

Kofu A. Henning → AS/af 481C - Cond.

## Electric Auxiliary Drive

### - An Alternative 4WD Concept -

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#### Introduction

Driving on slippery road surfaces does not require high traction but the more a distribution of engine power to all four wheels.

4WD-vehicles driven by combustion engines are characterized by considerable efforts in investment, packaging disadvantages and high piece-cost.

Therefore a front-wheel-driven S-car has been equipped with an electric driving motor connected via freewheeling gears to the rear wheels and corresponding control hardware. This allows to drive the car in two supplemental modes:

- Alternative 4WD on slippery road conditions
- Electric driving only in the city and during stop and go traffic conditions resulting in low exhaust emissions and low vehicle noise

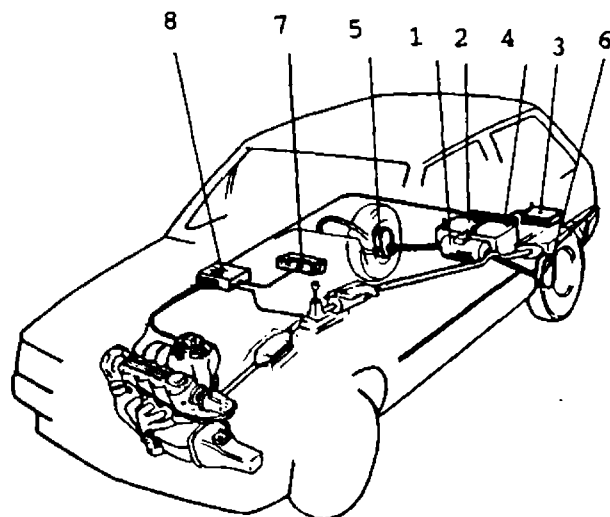
#### System Description

The S-car has been changed at the rear end to admit the installation of a modified rear axle, the DC-motor, the traction batteries and the motor control unit. Two reduction-gear boxes have been mounted to the suspension carrier arms on the left and right side. The gears are equipped with freewheels to allow free running of the wheels when the DC-motor is not operated. Its start of operation will block the freewheels and thus additional traction will be fed to the rear wheels.

For controlling the automatic 4WD and stop and go modes additional software has been integrated in the control unit of the throttle body injection system.

Experiences so far gained will be discussed in this presentation.

## Electric Auxiliary Drive for S-Car System Components



- 1 DC-Motor 3kW
- 2 Batteries 2 x 115 Ah
- 3 Battery charging control unit
- 4 DC-motor control
- 5/6 Wheel transmissions + speed sensors
- 7 Display panel and switches
- 8 Multec ECU

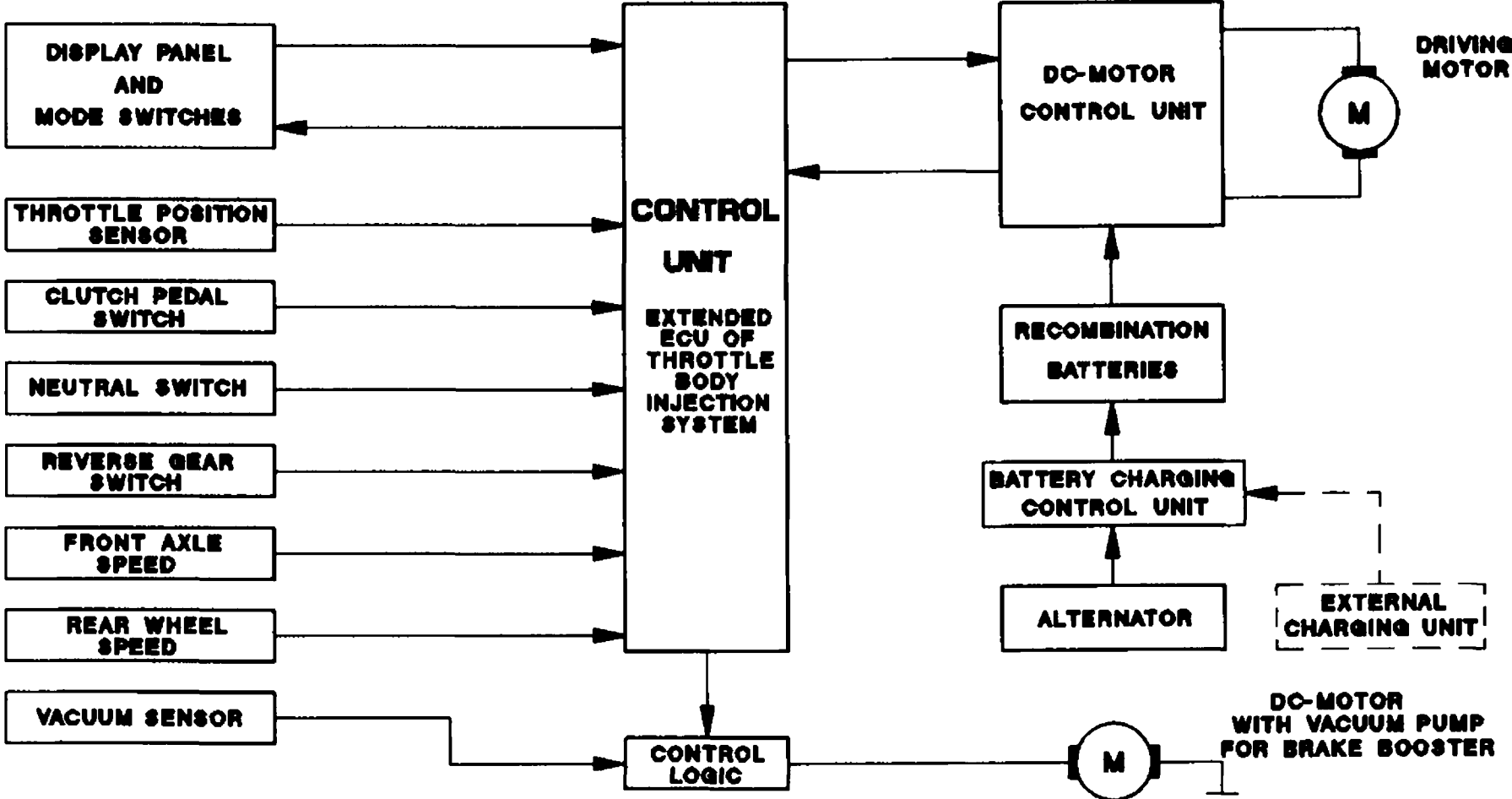
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**- ELECTRIC AUXILIARY DRIVE -  
AN ALTERNATIVE 4WD CONCEPT**

# ELECTRIC AUXILIARY DRIVE

## SCHEMATIC OF CONTROL SYSTEM



# ELECTRIC AUXILIARY DRIVE

## DATA OF ELECTRICAL EQUIPMENT

- ALTERNATOR 12 V, 105 A
- BATTERIES (CONVENTIONAL RECOMBINATION TYPE) 24 V, 115 AH
- DC-MOTOR
  - RATED POWER 3 KW
  - RATED SPEED 4000 RPM
  - RATED TORQUE 7.11 NM
  - STARTING TORQUE 35.5 NM
  - SUPPLY VOLTAGE 24 V

