelerator % is shown in the hand held then follow the Acc adjustment checks. If No follow the flow chart for car not moving
Attach Summary and Error Data			
Additional Remarks			
Previous History of Controller			
Checked By	**Dealers Stamp & Signature.**		

6.8 CONTROLLER TROUBLE SHOOTING CHART: (Table 1.)

TYPE OF LED DISPLAY	
DISPLAY	STATUS
Neither LED illuminated	Controller is not powered on, has a dead battery, or is severely damaged.
Yellow LED flashing	Controller is operating normally.
Yellow and red LED's both on solid	Controller is in flash programming mode.
Red LED on solid	Watchdog failure. Cycle KSI to restart.
Red LED and yellow LED flashing Alternately.	Controller has detected a fault. 2-digit code Flashed by yellow LED identifies the specific fault. One or two flashes by red LED indicate whether first or second code digit will follow.

Fault Codes and Causes

CODE	EXPLANATION	POSSIBLE CAUSES
1,2	Controller Over Current	1. External short of phase U, V and W motor connections. 2. Motor parameters mistuned. 3. Controller defective.
1,3	Current Sensor Fault	1. Leakage to vehicle frame from phase U, V and W. 2. Controller defective.
1,4	Precharge Failed	1. External load on capacitor bank that prevents capacitor bank from charging.
1,5	Controller Severe Under Temperature	1. Controller operating in extreme environment.
1,6	Controller Severe Over Temperature	1. Controller operating in extreme environment. 2. Excess load on vehicle. 3. Improper mounting of controller.
1,7	Severe Under Voltage	1. Battery menu parameters are misadjusted. 2. Non-controller system drain on battery. 3. Battery resistance too high. 4. Battery disconnected while driving.

CODE	EXPLANATION	POSSIBLE CAUSES
1,8	Severe Over Voltage	1. Battery menu parameters are misadjusted. 2. Battery resistance too high for given regen current. 3. Battery disconnected while regen braking.
2,1	Controller Under Temperature Cutback	1. Controller performance –limited at this temperature. 2. Controller is operating in extreme environment.
2,2	Controller Over Temperature Cutback	1. Controller performance – limited at this temperature. 2. Controller is operating in extreme environment. 3. Excessive load on vehicle. 4. Improper mounting of controller.
2,3	Under Voltage Cutback	1. Normal operation. Batteries need recharging. 2. Battery parameters are misadjusted.

		3. Non- controller system drain on battery. 4. Battery resistance too high. 5. Battery disconnected while driving.
2,4	Over Voltage Cutback	1. Normal operation. Shows regen braking currents elevated the battery voltage during regen. 2. Battery parameters are misadjusted. 3. Battery resistance too high for given regen current. 4. Battery disconnected while regen braking.
2,5	+5V Supply Failure	1. External load impedance on the +5 V supply is too low.
2,6	Digital Out 1 Over Current	1. Nominal voltage parameter needs to be adjusted.
2,8	Motor Temperature Hot Cutback	1. Motor temperature is at or above programmed temperature. 2. Motor temperature control menu parameters are mistuned.
2,9	Motor Temperature Sensor Fault	1. Motor thermistor not connected properly. 2. Motor temperature control menu parameters mistuned. 3. Motor temperature above the programmed setting.
3,1	Coil 1 Driver Open / Short	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.
3,1	Main Open / short	1. Open or short on driver load. 2. Dirty connector pins. 3. Bad crimps or faulty wiring.
3,8	Main Contactor Welded	1. Main contactor tips are welded. 2. Motor phase U is disconnected or open. 3. An alternating voltage path is providing a current to the capacitor bank (B+ stud).

CODE	EXPLANATION	POSSIBLE CAUSE
3,9	Main Contactor did not close	1. Main contactor did not close. 2. Main contactor tips are oxidized, burned or not making good contact. 3. External load on capacitor bank that prevents it from charging.
4,1	Throttle wiper high	1. Throttle pot wiper voltage too high.
4,2	Throttle wiper low	1. Throttle pot wiper voltage too low.
4,3	Brake wiper high	1. Brake pot wiper voltage too high.
4,4	Brake wiper low	1. Brake pot wiper voltage too low.
4,7	HPD / Sequence fault	1. KSI, interlock, direction and throttle inputs applied in incorrect sequence. 2. Faulty wiring, crimps or switches at KSI, interlock, direction or throttle inputs.
4,9	Parameter change fault	1. This is a safety fault caused by a change in certain 1311 parameters settings so that vehicle will not operate until KSI is cycled.

CHAPTER 07

CHARGER

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CHAPTER 07

CHARGER

7.1 PURPOSE OF CHARGER :

In Reva car the source of power to drive the motor is from power pack. Power pack consists of 8 Batteries of 6 volts in series to give an out put of 48volts. When these batteries get discharged it needs to be charged to bring up the specific gravity and voltage.

Charger provides the feed back supply to charge the batteries. Other purpose of charger is to provide 12V D.C supply for the accessories of the car like head lights, combination lights, reverse lights, parking lights, cabin lights, fan, wiper, I.P cluster, horn, turn signals and radio. SPS-5326 is a 2000w, off line, 48V-battery charger and is integrated with a DC-DC converter. The specifications are given below for inputs and outputs:

7.2 Features

Charger used in Reva is unique and has many features

- Wide mains voltage range
- Input power factor correction to ensure green operation
- Input over current protection
- EMI filtering to minimize harmonics
- Built in DC - DC converter for powering accessories
- Light weight and suitable for on board application
- Output short circuit protection for DC – DC converter

7.3 Input Characteristics:

Input voltage : 160-260 volts AC, rms, 47-63HZ Single Phase
Input current : 16.4 amperes AC, rms, maximum at 160 V AC
Efficiency : 87%
Under voltage: The battery charger will not be damaged while operating at input voltages below the minimum rated input voltage, 100V AC. Charger will shut down at a voltage at least 5 volts below its start up point.

7.4 Output Characteristics:

- Output voltage: 42.0 to 64 volts
- Output current: 40 amps, maximum at an output voltage of 56.9 volts.
- Output power: 2276 watts, maximum

7.5 Protection: The charger has the following protections.

Output over voltage protection: Shutdown occurs if the output voltage exceeds 66.5 volts.

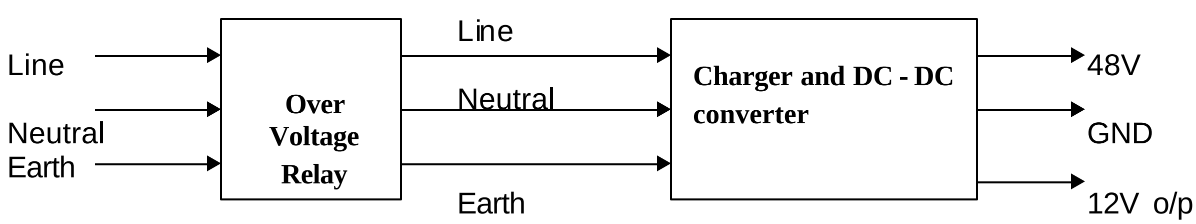
OVP is latching type and is reset by recycling the input voltage.

Output charging: Automatic, internal current limiting circuit limits over current protection: output current to 42 amperes, short circuit protected with automatic recovery at removal of short. Note externally supplied fuse is required to protect battery from fault in charger.

Over temperature protection: In the event of an over temperature condition, internal thermal protection circuitry will scale back maximum output power, thereby limiting the temperature of its semiconductor heat sink to a safe value.

Input over current: Internally supplied 20A, 250V AC fuses in each leg of the input line protect the AC line from over currents caused by internal circuit faults.

Over Voltage Relay: **Over Voltage Relay** or **OVR** is an external protection device for the charger. AC supply from mains will first pass through OVR. The OVR does not allow the voltage spikes to reach the charger internal circuitry and damage them. When the AC voltage goes above 265V, its cuts off and resets when the voltage comes back to normal level. The operating voltage range is 160V to 265V.



7.6 Charging Features:

- Charger will deliver a constant current between 39.5 and 40.5 amps, for output voltages between 42 and 58 volts.
- Temperature induced 0.012 volts / ^{o}C, relative to 25^{o}C.
- Zero to five volts on I_prog line corresponds to 0 – 40 ampere programmed output current limit. Zero to five volts on V_prog line corresponds to 40-64 volts programmed O/P voltage limit.
- Charger minimum output current is ~2 amps and charger minimum output voltage is 42 volts. Charger will not respond to programming signals below

these values. TTL low or short circuit disables internal charging profile and enables EMS charge control. TTL high or open circuit enables internal charging profile and disables EMS charge control ± 2% duration maximum.

7.7 Electrical Characteristics – DC-DC Converter:

Input characteristics:

Input voltage	35 – 65 Vdc
Efficiency	82% minimum

Output characteristics:

Output voltage	13.5 Vdc +/-2%, non adjustable.
Output ripple	150 millivolts, peak to peak, maximum at $20MH_z$
Output power	400 Watts
Current Limit	Not less than 25Amps. Output is short circuit protected with automatic recovery at removal of short.
Over temperature	internal thermal protection circuitry will scale back thereby limiting the temperature of its semiconductor heat sink to a safe value.

7.8 Environmental Specifications:

Cooling	Conduction cooling to heat sink.
Operating temperature	Zero to 50^oC.

7.9 Location Of The Charger :

Charger is fitted below the rear seat in the Tub.

7.10 How Is The Cooling Provided:

A heat sink is fitted below the charger. This Heat Sink is cooled by a stream of cold air thrown by cooling fans through a duct. Cooling is very important hence one must ensure that the ventilation fan works while battery is charging.

7.11 Specifications for Charger

1. Model	SPS 5326
2. Type	2000 W, off line, 48 V- battery chargers integrated with a DC-DC converter.

3. **<u>Input Characteristics:</u>**

Input Voltage	160 – 260 V AC, rms, 47-63 Hz, Single Phase
Input Current	16.4 Amperes AC, rms, maximum at 160 V AC
Efficiency	87%
Under Voltage	The battery charger will not be damaged while operating at input voltages below the minimum rated input voltages. Charger will shut down at voltage at least 5V below its start up point.

4. <u>Output Characteristics</u>:

Output voltage	42.0 to 64 volts
Output current	40 amps, maximum at an output voltage of 56.9 volts.
Output power	2276 watts, maximum

5. <u>Protection: The charger has the following protections.</u>

Output over voltage: Shutdown occurs if the output voltage exceeds 66.5 protection volts.

Output charging: Automatic, internal current limiting circuit limits over current protection: output current to 42 amperes, short circuit protected with automatic recovery at removal of short.

Note: Externally supplied fuse is required to protect battery from fault in charger.

Over temperature Protection: In the event of an over temperature condition, internal thermal protection circuitry will scale back maximum output power, thereby limiting the temperature of its semiconductor heat sink to a safe value.

Input over current: Internally supplied 20A, 250V AC fuses in each leg of the input line protect the AC line from over currents caused by internal circuit faults.

IMPORTANT

For charger to work the following are Important.

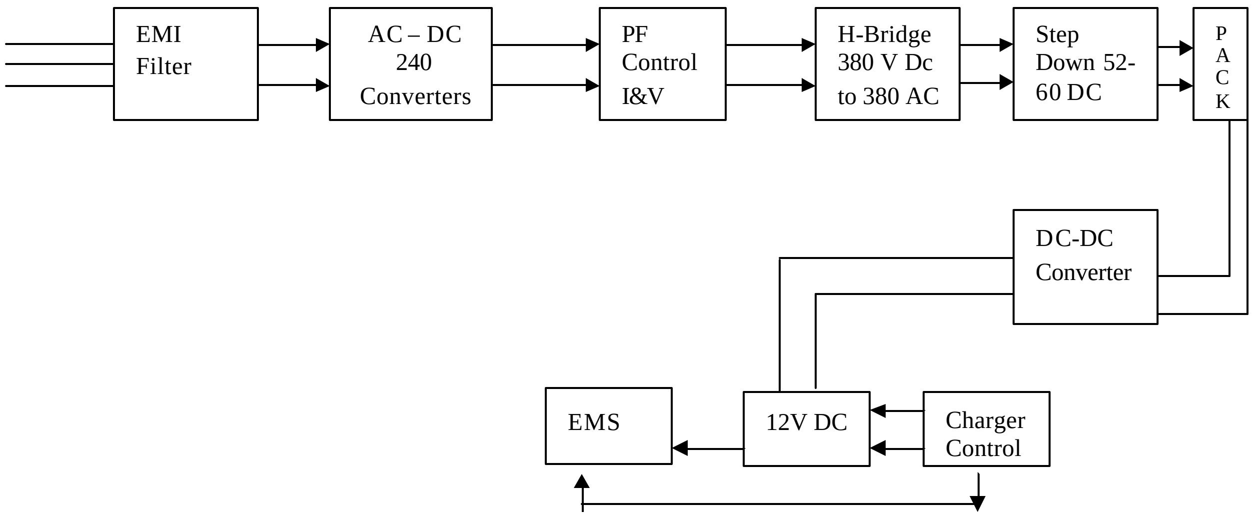
- Battery should be connected.
- Battery voltage should be min 42V (D.C).
- Input voltage should be more than 160 volt A.C
- Charger temp. Should not be more than specified 82 C.

7.12 How The Charger Functions?

The charger has an EMI (electro magnetic interference) filter to take care of the interference. An AC/DC bridge converter converts the input AC voltage to 240V DC. The pie circuit with inductance and capacitance has a p.7. (Power factor) controller. The DC is now converted to high frequency AC and fed to the step down transformer. From here the battery is fed for the charging. Battery through the DC/DC converter provides 12V to the charger controller and 15V DC to the p.f controller. From charger controller, EMS also gets 12V supply.

160-270V DC-240V

(HIGH FREQ)



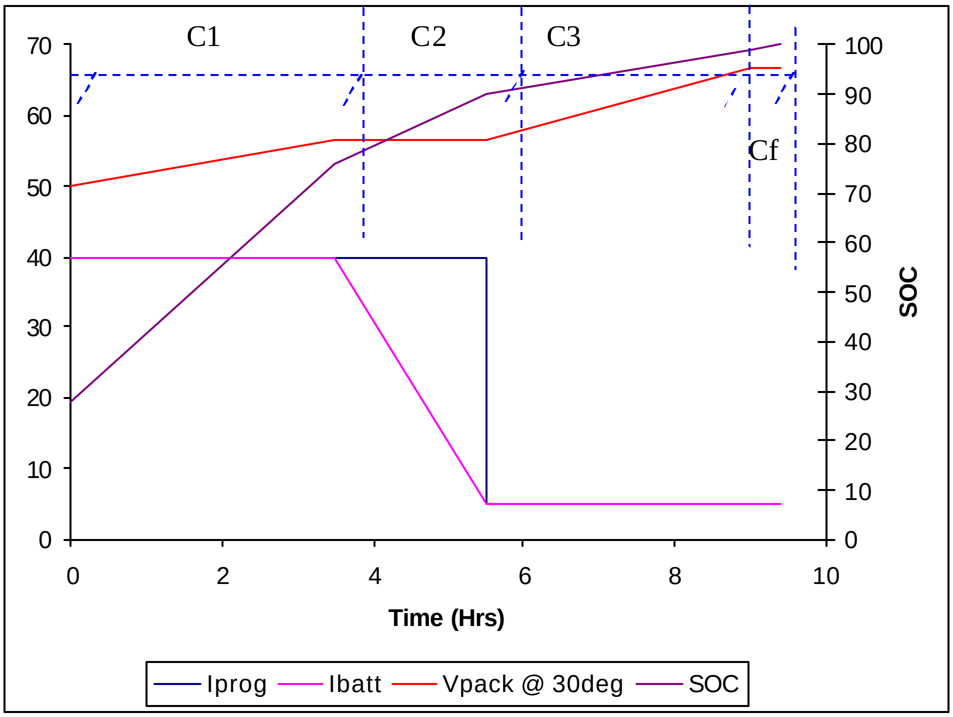
7.13 Terms Explained:

Charge Under – Input voltage should be 160V AC (min). 160V AC – charger cuts off at voltage 5V below the startup.
Iprog Vprog – Are the programmed current & the programmed voltage by the EMS. Iprog & Vprog should follow the battery charging current & the battery pack voltage in an ideal condition.

Charging Cycle - The lead acid batteries are charged according to the charging profile specified by the battery manufacturer. This is ensured by continuously controlling the current & the voltage during charging. The profile is exactly followed to ensure that there is no over charging & the electrical energy pumped in; at a given time is the appropriate amount, which the battery can convert into chemical energy. Any amount above this will cause gassing inside & shorter life of the battery. The profile that is given is ideal (at 30ºC) & for any charge in ambient temp, it is to be compensated. The spec is 05mv/degree/cell. The battery efficiency is around 90% hence, after a complete discharge, we should pump in additional 8%Ahr while charging i.e. for a normal battery, and we can pump in 145 Ahr & can draw at least 130 Ahr i.e. 11 – 12% over charge. If this does not match, it indicates that the batteries are not working properly on full charge & 80% discharge. Over charging will cause gassing & disintegration of plates.

Equalization charge automatically takes place for 25min during C_f (final phase). When deviation between batteries exceed = 50mv, in case deviation exists for 3 consecutive cycles, the equalizing charge has to be set for 10 hrs after complete charge.

The battery is charged as
Phase I - 76%
Phase II - 90%
Phase III - 99%



DC-DC Converter – This provides 12V DC for various auxiliary functions. This is integral part of the charger. It has an efficiency of 82% min, receives 35-65V DC. This output is 13.5 vdc ± 2% non adjustable DC. 250watt. It has an output over current & over temperature protections. The cooling is provided through a heat sink & a cooling fan.
Latching – shutdown occurs if output voltage exceeds 66V. The over voltage protection (OVP) is latching type. It can reset by recycling the input voltage.

Check List for Diagnostics:

Phase	Vpack	SOC
C_1 to C_2	57.6	76%
C_2 to C_3	57.8	90%
C_3 to C_f	59.2	99%
C_f		100%

- Vpack = 57.6 (Batt temp – 30º) * 0.12
- Iprog = 0 - 40A in C_1 phase
  40 - 5A in C_2
  5 A in C3
- Battery current should follow the Iprog.
- Kwhr = (Ahr * Av Vpack) ÷ 1000. Ahr is completed by EMS and it should not exceed 200Ah.
- Charger temp - 20ºC to 75ºC
- Deviation in battery voltage (BV_1 to BV_8) (max 0.3V).

7.14 Possible problems during charging.

- Rise in T-batt or T-Ch: due to improper ventilation. Fan may not be Working.
- Fan is not working from beginning, charging will stop when Vpack reaches 54.5V to prevent gassing. Also TTL will be zero.
- Co – over voltage shutdown if Vpack reaches 66V during charging.
- C_t – time out shutdown if charging goes beyond 12 hrs.
- When sensor is not working, temp value is set to 30ºC which means sensor has failed.

7.15 Checklist for charger failure

<table>
<tr><td colspan="7">AC POWER SUPPLY CHECK LIST FOR INSTALLATION</td><td>REPORT NO:</td></tr>
<tr><td colspan="8">REPORT DATE:</td></tr>
<tr><td colspan="2">CUSTOMER NAME</td><td colspan="2"></td><td>LOCATION</td><td colspan="3"></td></tr>
<tr><td colspan="2">DEALERS NAME</td><td colspan="2"></td><td>LOCATION</td><td colspan="3"></td></tr>
<tr><td>VIN NO</td><td></td><td>CHARGER NO</td><td colspan="3"></td><td>INSTALLED POWER CAPACITY(Min-3KW)</td><td></td></tr>
<tr><td colspan="2">ELCB CONNECTED (30MA)</td><td colspan="2">POWER SOCKET-3PIN (15A)</td><td colspan="4">ELCB DETAILS IF ALREADY EXISTS</td></tr>
<tr><td colspan="2">YES/NO</td><td colspan="2">YES/NO</td><td colspan="4"></td></tr>
<tr><td colspan="8">CHECK INPUT AC VOLTAGE (ON CHARGE)</td></tr>
<tr><td colspan="2">IN BETWEEN</td><td>STANDARD</td><td>ACTUAL</td><td colspan="4">REMARKS</td></tr>
<tr><td colspan="2">LINE & NEUTRAL VOLTAGE</td><td>230v</td><td></td><td colspan="4"></td></tr>
<tr><td colspan="2">LINE & GROUND VOLTAGE</td><td>230v</td><td></td><td colspan="4"></td></tr>
<tr><td colspan="2">NEUTRAL & GROUND</td><td>0V (MAX3V)</td><td></td><td colspan="4"></td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="8">INSULATION RESISTANCE CHECK (MEGGER)- CHECKED /NOT CHECKED</td></tr>
<tr><td colspan="8">LINE, NUTRAL AND GROUND -(MIN 20 M OHM AT 100V)(MEGGER VALUE)-</td></tr>
<tr><td colspan="8">ANY ADDITIONAL REMARKS</td></tr>
<tr><td colspan="2">CHECKED BY LOCAL ELECTRICIAN SIGN / DATE</td><td colspan="4">CUSTOMER SIGN / DATE</td><td colspan="2">DEALERS STAMP & SIGNATURE</td></tr>
</table>

CHECK LIST FOR CHARGER FAILURE				REPORT NO:
				REPORT DATE:
CUSTOMER NAME			LOCATION	
DEALERS NAME			LOCATION	
VIN NO	CHARGER NO	CYCLE NO	CHARGER INSTALLATION DATE	FAILURE DATE
TOTAL KMS COVERED BY CAR			KMS COVERED BY CHARGER	

CHECK LIST FOR INPUT AC VOLTAGE (ON CHARGE)

IN BETWEEN	**STANDARD**	**ACTUAL**	**REMARKS**
LINE & NEUTRAL VOLTAGE	230v		
LINE & GROUND VOLTAGE	230v		
NEUTRAL & GROUND	0		

CHECK OUTPUT DC VOLTAGE (ON CHARGE)

IN BETWEEN	**STANDARD**	**ACTUAL**	**REMARKS**
48V TERMINAL & GROUND	48V - 64.5V		
12V TERMINAL & GROUND	13.2 - 13.8V		

CHECK THE TEMPERATURE

BATTERY TEMP IN PALM	< 50 DegC		
CHARGER TEMP IN PALM	< 78 DegC		

1. CHECK WHETHER THE BATTERY FAN IS RUNNING DURING CHARGING YES / NO

2. FAN TTL COUNTS DURING CHARGING IN PALM

3. CHECK FAN TTL SIGNAL (2.5V TO 3V) IN BETWEEN YELLOW AND BLACK OF 3 PIN FAN CONNECTOR

4.PUT THE CAR ON C HARGE BY DISCONNECTING EMS, CHECK FOR BATTERY COLTAGE RISE

5. CHECK PHYSICAL CONDITION OF THE CHARGER FOR ANY DAMAGES / BURNING.

6, PLEASE ATTACH THE SUMMARY DATA AND ERROR DATA AT THE TIME OF FAILURE(Start from at least five cycles before failure)

CHECKED BY **DEALERS STAMP & SIGNATURE**

7.16 Charger Maintenance

1. Check with Multimeter at following Points:

(a). Between + 12V and Ground on Charger. It should be 11.23 to 13.77 V. If 12V is not available, check at RT1 and RT2 on Charger. If 12v is available and still charging is not taking place - charger is faulty and needs replacement.

(b). Between 48 V and Ground on Charger. It should be minimum 40 V. If it is less then on board charger will not Charge and an external Charger will be required to charge Individual Battery Blocks till the pack Voltage is above 40V.

(c). Charger will not charge if Battery temperature exceeds 50C. Charger Temperature is measured by Voltage differential from Charger. The voltage equivalent of Temperature is 3V @ 27°C and increases by 0.01V for every 1°C rise. Thus at 40°C, the Voltage is equal to 3.13V. This can be checked between pin 12 and 14 (CN 63).

(d). Charger will not Charge if Charger Temperature exceeds 72°C. In this case, EMS will reduce I (prog) Charger will stop Charging when Charger temperature exceeds 78°C.

(e). In Battery Charge plot Battery Charge Current should follow the I (Prog)

- Deviation between Battery Voltages should not exceed 0.7 V.
- Maximum Deviation between the Battery Voltages should not exceed IV.
- There should be continuous rise in all the battery Voltages. In case of abrupt Charge, particular Battery Block needs to be checked.
- 100% charging, watering and then equalization would solve most of the Battery problems. For Watering and Equalization refer Service manual.

(f). Check for Loose and burnt contacts, rectify.

(g). Charger under Voltage (CUV) should be Zero at (CN63, pin 5 and gnd). While Charging and 5V when it is not Charging. If CUV is 5 V while Charging then the Charger is faulty, replace it.

