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Final Report

Department of Energy

Site Operator Program

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MASTER

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Prepared by

York Technical College

YORK TECHNICAL COLLEGE

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Summary

York Technical College is a two-year public institution accredited by the Commission of Colleges of the Southern Association of colleges and Schools. York Technical College has been involved with electric vehicles since the late 1980's

At the beginning of the Site Operator program, the York Technical College electric vehicle fleet consisted of a variety of old technology vehicles received from a number of organizations. The College received two vehicles from China Lake NAS, three vehicles from Long Island Power and Light, three vehicles from the Northrop Corp., two vehicles from INEL and five vehicles from Detroit Edison. This fleet consisted of

- a. Volkswagen pick-up trucks and sedans with nickel iron batteries
- b. Unique Mobility Concept car with lead-acid batteries
- c. Griffon vans with lead-acid batteries
- d. Ford Escorts with lead-acid and nickel iron batteries

During the term of this contract, many of these vehicles were either transferred to other federal organizations (i.e. the Griffon vans), up-graded with new technology or retired. New vehicles were added to the fleet.

- a. Ford Escort Station Wagon with a brushless DC motor and lead-acid batteries
- b. Geo Metro Force with an AC motor and lead-acid batteries
- c. Chevrolet S-10 pick-up truck with an AC motor and lead-acid batteries

The four major objectives of the Site Operator Program were

- a. field test and evaluate electric and hybrid vehicles and related components
- b. define and develop a national infrastructure system including electric charging systems, service/training education programs, utility system impacts and safety standards

- c. increase public awareness regarding environmental benefits, reduced dependency on foreign oil, technology development, and economic impacts
- d. assist local, state and federal agencies and fleet operators in developing electric and hybrid vehicle programs

The primary thrusts of the electric vehicle program at York Technical College, supporting the objectives of the Site Operator program were:

- a. public awareness
- b. public education
- c. EV maintenance curriculum development and maintenance training
- d. field data collection
- e. vehicle modification and upgrade
- f. establish electric vehicle partnerships

Public Awareness

During the term of the contract, York Technical College participated in and supported over 500 public awareness activities. These activities included

- a. programs at area schools (elementary and secondary)
- b. participation in area events such as parades, civic events, fairs, and orientation programs
- c. displays at museums and shopping malls

At these events, York Technical College displayed electric vehicles, provided electric vehicles for people to drive and made presentations on the current electric vehicle technology, their impact on the environment and energy consumption and the performance, availability, and future of electric vehicles.

In conjunction with public awareness, York Technical College developed a network of public and private partners to support and expand the use of electric vehicles in the Carolinas. Initially, York Technical College's partners

were Duke Power and the South Carolina State Energy Office. During the term of this program the list of partners grew to include

- a. Duke Power
- b. SC State Energy Office
- c. SC Central Electric Power Coop
- d. City of Charlotte
- e. City of Rock Hill
- f. Discovery Place Science Museum
- g. NC Alternative Energy Center
- h. Palmetto Electric Coop
- i. Santee Cooper Electric Coop
- j. SC Coastal Center
- k. York Electric Coop

These partners enabled York Technical College to expand its public awareness program in North and South Carolina. With support from York Technical College, these partners were provided with electric vehicles to evaluate their performance in a number of different applications and to determine if electric vehicles could be a viable alternative for their fleets. These vehicles were also used at local public events.

Public Education

York Technical College also developed and published a series of educational brochures on electric vehicles.

- a. History of Electric Vehicles
- b. The Effect of Electric Vehicles on the Environment
- c. Electric Vehicle Systems

Vehicle Modification

In order to support the primary objective of developing electric vehicle training programs, York Technical College was actively involved in the modification and upgrade of a number of vehicles. This involvement allowed the

college staff and faculty to become familiar with the operation, function, and interaction of the components of electric vehicles.

Most notable of these modifications was the conversion of a Ford Escort from lead-acid batteries to Ni-Cd batteries and the subsequent testing of the vehicle by the SAFT Battery Company. Results of this test were provided by SAFT Battery Company.

Field Data Collection

The majority of the field testing of electric vehicles done by York Technical College was performed on vehicles using old technology and did not provide useful results. However, York Technical College did test three vehicles with new technology components. These were a Ford Escort Station Wagon using an advanced DC motor with Genesis lead-acid batteries, a Solectria Geo Metro with an AC motor and Sonnenschein lead-acid batteries and a US Electricar S-10 pick-up truck with an AC motor and Genesis lead-acid batteries.

The vehicles using the Genesis lead-acid batteries experienced rapid battery degradation due to inadequate and improper battery charging profiles. The batteries in the Ford Escort Station Wagon deteriorated in just 1800 miles. All efforts to rejuvenate these batteries according to the charging profiles suggested by the manufacturer, Hawker, were unsuccessful. The batteries in the S-10 pick-up truck lasted longer, over 5,000 miles, before they failed. In the case of the S-10 pick-up, approximately 50% of the batteries are bad. A few of these batteries were rejuvenated, but the great majority are beyond repair. Prior to the degradation of these batteries, the range of the truck was

consistently 65-75 miles. If it were not for the premature failure of the batteries, this truck would have performed well.