# ELECTRIC AUXILIARY DRIVE

## 4WD MODE

- ELECTRIC DRIVE IS COUPLED TO THE REAR WHEELS IF
  - "4WD"-SWITCH IS CLOSED
  - ENGINE IS RUNNING
  - BATTERIES VOLTAGE IS GREATER THAN 18 V
  - SLIP DIFFERENCE BETWEEN FRONT AND REAR WHEELS IS RECOGNIZED
  - CAR SPEED IS LOWER THAN 50 KM/H
- DIRECTION OF ROTATION OF DC-MOTOR
  - DETERMINED BY REVERSE GEAR SWITCH
- ELECTRIC MOTOR CONTROL
  - CORRESPONDING TO THE DIFFERENCE BETWEEN FRONT AND REAR WHEEL SPEED, THE ELECTRIC POWER IS CONTROLLED IN PI-MODE BY THE ECU
- ENGINE TORQUE REDUCTION
  - IF 4WD-MODE IS ENABLED, SPARK TIMING IS MODIFIED

# ELECTRIC AUXILIARY DRIVE

## STOP AND GO MODE

- AUTOMATIC ENGINE SHUT OFF  
IF
  - "STOP AND GO" PUSH BUTTON IS PRESSED
  - OPERATING VOLTAGE IS GREATER THAN 22V
  - THROTTLE IS CLOSED
  - GEAR IN NEUTRAL POSITION
  - CAR IS NOT RUNNING
  
- AUTOMATIC ENGINE CRANKING  
IF
  - POWER IS REMOVED FROM ELECTRIC MOTOR
  - CLUTCH PEDAL IS DEPRESSED
  
- INDICATION OF OPTIMUM GEAR
  - WILL BE DISPLAYED TO THE DRIVER DURING THE AUTOMATIC CRANK OPERATION

# ELECTRIC AUXILIARY DRIVE

## STOP AND GO MODE

- USING THE CAR AS ELECTRIC VEHICLE  
IF
  - PUSH BUTTON "STOP AND GO" HAS BEEN ACTUATED
  - GEAR IN NEUTRAL POSITION
  - CLUTCH PEDAL IS NOT PUSHED
  
- DRIVING OF THE CAR OCCURS BY ACTUATION OF THE FORWARD OR REVERSE SWITCH AND ACCELERATOR PEDAL
  
- DISABLE INDICATION BY ENERGIZING "DEPRESS CLUTCH"  
INDICATOR LAMP  
IF
  - GEAR IS NOT IN NEUTRAL POSITION
  - CAR SPEED EXCEEDS 30 KM/H
  - OPERATING VOLTAGE DROPS BELOW 18V

# ELECTRIC AUXILIARY DRIVE

## BASIC PHYSICAL CONSIDERATION

- DRIVEN REAR AXLE WITH RELATIVELY SMALL POWER IMPROVES EFFECTIVELY TRACTION ON ROAD SURFACES WITH LOW FRICTION COEFFICIENTS
- REALIZATION WITH SEPARATE ELECTRIC DRIVE INTEGRATED IN THE REAR AXLE



# ELECTRIC AUXILIARY DRIVE

## MAIN CHARACTERISTICS

- OPERATION AS 4WD  
TOGETHER WITH PRODUCTION POWERTRAIN
  
- OPERATION AS PURE ELECTRIC DRIVE  
WITHOUT COMBUSTION ENGINE
  - FOR STOP AND GO IN CITY TRAFFIC
  - FOR DRIVING IN RESIDENTIAL AREAS
  
- RESTRICTION TO SMALL CARS

# ELECTRIC AUXILIARY DRIVE

## ADVANTAGES IN COMPARISON TO MECHANICAL 4WD

- LOW INVESTMENT
  - NO MODIFICATIONS OF THE CAR FRONT END
  - NO MODIFICATIONS IN THE TUNNEL REGION
- LOW COST
- REDUCTION OF VEHICLE MASS
- TRUNK VOLUME COMPARABLE TO FWD VERSION
- CAR DRIVING AS ELECTRIC VEHICLE WITH LOW EXHAUST EMISSIONS AND LOW VEHICLE NOISE
- NO INFLUENCE TO STEERING BEHAVIOUR DURING PARKING MANOEUVRES  
(IN COMPARISON TO PERMANENT 4WD SYSTEM)

## **ELECTRIC AUXILIARY DRIVE**

### **DISADVANTAGES OF 4WD CARS DRIVEN BY COMBUSTION ENGINES**

- HIGH INVESTMENT DUE TO CONSIDERABLE CHASSIS AND POWERTRAIN MODIFICATIONS
- HIGH SYSTEM COST
- HIGH SYSTEM MASS
- PACKAGING PROBLEMS INHIBIT INSTALLATION IN SMALL CARS

# ELECTRIC AUXILIARY DRIVE

## MASS COMPARISON

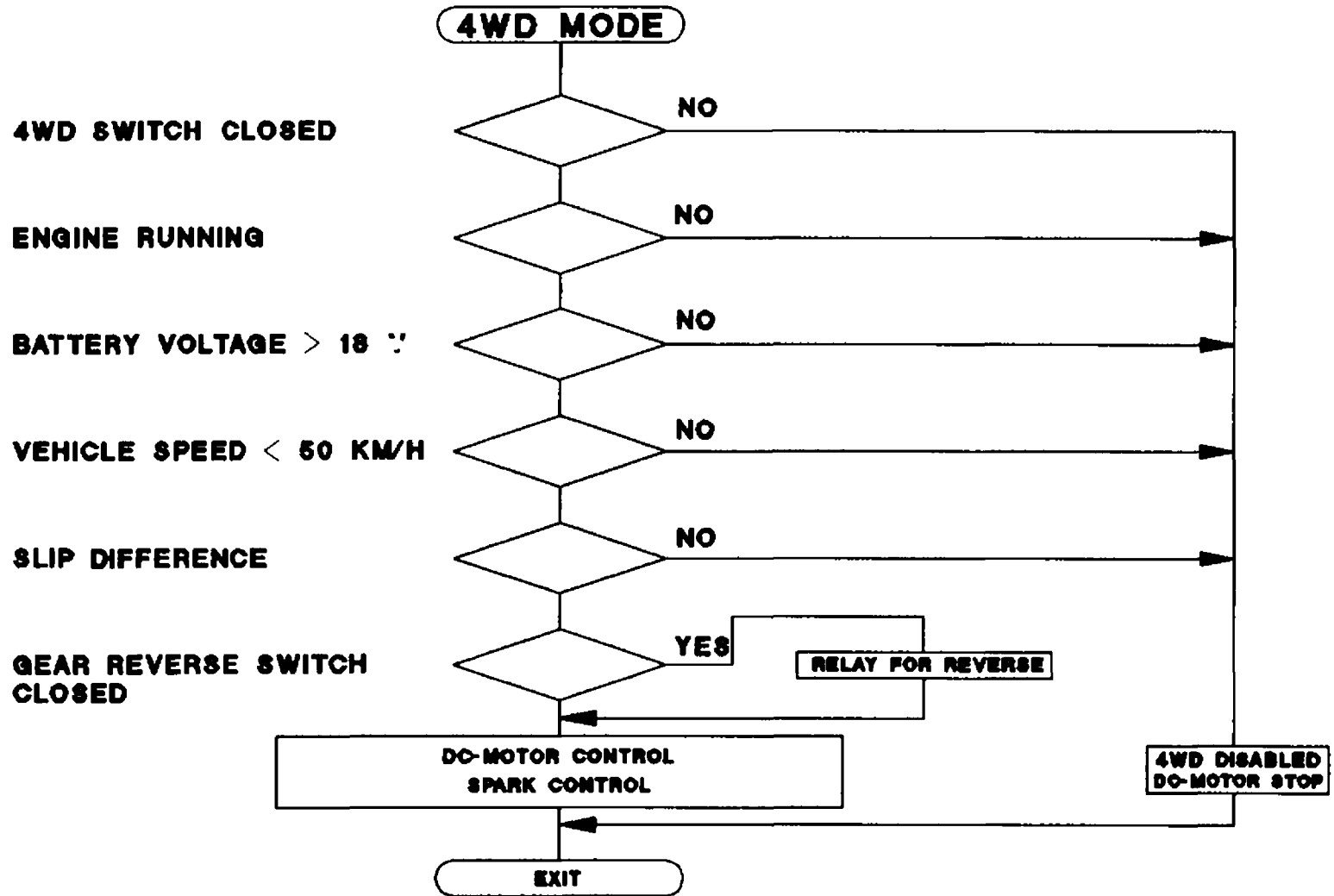
4WD MECHANICAL	ELECTRIC AUXILIARY DRIVE
+ 130 KG	+ 110 KG