(h). Check at battery (+) and (-). There should be rise in Voltage every 2 sec.

2. Check for Fan functions by running sound. Also check voltage at pin 18 and gnd (CN 66). It should be between 2 to 2.5V. Fan is defective if Voltage is low or TTL is Zero and V(Prog) is 54.5V.

3. For problems related to individual battery Voltage, deviation in Battery voltage, I(Prog), over Voltage, Battery Shunt etc, calibration parameters need to be adjusted through PET. Refer Service manual for setting Charging Factor, I Prog factor, V prog factor, SOC factor and speed factor.

4. Measure the value across shunt while charging to know the value of Charging current.

5. When EMS is not connected, the Charger inner profile takes over from EMS and regulates Charging current from 40A to 16A and further reduced to 4A.
6. There should be no Voltage between ground and neutral.

7.17 Frequently Asked Questions

1. What are the Protections provided in the Charger?

- It has over Voltage protection.
- It has an under Voltage protection, so that Charger is switched off at 151 V input.
- OVP (over voltage protection) should be less than 66V.
- It has over current protection (OCP < 42A).
- It has input over current fuse of 20A.
- It has over temperature protection so that the Charging current is reduced depending on the ambient temperature.

2. What are the input and output specifications of the Charger?

- **Input:**
  160 - 260 V AC, Single phase, 40 to 60 Hz. Max input current is 16.4 A.
- **Output**:
  42 - 65 V DC, 40 A (Max) for pack charging 13.6 V +/- 2%, 300 w/400w. (DC-DC Converter) for car lighting and accessories.

3. What are the Charging Phases?

- C1 Phase: Charging current is 40A. It is regulated by ambient temperature EMS reduces the I_{prog} value so that charging current is lower than 40A for higher ambient temp. Pack Voltage rises to 56 V.
- C2 Phase: The Charging current is reduced (tapered) from 40A (standard) to 5 A While the pack voltage rises to 57 V.
- C3 Phase: Again the current is maintained at 5A while the pack voltage rises to 58 V and dv/dt should be less than 60 mV/10 min.
- Cf Phase: The pack Voltage further rises to 59.6 V for next 10-15 minutes, the charging continues @ 5 to 6 A for equalization.

4. What is the protection provided against Electro magnetic interference (EMI)?
The Charger has adequate filtering circuits to provide EMI protection at both ends for 100 to 150 kHz.

5. **What are the types of Charger in use?**

There are two types of Charger - fully self-compensating Charger and pre - programmed Chargers. Reva uses pre - programmed two step taper chargers. Initially higher current and subsequently lower current from the point of gassing is permitted. Voltage sensitive relays operate a contactor, which reduces the current to the required finishing rates.

CHAPTER 08

INSTALLATION OF SOFTWARES

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CHAPTER 08

INSTALLATION OF SOFTWARES

8.1 To Install Palm Desktop Software in PC

To install and operate Palm Desktop Software, you need the following minimum system requirements.

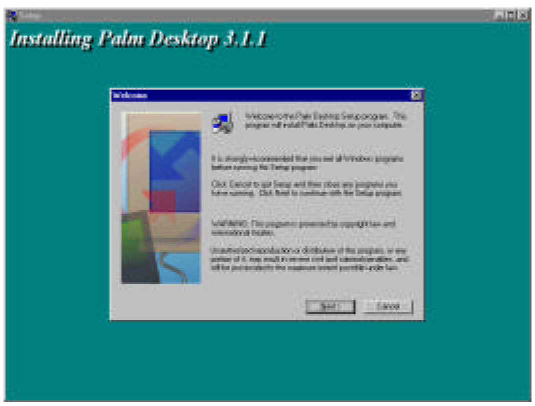
1. 386 PC or higher.
2. Windows 98 or Windows NT operating System.
3. 16MB RAM.
4. CD-ROM Drive.
5. Palm Desktop Software CD (As provided by the RECC along with the PALM).
6. Mouse
7. One Serial Port for Hot sync process.

- If you have connected Palm to the PC, remove it during software installation.
- Disable or turn off any anti virus software.
- Exit all windows programs.
- Turn off any Screen Saver software.
- Exit from Microsoft Office Toolbar.
- Insert Palm Desktop CD into the Computer's CD Drive.
- Click Auto run.

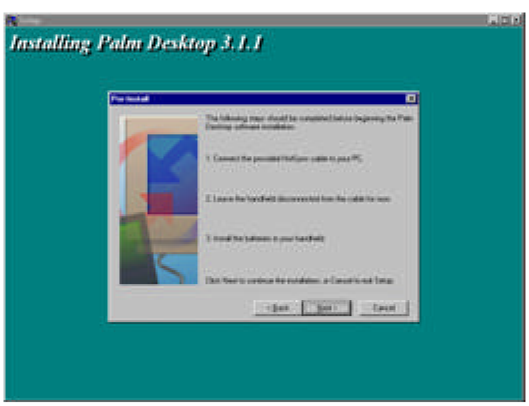
- After clicking Auto run, an **Auto run** Dialog box is displayed.

- Select English from **Auto Run** Dialog box. Once the English is highlighted another **Auto Run** Dialog box is displayed.

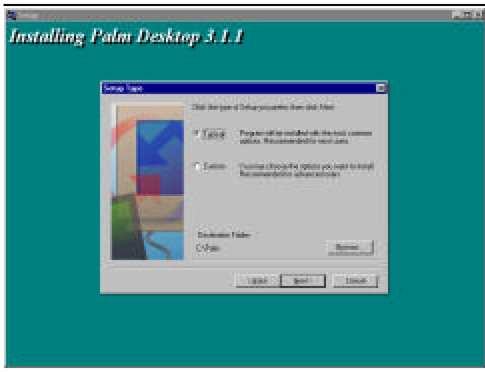
- Click on Continue. A **Welcome** Dialog box is displayed. Click Next Button in the Welcome Dialog box.



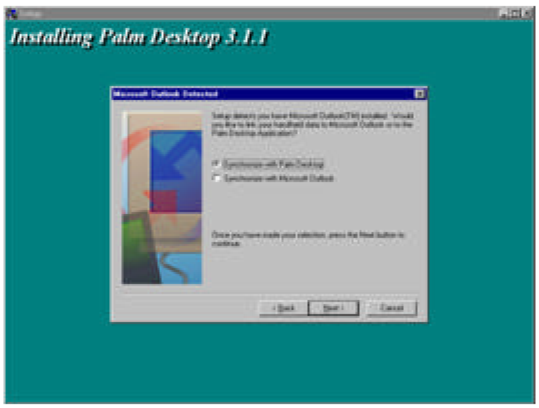
- A **Pre-Install** Dialog box is displayed. Press Next Button in Pre-Install Dialog box.



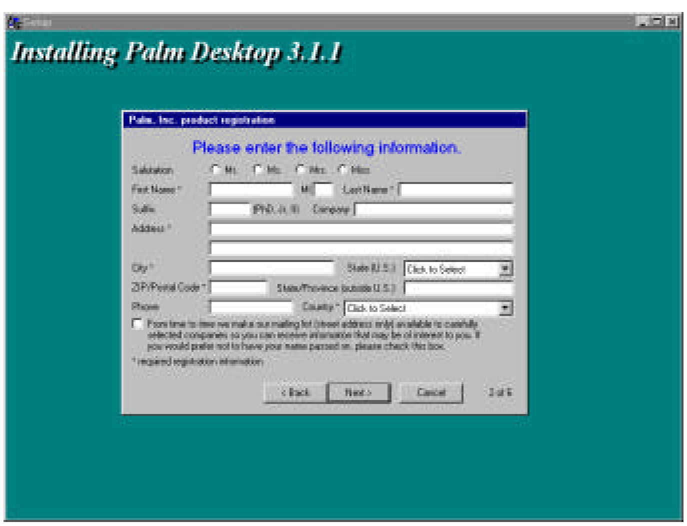
- A **Setup Type** Dialog box is displayed. Select **typical** option. By default, in "C\Palm" is selected.



- After selecting the required Destination folder, click Next Button.
- **Microsoft Outlook Detected** Dialog box is displayed. Select **Synchronize with Palm Desktop** option and press Next Button.



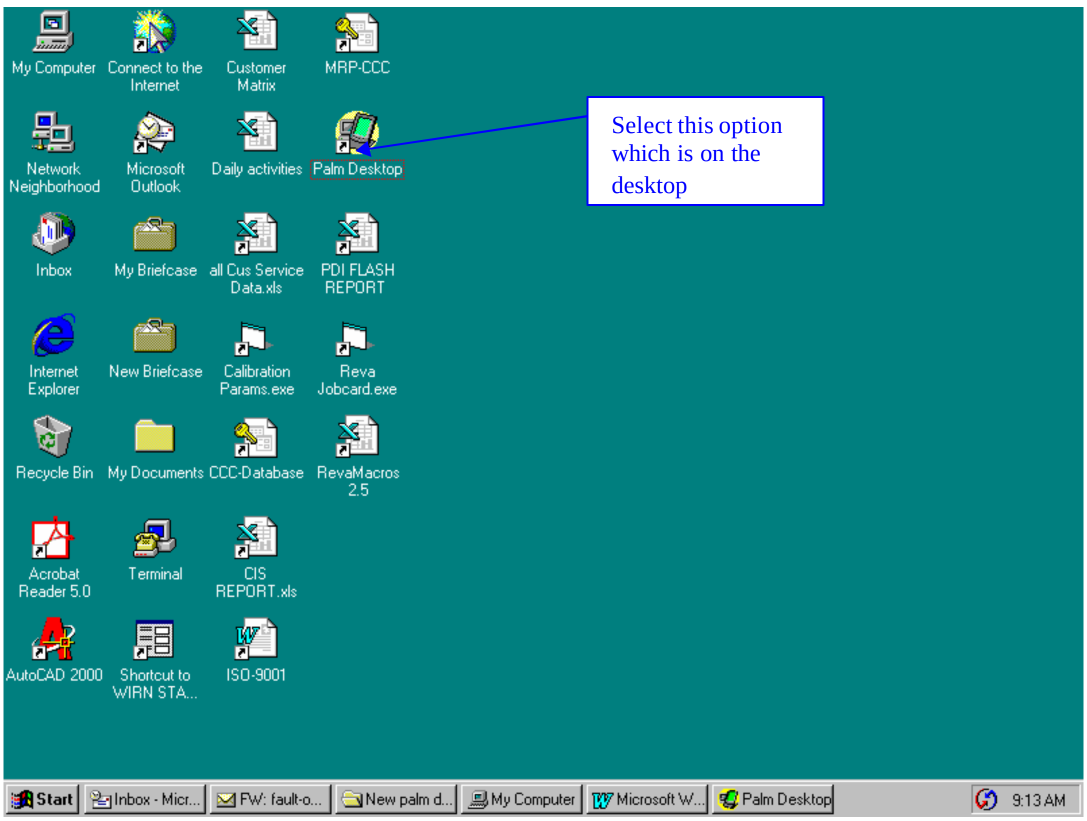
- **Create User Account** Dialog box is displayed. Type the **User Name** and press Next Button.
- Press Ok button in **Serial Port Setup** message box is displayed.
- Press Ok button in **Serial Port Setup** Dialog box is displayed.
- Press Next Button in Product Registration Dialog box.
- Press Cancel in second Product Registration Dialog box.



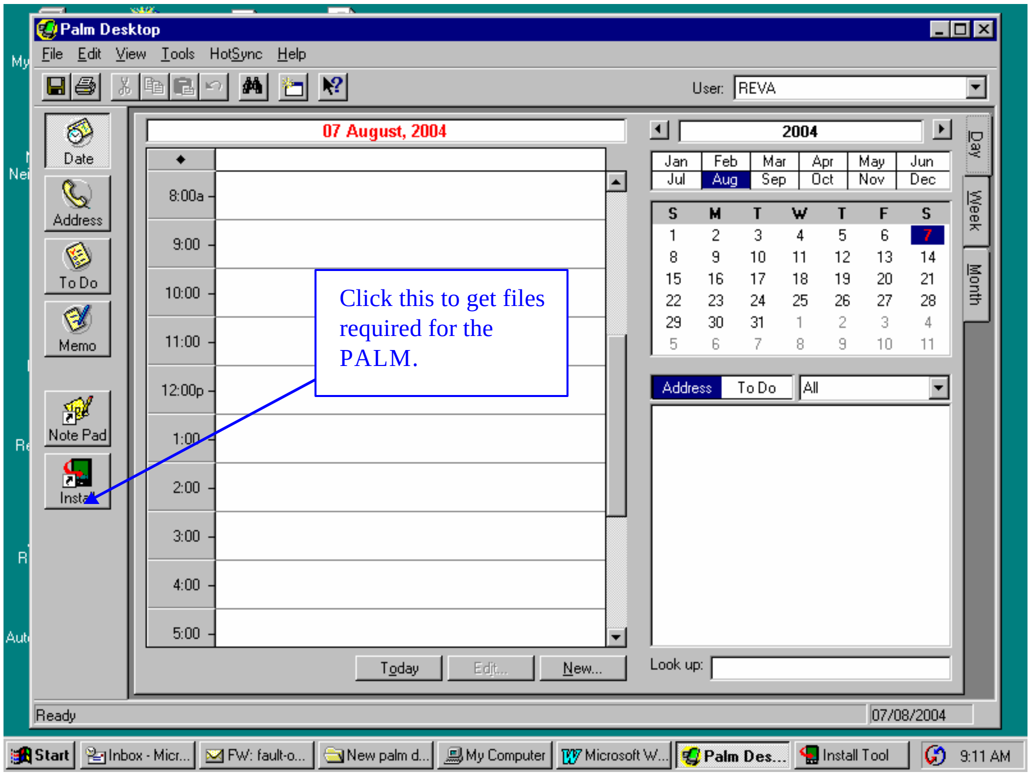
- After pressing Cancel button, cancel Registration? Message is displayed. Click Exit Registration Button.
- Click **Finish** Button in **Setup Complete** Dialog box.
- A RED and BLUE arrow symbol appears as shown below on the task bar to confirm PALM installation.

8.2 Installation of PET soft to palm computer:

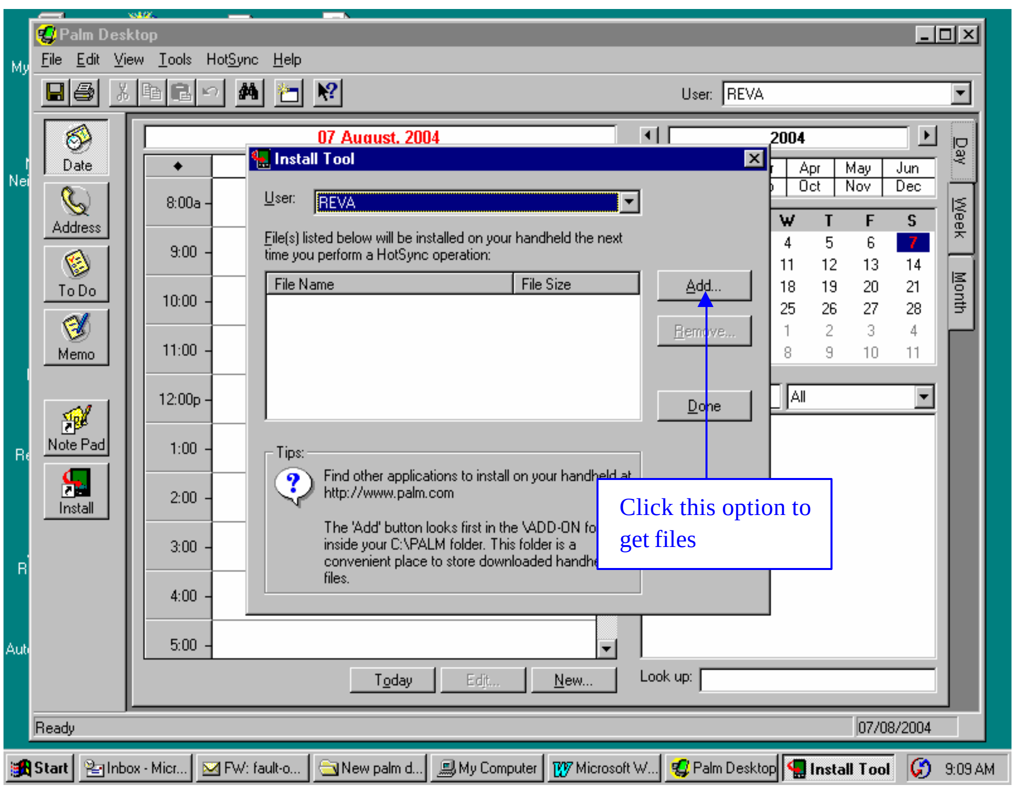
1) Select the Palm Desktop option menu on the computer desktop.



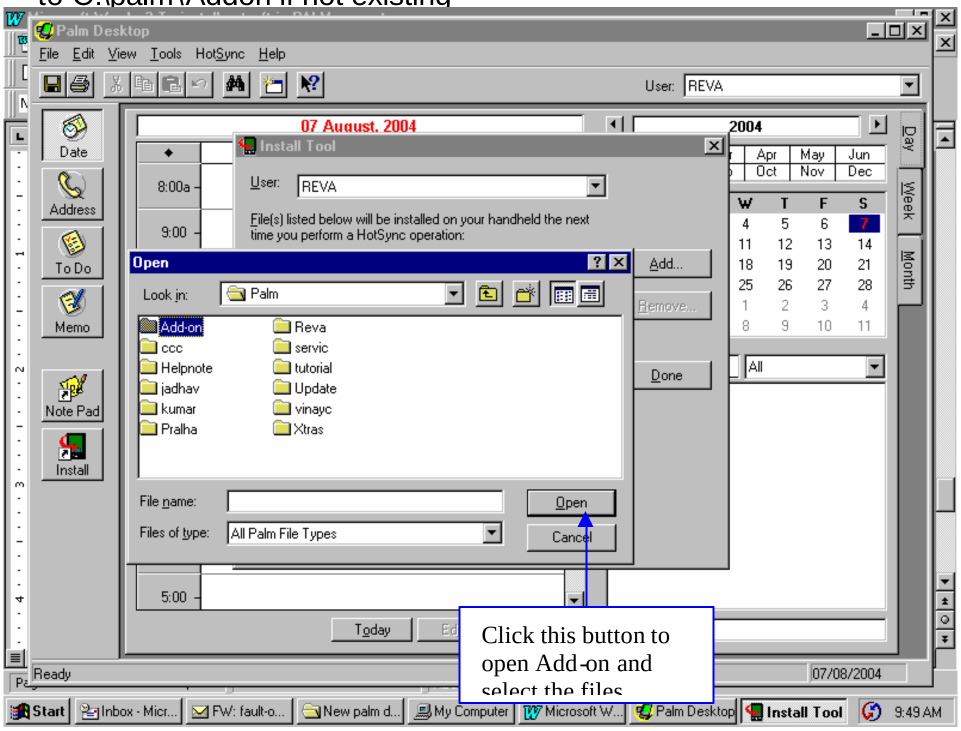
2) Click on the install button.



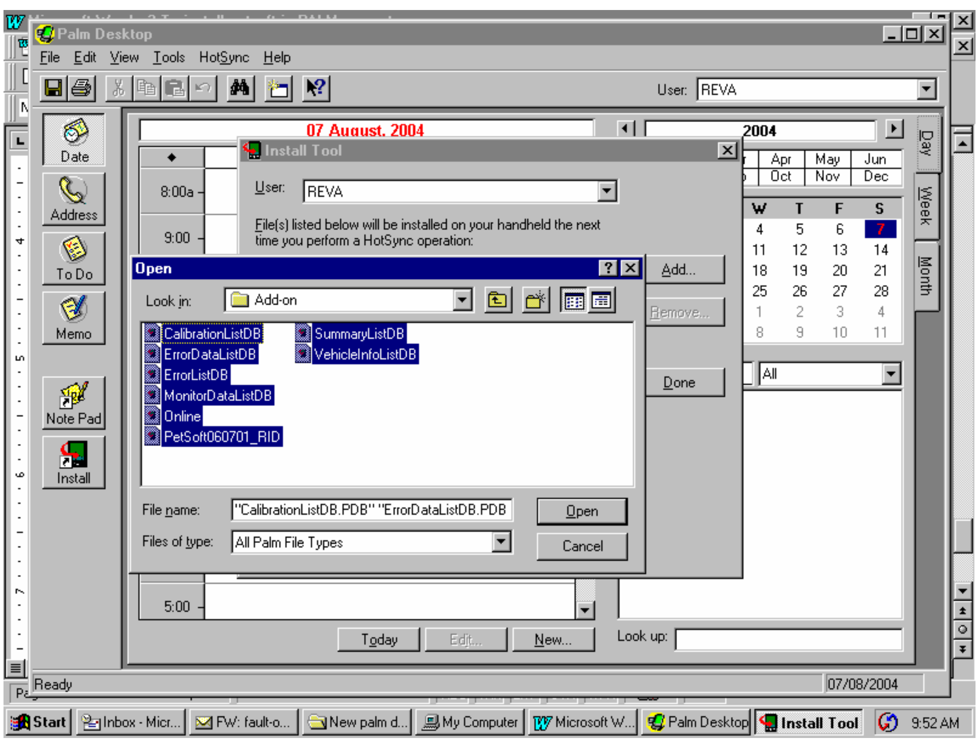
3) Click the Add button to select the file from the respective folder.



2) Select C:\palm\ Add on as shown in the below figure. Copy and paste the palm files to C:\palm\Addon if not existing



3) After selecting all the palm files you have to press DONE.



6) Then you press the below hot sync button of the PALM (PET) to finish the process.

7) Then the PETSOFT option will be available on your PALM computer.

8.3 To transfer the data from PALM to PC.

The summary, error data in the PALM should be transferred to PC for further analysis. This process is called HotSync.

- The PALM software should be installed in your computer before the hot synch process.(Refer another attached file to install PALM Desktop software in PC)
- By pressing the right button of the mouse on the RED/BLUE arrow displayed in the right bottom corner of your desktop (task bar) the HotSync menu will be obtained. Then choose Setup. When Setup Dialog appears, click Local tab to display settings.
- Check the selected Serial Port and make sure it corresponds to the port number that is connected to the Palm.
- Choose a Speed. The default is **as fast As Possible.**
- Click OK to close Setup Dialog and activate your settings.
- Press HotSync Button on the front of the Palm cradle
  Note: During the course of the first HotSync, you will be asked for the username that will correspond to the Palm. Every Palm should have a unique name. Never try to synchronize more than one Palm to the same user name.
- After HotSync process is done, a directory will be created under Palm directory (Where Palm Desktop software is installed) with a user name for e.g. is Palm user name is Service then all files are stored under C:\Palm \Service\Backup\files.
- Summary Data is stored in SummaryDB.pdb file
  Error Data is stored in ErrorDB.pdb file
  Monitor Data (ie, Charge, Drive & Equalize Data) stored in Monitor Data DB.pdb
  Vehicle Information Data is stored in C:\Palm \Servic\memopad\memopad.bak or memopad.dat files.
- If you are sending the data through the E-Mail the below files are to be attached.
  Summarydb.pdb
  Errordb.pdb
  Monitordatadb.pdb
- Relevant portions of the above files can be copied and pasted to make the communication faster and precise.

8.4 Installation of Macros (Reva Automation)

Introduction

Macros are nothing but automating tasks you perform frequently

If you perform a task repeatedly in Microsoft Excel, you can automate the task with a macro. A macro is a series of commands and functions that are stored in a Visual Basic module and can be run whenever you need to perform the task.