# ELECTRIC AUXILIARY DRIVE

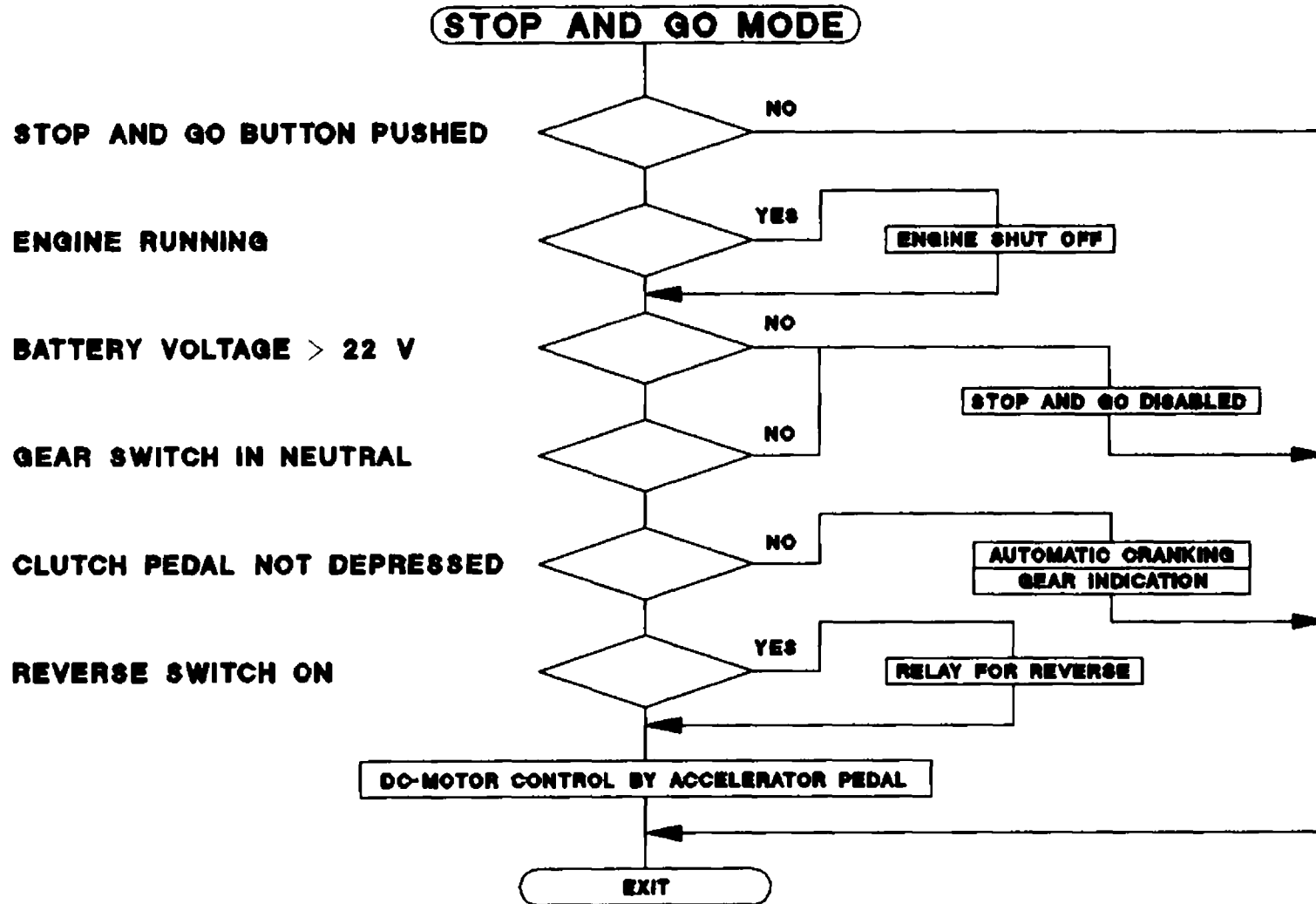
## PERFORMANCE OF ELECTRIC VEHICLE

- MAXIMUM VEHICLE SPEED
  - IN "STOP AND GO" MODE : 30 KM/H
  - IN 4WD MODE : 50 KM/H
  
- FOR "STOP AND GO" MODE WITH 50% REDUCTION OF BATTERY CAPACITY
  - ESTIMATED VEHICLE RANGE : 30 KM  
(CONSTANT VEHICLE SPEED 30 KM/H ON LEVEL ROAD)
  - ESTIMATED NUMBER OF ACCELERATION : 15  
(UP TO VEHICLE SPEED OF 30 KM/H)

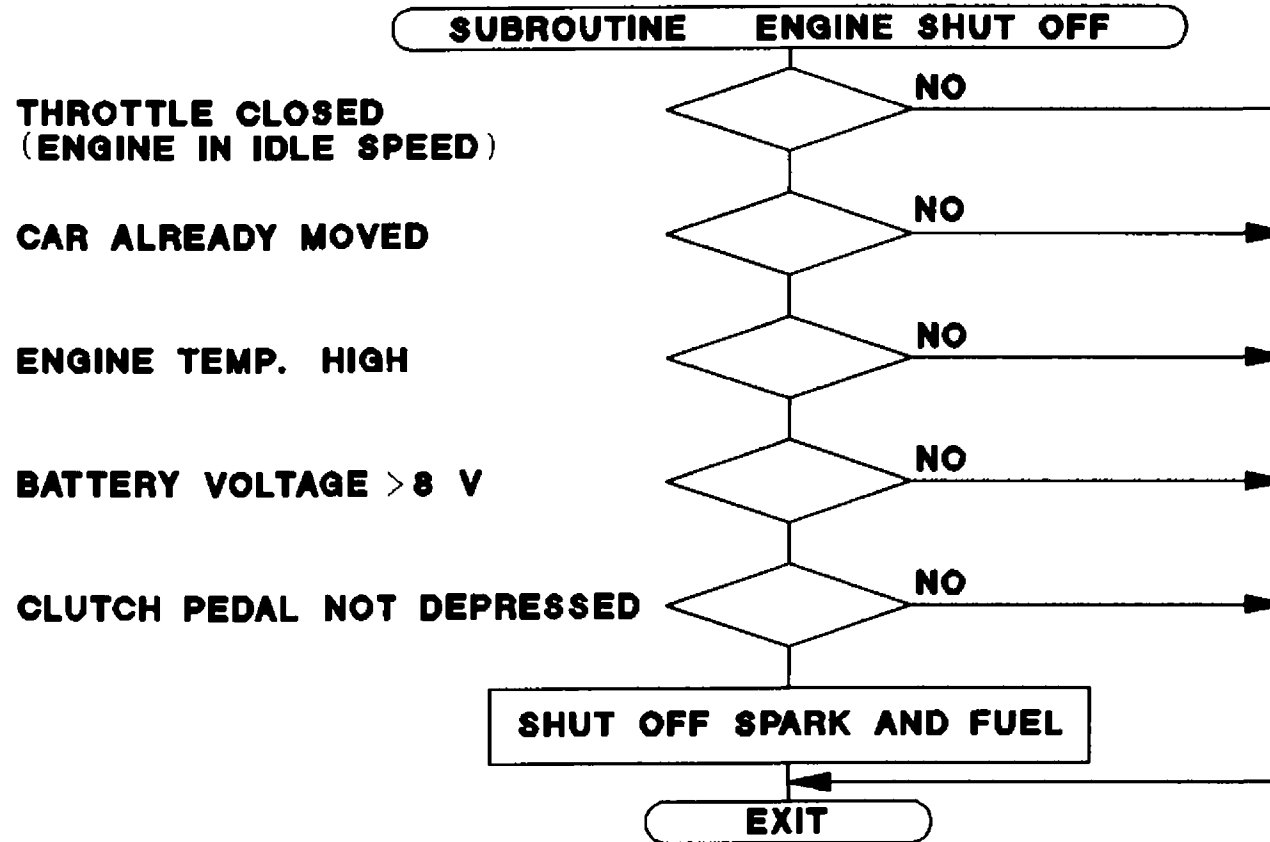
# ELECTRIC AUXILIARY DRIVE



# ELECTRIC AUXILIARY DRIVE



# ELECTRIC AUXILIARY DRIVE





# ELECTRIC AUXILIARY DRIVE

## SUBROUTINE : AUTOMATIC CRANKING

ENGINE NOT RUNNING

CLUTCH PEDAL DEPRESSED

CRANKING MOTOR ON

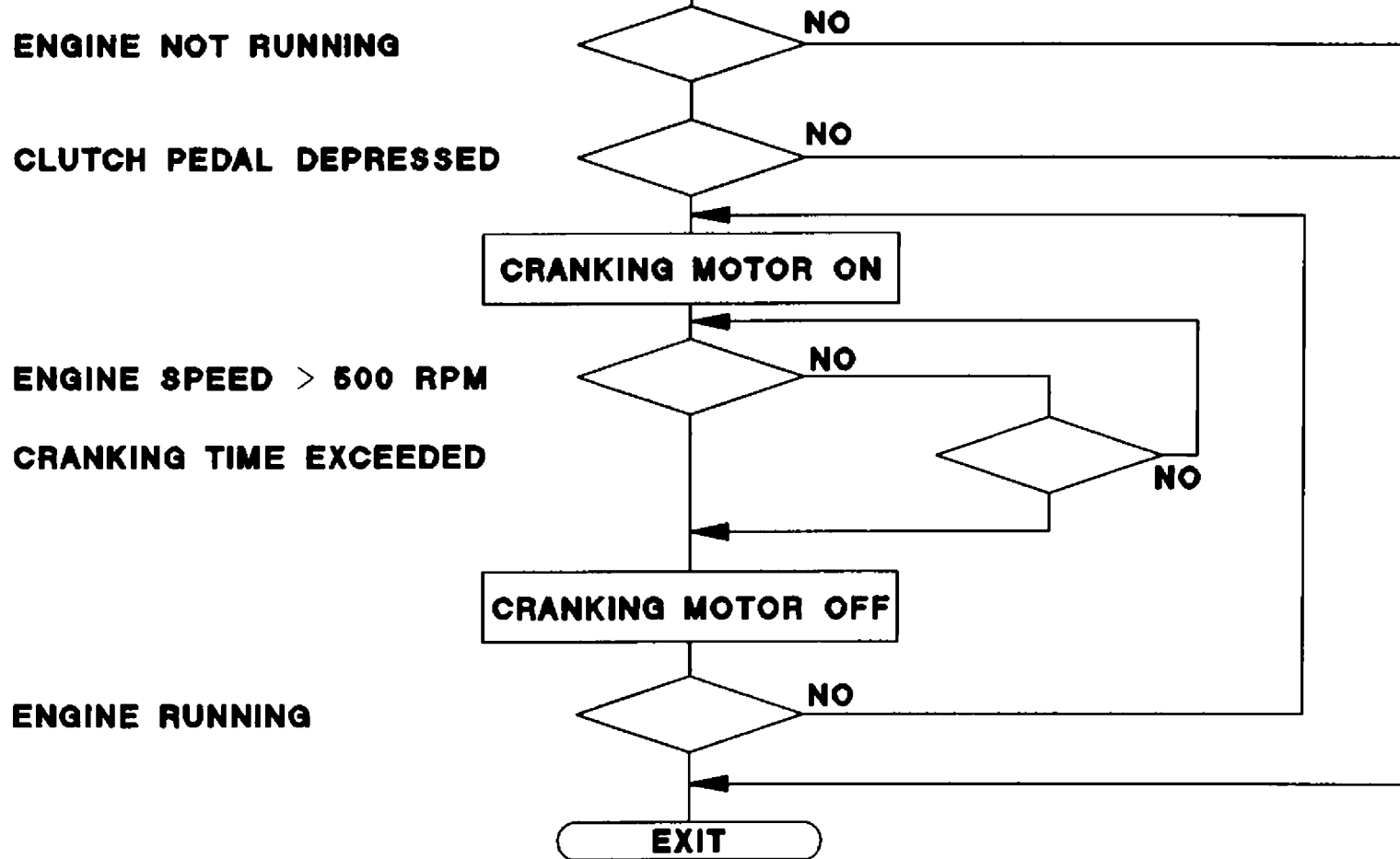
ENGINE SPEED > 500 RPM

CRANKING TIME EXCEEDED

CRANKING MOTOR OFF

ENGINE RUNNING

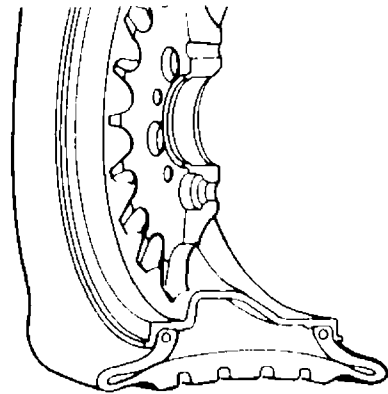
EXIT