Features

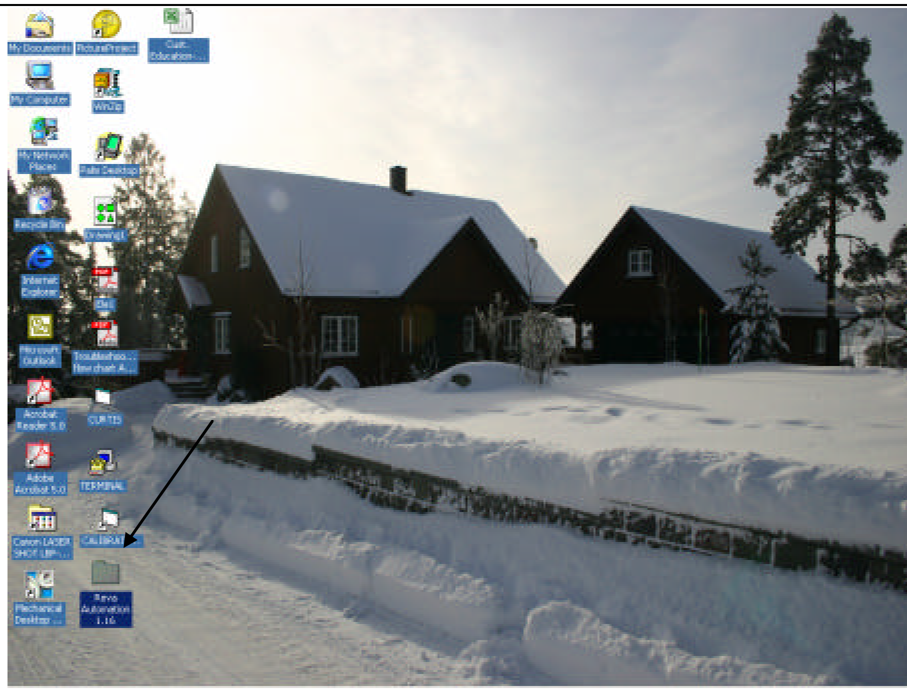
- Easy for Service Personal, QA, assembly or dealer to analyze the different parameters in REVA during Charge, Equalize or Drive. It takes very short time in deleting unwanted data, calculating the parameters, plotting the data, and formatting plots according to user requirement.
- It gives the summary of Charge and Drive data. It calculates total time, total number of Charge/Discharge cycles, total Ampere-Hour, Ampere Regen, Ampere Drive and kilowatt-hour during Charge and Drive. It also finds averages of Battery Temp, Motor Temp, Charger Temp, Controller Temp, State of Charge, Battery Current, Pack Voltage and Kilometers separately during Charge and Drive. It identifies the parameters, which are out of Range. It gives % Over Charge, % Regen, Theoretical Capacity and Whr/Kms.
- Description of errors and highlighting the different types of errors. It also identifies the parameters, which are out of range in the error data.
- It gives formatted Summary and Error data. In this, errors belonging to each cycle are displayed in a systematic manner.
- Battery Warranty Verification Data gives you the capacity of Battery used i.e. Ampere-Hours given to the battery, total Kilometers, total time spent in Charge, total number of Charge/Discharge cycles and Battery watering details.
- Neat display of Vehicle Information Data for all cars.

Hardware & Software Requirements

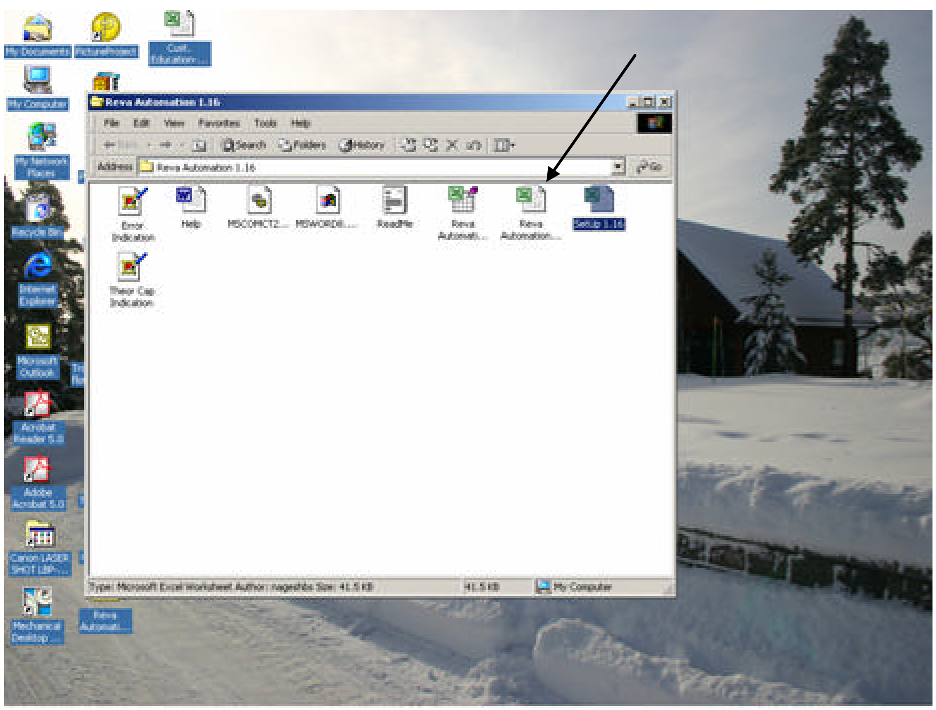
- Personal PIII Computer with Microsoft Excel.

Procedure

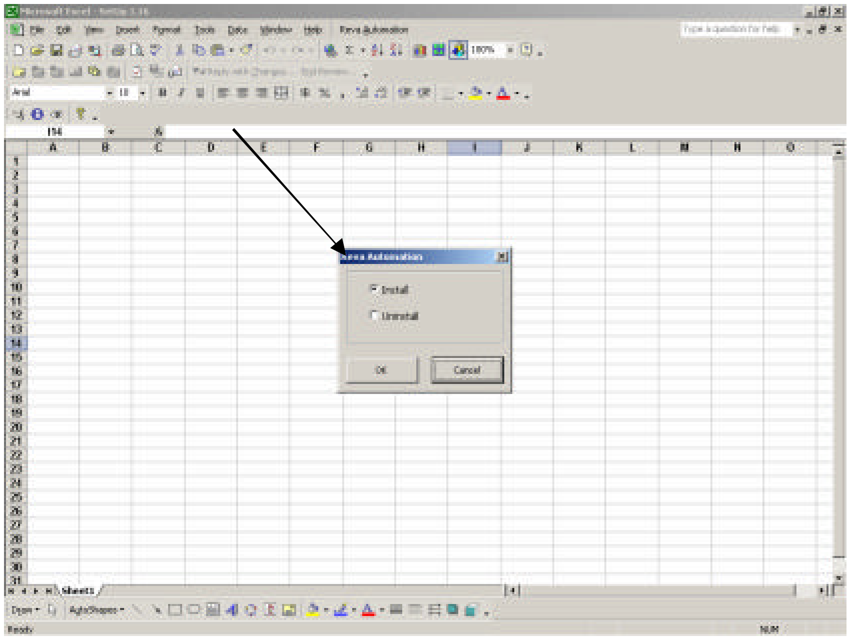
1. Insert the floppy or CD into the drive which contains Reva automation and copy the folder onto the desktop.



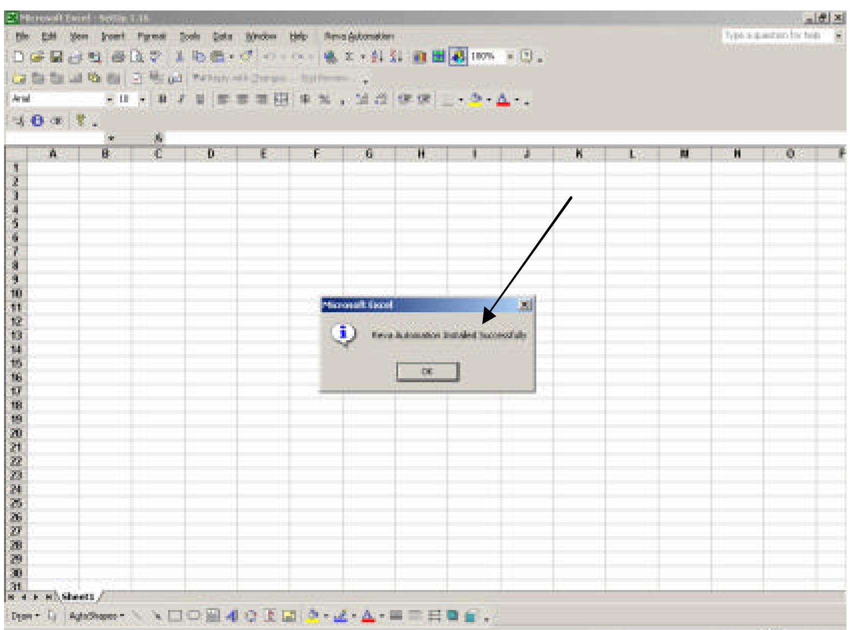
2. Open the Reva automation folder and click on the set up.



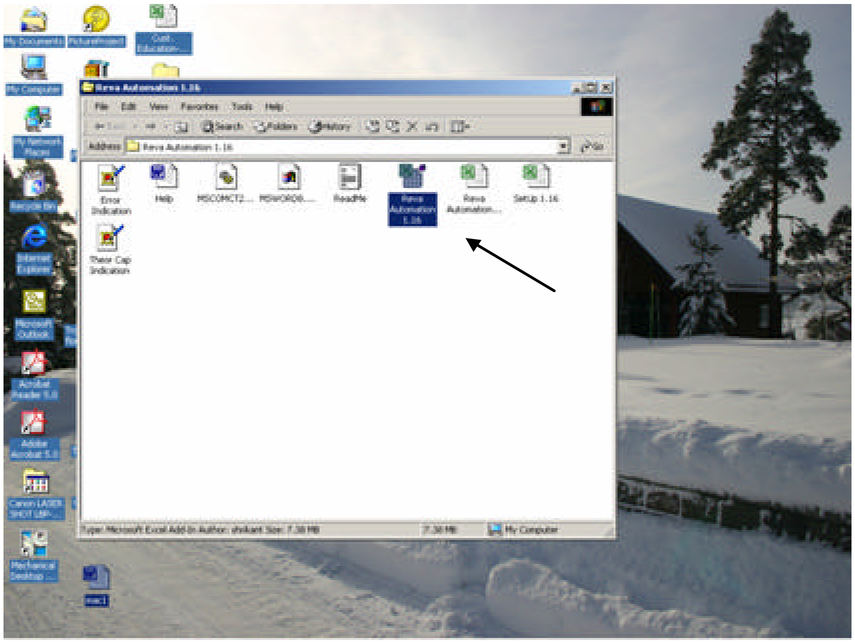
3. Click on install button to install automation.



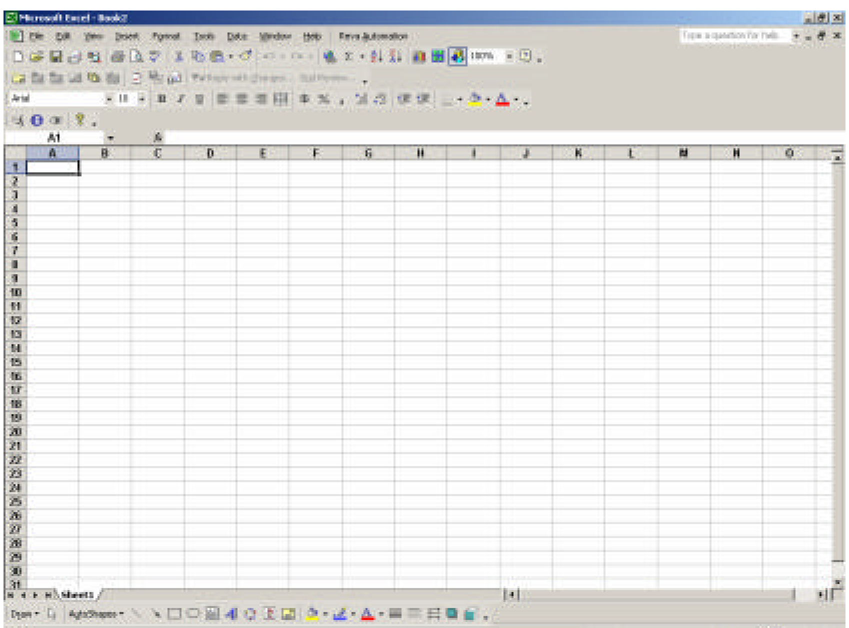
4. Check for dialogue box display Reva automation installed successfully.



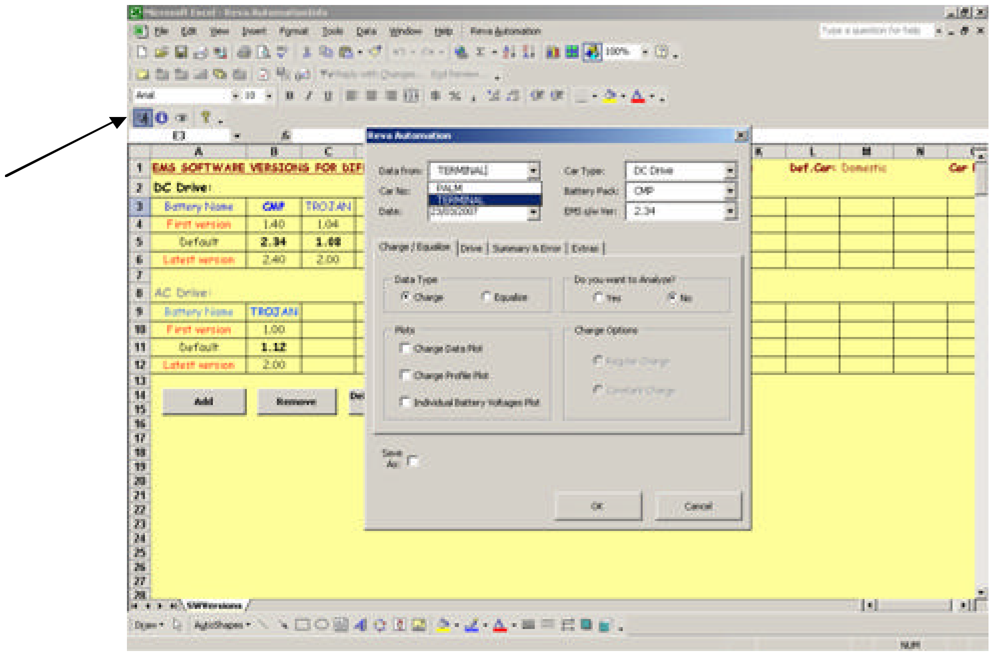
5. Click ok and then copy Reva automation version and paste it onto the desktop.



6. Click on Reva automation to run



7. Click on run button and select the data ie, Drive, Charge, Summary, Error, Battery warranty data and Vehicle info for analysis.



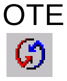
8.5 Terminal Programming

Introduction

To analyze the data (i.e. Charge data, Drive data, Summary, Error and Vehicle Information data), it can be downloaded through Terminal software in PC.
For collecting the data in Terminal package, connection is done from a PC's serial port to EMS via RS 232 cable.
Terminal Settings :

Before downloading any kind of data, preliminary Terminal settings has to be done

- Open Terminal.exe.
- If you want the data to be displayed in 132 columns (by default 80 columns will be selected), then select **Terminal Preferences** from **Settings** menu.

NOTE: During the operation of Terminal software, Exit the Hot sync button or  you will find that the com does not communicating with the PC.

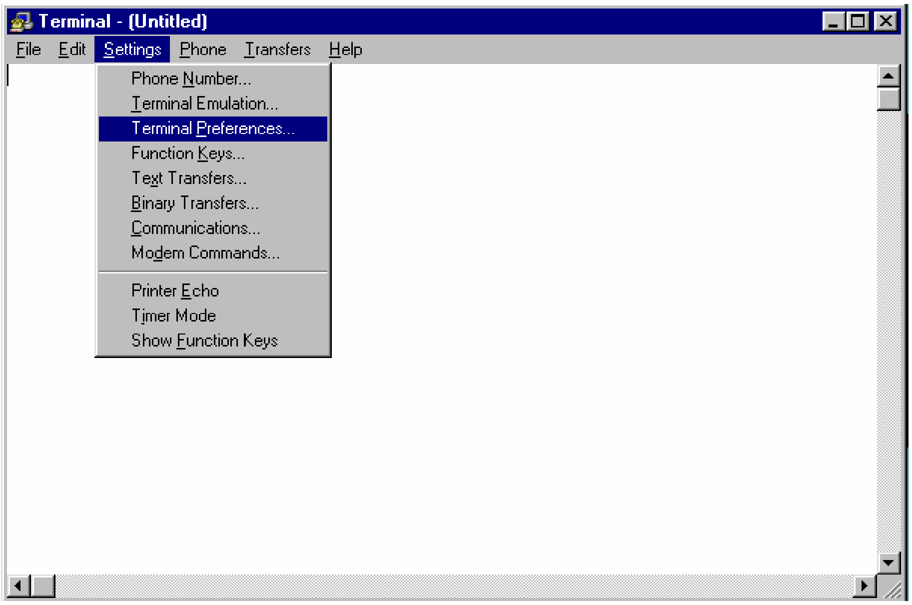


Fig 1 Terminal Screen

- The **Terminal Preferences** dialog box is displayed as shown in Fig 2.

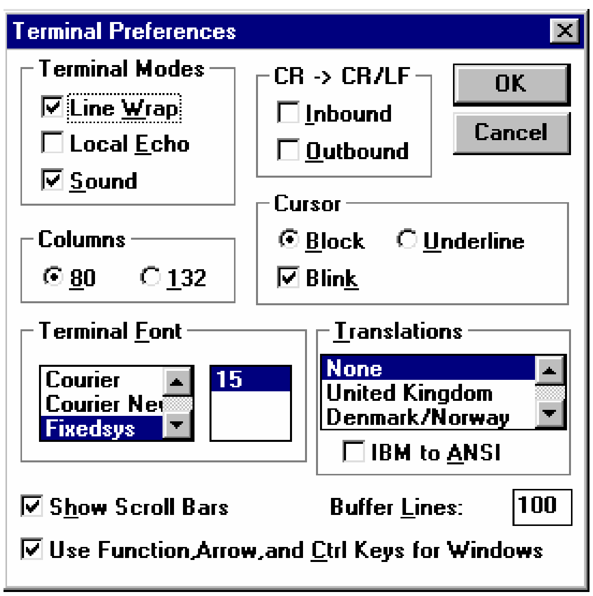


Fig 2 Terminal Preferences Dialog Box

- Select **132** from **Columns** and press **OK** button.
- Before downloading the data in Terminal, communication must be set up. For that select **Communications** menu from **Settings** menu. The **Communications** dialog box is displayed as shown in Fig 3.

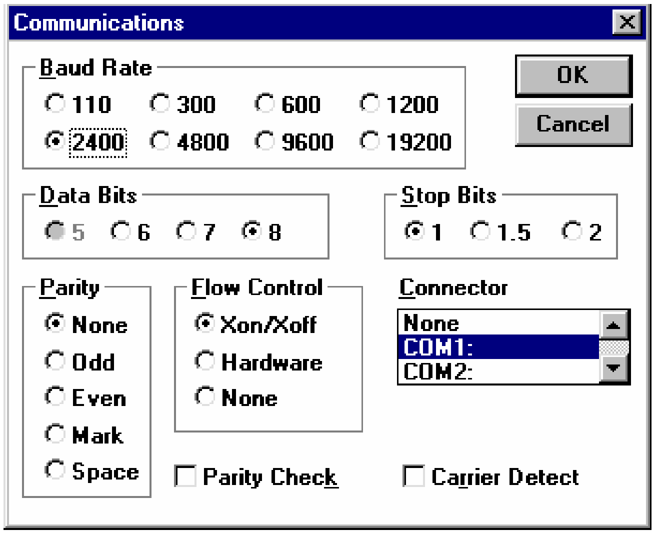


Fig 3 Communications Dialog Box

- Select 2400-Baud Rate, 8 - Data Bits, 1 - Stop Bits, and Connector is selected depending on the serial port selected.
- If you want to save the file or append to the existing file, then select **Receive Text File** from **Transfers** menu. The **Receive Text File** dialog box is displayed as shown in Fig 4.

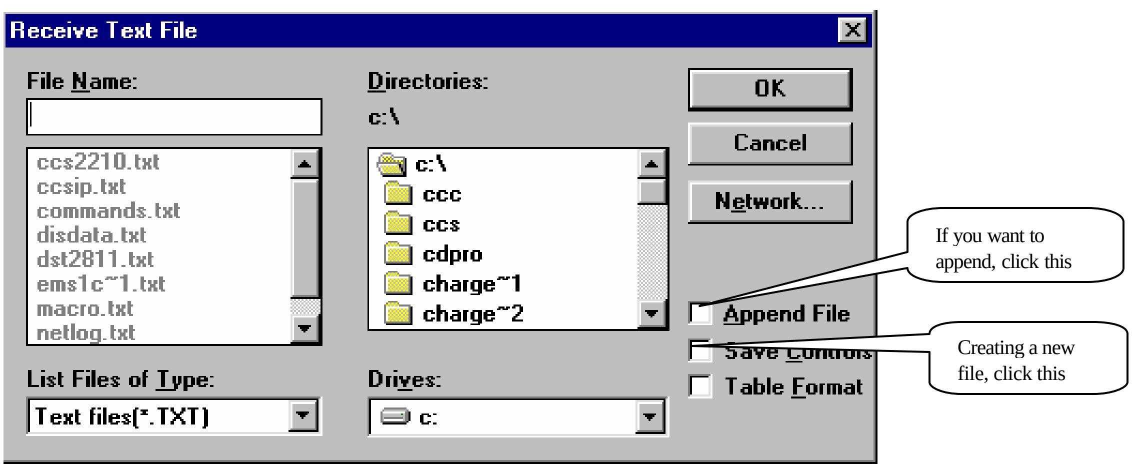


Fig4 Receive Text File Dialog Box

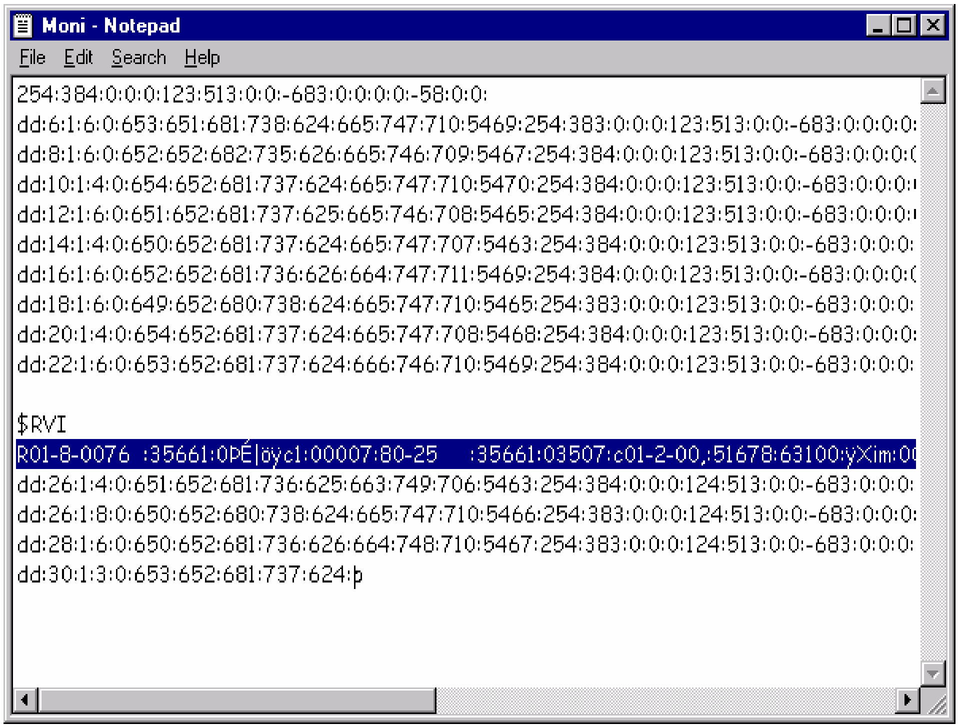
- Enter the file name with *.Txt type, click **Append File** or **Save Controls** depending on the requirement and press **OK** button.
- If you stop from saving the file, then select **Stop** from **Transfers** menu.

<u>Vehicle Information Data</u>

Vehicle Information Data has assembled of component details and last service details. From this, we can able to see the serial number of Car, Charger, Motor, Controller, EMS and Battery, software versions of EMS, Controller, kilometers and last service date and installation date of all the above components.

To download Vehicle Information Data in Terminal,

- Connect RS232 cable from EMS to PC's serial port COM1, COM2… depending on the availability of port.
- Open Terminal.exe
- Follow the steps given in pages to make settings in the Terminal software.
- Type **$RVI** or **$rvi** command. After downloading the vehicle information data, the text file looks like as shown in Fig 5.