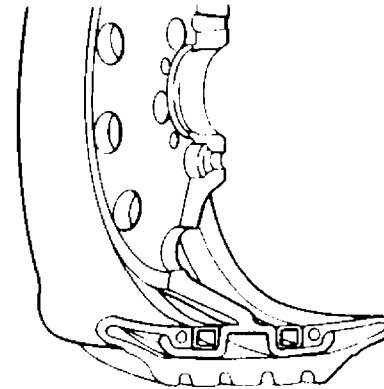
# ELECTRIC AUXILIARY DRIVE

## REGULAR AND "CTS" TIRE COMPARISON

DEFLATED REGULAR TIRE



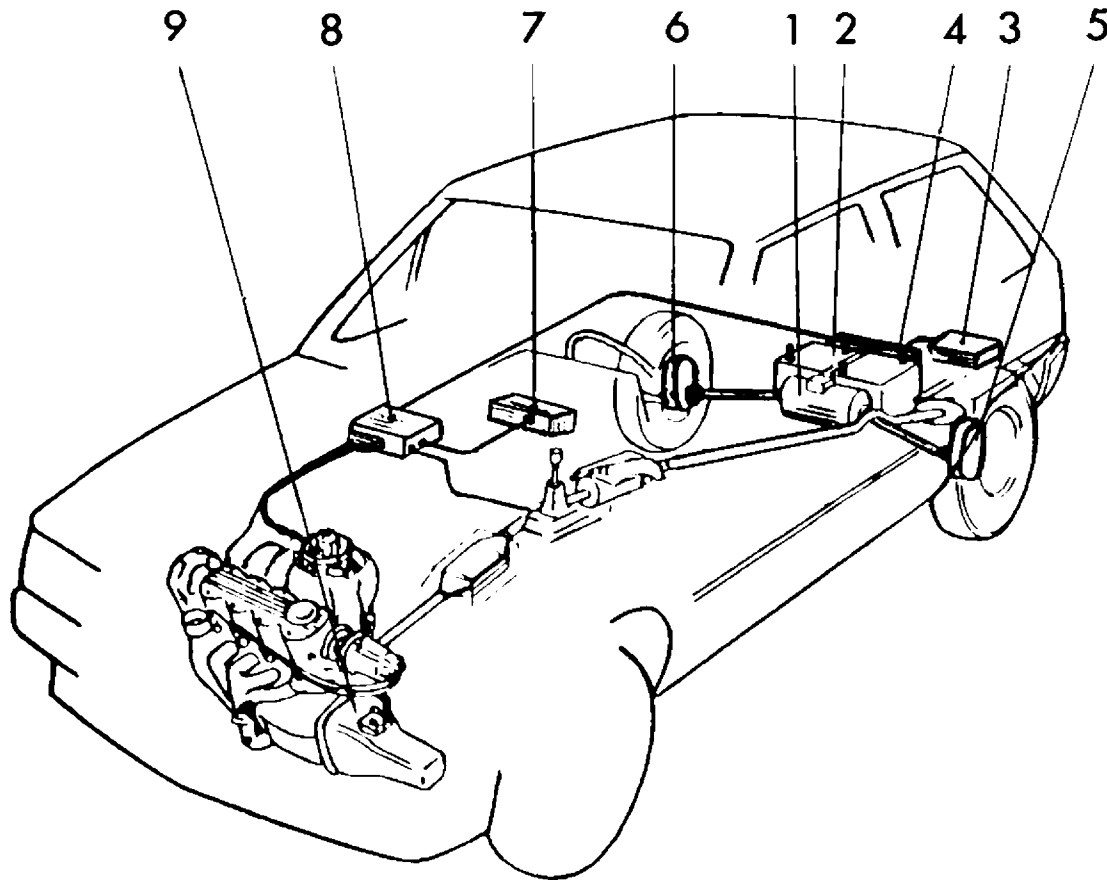
DEFLATED CTS-TIRE



DRIVING WITH DEFLATED CTS-TIRE IS POSSIBLE FOR  
DISTANCES OF ABOUT 200 KM

# ELECTRIC AUXILIARY DRIVE

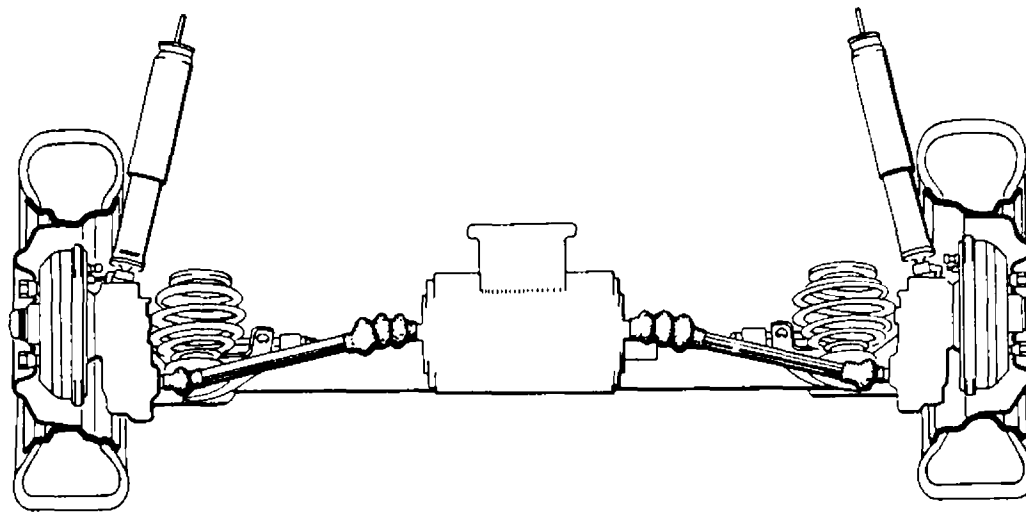
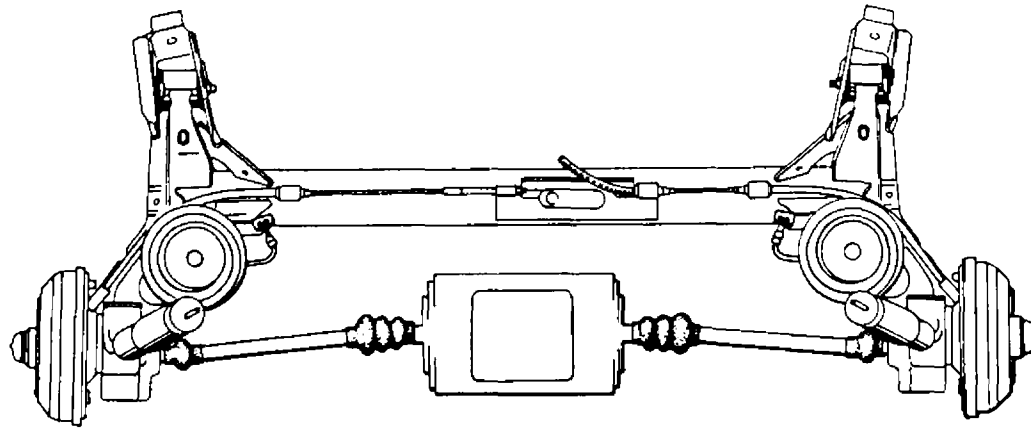
## COMPONENTS OF ELECTRIC SYSTEM AND ELECTRONIC CONTROL



- 1 DC-MOTOR 3 KW
- 2 BATTERIES 2 X 115 AH
- 3 BATTERY CHARGING CONTROL UNIT
- 4 DC-MOTOR CONTROL
- 5/6 WHEEL GEAR BOX WITH FREEWHEELING AND SPEED SENSOR
- 7 DISPLAY PANEL AND SWITCHES
- 8 MULTEC ECU
- 9 SPEED SENSOR

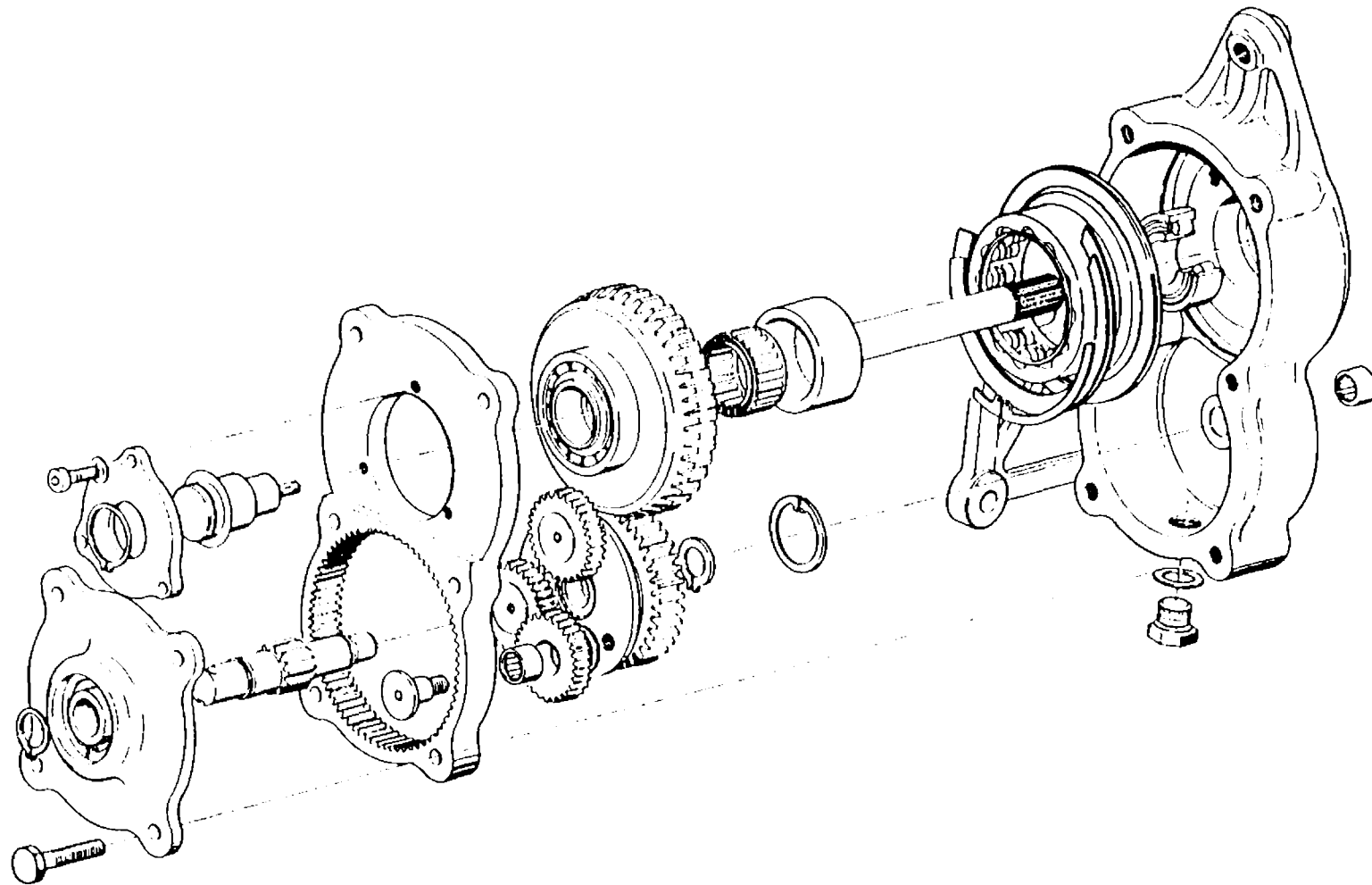
# ELECTRIC AUXILIARY DRIVE

## REAR SUSPENSION



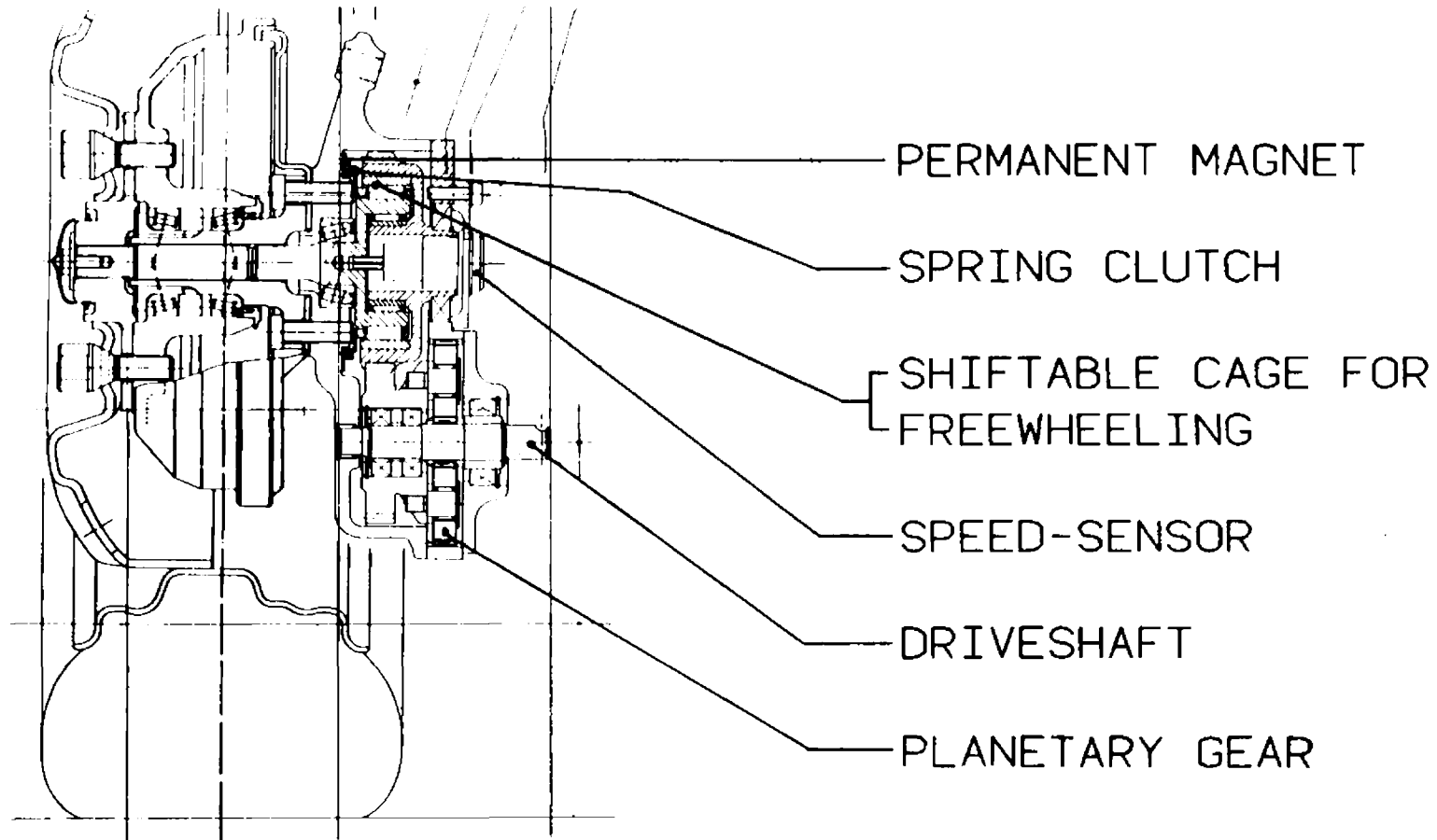
# ELECTRIC AUXILIARY DRIVE

## FREEWHEELING TRANSMISSION ASSEMBLY

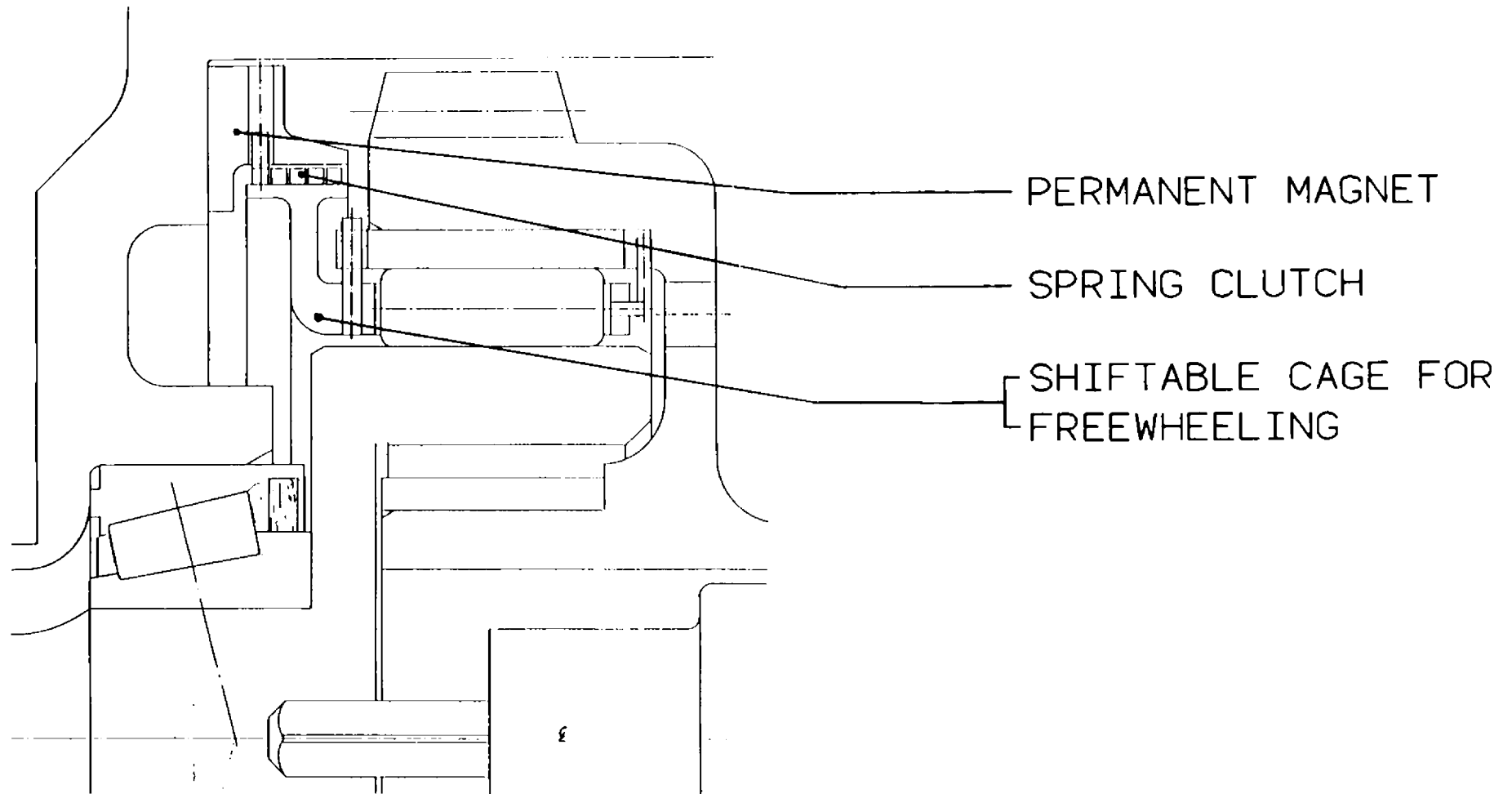


# ELECTRIC AUXILIARY DRIVE

## FREEWHEELING - TRANSMISSION SECTION



# ELECTRIC AUXILIARY DRIVE FOR S-CAR



# ELECTRIC AUXILIARY DRIVE

## S-CAR BASED CHARACTERISTICS OF EXPERIMENTAL CAR

- SEDAN HATCHBACK, 2 DOORS
  - CURB WEIGHT 780 KG
  - GROSS WEIGHT 1245 KG
- ENGINE WITH SINGLE POINT INJECTION
  - DISPLACEMENT 1.3 L
  - POWER 52 KW AT 5600 RPM
  - MAXIMUM TORQUE 96 NM AT 3200 RPM
- MANUAL TRANSMISSION 5-SPEED (FWD)
- TOP SPEED 155 KM/H