Moni - Notepad
File Edit Search Help
```
254:384:0:0:0:123:513:0:0:-683:0:0:0:0:-58:0:0:
dd:6:1:6:0:653:651:681:738:624:665:747:710:5469:254:383:0:0:0:123:513:0:0:-683:0:0:0:0:
dd:8:1:6:0:652:652:682:735:626:665:746:709:5467:254:384:0:0:0:123:513:0:0:-683:0:0:0:(
dd:10:1:4:0:654:652:681:737:624:665:747:710:5470:254:384:0:0:0:123:513:0:0:-683:0:0:0:
dd:12:1:6:0:651:652:681:737:625:665:746:708:5465:254:384:0:0:0:123:513:0:0:-683:0:0:0:
dd:14:1:4:0:650:652:681:737:624:665:747:707:5463:254:384:0:0:0:123:513:0:0:-683:0:0:0:
dd:16:1:6:0:652:652:681:736:626:664:747:711:5469:254:384:0:0:0:123:513:0:0:-683:0:0:0:(
dd:18:1:6:0:649:652:680:738:624:665:747:710:5465:254:383:0:0:0:123:513:0:0:-683:0:0:0:
dd:20:1:4:0:654:652:681:737:624:665:747:708:5468:254:384:0:0:0:123:513:0:0:-683:0:0:0:
dd:22:1:6:0:653:652:681:737:624:666:746:710:5469:254:384:0:0:0:123:513:0:0:-683:0:0:0:

$RVI
R01-8-0076 :35661:0ÞÉ|öyc1:00007:80-25    :35661:03507:c01-2-00,:51678:63100:ÿXim:0(
dd:26:1:4:0:651:652:681:736:625:663:749:706:5463:254:384:0:0:0:124:513:0:0:-683:0:0:0:
dd:26:1:8:0:650:652:680:738:624:665:747:710:5466:254:383:0:0:0:124:513:0:0:-683:0:0:0:
dd:28:1:6:0:650:652:681:736:626:664:748:710:5467:254:383:0:0:0:124:513:0:0:-683:0:0:0:
dd:30:1:3:0:653:652:681:737:624:þ
```

Fig 5 Vehicle Information Data

- The Vehicle Information Data displayed in the sequence as shown.

1. Vehicle Serial Number
2. Build Date
3. Motor Serial Number
4. Motor Installation Date
5. Controller Serial Number
6. Controller Installation Date
7. Controller Software Version
8. EMS Serial Number
9. EMS Installation Date
10. EMS Software Version
11. Charger Serial Number
12. Charger Installation Date
13. Battery Pack #1 Serial Number
14. Battery Pack #1 Installation Date
15. Kilometers of Battery Pack #1 Installed

16. Battery Pack #2 Serial Number
17. Battery Pack #2 Installation Date
18. Kilometers of Battery Pack #2 Installed
19. Battery Pack #3 Serial Number
20. Battery Pack #3 Installation Date
21. Kilometers of Battery Pack #3 Installed
22. Battery Pack #4 Serial Number
23. Battery Pack #4 Installation Date
24. Kilometers of Battery Pack #4 Installed
25. Last Service Date
26. Odometer (Total Kilometers) at last Service

Summary Data

It summarizes the necessary parameters, which are important in the Charge & Drive as eoc and eod respectively.
"eoc" – end of charge
"eod "– end of drive.

To download the summary data in Terminal (Desktop), follow the steps given in

- Connect RS232 cable from EMS to PC's serial port COM1, COM2… depending on the availability of port.
- Open Terminal.exe
- Follow the steps given in pages to make settings in the Terminal software.
- Type **$RSD** or **$rsd** command. After downloading the summary data, the text file looks like as shown in the figure below.

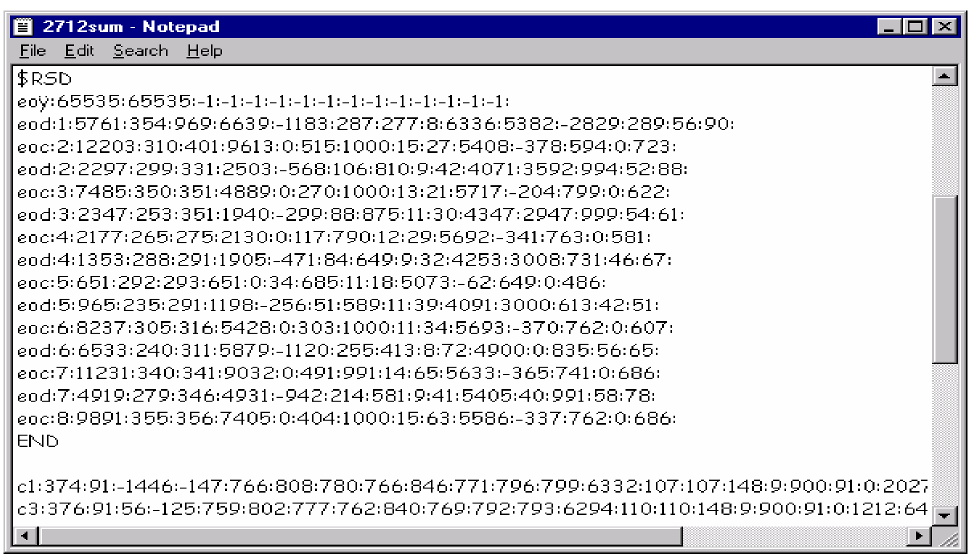


Fig 6 Summary Data

- The Summary Data displayed in the sequence as shown.

1. eoc / eod – End of Charge/ End of Drive.
2. Cycle - Number

3. Time (seconds)
4. Tbatt_Avg (Deg C)
5. Tbatt_Max (Deg C)
6. Ampere – Hour
7. Ampere_Regen
8. Kilowatt Hour
9. State of Charge
10. W fault
11. Dv_Maximum
12. @V_batt
13. @I_Batt
14. @SOC/Kms
15. Controller Temperature
16. Charger Temperature/Motor Temperature
17. % over charge
18. % regen
19. Theo capacity
20. Ahr / SOC
21. Ahr / min / Ahr / kms
22. Whr / kms
23. Date
24. Odometer

To collect summary data

Summary data is displayed after every charge or drive is done. The summary data is stored in EEPROM. After 300 cycles of charge and drive (i.e. 300 charge and 300 drive cycles), the cycle number 1 is replaced by 301 cycle number.

From this, it is easy to find out the fault values, total number of charge/discharge cycles, total kilometers, theoretical capacitance, and %over charge, %Regen and Whr/Kms can be calculated from summary data.

The summary data consists of type to identify whether it is end of drive or end of charge. Cycle number, total time in seconds, average of battery temperatures through out the charge and drive. It also consists of Maximum battery temperature in charge and drive, total ampere-hour and kilowatt-hour. Average deviation between battery voltages, maximum deviation in battery voltages, state of charge, total kilometers taken by individual drive, motor charger controller temperature.

1. To collect the end of drive "eod" (summary), follow the steps in the order given below

- Connect RS232 cable from EMS to PC's serial port.
- Switch **OFF** the startup key.
- Plug on to 230volts AC.
- Switch **ON** mains, end of drive "eod" is displayed. If you want to make a note of eod, press **F10** key.
- The parameters in eod are Type (eod): Cycle: Time (secs): Avg. Battery Temp: Max Battery Temp: Total Ampere Hour: Ampere Regen: Kilowatt Hour: SOC: Avg. DV: Max DV: @Pack Voltage: @Battery current: total kilometers: Controller Temp: Motor Temperature.

2. To collect end of charge "eoc", follow the steps mentioned below

- Switch **OFF** the power supply; disconnect the charging cable from external power source (15 Amps, 220-240V).
- Switch **ON** the startup key.
- End of charge "eoc" is displayed on the screen. If you want to make a note, press **F10** key.
- The parameters in eoc are Type (eod): Cycle: Time (secs): Avg. Battery Temp: Max Battery Temp: Total Ampere Hour: Ampere Regen: Kilowatt Hour: SOC: Avg. DV: Max DV: @Pack Voltage: @Battery current: @SOC: Controller Temp: Charger temp

Error Data

To download the error data in Terminal (Desktop),

- Connect RS232 c able from EMS to PC's serial port COM1, COM2… depending on the availability of port.
- Open Terminal.exe
- Follow the steps given in pages to make settings in the Terminal software.
- Type **$RER** or **$rer** command. After downloading the error data, the text file loo ks like as shown in the Fig 7.

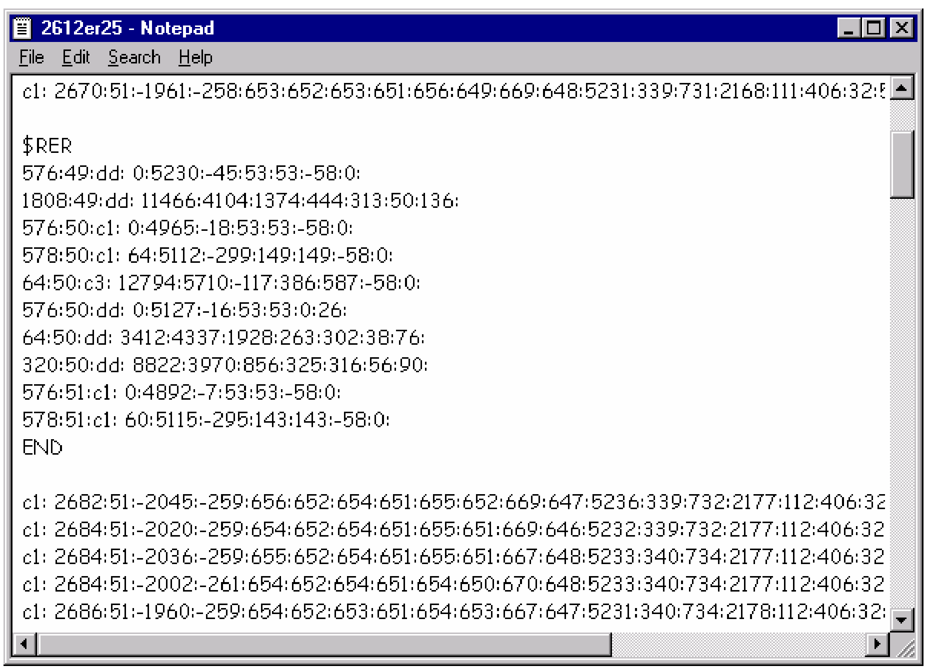


Fig 7 Error Data

- **The Error Data displayed in the sequence as shown.**

1. Error Number.
2. Cycle
3. State – c1, c2, c3, cf, cp, ct, co, ci, im, dd, ce
4. Time (Secs)
5. Vpack
6. Battery Current

7. Battery Temperature
8. Charger Temperature
9. Controller Temperature
10. Motor Temperature

Charge Data

To download the charge data in Terminal (Desktop), follow the steps in the sequences given below.

- Make sure parking brake is engaged.
- Ensure control knob is in Neutral [N] mode.
- Turn startup key to **OFF** position and remove it from key slot.
- Connect RS232 cable from PC's serial port (COM1 or COM2, COM3…) depending on the availability of port to the EMS.
- Connect the charging cable's female end to REVA's on board charge port lid, the other end of the charging cable is plug into a 15 Amp, 220 -240V external power source.
- Open Terminal.exe.
- Follow the steps given in pages to make settings in the Terminal software.
- Switch **ON** the power supply.
- Once Mains is **ON**, an information is displayed about the company name, EMS software version, a message "Copyright RECC".
- The charge data is displayed every 2 seconds with a prefix

  C1 for phase 1,
  C2 for phase 2,
  C3 for phase3,
  Cf for final phase,
  Cp for over temperature,
  Ct for over time (> 43200s) shut down,
  Co for over voltage shut down,
  Im for idle mode,
  Ci for idle phase after charge finished.

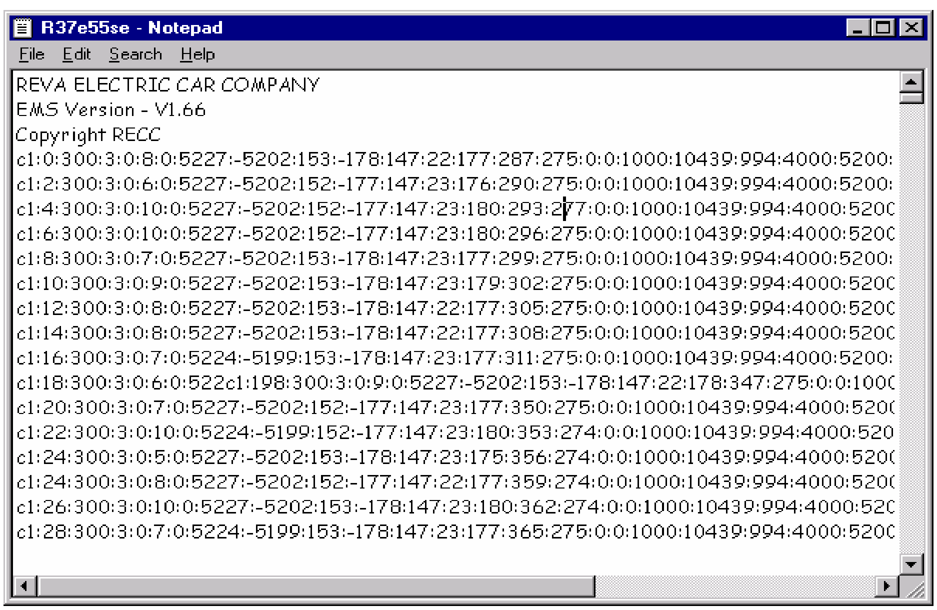

R37e55se - Notepad
File Edit Search Help
REVA ELECTRIC CAR COMPANY
EMS Version - V1.66
Copyright RECC
c1:0:300:3:0:8:0:5227:-5202:153:-178:147:22:177:287:275:0:0:1000:10439:994:4000:5200:
c1:2:300:3:0:6:0:5227:-5202:152:-177:147:23:176:290:275:0:0:1000:10439:994:4000:5200:
c1:4:300:3:0:10:0:5227:-5202:152:-177:147:23:180:293:277:0:0:1000:10439:994:4000:5200
c1:6:300:3:0:10:0:5227:-5202:152:-177:147:23:180:296:275:0:0:1000:10439:994:4000:5200
c1:8:300:3:0:7:0:5227:-5202:153:-178:147:23:177:299:275:0:0:1000:10439:994:4000:5200:
c1:10:300:3:0:9:0:5227:-5202:153:-178:147:23:179:302:275:0:0:1000:10439:994:4000:5200
c1:12:300:3:0:8:0:5227:-5202:153:-178:147:22:177:305:275:0:0:1000:10439:994:4000:5200
c1:14:300:3:0:8:0:5227:-5202:153:-178:147:22:177:308:275:0:0:1000:10439:994:4000:5200
c1:16:300:3:0:7:0:5224:-5199:153:-178:147:23:177:311:275:0:0:1000:10439:994:4000:5200:
c1:18:300:3:0:6:0:522c1:198:300:3:0:9:0:5227:-5202:153:-178:147:22:178:347:275:0:0:1000
c1:20:300:3:0:7:0:5227:-5202:152:-177:147:23:177:350:275:0:0:1000:10439:994:4000:520
c1:22:300:3:0:10:0:5224:-5199:152:-177:147:23:180:353:274:0:0:1000:10439:994:4000:520
c1:24:300:3:0:5:0:5227:-5202:153:-178:147:23:175:356:274:0:0:1000:10439:994:4000:520
c1:24:300:3:0:8:0:5227:-5202:152:-177:147:22:177:359:274:0:0:1000:10439:994:4000:520
c1:26:300:3:0:10:0:5227:-5202:153:-178:147:23:180:362:274:0:0:1000:10439:994:4000:520
c1:28:300:3:0:7:0:5224:-5199:153:-178:147:23:177:365:275:0:0:1000:10439:994:4000:520

Fig 8 Charge Data

- The Charge Data displayed in the sequence as shown below

1. State – c1, c2, c3, cp, co, ct, cf, ci
2. Time – in Seconds
3. Cycle
4. Ch Cur – Charger Current – [A*100]
5. Bat Cur – Battery Current – [A*10]
6. BV1 – Battery Voltage 1 – [V*100]
7. BV2 – Battery Voltage 2 – [V*100]
8. BV3 – Battery Voltage 3 – [V*100]
9. BV4 – Battery Voltage 4 – [V*100]
10. BV5 – Battery Voltage 5 – [V*100]
11. BV6 – Battery Voltage 6 - [V*100]
12. BV7 – Battery Voltage 7 – [V*100]
13. BV8 – Battery Voltage 8 – [V*100]
14. Vpack – Battery Pack Voltage – [V*100]
15. T_batt – Battery Temperature – [T*10]
16. T_chg – Charger Temperature – [T*10]
17. Ahr – Ampere Hour – [Ah*100]
18. Kwhr – Kilowatt Hour – [Kwhr*100]
19. SOC – State of Charge – [%]
20. Max Dv – Maximum Deviation – [V*100]
21. Fault – Error Number
22. Iprog – Programmable Current – [A*100]
23. Vprog – Programmable Voltage – [V*100]
24. None
25. None
26. Fan TTL – Count
27. None
28. None
29. None
30. None

Equalize Data

To download the equalize data in Terminal (Desktop), follow the steps in the order given below.

- Make sure parking brake is engaged.
- Ensure control knob is in Neutral [N] mode.
- Turn startup key to OFF position and remove it from key slot.
- Connect RS232 cable from PC's serial port (COM1 or COM2, COM3…) depending on the availability of port to the EMS.
- Connect the charging cable's female end to REVA's on board charge port lid, the other end of the charging cable is plug into a 15 Amp, 220 -240V external power source.
- Open Terminal.exe.
- Follow the steps given in pagesto make settings in the Terminal software.
- Switch ON the power supply.
- Once Mains is ON, information is displayed about the company name, EMS software version, a message "Copyright RECC".

- The charge data is displayed every 2 seconds with a prefix
  C1 for phase 1,
  C2 for phase 2,
  C3 for phase3,
  cf for final phase,
  Cp for over temperature,
  Ct for over time (> 43200s) shut down,
  Co for over voltage shut down,
  Im for idle mode,
  Ci for idle phase after charge finished.

- To put the car for equalize, type **$EQU** or **$equ** command. The equalize data is displayed every 2 secs with a prefix "ce".
- The parameters in equalize data are similar to that of charge data.

Drive Data : Since it is not possible to collect the data in desktop, use Laptop to collect drive data.

- Connect RS232 cable from EMS to Laptop's serial port (COM1, COM2… depending on the availability of port.
- Open Terminal.
- Follow the steps given in pages to make settings in Terminal software.
- Switch **OFF** the power supply; disconnect the charging cable from external power source (15 Amps, 220-240V).
- Check and ensure that the Control Knob is in **Neutral [N]** mode.
- Insert the startup key and turn **ON**. Check to see that all lights on the Instrument Cluster lights up.
- Information is displayed about the company name, EMS software version, a message "Copyright RECC".
- The drive data is displayed every 2 seconds with a prefix "dd".
- The Drive Data is displayed in the sequence as shown below

1. State – dd
2. Time – in Seconds
3. Cycle – Number]
4. Ch Cur – Charger Current – [A*100]
5. Bat Cur – Battery Current – [A*10]
6. BV1 – Battery Voltage 1 – [V*100]
7. BV2 – Battery Voltage 2 – [V*100]
8. BV3 – Battery Voltage 3 – [V*100]
9. BV4 – Battery Voltage 4 – [V*100]
10. BV5 – Battery Voltage 5 – [V*100]
11. BV6 – Battery Voltage 6 - [V*100]
12. BV7 – Battery Voltage 7 – [V*100]
13. BV8 – Battery Voltage 8 – [V*100]
14. Vpack – Battery Pack Voltage – [V*100]
15. T_batt – Battery Temperature – [T*10]
16. T_chg – Charger Temperature – [T*10]
17. Ahr – Ampere Hour – [Ah*100]
18. Kwhr – Kilowatt Hour – [Kwhr*100]

19. SOC – State of Charge – [%]
20. Max Dv – Maximum Deviation – [V*100]
21. Fault – Error Number
22. Estimated State of Charge – [%]
23. Speed
24. Motor Temperature
25. Controller Temperature
26. %Throttle
27. Motor power

Calibration Data

These are the parameters, which are stored in the EMS to correct input individual Battery voltage Battery current & Charger current. And also the limit of Motor Temperature, Iprog Calibration factor, Maximum Deviation, Average Deviation and Over Voltage limit factors are stored. The Calibration parameters are stored in EEPROM.

- Connect RS232 cable from EMS to Laptop's serial port (COM1, COM2… depending on the availability of port.
- Open Terminal.
- Follow the steps given in pages to make settings in Terminal software.
- Type $RDP or $rdp to read actual stored parameters from the EEPROM.
- The Calibration parameters are displayed in the sequence as shown below

1. c_fact_BV1
2. c_fact_BV2
3. c_fact_BV3
4. c_fact_BV4
5. c_fact_BV5
6. c_fact_BV6
7. c_fact_BV7
8. c_fact_BV8
9. cs_factor
10. csos_factor
11. bs_factor
12. bsos_factor
13. Tmot_factor
14. Iprog_factor
15. Max_Dv_factor
16. Avg_Dv_factor
17. Over_Vtg_factor

To Clear Summary, Error, Reset Service Light

- Type $RSL or $rsl to Reset Service Light.
- To clear error data, which are stored in EEPROM, then type $CER or $cer command.
- To clear Summary Data, stored in EEPROM, type $CSD or $csd command.
- To clear Vehicle Information Data, stored in EEPROM, type

To Set SOC

- Note down the actual SOC. (For e.g. 700)

- Set SOC to previous noted SOC value.
  For e.g. If previous noted SOC is 700 then, type $SOC 700 or $soc 700

CHAPTER 09

PROGRAMMING THE CONTROLLER USING HAND HELD PROGRAMMER

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CHAPTER – 09

Programming Motor controller

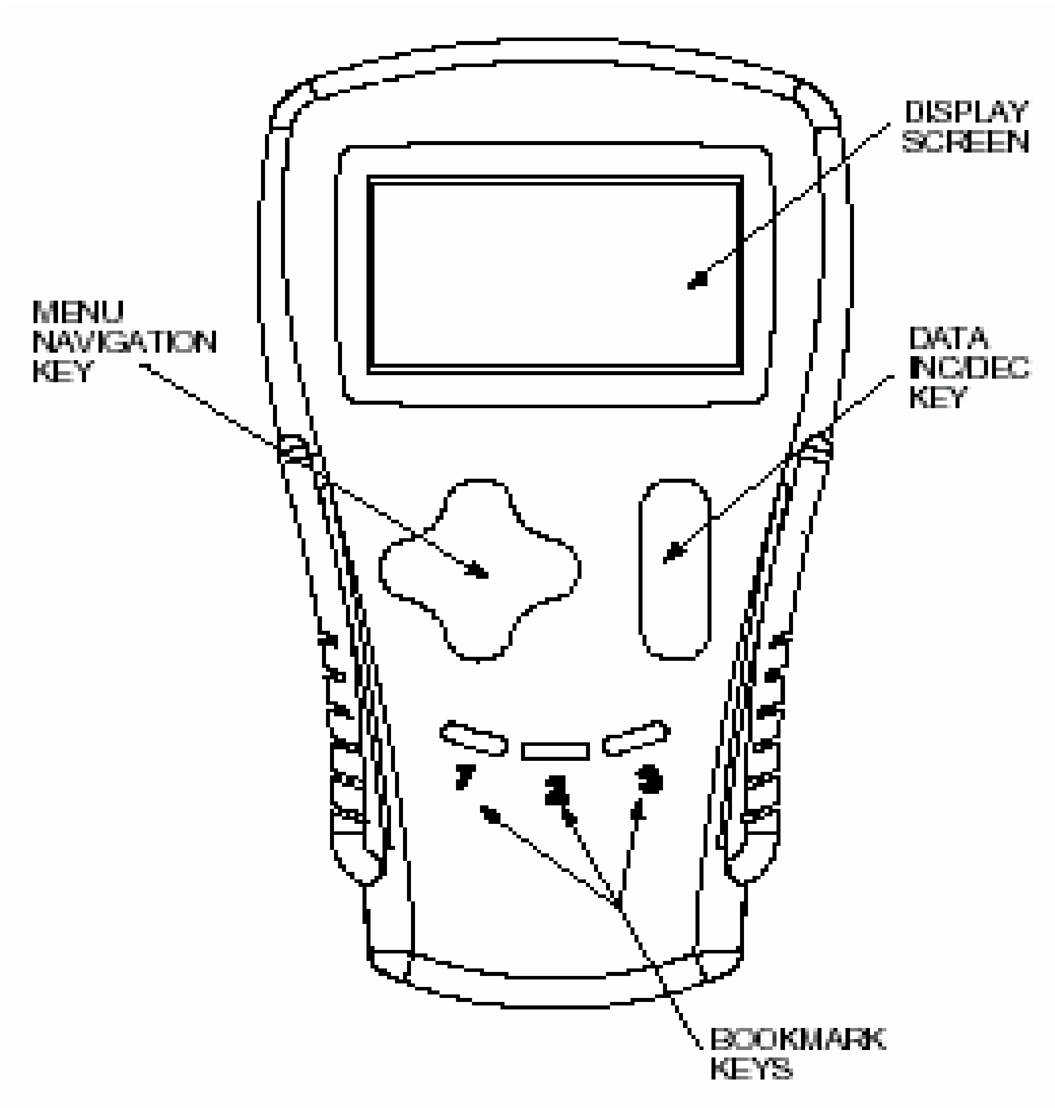
9.1 Introduction

The Curtis Model 1311 Handheld Programmer simplifies programming, Testing and diagnosing Curtis Speed Controllers and Auxiliary Devices. It provides a simple and intuitive interface to Curtis Products for Testing, Diagnosing and parameter adjustments.

Features of Hand held programmer:

- A portable tool for Programming, Testing and diagnosing
- Consists of LCD display and interactive keys
- Curtis proprietary product
- Models used : 1311
- Compatible for Reva application

Menus and programming:



Main Menu

- Program
- Monitor
- Faults
- Functions
- Information
- Programmer setup

9.2 PROCEDURE FOR REGEN BRAKE SETTING

STEP 1. Before going for REGEN Brake setting first check the mechanical brake.

STEP 2. To check mechanical brake put the Hand-Held to controller select program menu and scroll down switch "**OFF**" " BRAKE ENABLE" (initially it will be "ON").

STEP 3. Put the Car on Ramp and check the free rotation of the wheels manually.

STEP 4. If the wheels are not rotating freely than it has to be made free by adjusting the Pawl mechanism in the back plate.

STEP 5. Brake Bleeding has to be done if required.

STEP 6. Connect the Handheld and select the Program Menu switch "**ON**" BRAKE ENABLE.

STEP 7. Select Monitor menu checks the initial Brake Voltage, which should be 0.3 volts to 0.5 volts. (At Good Condition)

STEP 8. If not than Brake pot to be adjusted between 300 Ohms to 500 Ohms.

STEP 9. Check the brake pedal stopper. If not O.K than adjust it.

STEP 10. Select monitor menu, Check the initial brake voltage and note down.

STEP 11. Select program menu scroll down to "BRAKE DEAD BAND" (BDB) and set the value to 0.5 V.

STEP 12. Select program menu and scroll down to “BRAKE MAP”. Set the mapping to 50%

STEP 13. Select monitor menu and press the brake pedal at 100% Regen Brake and 30 to 40% of hydraulic brake and note down the brake voltage.

STEP 14. Select program menu, scroll down to “BRAKE MAX” Put the same value. (Normal value is 1.1volts).

STEP 15. After the Regen Brake setting take a drive test along with the Handheld

STEP 16. Drive the vehicle at a speed of 60 to 65 Kmph and apply the brake suddenly (Maximum). If the rear wheels lock suddenly and car drags, then adjust and fine tune the value of "BRAKE MAX" by 0.1 V and try again.

Following reasons may disturb the Regen Brake setting.

a) Changing of the brake pot.
b) Brake fluid leakage.
c) Changing of controller.
d) Changing of brake assembly, brake drums
e) Brake bleeding.

NOTE: Before changing the brake pot and controller note down the following values and put back the same values.

a) Initial brake voltage (0.5 V)
b) Brake Map (50%)
c) Brake Max (1.2 V)

Checklist for Regen braking and hydraulic brake adjustment

Specification		% Brake observed	OK / Not OK	Remarks
Normal pedal Position	% Brake should be zero in the Handheld/ Palm.			
Free play of brake pedal	% Brake should be zero in the Handheld/ Palm for 5 - 7 mm of pedal travel			
% brake start	Position where the Brake % starts reading in the Handheld / Palm.			
Hydraulic Brake starts	% Brake should be 75 to 85% in the Handheld / Palm.			
Hydraulic brake up to 30 to 40%	Brake % should be 100% in Handheld / Palm.			
Hard Braking (Hard pressing of brake)	Brake % should be around 30% in the Handheld / Palm.			
Check for free movement of brake pedal	Pedal should retract back and show 0% in hand held. Brake should not be hard. (If found hard loosen the brake pedal mounting bolt little and make movement free)			

9.3 THROTTLE SETTING:

- Ensure that the car is in neutral position
- For throttle setting, check the initial voltage (IV) and the throttle % in idle mode. These should be 0.4 - 0.5 V and 0% in idle mode.
- Check the brake voltage and the brake % in idle mode. This is say 0.5V (normally) and 0% in idle mode.
- For forward dead band, set it to 0.5V for the throttle forward dead band in program mode.
- For forward map, set it to 50% for linear acceleration.
- For throttle Max, Set it to 4.5V and check for reading 100% when accelerator pedal is fully pressed.
- Test mode on hand held is selected for reading the IVs and for setting the values, program mode is selected in hand held programmer.
- Standard values are 0.5V, 50% and 4.5V.

PARAMETERS FOR ACCELERATOR AND BRAKE SETTINGS					
THROTTLE					
	THROTTLE TYPE	2	1	5	
	FORWARD DEAD BAND	0.6	0	5	VOLT
	FORWARD MAP	50	0	100	%
	FORWARD MAX	3.5	0	5	VOLT
	FORWARD OFFSET	0	0	100	%
	REVERSE DEAD BAND	0.6	0	5	VOLT
	REVERSE MAP	50	0	100	%
	REVERSE MAX	3.5	0	5	VOLT
	REVERSE OFF SET	0	0	100	%
	HPD/SRO ENABLE	1	0	1	
	SEQUENCING DELAY	0.1	0	5	SECONDS
BRAKE					
	BRAKE PEDAL ENABLE	1	0	1	
	BRAKE TYPE	2	1	5	
	BRAKE DEAD BAND	0.5	0	5	VOLT
	BRAKE MAP	50	0	100	%
	BRAKE MAX	1.01	0	5	VOLT
	BRAKE OFF SET	0	0	100	%

CHAPTER 10

FIELD FIX

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CHAPTER 10

10.1 RUNNING BREAKDOWNS

To attend to the Customer problems observe the following:

- Observation with respect to the physical state.
- Physical Damages
- Fuse failures
- Unit failures
- Cable damages

1. Connect handheld
   - Go to the Program menu and note down controller parameters.
   - Go to the Test menu and note
     (a) The Throttle voltage and throttle percentage.
     (b) The Brake voltage and brake percentage.

2. Connect PET and observe the following data.
   - Vehicle information data.
   - Battery voltages
   - Error code
   - SOC
   - Avg DV
   - Calibration parameters of EMS
   - Individual battery voltages.

3. Drive Test with hand-held connected.

4. For POT SETTING use the Hand Held programmer:
   - Set throttle pot for the range 0.3 K ohms to 0.5 K ohms which corresponds to a voltage between 0.3 V to 5 V
   - Set brake pot for the range between 0.3 K ohms to 0.5 K ohms, which corresponds to a voltage between 0.3V to 1.5V.

5. PARAMETERS are to be checked against the original values and SETTING is required if the values differ from the original values:
   - Setting for Boost, Forward and Reverse mode of drive.
   - Throttle voltage and percentage setting.
   - Brake voltage and percentage setting.

6. MAINTENANCE OF BATTERIES is to be ensured by observing the following standard values:
   (a) Specific Gravity (1.275 to 1.285, when fully charged)
   (b) Watering should be done as and when required. It should be done after the battery is fully charged.
   (c) Individual battery voltages should be checked after full charge.

(d) If necessary, the battery is to be put for equalization charge (after the battery is fully charged) for 10 hours.

6. **TROUBLESHOOTING:**

(a) Vehicle is not moving:
Check the following components individually for physical and visual damages.

- Controller
- Contactor
- Motor
- Throttle potentiometer
- Brake potentiometer
- Harness
- Loose connections

(b) Vehicle moves in idle:
Check the following-

- Throttle Potentiometer.
- Check for voltage across pin numbers 16 & 18 of CN 600. The voltage should be between 4.0 to 4.5 V when throttle pedal is fully pressed.
- Ensure that there is no loose connection in crimping of pin no. 18 in CN 600.
- Replace controller, if necessary, after above checks.

(c) Vehicle stops while running:
Check the following -

- Check brake potentiometer settings.
- Check for loose connections (Pin number 18 of CN 600) & ensure that voltage across pin numbers 17 & 18 is between 1.5 to 2.0 V when pedal is fully pressed.
- Replace the controller if required after carrying out the above checks.

(d) Vehicle does not move in Reverse:
Check the following-

- Check for loose connection in pin number 33 of CN 600
- Check for loose connection in RNFB switch.
- Check for 48V across pin number 33 & Gnd with Key switch in ON position and RNFB switch in Reverse mode.
- Replace RNFB switch if necessary.
- Replace controller if necessary.

(e) Vehicle is not taking Charge:
Check the following-

- Check the charging point i.e. mains and CN41 for loose connection. Pack voltage should not be less than 42 V.
- Check availability of 230 V at CN 41. Repair charging cable if required.

- Check wires RT1, RT2, RT3 for loose connections.
- Check for an increase in voltage across positive & negative terminals of batteries with mains ON. It should be above 48V.

(f) 12 V circuit does not work.

Check the following-

- Check for 12 V across RT1 & RT2.
- Check for loose connections in the fuse box.
- Repair charger if required.

(g) Switched circuit does not work:

Check the following-

- Check the Key Relay.
- Check and correct wiring harness if required.
- Check for loose connections in Tree switch at the steering wheel.

(h) Brake light not working:

Carry out the following checks -

- Check fuse F2 and replace if required.
- Check brake light switch and replace if necessary.
- Replace the bulbs if required.

(i) Reverse light does not glow:

Carry out the following checks-

- Check the fuse F7 &and replace if required.
- Check for loose connections in RNFB switch.
- Check for loose connections in Pin number 5 of CN 12.
- Replace bulbs if required.

(k) Head light does not glow:

Carry out the following checks-

- Check the fuse F3 and replace if blown
- Check for loose connections in fuse box and the tree switch connector CN 11
- Check for loose connections of bulb holder.
- Replace head light bulbs if necessary.

(l) Side turn lights do not work

Carry out the following checks-

- Check fuse F7and replace if blown
- Check for loose connections in Tree switch CN 11 & CN 12.
- Check for loose connections in flasher.
- Replace bulbs if necessary.

(m) No response to key 'ON'

Check the following-

- Check if the car has been put for charging.
- Battery voltage should be about 48 V dc on battery positive and

negative terminals for taking the car for drive. If it is less than 44.5 V dc then it is an under-charge condition. Put the car for charging.

- If the battery voltage is drastically low then something is wrong with battery pack and its cables. Check all battery cables carefully for any sign of loose contact, overheating or burning. Check the voltage of individual batteries. There could be a faulty battery showing very less voltage.
- If 48 V dc is Ok on the battery + ve & -ve terminals than check 5 A fuse on 48 V key on line.
- With the Key 'OFF' check individually to ensure that there is no short between motor terminals with respect to ground and shield mesh.
- Switch ON the Key & check for 48V on main contactor coil terminals. There will be zero volts when key is OFF and 48 V when key is ON. If the voltage is OK but still the contactor is not changing over then isolate it and check it separately. Even then, if the contactor does not work, it means the contactor is faulty. Replace it with a new one.
- If the contactor is found to be good when isolated and checked, then there could be a problem with the motor controller. Remove the controller connector CN 600 from its slot and check for 48 V dc on its pins 1 & 13. If the voltage is present but still the problem persists the controller could be faulty. Check with CURTIS hand held unit to find out the exact cause of the problem.
- If 48 V dc is absent, then check the key switch at its input and out put. If the key switch is faulty then replace it with a good one.

(n) Key ON, the contactor responds but car does not move forward or reverse when accelerator is pressed.

<u>Car does not move:</u>

- Check if the controller connector CN 600 is fixed properly in its slot and there are no loose contacts or open wires.
- With key OFF check the cold resistance of the field windings. If it shows open circuit then problem is with the motor. This can also be verified with the CURTIS hand held unit also.
- With key OFF check individually that there is no short between motor cables and motor body or shield mesh on motor cables. If it is internal to the motor then motor is faulty. Replace it. If the short is on the controller side then controller could be faulty, find out exact cause with hand held before replacing it.
- If none of the above said faults is found then remove CN 600 from its slot, switch ON the key. Put RNFB switch in forward (F) position. Check for 48V DC on pin1, 22 of CN600. Now put RNFB switch in reverse (R) position and check for 48V DC on pins 1, 33 of CN 600. If 48V DC on the above said pins is not available, then check RNFB switch for it's I/P, its operation, any loose or open wires. Also check CN 24 related to RNFB switch.
- If the RNFB switch is Ok and the voltages are available on CN 600 then check for resistance variation between 0 – 2.5Kohm on CN 600 pins 16 & 18 when accelerator pedal is operated and on CN 600 pins 17 & 18

when brake pedal is operated fully. If there is no variation in resistance then check the potentiometer/s and related wiring/connectors.

- Despite all the above checks, if the problem still persists when CN 600 is inserted back in its slot, then the problem rests with the motor controller. Find out the exact cause of the problem with the CURTIS hand-held unit before replacing the controller.

(o) Vehicle moves in forward direction but not in reverse direction.

- Put RNFB switch in reverse direction. Take out connector CN 600 and check for 48V DC on pin 1 & pin 33. If the voltage is not observed, then check RNFB switch and its related wires, particularly CN24 (check continuity between red/black & yellow/green wires). If no continuity is found then the switch is faulty and needs replacement.
- If the voltage (as in check (I) is present on CN 600 but still the problem persists then motor controller is faulty. Check with Curtis hand-held unit to find out the exact fault before replacing controller.

(p) Vehicle moves in reverse direction but not in forward direction.

- Put RNFB switch in forward direction. Take out CN 600 and check for 48V DC on pin1 and pin 22. If the voltage is absent check RNFB switch and its related wires, particularly CN24 (Check continuity between red/black & orange/red wires). If no continuity is found then the switch is faulty and needs replacement.
- If the voltage (as in check (I) is present on CN600 but still the problem is not solved then motor controller is faulty. Check with Curtis hand-held unit to find out the exact fault before replacing the controller.

(q) Electrical brake not effective. (Vehicle stops at a longer distance when brake is applied.)

- Remove pot connection and Check for variation in resistance from 0 to 2.5Kohm between pins 17 and 18 as you vary the brake pedal position to its full range. If there is no variation in resistance, check the brake pot. Possibility is that it could be open or non-linear. Before changing the pot, ensure that the pot wiring connector CN 13 and pin terminals are all ok.
- If the potentiometer and its related wiring is Ok and you are getting resistance variation as per specification, then connect back pot connection. Check for variation in voltage from 0 to 5V dc between pins 17 and 18 as you operate the brake pedal to its full range with key ON. If there is no variation in voltage then controller could be faulty. Check up the exact cause of the problem before replacing the controller.

(r) Vehicle moves in forward and reverse direction but 12V DC systems (like head lights, horn, hazard indicators, brake lights, wiper motor etc) are not working.
12V system is totally absent.

- Check that all the 3 chassis ground connections are proper and there are no loose contacts or open wires.
- Check that 40A fuse on ground line in the rear tub is properly fitted in its holder terminals and is Ok.

- With key OFF check for 12V on charger out put. If 12V DC is absent, remove 12V wire on charger and check for 12V again on charger 12V out put. If 12V DC out put is absent then charger is faulty. Replace the charger unit.
- If 12V DC out put is present on charger (as in check third bullet) then check for the continuity between 12V wire (removed from charger 12V out put) and the common ground. It is likely that 12V line is shorted with the chassis ground. If that is the case then trace the circuit back to locate the short.
- If the charger out put is Ok and 12V DC line is not shorted with ground, then check 12V to the fuse box and key relay. The wire might have come out or there may be a loose contact.

(s) Charging does not take place when the car is put for charging.
(Voltage does not increase in E-Meter/fuel gauge. Click' sound is not heard from inside the charger when AC supply is switched ON. Charger top surface is not warm.)

- Check AC supply on charge plug. If it is Ok, check AC supply on charger connector (3 pin male). Check if the connector pins and wires are Ok on both charger and the cable.
- If the AC input to the charger is Ok (as per check) then check if the internal relay is switching over .You hear a 'click' sound when AC supply is switched ON. Also check if 12V DC, 48V DC output is available on charger. If output is absent, isolate the charger and check for output once again. If there is no out put and the internal relay is not operating, then it indicates that the charger is faulty.
- If charger gives out put voltages when isolated but does not when cables are connected then the problem lies in battery packs and its cables. Check battery cables, and individual battery voltages. One of the batteries could be faulty, causing discontinuity in the serial pack. Check for water level in the batteries also.

(t) Switched and unstitched 12V systems are not working properly
- Check if 5A fuse on 48V line in the rear tub is ok or not. If the fuse is blown, check for a short on that line with ground. If there is no short replace the fuse with new one.
- Check if key switch is working properly i.e. its input & output are OK. If not, change the key switch.
- If key switch is ok (as in second bullet) then with key switch ON check key relay input on key relay terminal 86 for 48V DC input with respect to key relay terminal 85 i.e. ground. If 48VDC is absent trace the circuit back. If 48V DC input is present but it is not switching over (can be verified by checking continuity between terminals 30 & 87) when key is made on, then key relay could be faulty. Replace it.
- If the key relay is not faulty but still the problem is there, then check the circuit from key relay 87 to the fuse box bus bar connecting F6, F7, F8, and F9.

(u) If key is OFF, no 12V systems (including head lights, horn) are working but all 12V systems start working the moment key is made ON.

- Ensure that all chassis ground connections are proper.
- Check 40A fuse on the ground line in the rear tub. There is a possibility that fuse is not fitted properly in its holder or that the fuse quality has deteriorated & is on the

brink of failure (strange but true) with low quality fuses) or that the fuse had already blown. If it is blown change it.

(v) No side turn indicators either in LH/RH or hazard mode are working.

- Remove the flasher unit from its holder. Check for 12V DC between flasher terminals B & E with LH/RH side indicator switch or hazard switch ON. If the supply is not there, trace ground connections from terminal E back. If ground is OK but still supply is absent trace the circuit from terminal B till tree switch connector CN11 pin6. See if the connector is fixed properly. IF the supply is absent still, then remove CN11 and check for 12VDC on pin6 on tree switch side. If 12V DC is absent there also, then it indicates that tree switch is problematic. Replace it.
- If all the connectors/connections are proper (as per check 1) and 12V DC is available on flasher B terminal with respect to terminal E, and still the indicators are not working then flasher unit is faulty. Replace it with new one.

(w) <u>Indicators work in hazard mode only. Individual LH & RH side turn indicators are not working</u>.

- Check if fuse F7 (10 A) is blown. If yes, then check for a short between supply & ground on that line. If a short is found trace the circuit & rectify it. If the short is not found then replace the fuse with new one & check for 12 V dc.
- If 12 V is Ok, then check tree switch CN11 pin 4 for 12V on both sides of the connector. If supply is OK but the problem still persists, then tree switch could be faulty. Replace it.

(x) Head lights are not working totally or are partia lly working (only low/high beam). All other 12V system works normally.

- Check if bulbs are ok & replace if necessary.
- If the bulbs are OK but still the lights do not work then check the wires & terminals of holders for any loose contacts or open wires.
- Check for 12V supply on the holder on green wire wrt Red wire (for low beam) & wrt yellow wire for high beam wrt chassis ground.
- If supply (as in above check) is present wrt chassis ground but not wrt the other two wires, then the problem is with the tree switch or its connectors CN10, CN11. Fix both the connectors properly. Verify ground on CN10 pin 5. If it is OK then the problem is with the tree switch. Replacing the tree switch could solve the problem.
- If 12V dc supply on head light holder (as in check above) is absent then check fuse F3 (15 A) in the fuse box. If it is blown try to find out if there is any short between supply line & ground. If there is any short found trace the circuit & rectify it. If there is no short then replace the fuse with a new one.

(y) High beam to low beam change over is not happening in head lights.
Head lights work in either hi beam or low beam only.

- Check if head light bulbs are ok. If not change the bulbs.
- Check for 12 V dc supply on bulb holders.
- Check if the terminals have come out in CN 11, pins 7 & 8 or any loose contacts or open wires are visible.
- If the problem is still not solved then tree switch could be faulty. Replace it.

(z) Front & Rear drive lights are not working totally or partially. All other 12V systems are working.

- Check fuse F5 (10A) in fuse box. If it is blown, check for a possible short between supply line and the ground. If the short is found trace the circuit and rectify it. If there is no short then replace the fuse with new one and check for 12V at the fuse point.

CHAPTER 11

AIR CONDITIONING SYSTEM

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CHAPTER 11

AIR CONDITIONING SYSTEM

11.1 Introduction

- AC in a vehicle is used to bring down the cabin temperature, there by providing high level of comfort to the occupants.
- The principle used is Vapour compression by mechanical means.
- The compressed gas is cooled to ambient temperature and is then made to cool the cabin through the evaporator.
- The AC system will consists of following parts:
- **Compressor:** draws the refrigerant and compresses it. This process will increase the temperature and pressure of the refrigerant. The gas drawn will be compressed to a pressure of 14.1kg/c$m^{2.}$
- **Condenser:** helps in bringing down the temperature of the compressed refrigerant and thereby converting it into liquid.
- **Receiver:** removes moisture and filters out the dirt in the system. It also serves as a reservoir to store refrigerant
- **Expansion Valve**: Controls the flow of refrigerant into evaporator cores, there by reducing the temperature and pressure of the refrigerant.
- **Evaporator:** Here the refrigerant expands inside the evaporator tubes and removes the heat from the cabin there by reducing the cabin temperature.
- Since a dedicated PMDC motor drives the compressor, performance of the AC system remains unaffected irrespective of the vehicle speed.
- AC system has following control components:
- **Thermostat Switch**: It is a temperature sensing device which senses the temperature of air discharge from the evaporator. This will cut off when the temperature goes below the low limit and above the upper limit.
- Operating pressure of this switch is OFF – 27 kg/cm^2, ON – 21-kg/ cm^2.
- **Dual Pressure Switch**: This avoids the bursting of the components like pipes, hose etc. This senses any abnormal rise in pressure due to over temperature & high refrigerant level or low pressure due to leakage or lack of refrigerant.
- **PMDC Motor**: This drives the compressor. It draws the power from the battery pack and houses permanent magnets inside the stator instead of field winding.

- **Relays:** Following are the relays used –

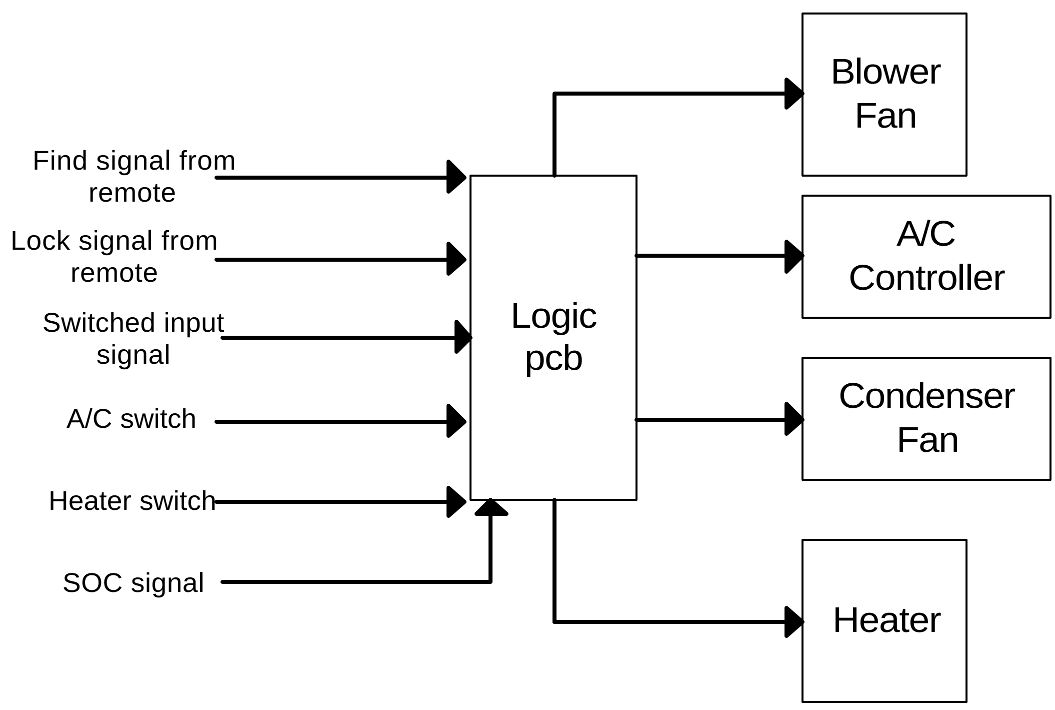
- **A/C relay (R1):** Provides 48V supply to A/C system. This cuts off when the SOC is less than 25%. Motor runs on this supply.