# ELECTRIC AUXILIARY DRIVE

## MASS OF ADDITIONAL COMPONENTS

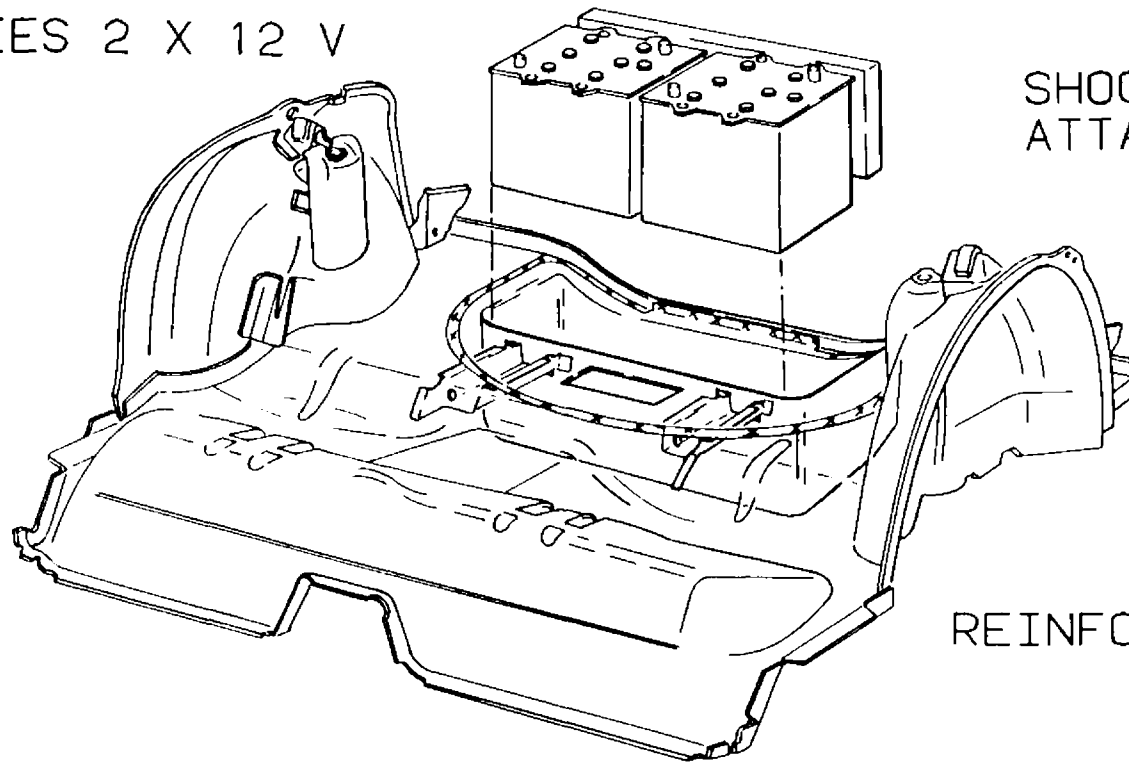
- 2 BATTERIES 12 V ; 115 AH 70 KG
- DC-MOTOR 24 V ; 3 KW 22 KG
- FREEWHEELING GEARBOX LEFT AND RIGHT 11 KG
- WIRING HARNESS 1 KG
- MOUNTINGS 2 KG
- ELECTRIC / ELECTRONIC COMPONENTS 4 KG

# ELECTRIC AUXILIARY DRIVE

## BODY CHANGES AND BATTERY ARRANGEMENT

DC-MOTOR CONTROL  
BATTERIES 2 X 12 V

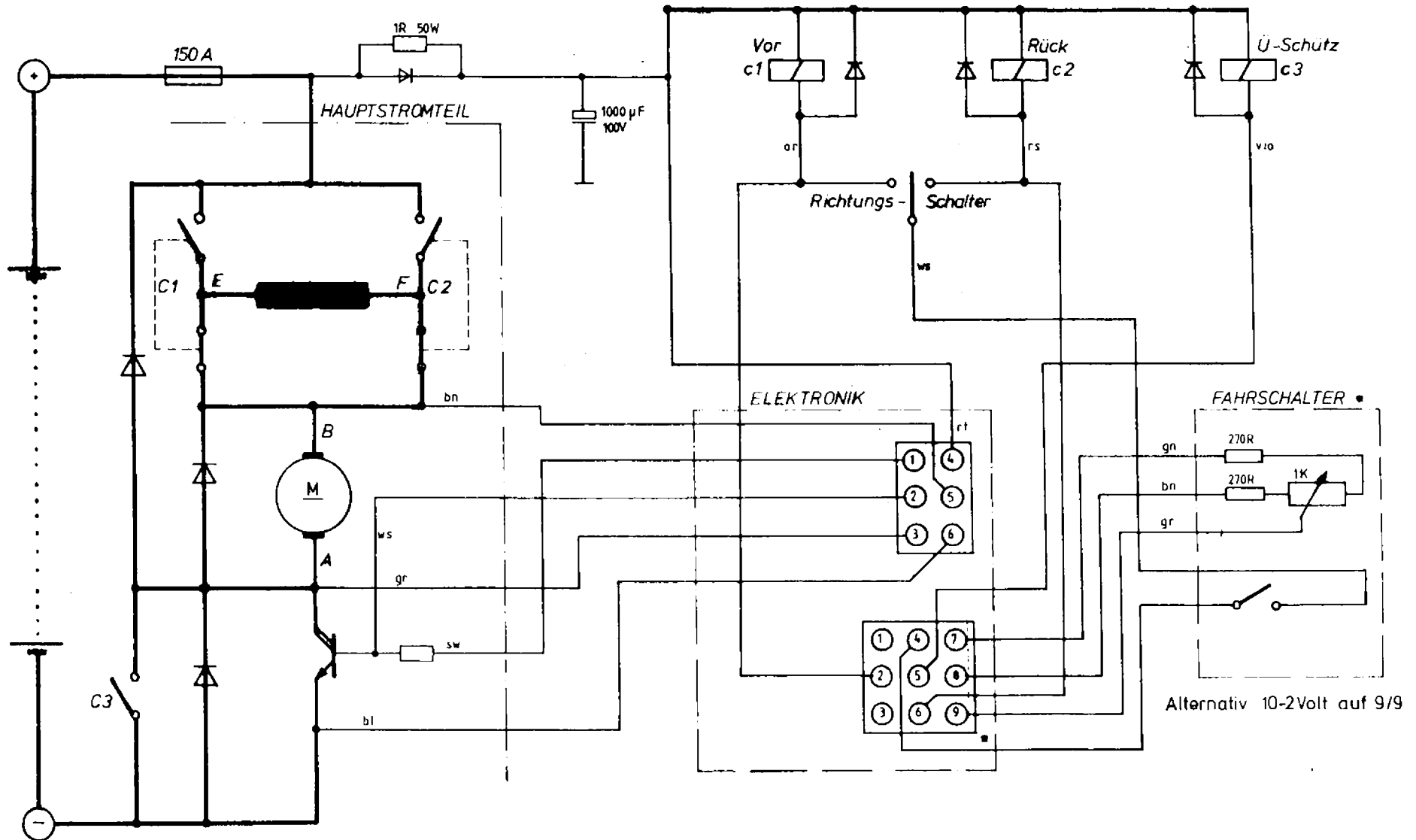
SHOCK ABSORBER  
ATTACHMENT



REINFORCEMENTS

# WIRING DIAGRAM

## DC-MOTOR CONTROL



# S-CAR MIT ZUSATZANTRIEB

## BATTERIESYSTEME

SYSTEM	Pb / Pb O <sub>2</sub>	Fe / Ni	Ni / Zn	Na / S
BETRIEBSTEMPERATUR	20°C	20°C	20°C	350°C
ENERGIEDICHTE	35 Wh / kg	70 Wh / kg	97 Wh / kg	130 Wh / kg
LEISTUNGSDICHTE	100 W / kg	150 W / kg	-	150 W / kg
LEBENSDAUER (ZYKLEN)	1000	1000	1000	1000
MASSENFERTIGUNG	JA	MÖGLICH	1992 IN USA	NEIN
ROHMATERIALIEN VERFÜGBARKEIT IN JAHREN	Pb 30	Ni 30	Ni 30	Na 6000
REICHWEITE FÜR S-CAR MIT ZUSATZANTRIEB *)	10 km	20 km	25 km	38 km
REICHWEITE BEI TIEFENTLADUNG	20 km	40 km	50 km	70 km
GESCHÄTZTE KOSTEN FÜR EINEN BATTERIESATZ	400,- DM	1600,- DM	1200,- DM	-
HERSTELLER	FA. HAGEN; VARTA	FA. SAFT; VARTA	FA. DELCO	FA. BBC

\*) NUR E-FAHRBETRIEB UND 50 % ENTNAHMEKAPAZITÄT