- **Remote Relay (R2):** This relay functions when the A/C system is selected with remote operation. This also provides 12V supply to the RC-Delay relay and runs the blower at 4th speed.

- **Condenser Fan Relay (R3):** This relay connects 48V supply to the condenser fan. This relay operates in both manual and remote mode.
- RC Delay relay: This is used to avoid the circulating current. When selected in remote mode gets 12V supply from R2 relay.

- Relay AC and Heater Inter lock: This relay is used to prevent both AC and Heater coming on instantly.

Block Diagram of REVA A/C system



Air conditioning in REVA provides following options. (However **Classe** models will have **all the 3 modes** by default)

1. **A/C with cooling**: Motor drives the compressor in this mode. A 48V-condenser fan is used to reduce the temperature of the compressed gas. Blower fan pumps the cooled air in to the cabin through the evaporator grills.

2. **A/C with Heating:** A 48V-heater coil is placed in the blower fan assembly to provide warm air in the cabin. Heater comes ON when the blower switch is pulled.

3. **A/C with heating and cooling:** This mode provides both heating and cooling effect at a time by running motor, condenser and heater. This mode can be selected either manually or remote.

11.2 Modes of operation:

Manual Mode: In manual mode turn on the key switch, blower and A/C Vero Knob. Both cooling and heating is available by choosing both A/C and heater switch. If any one of the switches goes off, A/C will be put off.

Remote Mode: In remote mode Press
L for locking the door and turning off the A/C
C for turning on A/C
U for unlocking the door.

A logic controller will govern the working of the A/C system. It has a 12-pin connector through which it receives and sends the data. It is as shown below.

Pin No.	Description
1	Active low GND signal to the R1 relay.
2	Active low GND signal to the R2 relay.
3	12V UN switched supply
4	Ground
5	12V signal coming through thermostat. It gives active high when A/C starts functioning
6	Blower 4th position voltage level.
7	Signal coming from CDL unit. When "C" is selected, this pin has to give Continuous 2V DC pulses for 30sec's
8	A door signal coming from CDL unit by pressing "L" button on remote. This is a 12 V pulses for duration of less than 1 sec's.
9	This is a SOC signal tapped from SOC signal indicator ling going to EMS. If SOC is less than 25%, A/C will be off.
10	Not used
11	12 V supply (Switched).
12	12 V signal from key switch.

11.3 Specifications of A/C system:

For AC controller:

Input Voltage: 42V min and 65V max.
Input Current: 23A nominal

Output Voltage: 42V min and 65V max.
Output Current: 23A nominal.
Over current trip protection

Other specifications:

- Cooling system by mechanical vapour compression
- Refrigerant – HFC 134A, a non explosive and non toxic chemical
- Cabin temperature drops by 6 degrees in 10 minutes and 10 degrees in 25 minute
- Power consumption – 1200W (instantaneous)
- Range reduction – 20 kms (approximate)
- Cuts off – Dual pressure, low battery and thermostat
- PMDC motor drives compressor with a speed of 3000 rpm

11.4 Checks on A/C system:

1. If V-belt is loose or torn, replace the belt. Alignment of the compressor and motor pulley should be proper. Otherwise misalignment will generate lot of noise in the AC system.
2. If there is noise around the compressor check the mounting bolts and nuts, and tighten them if found loose.
3. Check for mud and dirt deposition of the condenser fins. Clean the fin carefully otherwise cooling effect will be declined.
4. Check the quantity of the refrigerant through the sight glass. It should be 530 gms. If low, bring it to the proper level. Also check for leakage of the refrigerant through pipes and joints. If leakage found, tighten/replace the related parts to prevent further damage.

11.5 Do's and Don'ts

Do's:

Clean condenser during regular service of the vehicle.
Maintain proper refrigerant level. Use only recommended refrigerant.
Clean evaporator periodically to remove dust and foreign particles.
Check for belt tension.

Don'ts:

Do not operate without refrigerant in the A/C system.
Do not leave A/C joints open which otherwise results in dust entry & leakage.
Do not charge the refrigerant without proper vacuum.

CHAPTER 12

SUSPENSIONS IN REVA

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CHAPTER 12

SUSPENSIONS IN REVA

12.1 INTRODUCTION:

The automobile chassis is mounted on the axles, not direct but through some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the parts, which perform the function of isolating the automobile from the road shocks, are collectively called a suspension system. It includes the springing device used and various mountings for the same.

Broadly speaking, suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper, which is more commonly called a shock absorber.

12.2 OBJECTIVES OF SUSPENSION:

- To prevent the road shocks from being transmitted to the vehicle components.
- To safeguard the occupants from road shocks.
- To preserve the stability of the vehicle in pitching or rolling, while in motion.

12.3 FRONT SUSPENSION SYSTEMS:

The front suspension system allows the front wheels to move up and down and absorb road shakes. But the system must also allow the front wheels to swing from side to side so that the car can be steered.

Different types of suspension are in use for the front axle. In Reva, we use the **Mac Pherson Strut Type** (refer figs 1).

In this suspension the lower end fits into an upright while the upper end rests in a spring tower chassis in the front end of the body.

The Strut carries the wheel spindle. As the wheel meet holes or bumps on the road, the spring expands or compresses to allow the wheel to move up or down. This type of suspension is commonly being used in Maruti and other cars, and now on Reva.

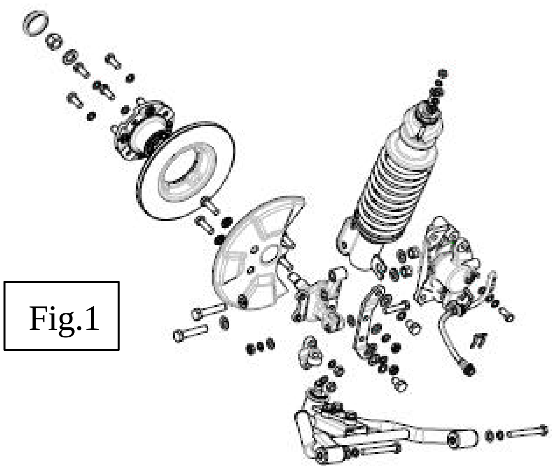

Fig.1

12.4 REAR SUSPENSION SYSTEMS:

The Reva car uses a coil spring rear suspension system. Here there is a coil spring at each wheel. The wheels are allowed to move up and down, compressing and expanding the springs.

The coil springs are located between the bracket fitted to the trailing arm and the chassis frame (as shown in fig 3). Coil springs do not have noise problems, nor do they have static friction causing harshness of ride as in case of leaf springs. The spring takes the shear as well as bending stresses. It also has 'Pan Hard' rod to take the rolling stress while on sharp turns or on uneven ground when one wheel goes up and the other wheel goes down.

For removal, inspection and replacement of suspensions refer service manual.

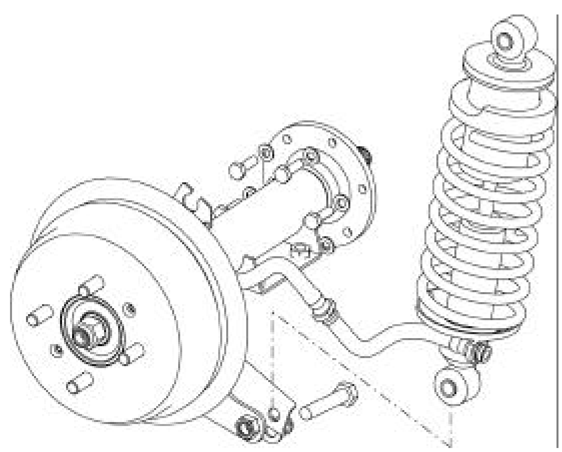

Fig.3

CHAPTER 13

STEERING MECHANISM

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CHAPTER 13

STEERING MECHANISM IN REVA

13.1 INTRODUCTION:

The steering of a four wheeled vehicle is, as far as possible, arranged so that the front wheels will roll truly without any lateral slip. The front wheels are supported on front axle so that they can swing to the left or right for steering. The movement is produced by gearing and linkage between the steering wheel in front of the driver and the steering arm or wheel. The complete arrangement is called the steering system. The steering system includes the steering wheel which the driver controls the steering ears which changes the rotary motion of the wheel into straight line motion and the steering linkages (Fig 1)

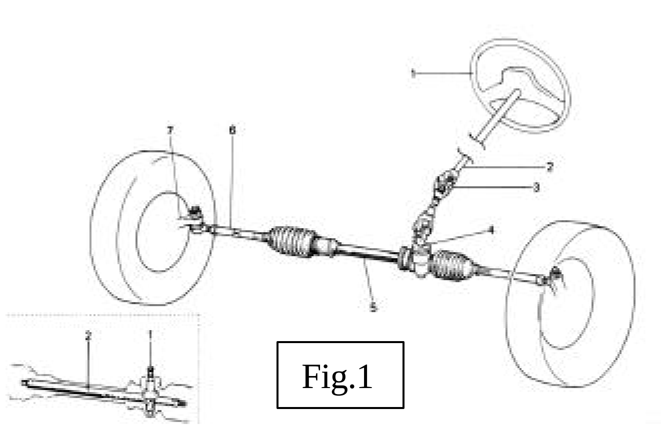


Fig.1

The function of the steering system is to convert the rotary movement of the steering wheel into angular tern of the front wheels. The steering system also absorbs a large part of the road shocks, thus preventing them from being transmitted to the driver.

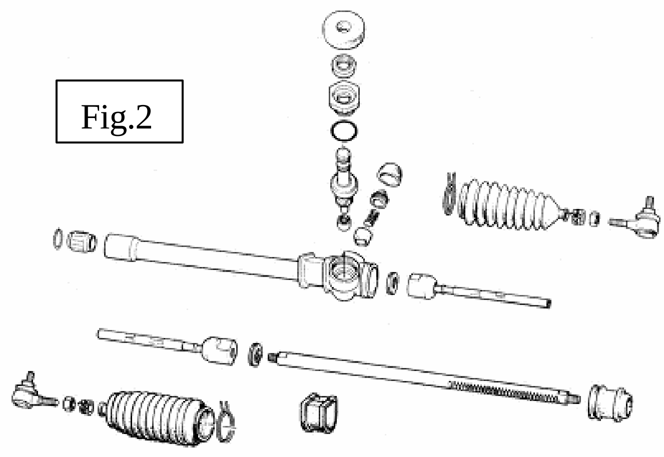
13.2 STEERING GEARS:

If the steering wheel is connected directly to the steering linkage, it would require a great effort to move the front wheels. Therefore, to assist the driver a reduction system is used. Hence the purpose of the steering gears is to convert the rotary motion of the steering wheel into straight line motion of the linkage with a mechanical advantage. The steering gears are enclosed in a box, called the 'STEERING GEAR BOX'

There are many different designs of the steering gear box. In Reva we use the 'Rack & Pinion' type of gear box as shown in fig. 2.

The rack and pinion steering gear has become increasingly popular for today's smaller cars. It is simpler, more direct acting, and may be straight mechanical or power-assisted operation. The figure shows a complete rack and pinion steering system. As the steering wheel and shaft are turned, the rack moves from one side to the others. This pushes or pulls on the tie rods, forcing the wheel spindles to pivot on their ball joints. This turns the wheels to one side or the other so that the car is steered.

Fig.2



13.3 STEERING GEAR RATIO:

The steering gear ratio or reduction ratio has been defined as the number of turns on the steering wheel required to produce one turn of steering gear rack to which the tie rod is attached. Since the cross shaft turns much less than a completed rotation in operation, the steering gear ratio can also be defined as the ratio between the number of degree of rotation of the steering wheel and number of degrees through which the cross shaft is made to rotate at the same time. This ratio varies between 14:1 and 24: 1 in passenger cars without power steering. The vehicles equipped with power steering have this ratio about 20% less than vehicles with manual steering. The steering gear ratio is generally low for small, light cars and high for large cars. The low steering gear ratios produce fast steering while high ratios produce slow steering. Many steering gears have a variable gear ratio, which is higher for the straight ahead range and lower for the outer range. It is obtained by varying the pitch of the worm or cam so that it is flatter at the center.

Since the steering linkage also provides a mechanical advantage or leverage, the front wheels turn through a smaller angle than the cross shaft and the resultant ratio called the overall steering ratio is obtained. The overall steering ratio has been defined as the ratio between the number of degrees through which the steering wheel is turned and the number of degrees through which the front wheels turn. The ratio is generally from 15 to 20% higher than the steering gear ratio in both manual and power steering.

13.4 TURNING RADIUS:

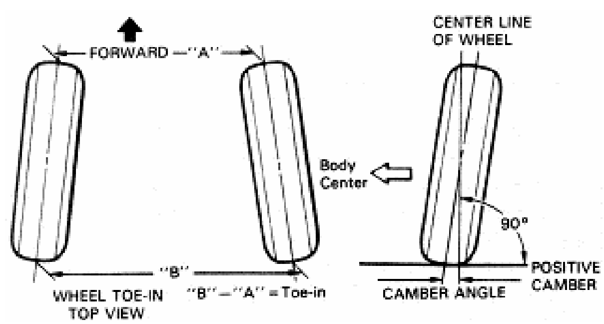
Turning radius is the radius of the circle on which the outside front wheel moves when the front wheels are turned to their extreme outer position. This radius is 5 to 7.5m for buses and trucks. The turning radius is usually proportional to the wheel base of the car, because the maximum rotation of the steering arm is seldom more than 35 degrees. In Reva cars, the wheel base is 1.71m and the turning radius is 3.80m.

13.5 STEERING GEOMETRY:

- **Camber**

The angle between the center line of the tyre and the vertical line when viewed from the front of the vehicle is known as camber as shown in fig 5. When the angle is outward, so that the wheels are farther apart at the top than at the bottom, the camber is positive. When the angle is inward, so that the wheels are closer together at the top than at the bottom, the camber is negative. Any amount of camber, positive or negative, tends to cause uneven or more tyre wear on one side that on the other side. Camber should not exceed 2º.

The front wheels are not usually mounted parallel to each other, but are fitted outward slightly at the top and inward at the bottom to have positive camber. The purpose of the camber is to prevent the top of the wheels from tilting inward too much because of excessive loads or play in the king pins and wheel bearing. When the vehicle is loaded and rolling along on the road, the load will just about bring the wheels to a vertical position. On vehicles having negative camber the opposite is true.



Excessive camber prevents the tyre from having correct contact with the road, which causes it to wear only on the side directly beneath the load. Unequal camber causes vehicle to roll in the direction of the wheel having greater camber, which upsets directional stability and tends to scuff the tread on the opposite tyre. Camber on Reva cars is set between 0.5º to 1.0º.

- **King-pin Inclination or Steering Axle Inclination**

The angle between the vertical line and center of the king pin or steering axle, when viewed from the front of the vehicle is, known as king pin inclination or steering axle inclination as shown in fig 5. The king pin inclination in combination with caster is used to provide directional stability in modern cars, by tending to return the wheels to the straight-ahead position after any turn. It also reduces steering effort particularly when the vehicle is stationary. It reduces tyre wear also. The king pin inclination is modern vehicle range from 4 to 8 degrees. It must be equal on both the sides. If it is greater on one side than the other, the vehicle will tend to pull to the side having the greater angle. Also, if the angle is too large, the steering will become exceedingly difficult. The king pin inclination in Reva car is fixed at 14.01º and is not adjustable.

- **Included Angle**

The combined chamber and king-pin inclination is called the included angle. The angle is important because it determines the point of intersection of the wheel and the kingpin centerlines. This, in turn determines whether the wheel will tend to toe-out or toe in. If the point of intersection is above the ground, the wheel tends to toe-in. If it is below the ground, the wheel tends to toe-out. If it is at the ground, the wheel keeps its straight position without any tendency to toe-in or toe-out. In this position the steering is called center point steering, refer to fig 4.

- **Caster**

In addition to being tilted inward toward the center of the vehicle, the king pin axis may also be tilted forward or backward from the vertical line. This tilt is known as caster as shown in fig.5. Thus, the angle between the vertical line and the king pin center line in the plane of the wheel (when viewed from the side) is called the caster angle. When the top of the king pin is backward, the caster angle is positive, and when it is forward the caster angle is negative. The caster angle in modern vehicles ranges from 2 to 8 degrees.

The caster produces directional stability by causing the wheels to lead or follow in the same direction as the vehicle travels. When both the front wheels have positive caster the vehicle tends to roll out or lean out on turns. But if the front wheels have negative caster, then the vehicle tends to back or lean in on turns. There is another important effect of the caster angle. Positive caster tries to make the front wheels toe-in. With positive caster, the vehicle is lowered as the wheels pivots inward. Thus, the weight of the vehicle is always trying to make the wheel toe-in with negative caster; the wheels would try to toe-out. The positive caster increases the effort required to steer and tries to keep the wheels straight ahead. In the heavy-duty trucks negative caster is provided. This makes steering easier. Caster in Reva cars is fixed at 10º and is not adjustable.

- **Toe-in and Toe-out**

The front wheels are usually turned in slightly in front so that the distance between the front ends A is slightly less than the distance between the back ends B, when viewed from the top. The difference between these distances is called toe in as shown in fig.6. On a car with toe-in, the distance between the front wheels is less at the front (A) than at the rear (B), when viewed from the top. The amount of toe-in is usually 3 to 5mm. The toe-in is provided to ensure parallel rolling of the front wheels, to stabilize steering and prevent side slipping and excessive tyre wear. It also serves to offset the small deflections in the wheel-support system which comes out when the car is moving forward. Although the wheels are set to toe-in slightly when the car is standing still, they tend to roll parallel on the road when the car is moving forward. Some alignment specialists set the front wheels in “straight away alignment” in preference to “toe-in adjustment”. Toe-in in Reva cars is 1.0 mm.

Toe-out is the difference in angles between the two front wheels and the car frame during turns. The steering system is designed to turn the inside wheel through a larger angle than the outside wheel when making a turn. This condition causes the wheels to toe-out on turns, due to the difference in their turning angles. When the car is taking a turn, the outer wheels rolls on a large radius than the inner wheel, and the circles on which the two front wheels must roll are concentric. Therefore, the inner wheel must make a larger angle with the car frame than that the outer wheel makes. As shown in fig 6, when the front wheels are steered to make a turn, the inner wheel turns to an angle of 23^o with the car frame, while the outer wheel turns only 20^o with the car frame.

13.6 REVERSIBLE AND IRREVERSIBLE STEERING:

When deflection of the steered wheels due to road surface is transmitted through the steering linkage and steering gear box to the steering wheel, the system is said to be reversible. If every small imperfection of the road surface causes the steering wheel to rotate, the driver would find much tiring and frustrating. Such reversibility is not desired. Some degree of reversibility is desired so that the wheels will find to straighten up after negotiating a bend. Some degree of irreversibility is desired to stop shocks sustained by the road wheels. Such a steering system is known as semi-reversible. When the steered wheels do not transfer any deflec tion to the steering wheel, the steering system is said to be irreversible. It would not tend to straighten out after negotiating a turn, and would not easily follow the course of a rutted road without undue stress on the mechanism. Therefore, in most of the passenger cars semi-reversible steering gears are used.

13.7 UNDERSTEERING AND OVERSTEERING:

While taking a turn, the wheels are not always pointing in direction in which the vehicle is moving, due to the distortion of tyre tread. The angle between the wheel inclination and the path taken by the wheel is known as slip angle. When the angle is greater at the rear than at the front, the vehicle tends to over steer, than is to turn into the curve more that the driver intended.

When the slip angle is smaller at the rear than at the front, the vehicle tends to under steer. Of course, the under steer is opposite to over steer and is preferred because correction by the driver involves rotating the steering wheel a little more in the direction of the tu rn. It is to be noted that
the slip angle is affected by the road camber, side winds, tyre inflation and variations in the load on either the front or rear axle.

13.8 WHEEL ALIGNMENT:

The wheel alignment refers to the positioning of the front wheels and steering mechanism that gives the vehicle directional stability, promotes case of steering and reduces tire wear to a minimum. A vehicle is said to have directional stability or control if it can run straight down a road, enter and leave a turn easily and resist road shocks. The front wheel alignment depends upon the following terms –

camber, caster, king pin inclination toe-in and toe-out on turns. The front wheel geometry or steering geometry refers to the angular relationship between the front wheels, the front wheels, the front wheel attaching parts and the car frame. All the above terms are included in the front wheel geometry. There are many types of wheel aligns. Some are mechanical types that attach to the wheel spindles fig 9. Some have light beams that display the measurements on a screen in front of the car. Others are electronic that indicate the measurements on meters, displays, or printouts.

When doing a front-wheel alignment, you check and adjust (if needed) caster, camber, and toe. You also measure SAI and turning radius. These are not adjustable. If they are out of specifications, it means parts are bent or damaged and must be replaced. However, before you make the alignment checks, the following pre-alignment inspection must first be made.

- Check and correct tyre pressure
- Check and adjust wheel bearings.
- Check and adjust wheel run-out.
- Check ball joints and, if they are too loose, replace them.
- Check steering linkages, and make any corrections necessary.
- Check wheel balance, and correct it if necessary.
- Check front suspension height.
- Check shock absorbers, and replace them if they are defective.
- Check wheel tracking. This means checking whether the rear wheels follow the front wheels or is off the track. If the wheels are off the track, it usually means a bent frame. The frame must be straightened before you can do a wheel alignment.
  Wheel alignment on Reva cars at the plant is done by using a Smart Infrared wheel alignment machine. The dealers can have the wheel alignment facility at the service center or have a tie up with another agency doing the wheel alignment.

13.9 ADJUSTING THE CAMBER ANGLE

- Adjust the camber angle to (0º 20'-40').
- These is done by loosening the camber plate bolts and then slide the strut by tapping lightly, till the required amount of angle displayed on the monitor.
- Repeat the same for both the struts and adjust the camber angle.
- After adjusting, tighten the camber plate bolts lightly.

13.10 ADJUSTING THE TOE-IN

- The toe-in is adjusted by turning the tie-rod end adjusting nuts on both the sides.
- The value of front toe partial is adjusted to either between (0º 75'to 1º 25').
- After adjusting to correct values, tighten the lock nut next to it firmly.
- Retighten the camber plate bolt giving a torque of 20 NM.

13.11 STEERING TROUBLE SHOOTING

The common faults occurring in the steering systems are discussed below along with their remedies.

1. **Excessive Backlash in Steering**
   The most probable cause of this trouble is the slackness in the steering linkage due to wear of ball joints and the steering box. Check these and rectify as required. If the slackness is not present, then the fault may be any of the following:

- Steering gear box may be loose in chassis frame which can be tightened.
- Steering drop arm may be loose on splines. The damaged part has to be replaced.
- The bearings at the front wheel stub axle may be loose or worn. They should be tightened or replaced as required.
- The adjustment of the steering gear or linkage may not be proper, which may be done correctly.

2. **Wander**
   When the vehicle is being driven straight, it turns slightly to one side and then when the driver turns the steering to bring it back to the straight ahead, it turns slightly to the other side. Thus the driver has to adjust steering constantly to keep the vehicle direction straight. The defect is called wander. It may be caused due to any one or more of the following:

- The tyre pressures on two sides may not be equal, which may be checked and corrected.
- Tyres may be badly worn. Install new tyres and check wheel alignment which may require resetting.
- The bearing of steering knuckle arm may be tight which may be corrected.
- The front wheel bearings may be worn out. If so, the same ought to be replaced.
- The car may be simply overloaded at the rear.
- The toe-in may be incorrect, which can be reset by adjusting tie-rod length.
- The ends of tie rod, the spring U-bolts or the steering gear mountings may be loose, which may be tightened.

3. **Pulling to one side.**
   Sometimes the vehicle constantly pulls towards one side. This may be due to one more of the following causes:

- The tyre pressures may be uneven which should be checked and corrected if necessary. Steering pulls to the side having low air pressure.
- The worn out tyres may also be source of this trouble which may be replaced.
- Some of the brakes may be dragging, which can be adjusted.
- The camber may have changed due to wearing of bushes or any damage to front suspension. The vehicle pulls to the side of axle having greater camber. The damaged part in such a case has to be replaced and camber readjusted.
- Alignment of front wheels may be incorrect, which should be adjusted correctly.
- The front wheel bearings may be tight, which may be adjusted as required.
- The suspension spring may be broken, which has to be replaced.

- The stiffness of the front springs may have become uneven with use. The only remedy is to replace both the springs.

- Spring tie bolts may have broken. Replacement is the only solution.

4. Wheel Wobble (Low Speed Shimmy)

The oscillation of the front wheels at low speeds is called wheel wobble. This is generally due to dynamic unbalance of the wheel assembly, which may have developed due to following reasons:

- Tyres may have worn unevenly, which should be replaced.

But apart from these there are other reasons also:

- The tyre pressure may be uneven. The same can be remedied by inflating the tyres to the specified pressure.
- The ball joints may have worn out, which should be replaced.
- Steering gear or wheel bearings may be loose which can be adjusted or replaced as required.
- The stiffness of the springs may be less.
- The camber may be incorrect or uneven, which may be suitably adjusted.
- The castor may have become excessive due to wear of bushes or damage to front suspension. The damaged parts in such a case have to be replaced.

5. High Speed Shimmy

The oscillation of the front wheels at high speed is called high speed shimmy. Apart from the dynamic unbalance, the following factors may cause this trouble:

- Wheel rim may be buckled, which can be straightened or replaced as required.
- Front tyres may be having uneven pressure, which may be inflated correctly.
- The bearings of front wheels may have worn out or otherwise loose. If so, the same have to be replaced.
- Hydraulic shock absorber may be faulty. The only solution in such a case is the replacement.
- The toe-in of front wheels may not be correct, which can be reset.

6. Wheel Tramp

Sometimes the front wheels of vehicle at high speeds vibrate so violently that an almost uncontrollable motion of the front portion of the vehicle is caused. That is called wheel tramp and it may be due to any or more of the following reasons:

- The tyre pressure in the wheels may be unequal, which may be checked and adjusted if required.
- The wheel assembly may not be balanced dynamically, which should be taken out and balanced.
- The front shock absorber may be defective, which has to be replaced.

7. Excessive Tyre Wear

The probable main reasons for excessive wear of the tyres are given below. For detailed discussion on his, refer Art 13, Chapter 8.

- Tyre pressure may not be correct, which may be checked and corrected if necessary.
- Excessive toe-in or toe-out. These may be checked and reset if necessary.
- Excessive camber, which may have developed due to wear of wheel bearings or some damage to front suspension system. The damaged part should be replaced.
- The brakes may be dragging, which can be readjusted.

8. Hard Steering

When the effort required for steering is more than the normal it may be due to any or more of the following reasons:

- Tyre pressure may be too low, which can be tested and corrected if necessary.
- Excessive caster may be there, which should be adjusted properly.
- There may be excessive friction in the steering gear box or linkage or ball joints.
- Steering gear adjusted too tightly or binding condition in steering column. Adjust steering gear and align steering column.
- Incorrect wheel alignment, which may be checked and corrected as required.

9. Poor Return ability

Poor return of the steering wheel to center may b e due to the following reasons:

- Tyre pressure may not be correct. Inflate to the specified value.
- Steering gear to column misalignment. Align the steering column.
- Tight or frozen steering shaft bearings which will have to be replaced.
- Tight steering linkage. If required, the defective pivots may be replaced.

13.12 REMOVAL AND INSPECTION

Refer service manual

CHAPTER 14

POWER TRAIN

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CHAPTER 14

POWER TRAIN

14.1 INTRODUCTION

The power train in REVA comprises of the AC Motor, Transmission, which includes the differential, rear axles and wheels.

14.2 TRANSMISSION

The transmission-input shaft coupling receives drive from the motor. The input shaft then drives the intermediate gear by the external meshing of the helical gears on the input shaft and the intermediate shaft.

A second reduction takes place by the gear No.2 on the intermediate shaft and the mother gear / crown gear. Thus there is double reduction taking place in the transmission, thereby reducing the speed and increasing the torque.

Gear ratio between input gear and intermediate gear

is $G_1 = \frac{\text{No. of teeth on driven gear}}{\text{No. of teeth on driver gear}}$

$G_1 = \frac{58}{19}$ => G1 = 3.053

Gear ratio between intermediate gear and mother gear

is G_2 = 74 /24 => G2 = 3.083

÷ the total gear ratio or torque multiplication that takes place in the transmission is G = G1 x G_2 = 9.41 => G = 9.4

14.3 DIFFERENTIAL

If a car travels in a straight line, the 2 rear wheels turn on the road exactly at the same speed. There is no relative movement between the 2 rear wheels. But when the car takes a turn as shown in fig.2 the outer wheel travels on a longer radius than the inner wheel. The outer wheel turns faster than the inner wheel; that is, there is a relative movement between the two rear wheels. If the two rear wheels are rigidly fixed to a rear axle the inner wheel will slip which will cause rapid tyre wear, steering difficulties and poor road holding. Therefore, there must be some devices to provide relative movement to the two rear wheels when the car is taking a turn. The differential serves this purpose.

The purpose of the differential is thus to provide the relative movement to the two rear wheels when the car is taking a turn. The torque transmitted to each wheel is however, always equal.

CONSTRUCTION

Fig. (3) shows the construction of a simple differential. Planet pinions are mounted on the inner end of each axle (called the half shaft).

A differential cage is assembled with 4 planet pinions (called the differential pinion gears). A mother / Crown gear is attached to the cage, so that the cage rotates with the crown gear. The crown gear in turn is driven by the gear no.2 mounted on the intermediate shaft.

Now, when the car is driving straight, the cage rotates, as a unit (i.e. there will be no relative movement between the planet pinions). However, when a car takes a turn, there is greater road resistance to the inner wheel thereby tending to hold it stationary. This will result in relative movement between the planet pinions thereby transmitting more rotary motion to one rear wheel than to the other.

14.4 REAL AXLES

In between the differential and the driving wheels is the rear axle to transmit power from the differential to the driving wheels. It is clear from the construction of the differential, that the rear axle is not a single piece, but it is in two halves connected by the differential, one part is known as half shaft. Inner end of the half shaft is connected to the sun gear of the differential, and the outer end of the driving wheel. In rear wheel drive vehicles, the rear wheels are the driving wheels, whereas in front wheel drive vehicles, the front wheels are the driving wheels. Almost all rear axles on modern passenger cars are live axles; that is, they revolve with the wheels. Dead axles simply remain stationary; do not move with the wheels. Housing completely encloses the rear axles and the differential, protecting them from water, dust and injury, in addition to mounting their inner bearings and providing a container for the lubricant.

14.5 LOADS ON A REAR AXLE

When the wheels have plain bearings on the axle casing, the rear shafts merely transmit the driving torque from the differential to the wheels. But this is not always so. The shafts sometimes play as essential part to support the axle casing and thus the weight of the body. The vertical load, which comes on to the axle casing, through the springs, is transmitted through these bearings to the shafts and hence through the wheels to the ground. The reaction of this load between the wheel and the ground act upward on the wheel.

This force has a tendency to bend the overhanging part of the shaft, as at (a) and the shear it as at (b) in Fig.4. Again, if a side forces acts upon wheel due to any reaction, it will tend to push the shaft into the axle casing. The thrust bearing situated at the center of the axle resists this tendency. If the force acts outwards the end thrust becomes a pull. The force tends to bend the hanging part of the axle, as at (c).

Therefore, it is concluded that, depending upon the arrangement of the bearings the rear axle or the axle casing must support:

- The total rear weight of the vehicle, causing both bending and shearing action.
- Side thrust on the wheels when cornering, which imposes bending load and an end thrust or a pull.
- Driving torque.

14.6 TYPES OF REAR AXLES

Depending upon the methods of supporting the rear axles and mounting the rear wheels, the rear axles are of the three types:

- Semi-floating axle
- Full floating axle
- Three quarter floating axle, In REVA, we use a semi-floating axle

14.7 SEMI FLOATING AXLE

A semi-floating axle has a bearing located on the axle and inside the axle casing. It has to support all the loads as listed above. For the same torque output, than any other type. The differential side gear supports the inner end of the axle. It is thus relieved of the job of supporting the weight of the car by the axle housing. The outer end has to support the weight of the car and take end thrust. The inner end of the axle is splinted to the differential side gear. The outer end is flanged so that the wheel can be bolted directly to it. In some designs, the hub of the wheel is keyed to the outer end of the axle. The vehicle load is transmitted to the axle through the casing and the bearing, which causes the bending or shearing of the axle. The semi-floating axle is the simplest and cheapest of all other types and widely used on cars.

14.8 TRANSMISSION BREATHER

The heat generated by the gears causes to expand the air in the transmission. It will also increase the oil pressure. To maintain oil pressure in the transmission within limits so that the oil is not forced out past the oil seal, an axle breather is provided in the transmission casing.

Always ensure that the breather tube is not clogged during periodic maintenance.

CHAPTER 15

WHEELS AND TYRES IN REVA

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CHAPTER 15

WHEELS AND TYRES

15.1 INTRODUCTION:

The importance of wheels and tyres in the automobiles is obvious. Without the engine the car may be towed, but even that is not possible without the wheels. The wheel along with the tyre has to take the vehicle load, provide a cushioning effect and cope with the steering control.

The various requirement of an automobile wheels are:

- It must be strong enough to perform the above function
- It should be balanced both statically as well a dynamically.
- It should be light as possible so that the unsprung weight is least
- It should be possible to remove and mount the wheel easily.
- Its material should not deteriorate with weathering and age.

15.2 TYRE:

A tyre is a cushion provided with an automobile wheel. It consists of mainly the outer cover. The tyre tube assembly is mounted over the wheel rim. It is the air inside the tube or in case of tubeless tyre, the air in the tyre that carries the entire load and provides the cushion.

15.3 FUNCTIONS OF TYRES:

- To support the vehicle load.
- To provide cushion against shock.
- To transmit driving and braking force to the road.
- To provide cornering power for smooth steering.

15.4 TUBELESS TYRE:

Reva is equipped with four special Han kook Tubeless Tyres and one standard tyre as tube tyre. These tyres as exclusive original equipment for Reva. These tyres are best suited for Electric Vehicles. A conventional tyre has an air filled rubber tube inside i.e. the tyre rides on a cushion of air filled inside a tube. In a tubeless tyre, the tyre rides on a cushion of air filled directly into the tyre. The tyre is sealed to the rim to prevent any air loss.

These tyres have an Asymmetric Tread Pattern. It has 3 different tread zones. Each of them is designed for different task. The tread pattern on the inside has a high proportion of straight lateral grooves, providing efficient water evacuation during wet conditions and smooth driving during normal driving conditions.

The grooves in the center ensure a quiet drive. The outside tread pattern is in block form, which increases road grip and cornering accuracy.

These three features put together ensure:

- Lower roll-resistance, which enhances your driving range.
- Better road grip in wet conditions.
- Precise vehicle handling on the road.

15.5 ADVANTAGES OF TUBELESS TYRE OVER TUBE TYRE:

- **Lesser-unsprung weight** –Being lighter, unsprung weight is reduced, reducing wheel bounce.
- **Better cooling:** In case of tube tyre, it is found compressed air has to pass through the tube materials. Rubber is not a good conductor of heat. Since there is no tube in the tubeless tyres heat can be passed on to atmosphere directly resulting into better cooling & there by increasing the tyre life.
- **Slower leakage of air:** since the inner liner of the tubeless tyre is not stretched like a tube, it retains the air better resulting in it slower leakage.
- **Simpler assembly:**
  Only the tyre has to be fitted over the rim in case of a tubeless tyre.
- **Improved safety:** In case of any small puncture or a nail prick, the same can be repaired by plugging. Whereas in case of conventional tyres, it takes quite sometime to remove the tube for the repair. Apart from this, a tube less tyre retains the air pressure for a longer period even when punctured by nail, provided the same is held in place, thus the chances of sudden tyre puncture leading to accident are reduced and any tyre damage shows up only as slow leak.
- **Tread wear indicators:**
  To provide visible check of the tyre condition, tread wear indicators are provided at the bottom of the tread grooves. When the tread is worn to remainder thickness of 1.6 mm, these indicators appear in the form of 12mm wide bands, the tyre should be replaced.
- No Friction between the tube and tyre: This feature results in lesser heat generation giving you longer tyre life.

15.6 CROSS PLY TYPE:

In this type, the ply cords are woven at an angle (30º - 40º) to the tyre axis. There are two layers, which run in opposite directions. However, the cords are not woven like wrap and weft of ordinary cloth because that would lead to rubbing of the two layers and thus produce heat, which would damage the tyre material.

15.7 RADIAL PLY TYPE:

In this the ply cords run in the radial direction i.e. in the direction of the tyre axis. Over this basic structure, run a number of breaker strips in the circumferential direction. The material for the breaker strips must be flexible but inextensible, so that no change of circumference takes place with change in the amount of inflation. Without the breaker strips, radial plies would give very soft ride, but there will not be any lateral stability. The inextensible breaker strip behaves like a girder in its own plane and provides the directional stability.

15.8 CONSIDERATIONS IN TREAD DESIGN:

The main considerations in the design of treads are: grip, noise and wear. These will be discussed in detail in the following paragraphs.

- **Grip**

  The braking grip of a tyre depends upon two factors viz. The tread material and the tread pattern. In case of dry roads, the completely smooth tyre, no doubt, gives highest braking grip because it provides maximum area of contact with the road. However, in case of wet road, its grip becomes almost negligible.

  The grip for a particular tread pattern is affected mechanically as well as through friction. For better mechanical contact, the tread must provide suitable sharp edges that will engage with the road: while for a good frictional contact, it is very important that tyre must provide drainage of the water on the road, otherwise the tyre will aquaplane, i.e. float on the water film and loose contact with the ground. The various
  Tread designs aim at satisfying these two basic requirements. Sufficiently wide grooves at the middle of the tread serve to drain the road water. It has been found through experimentation that more number of comparatively narrower grooves provides better drainage as compared to small number of very wide grooves. To increase the grip on icy surfaces, studded tyres with steel studs inserted in holes in the tread rubber are used.

- **Noise**

  Apart from the ‘squeal’ a peculiar tyre noise which depends upon the nature of the rubber compound used for the tyre treads, various types of vibrations caused by the roughness of the road surface and by the distortion of the tyre carcass also produce noise. However, besides these, the type of tread pattern also contributes to tyre noise. It is seen that this source of noise is eliminated by providing intentional irregularities in the tread pattern by varying the size or shape of the tread blocks.

- **Wear**

  For less wear, the tyre must be such that the individual elements undergo minimum distortion during running.

15.9 TYRE MARKING:

145/70R 13 71T ENERGY XT1 TL

145 = section width in mm

70 = Aspect ratio
= Section height /section width ×100

R = Radial

13 = Nominal wheel diameter (inches)

71 = Load index
= 345 kg per tyre at pressure for maximum load

T = speed symbol
= 190 km/hr

ENERGY XT1 = tread pattern

TL = Tubeless

15.10 FACTORS AFFECTING TYRE LIFE:

- **UNAVOIDABLE :**
  Seasons: The tyre life is affected by the season. In winter, the mileage is more and heat failures are less compared to that in summer. With new treads, which are thicker, heat dissipation is slower. Thus if a new tyre is fitted in winter, its tread will wear out to some extent by the time summer arrives. In summer the thinner tread will help to dissipate the heat faster and run the tyre cooler to give better mileage. It has been found from experience that tyres fitted in winter give about 25 per cent more mileage than those fitted in the hotter season.

- **ROAD CONDITIONS :**
  The tyre life depends much on the condition of the road it has to travel on. Tread chipping is one type of damage caused due to broken roads or pot holes. For example if used on country roads, the life of the tyre may be only 50% of the value obtained on smooth, well-paved roads. Again, on even good roads in hilly areas, the tyre life is reduced to half of the normal value in plains. Poor quality roads with too many twisting in a hilly area would result in lesser tyre life.

15.11 VEHICLE MAINTENANCE:

The state of vehicle maintenance can also affect the tyre life. Following are the main mechanical irregularities which are revealed by the typical wear of the tyres:

- Wheel alignment – If the wheels are not aligned properly i.e. there is either excessive toe-in or toe-out, the tyres scrub along the road instead of rolling freely. These results in very rapid wear of tyre tread. In case of the tyre mounted on a misaligned wheel, the tread appears to have a file drawn across the surface and shoulder on one side is rounded off. In case of excessive toe-in the tyre wear shows feathered edges on the inside edge of the tyre, while in case of excessive toe-out, it is on the outside.

15.12 INFLATION:

The tyres must be inflated according to the specification of the original vehicle manufacturer. Both the under inflation as well as the over inflation are detrimental to tyre life. Some operators wrongly think that it would be safe to overload a tyre by over inflating. This is entirely misconceived idea & is dangerous. Such a practice only serves to strain the carcass of the tyre with consequent weakening of the entire structure and resulting ultimately in premature failure.

The main effects of over inflation are:

- Rapid wear of tyre tread in center only.
- Increased tendency for concussion breaks. This type of tyre break is caused when an object is hit with a force, the severe shock tearing the fabric of the tyre which is already under excessive tension on account of over inflation.
- Harsh damage because of reduction in the cushioning effect. Besides discomfort, this results in higher maintenance costs.
- Decreased resistance to skidding because of reduction in areas of contact of tyre tread with the road surface on account of over inflation. Because of this, over inflated tyres are particularly dangerous on wet roads.

On the other hand, the effects of under inflation are:

- Under-inflation causes excessive flexing resulting in irreparable damage to the tyre carcass, which is sometimes visible in the shape of side wall cracking 6 or loose cords inside tyre casing 7 or ply separation.

15.13 OVERLOADING:

In case of overloading the tyre has insufficient amount of air to support the dead Weight carried and the results of overloading therefore are the same as described above, for under inflation. A study of the tyre operating conditions has established that over loading results in decrease of tyre mileage.

The remedy for overloading is not over inflation. Rather, the only remedy for this is to fit a larger tyre with adequate loading capacity, provided the rim used is also of correct width and sufficient strength.

15.14 MANNER OF DRIVING:

Apart from inflation and the vehicle maintenance, the manner in which a vehicle is driven, affects the tyre life. Excessive speeding, quick starts and sudden stops all cause faster tread wear. Careless parking may lead to kerbing, when the side wall grazes the pavement and gets damaged.

15.15 POSITION IN WHICH TYRE IS FITTED:

It has been found from experience that front tyres generally wear slower than rear ones. The lighter conditions imposed on the front tyres enable them to run themselves in and the amount of tread rubber that is removed allows the tyres to run cooler when they are later fitted to rear wheels. The increase in tyre life in some cases with this method has been found to be as high as 100 per cent.

15.16 TYRE DAMAGES:

- Tread
- Sidewall
- Bead
- Interior

Condition - Penetration in the Crown Area
Penetration through the tread area by a foreign object which causes air loss and possible tyre destruction.

Solution
Although it is virtually impossible to avoid occasional punctures, hazardous areas such as construction sites can sometimes be avoided. If a puncture occurs, the damage may be repaired if within recommended limits.

Condition - Wear Due to Improper Camber
Improper camber reduces the tyre life due to faster and sloped wear and may ultimately ruin the tyre.

Solution
Properly align the vehicle and check for the suspension components.

Condition - Wear Due to Improper Toe In/Out
Improper toe-in or toe-out settings can cause "feathering" of the tread.

Solution
Periodic alignment of the vehicle to the vehicle manufacturer's specifications. Also check the vehicle for worn steering components.

Condition - Belt Deterioration Due to Penetrations
In the case of tread cuts, severe cracking on old tyres, or penetrations that extend to the steel belts, separations can result from air, moisture, and other contaminants that enter the opening and corrode the steel under the tread. Corroded steel tread belts and tread separations are not repairable.

Solution
Immediate repair of any tread cuts or penetrations, proper tyre maintenance.

15.17 SIDE WALL DAMAGE:

Condition – Pinch Shock
A severe impact can cause the tyre to be pinched between the rim and the obstacle, cutting the casing ply(s). This damage is not repairable and may be indicated by cuts on the tyres exterior or interior.

Solution
Avoid road hazards such as potholes, curbs, or other obstacles.

Condition – Under Inflation
The characteristic abrasion ring on the sidewall of the tyre indicates that the tyre has been run under inflated.
Solution
Regular visual inspection of tyres to spot injuries. Use new valve stems and cores when mounting new tyres. Follow proper mounting procedures. Use rims in good condition and check inflation regularly.

Condition – Run Flat
When car is run flat, the tyre overheats and begins to disintegrate. It is often difficult to determine the primary damage due to the extent of the tyres destruction.

Solution
Early detection of punctures, regular inflation checks, and replacement of valve stem when mounting will lessen chances of a run flat tyre.

Condition – Penetration in the Side wall Area
Damage caused by the penetration of the object or an impact to the side wall. Scratches and abrasions in the area of the penetration or cut will often indicate the entry point of a foreign object.

Solution
Michelin do not recommend repairs to the side wall. Care should be taken to avoid road hazards which are likely to cause damage to side walls.

Condition – Fatigue Rupture (Steel Casing)
Casing fatigue may occur, even in tyres that have very low mileage if they are parked for extended periods of time, operated while under inflated, or both.

Solution
When storing vehicles for extended periods of time, remove the wheels. Maintain proper air pressure.

Condition – Oil or Chemical Contamination
Tyres will absorb oil or other petroleum-based chemicals if exposed for any length of time. This will deteriorate its rubber and fabric components. There is no way to repair this sort of damage.

Solution
Avoid contact of tyres with petroleum-based products such as solvents, paints oil, and diesel fuel.

Condition – Air Infiltration Due to Penetration
When there is damage to the inner liner or bead, air can infiltrate along the casing cords, causing a separation and eventually a rupture in the tyre. If the tyres inner liner is penetrated, air may be forced through the injury under pressure, causing separation and ultimately, tyre failure.

Solution
Avoid tyre damage to the extent possible. If a puncture occurs, prompt repair may save the tyre.

15.18 BEAD DAMAGE:

Condition – Improper Mounting
Improper use of tyre mounting equipment can weaken, bend or break bead wires or damage the rubber in the bead area.

CAUTION: Broken or weakened bead wires may cause the tyre to explode upon inflation or dismounting.

Solution
Proper use of tyre mounting equipment and lubrication of the tyre and rim when mounting or dismounting.

15.19 INTERIOR DAMAGE:

Condition – Object Penetrating to the Interior
When a foreign object penetrates the steel belts of the tyre, damage to the inner liner can occur. A simple puncture can be repaired if the damage is within allowable limits. It is absolutely necessary to remove the tyre to inspect the extent of the damage.

Solution
Repair of the tyre, according to recommended procedures if the damage is within repairable limits.

Condition – Pinch Shock

A severe impact can cause the tyre to be pinched between the rim and the object being struck, cutting the casing ply(s). This damage is not repairable and may be indicated by cuts on the tyres exterior or interior.

Solution
Avoid road hazards such as potholes, curbs, or other obstacles.

Condition – Detached Inner Liner-Run Flat
When run flat, excessive heat buildup causes the inner liner to wrinkle and detach from the casing. Any tyre showing wrinkles or creases should be scrapped, as service people can only guess at the extent of the damage. Inner liner detachment is not repairable.

Solution
Early detection of punctures, regular inflation checks, and replacement of valve stem when mounting will lessen chances of a run flat tyre, although a sudden injury is not always avoidable.

WEAR INDICATORS

The original equipment tyres have built in tread wear indicators to show when tyres need replacement. These indicators will appear as lugs on the tread.

Tyre needs replacement when:

- The wear indicators are seen at three or more places around the tyre.
- Cord / Fabric can be seen through the tyres' rubber.

- The tread or sidewall is cracked, cut, or snagged deep enough to show cord or fabric
- The tyre has a bump, bulge or split
- The tyre has a damage, puncture or cut, that cannot be repaired well because of the size or location of the damage.

Caution: If tyres of different sizes or types (radial and bias-belted), are mixed and used, it could cause the loss of control to the driver and could end in a crash. Using different sized tyres may also effect the vehicle balance. Hence the same size and type of tyres on all running wheels is essential.

15.20 REPLACEMENT OF WHEEL DRUMS/DISCS:

Wheel drums must be replaced if they are bent, dented, have excessive lateral or radial run out, leak air through welds, have elongated bolt holes or lug nuts won't stay tight or if they are heavily rusted.
Wheels with run out greater than specified may cause vibrations. Replacement of wheel drums must be equivalent to the original equipment wheels in load capacity, diameter, rim width, offset and mounting configuration. A wheel of improper size or type would affect wheel and bearing life, Speedo / Odo calibration, car ground clearance and tyre clearance to the body and chassis.

Any wheel that is bent, cracked, or badly corroded must be replaced. If the wheel nuts keep coming loose, wheel bolts and wheel nuts should be replaced.

If the wheel leaks air, replace it or have it repaired. Each new wheel should have the same load-carrying capacity, diameter, and width, offset and be mounted the same way as the one it replaces.

CAUTION:
Using the wrong replacement wheels, wheel bolts, or wheel nuts on your vehicle can be dangerous. It could affect the braking and handling of your car, make your tyres lose air, and make the driver lose control.

Wheel repairs that use welding, heating, or penning are not approved. Damaged wheels should be replaced.

15.21 TYRE MOUNTING AND DEMOUNTING

Use a tyre-changing machine to mount or demount tyres. Do not use hand tools or tyre irons alone as to change tyres as they may damage the tyre beads or wheel rim.
Rim bead seats should be cleaned with a wire brush or coarse steel wool to remove lubricants, old rubber and light rust. Before mounting or demounting a tyre, the bead area should be well lubricated with an approved tyre lubricant.
After mounting, inflate to specified pressure and check that beads are completely seated.

IMPORTANT: Do not stand over the tyre when inflating. When inflating, if specified pressure will not eat the beads, deflate, re-lubricate and re-inflate.

TYRE REPLACEMENT

Tread depths should be checked regularly. Tyres carry tread depth indicators, which show whether a tyre is reaching its wear limit. At low tread depths, the risk of skidding on wet surfaces is increased.
In the case of replacing two tyres fit the new or least used tyres preferably to the rear axle. For safety reasons, it is recommended to fit a new tubeless valve with a new tubeless tyre.
It is recommended that new tyres be installed in pairs on the same axle. If there is a necessity of replacing only one tyre, then mate it with a tyre having the most tread, to equalize the braking traction.

15.22 TYRE CARE

INFLATION OF TYRES

The pressure recommended for Reva is carefully calculated to give a satisfactory ride, stability, steering, tread wear, tyre life and resistance to bruises.Tyre pressure, with tyres cold, (after the car has been set for 3 hours or more, or driven less than two kilometers) should be checked monthly or before any extended trip. Tyre pressure should be set to the specification on the tyre placard. It is normal for tyre pressure to increase 28 kPa (4 PSI) when the tyres get hot due to driving. Do not bleed or reduce tyre pressure after driving. Bleeding reduces the “cold inflation pressure”.

The optimum pressures for the tyres in the Reva Car are:

- Front tyres 35 PSI
- Rear tyres 40 PSI

15.23 TYRE REPAIR

There are different materials and techniques in the market to repair tyres. Tyre manufacturers have published detailed information on how and when to repair tyres. These instructions can be obtained from the tyre manufacturer.

15.24 When a tyre goes flat, during testing or driving:

It’s unusual for a tubeless tyre to “blow out” when driving, especially if the tyres are maintained correctly to specifications. If air goes out of a tyre, it is more likely to leak out slowly. If ever there is a blowout, here are a few tips about what to expect and what is to be done:

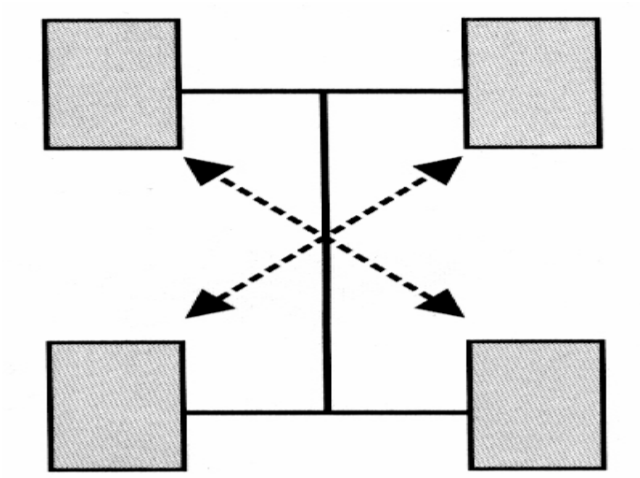
If a front tyre fails, the flat tyre will create a drag that pulls the vehicle toward that side. In such a situation, take your foot off the accelerator and grip the wheel firmly. Steer to maintain lane position, and then gently brake to a stop well out of the traffic lane.

A rear blowout, particularly on a curve, acts much like a skid and may require the same correction you’d use in a skid. In any rear blowout, remove your foot off the accelerator. Get the vehicle under control by steering the way you want the vehicle to go. It may be very bumpy and noisy, but you can still steer. Gently brake to a stop – well off the road if possible.

When a tyre goes flat, avoid further tyre and wheel damage by driving slow to a level place. Turn on the warning (hazard) lights.

15.25 TYRE ROTATION

To equalize wear, rotate tyres periodically as explained in Service Manual.



15.26 BALANCING WHEELS

There are two types of wheel and tyre balance: static and dynamic. Static balance is the dynamic distribution of weight around the wheels. Wheels that are statically unbalanced cause a bouncing action called tramp. This condition will eventually cause uneven tyre wear. Dynamic balance is the equal distribution of weight on each side of the wheel centerline so that when the tyre spins there is no tendency for the assembly to move from side to side. Balancing of wheels needs to be carried out every 6000 kms.

15.27 WHEEL REMOVAL

Refer Service Manual.

CHAPTER 16

CHASSIS AND BODY PANELS IN REVA

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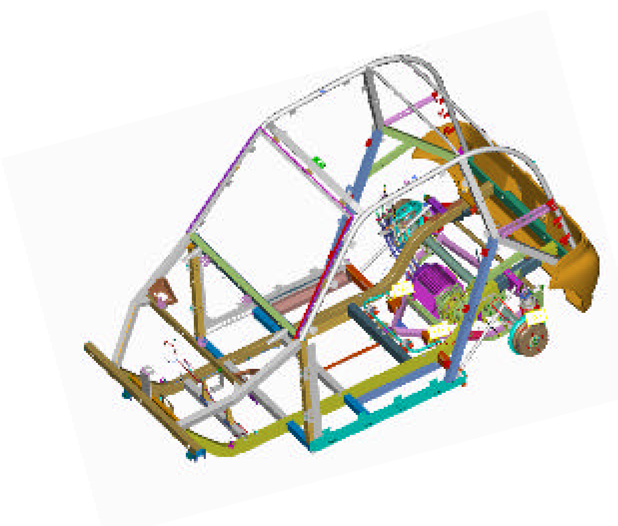
CHAPTER 16

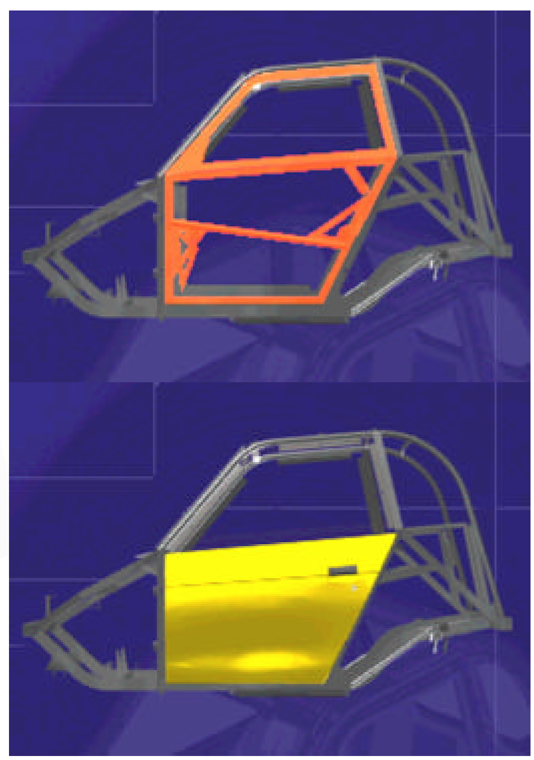
CHASIS AND BODY PANELS IN REVA

16.1 INTRODUCTION:

REVA chassis is constructed on space frame pattern. It consists of a very strong, self supporting, light weight space frame to house the motor, drive –train, steering, suspension, brakes, wheels, tyres and electronic / electrical systems. It has the following benefits:

- **Safety:** It cocoons the passenger in the event of a skirmish with another vehicle.
- **Light weight:** It is ideal for electric vehicle applications, since it offers maneuverability and better range.
- **Repairs:** Quick and economical.





16.2 CONSTRUCTION:

While constructing a chassis, it is made from different sub assemblies. Finally all the units are joined by CO2 welding. Some of the sections used in REVA chassis are round, tubular and RHS. This makes the chassis light in weight and strong. The chassis is constructed in wedged shaped, so that there is less wind resistance due to aerodynamic design. The triangular section in the chassis has got highest strength and does not collapse. The various sections of the chassis are shown in the figure 1 which is enclosed.

The running chassis consists of a very strong, self-supporting, lightweight space frame. Running chassis includes the following:

- The motor and controller to maximize power efficiency.
- Integrated power system.
- High efficiency, precision crafted drive-train.
- Energy Management System to monitor battery performance and provide precise range estimation.
- Steering, brakes, wheels, low resistance tyres and high voltage systems.
- A suspension system designed for stability and control.

The panels used in Reva Car are:

1. Roof Assembly
2. Cantrail LH / RH
3. Fender LH / RH
4. Door Inner / Outer LH/RH
5. Rear Quarter Panel LH / RH
6. Hood Panel
7. Tail L ight Panel
8. Front Bumper
9. Rear Bumper Material : Poly Ethylene
   Properties: High impact resistance
   Heat resistance
   Low cost of moulding.
10. Battery bottom tray
11. Battery top cover
12. Fire wall
13. Shroud retractor LH/RH
14. Rocker panel LH / RH
15. Wheel Well Front/ Rear (LH/RH)
16. Trim A-Pillar LH/RH
17. Trim BC-Pillar LH/RH
18. Instrument Panel
19. Cowl Panel

16.3 The Running Chassis Advantages:

- Enhanced Vehicle Range: The chassis structure is a lightweight extruded aluminum space frame that reduces weight and extends vehicle range.
- Multiple chassis configurations are possible from the same platform.
- Increased speed to Market: Basic chassis design quickly and easily adapts to new vehicle configurations. Low chassis platform allows rapid market testing of multiple vehicle configurations, speeding consumer feedback.

The Reva uses a lightweight tubular steel space frame that supports all the suspension and body components. The space frame completely encloses the passenger compartment and is designed with energy absorption sections. The space-frame including all supporting brackets weighs 69 kg.

The front suspension used is the McPherson (strut) type independent suspension system and consists of coil springs and front suspension struts. The rear suspension consists of trailing arm with pan hard rod to take the lateral loads. It is a solid axle with coils over springs and hydraulic shock absorbers.

The motor and transaxle is directly mounted on the A-arm and act as a structural member. Though unconventional, this type of suspension is inexpensive as it eliminates the use of CV or universal joints and still provides good ride and handling characteristics.

16.4 Exterior Body:

The body is made out of lightweight colour impregnated co-extruded acrylic over ABS plastic. The extruded sheets are thermoformed to the desired shape and have a high impact resistance. As the plastic is colour impregnated and has a clear acrylic coating, the painting process is eliminated for battery compartment, fire wall, IP panel, bumpers (Front & Rear). The bumpers are 1-piece hollow, rotationally molded parts.

The integrated bumpers include energy absorption cones and all light attachments. The doors incorporate a steel frame with side impact protection beams, sandwiched between two plastic panels. Together, the exterior plastic panels including the bumpers weigh less than 35 kg and are directly mounted on the vehicle space frame.

- **ABS in REVA**

  What is the material used for exterior body in Reva?
  The exterior body of Reva is made of ABS.
  In ABS, A = acrylonitrile
  B = butadiene
  S = styrene

ABS stands for "acrylonitrile butadiene styrene". It's a thermoplastic. It can be processed through injection moulding, vacuum thermoforming.

16.5 Unique properties of ABS:

In Reva the panels are vacuum thermoformed. Let's look at the various processes involved in making a final painted panel. Granule to sheet (through extrusion) to untrimmed part (through vacuum thermoforming) to Trimmed part (Trimming operation) to painted panel (through painting).

The Unique properties of ABS can be explained as:

- Acrylonitrile imparts chemical resistance, heat resistance & surface hardness.
- Butadiene imparts toughness & impact resistance.
- Styrene's imparts process ability, rigidity & strength.

In Reva, small dents do not appear due to the squirmishes while driving due to ABS (UNLIKE IN METAL in other cars). Due to the fact that the weight to volume ratio of ABS is 7 – 8 times lesser than that of MS, if helps to impart better fuel efficiency. Environmental aging unlike in metal does not corrode surface in Reva.

ABS surface is smooth and that helps to build body aesthetics. ABS is a borderline plastic. ABS is very tough, even tough enough to be used as an automotive bumper. Infact, it is not fragile, you can take a piece of ABS and try to brake it with a 5kg hammer, you will NOT be able to do that! In Europe, full car cladding is ABS these days.

16.6 Reva's Safety features:

- **Steel Space Frame Chassis and Side Impact Beams.**
  A specially developed steel frame chassis and side impact beams cocoons passengers in an inadvertent accident. The chassis used in Reva is similar to those used in rally cars for safety of the drivers.
- **Dent Proof Body Panels.**
  Most accidents in cities involve low speed skirmishes with other vehicles often leaving owners with expensive tinkering jobs. Reva's body panels are made of ABS.
- **Energy Absorbing Bumpers.**
  Reva has energy absorbing bumpers, which can withstand low magnitude impact and reduce external damage to it.
- **Special Crush Zone.**
  The frontal crush zone houses the spare tyre and reduces the effect of impact in a head on collision.

CHAPTER 17

BRAKES IN REVA

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CHAPTER 17

BRAKES IN REVA

17.1. PRINCIPLE:

It goes without saying that brakes are one of the most important control components of vehicle. They are required to stop the vehicle within the smallest possible distance and this is done by converting the kinetic energy of the vehicle into the heat energy which is dissipated into the atmosphere.

From this point of view the brakes may be classified as the service or the primary and the parking or the secondary brakes. The service brakes are the main brakes used for stopping the vehicle while in motion, whereas the parking brakes are meant to hold the vehicle on a slope.

17.2. BRAKING REQUIREMENTS:

The brakes must be strong enough to stop the vehicle within a minimum distance in an emergency. But this should also be consistent with safety. The driver must have proper control over the vehicle during emergency braking and the vehicle must not skid. The brakes must have good antifade characteristics i.e. their effectiveness should not decrease with constant prolonged application e.g. while descending hills. This requirement demands that the cooling of the brakes should be very efficient.

17.3. HYDRAULIC BRAKES:

In Reva, we use hydraulically operated foot brakes on all the four wheels with an additional hand brake mechanically operated on the rear wheels.

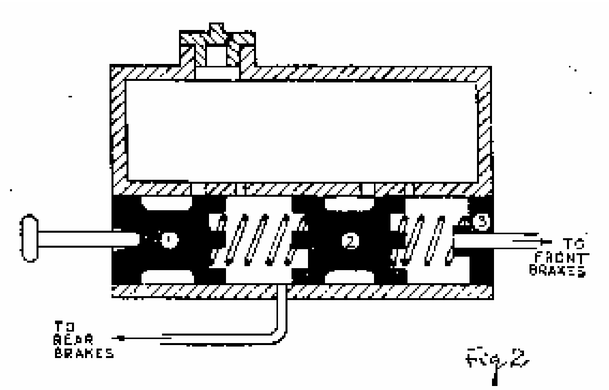
The main component in this is the master cylinder, which contains reservoir for the brake fluid. Master cylinder is operated by the brake pedal and is further connected to the wheel cylinders/calipers in each wheel through steel pipe lines, unions and flexible hoses.

The system is so designed that even when the brakes are in the released position, a small pressure of about 50 kPa is maintained in the pipe lines to ensure that the cups of the wheel cylinder/calipers are kept at required pressure. This prevents the air from entering the wheel cylinders when the brakes are released. Besides, this pressure also serves the following purposes:

- It keeps the free travel of the pedal minimum by opposing the brake shoe retraction springs.

- During bleeding, it does not allow the fluid pumped into the line to return, thus quickly purging air from the system.

Fig.2



17.4. TANDEM MASTER CYLINDER:

Tandem master cylinder ensures reliability. In this, separate lines go to different sections of the brake system, say the rear and the front brakes and it is so arranged that if the front brake lines are damaged, the rear brakes will still be effective. Similarly if rear brake line is defective, at least front brakes will be applied. A simplified diagram of the tandem master cylinder is shown in Fig. 2.

Such hydraulic brake system which employ tandem master cylinder to operate two different sections of the vehicle brakes, are called split systems. The system described above, wherein the front and the rear brakes are operated by different chambers of the tandem master cylinder is called axle-by-axle split system and is generally used for light vehicles say up to 1 tone, e.g. passenger cars. As the braking effect is proportional to the swept volume in the master cylinder chamber, the two different chambers can be designed different in size according to the braking effect required on the two axles. In passenger cars, generally, larger braking effort is required at the front axle; so the larger chamber of the master cylinder is connected to the front axle and the smaller chamber to the rear axle.

For medium duty vehicles (1- 3 tone rating) also the axle by axle split system as described above, may be used. However, when all the brakes are two-shoe-leading type, it is preferable to employ the system in which one line from master cylinder goes to the top wheel cylinder in all wheels while the other line goes to the bottom wheel cylinders of all wheels. The advantages of such a system are better directional stability and the property to retain almost the same ratio of brake torques on the front and the rear axles, even after failure of any brake line. In this case all brakes are used as two-shoe leading. In case of failure of any section, the two shoe leading brake becomes simply the common one leading-one trailing shoe brake. Thus the braking effectiveness even after failure remains up to about 75 per cent of the original value.

All vehicles employing tandem master cylinders use a pressure differential switch with warning light and proportioning valves. When disc brakes are used at front with drum brakes at the rear, a metering value is also required. These valves would now be described briefly.

17.5. PROPORTIONING VALVE:

This is employed to proportion the braking effect between the front and the rear axles. Different types of brakes at the front and the rear and the transfer of weight during brake application require different forces to be applied to the wheel cylinders or calipers at the front and at the rear. This is done by the proportioning valve. This is shown in fig.2.

17.6. ADVANTAGES OF HYDRAULIC SYSTEM:

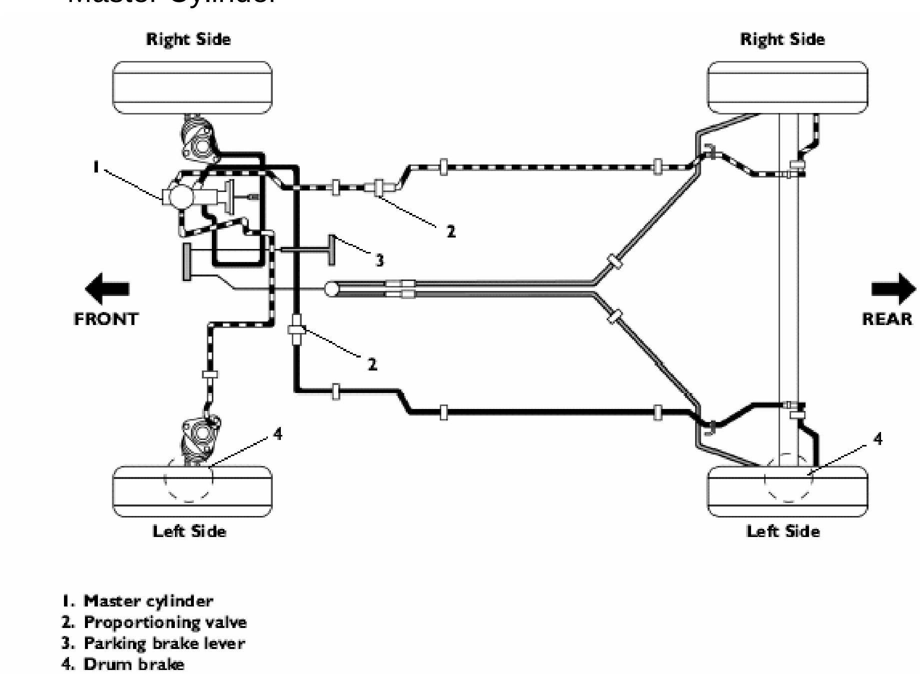
- The fluid exerts equal pressure everywhere in its circuit. For this reason equal braking effort is obtained at all the four wheels.
- The system is simple in construction, due to the absence of brake rods, joints etc. inherent in the mechanical system. Moreover, pipelines can be bent and shaped according to the underside of the body structure.
- Due to absence of joints compared to mechanical brakes, rate of wear is also less.
- The system is mostly self-lubricating.

Under ordinary conditions the brake fluid will transmit pressure both to front as well as to the rear brakes, when the brake pedal is applied. However, when, say, the front brake lines are damaged, piston (2) will move till it comes up against stop (3). After this pressure will start building up in space between pistons (1) and (2) and rear brakes will be applied. Similarly when the rear brake lines are damaged, no pressure will build up in space between pistons (1) and (2). So piston (1) will move freely till it comes up against (2). Further push at the brake pedal will move both pistons (1) and (2) together thereby applying the front brakes.

17.7 BRAKE SYSTEM:

Different components of brake system are:

- Pipe Brakes / Bundy Pipes
  - Hoses
  - Proportionate Valves
  - Master Cylinder



17.8(A) REAR WHEEL (BACK PLATE):

This has two brake shoes with the brake linking. They are held at the anchor points and the retractor spring is provided at the other end. See Fig.5. The fluid flows into the wheel cylinder from the master cylinder. This fluid causes hydraulic pressure against the pistons to increase. These further forces the pistons apart. Now the brake shoes are forced against the rotating drum. The resulting friction between the brake lining and the drum slows or stops the car. The adjuster automatically adjusts the brakes to compensate brake lining wear.

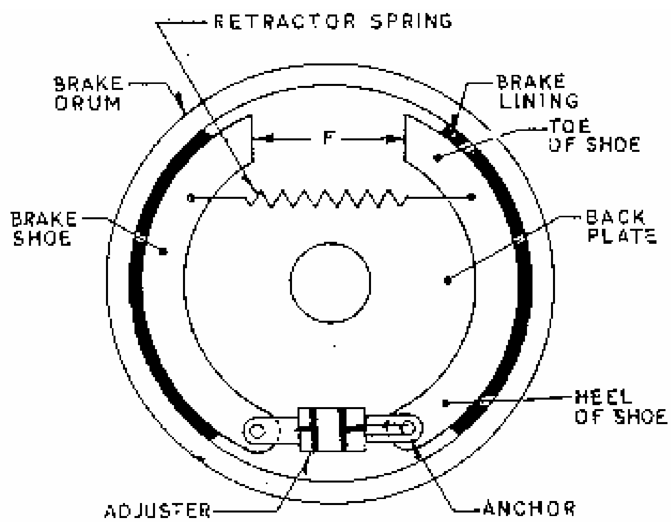


Fig. 5 Drum type brakes.

17.8(B) FRONT WHEEL (DISC BRAKES)

The front wheels of Reva are fixed with disc brakes. The brakes on the front wheels is applied using the brake pads housed in the caliper. When ever the brake is applied the brake fluid in the line pushes the piston in the caliper which in turn pushes the pads against the rotating brake disc resulting in retarding and stopping it. The disc is mounted on to the up right. The caliper is also mounted using a bracket.

17.9 PARKING BRAKE (HAND BRAKE):

Parking brake in REVA is mechanically operated by a wire and link lever system. The hand lever is on left hand side of the driver when the lever is pulled, the brakes are applied on to rear wheels only and the parking light on the IP cluster glows.

Here the application of parking brake forces only the rear wheel brake shoes or pads against the drum. However, the service brake operates the shoes hydraulically while the parking brake uses the cable pulley assy. The hand brake comprises of:

- Cable Assembly Parking Brake

- Pulley Cable
- Hand Brake Lever

17.10 BRAKE BLEEDING:

- **Necessity**

If air gets into the hydraulic brake system, it results in poor braking and spongy pedal. Air can get into the system if the air vent in the master cylinder cover or cap becomes plugged. This may tend to create a partial vacuum in the system, and allow the entry of air into the system. Probably the most common cause of air in the brake system is insufficient brake fluid in the master cylinder. If the brake fluid drops excessively, the hydraulic system will draw air in as the piston moves forward when braking.

The process of getting rid of any air trapped in the hydraulic brake line is called BLEEDING.

17.11 BRAKE FLUID:

The liquid used in the hydraulic brake system is called brake fluid. The brake fluid must have certain characteristics. It must be chemically inert, it must be little affected by high or low temperatures, it must provide lubrication for the pistons in the master cylinder, wheel cylinders, calipers and it must not attack the metal, plastic, and rubber parts in the braking system.

Three types of hydraulic brake fluid are used in automobiles. These are classified by the Department of transportation (DOT) as DOT3, DOT4 & DOT5. The brake fluid recommended by REVA is DOT3.

17.12 SAFETY PRECAUTIONS:

- Pay attention while the car is put on ramp. Make sure that the lifting points only are used. Inspect the brake connections for damage or cut before delivering the car to customer.
- Top up the brake fluid in master cylinder when ever required.
- Follow the correct procedure while bleeding the brakes.
- Use proper grade of brake fluid (DOT3 or equivalent).

17.13 PEDAL BOX – REMOVAL, DISMANTAL & ASSEMBLY:

(Refer Service manual).

17.14 INSTALLATION OF BRAKE & ACCELARATOR CABLE:

(Refer service manual).