Curriculum Development and Training

The main thrust of the Site Operator Program at York Technical College was focused on training and public education. Over the life of the contract, York Technical College developed training programs on EV maintenance, electric vehicle technology, safety, and EV operation. York Technical College conducted a "Develop a Curriculum" (DACUM) for electric vehicle technicians which resulted in the definition of the tasks and the level of competency required for an electric vehicle technician. From this competency profile, York Technical College developed a two-year associate degree program for an electric vehicle technician. Using this competency profile, York Technical College also developed and conducted a number of continuing education courses to train individuals working in the electric vehicle field.

In addition to the specific training for technicians, York Technical College developed and published a number of educational brochures to educate the public on electric vehicles and their impact on the environment. Specifically, brochures were developed on

- a. EV batteries
- b. EV motors
- c. a comparison of EVs and gasoline vehicles
- d. charging EVs
- e. auxiliary equipment for EVs
- f. history of EVs
- g. the environmental impact made by EVs

Lessons Learned

The most significant lesson learned in this program is that in an area where technology is changing and improving as rapidly as it is in the electric vehicle field, testing, training programs, and public education materials must be reviewed and updated regularly.

Field testing of vehicles must be accelerated so that the data can identify any problems and corrective action that must be taken before the next generation electric vehicle is introduced. Field test data collected on old vehicles is not useful and not only takes up valuable time and resources, but also clouds the issue on the performance of the current generation electric vehicle.

The lack of service manuals and manufacturer supplied vehicle specific training meant that each operator had to invent the maintenance procedures to keep his electric vehicle in operation. For future purchases, a service manual and schematics, even if they are basic, must be provided with each vehicle. Failure to do this severely limits the operator's ability to maintain his fleet of electric vehicles.

Vehicle Development and Field Testing

Until the last 18 months of the contract, York Technical College's fleet of electric vehicles consisted of old, converted electric vehicles such as the:

- Jet Escort
- South Coast Technologies VW pickups
- Griffon van
- GMC - G-Vans

While these vehicles were used to support the public awareness objectives of the program, they did little to support the field test data collection program because of their age and low reliability.

However, these vehicles contributed to our understanding of the problems associated with maintaining electric vehicles and played a key role in establishing the maintenance data base which was used to develop the maintenance training programs.

These vehicles also provide ideal platforms to incorporate new technology components and at the same time allowed the college staff and faculty to gain the hands-on experience that proved invaluable in the development and publication of the various training programs on electric vehicles offered by the college.

Of special note are the upgrades made on the VW pickups and the Ford Escort.

The VW pickups were upgraded with a new advanced DC motor and controller and the nickel iron batteries were replaced with flooded lead-acid

batteries. These trucks have been in use with the Palmetto Electric Coops and continue to provide good service with ranges of 40-50 miles.

The second significant modification made on the Ford Escort, was the replacement of the lead-acid batteries with Ni-Cd batteries donated by the SAFT battery company. York Technical College designed and performed the conversion and working with SAFT developed the charging profile. One of the problems from the start, was the unavailability of a charger that would provide the charging algorithms required by the SAFT Battery Company. Prior to sending it to SAFT, York Technical College testing showed that there was a 20-30% range improvement with the Ni-Cd batteries. Final testing and optimization of the charge algorithm was left to SAFT when York Technical College delivered the vehicle to them.

During the last 18 months of the program, York Technical College acquired three new electric vehicles with the latest technology.

The first was a 1993 Ford Escort Station Wagon converted to electric by Bearskin Technologies of Monroe, NC. This vehicle used an advanced brush DC motor operating at 120 volts and powered by two parallel battery packs using the Hawker Genesis seal lead-acid battery. This battery pack provided approximately 8.4 kwhr of energy. While the vehicle was relatively efficient at 0.28 kwhr/mile, the range of 25 to 30 miles was disappointing and prevented a great deal of field testing. At approximately 1500 miles, the range began to decrease and at approximately 1800 miles, the vehicle would no longer operate. A battery capacity test of the battery pack showed that the Hawker Genesis batteries would not hold a charge. Using the Hawker recommended

charging algorithm to rejuvenate the batteries failed to improve their charge acceptance and retention. This vehicle is currently waiting a new set of batteries.

The US Electricar 1995 S-10 pick up was delivered with a number of options not installed and a number of deficiencies. Even with the known deficiencies, the S-10 initially performed well and had a range of 68 to 75 miles. Minor problems were corrected by the college staff and this vehicle accumulated over 5,000 miles. The efficiency of this vehicle was 0.3 kwhr/miles.

However as reported elsewhere, range began to decrease, and the trouble was traced to the Hawker Genesis batteries. The majority of the 52 batteries failed to hold a charge. The staff tried to recondition them using the Hawker recommended procedure, but this was only successful with about 10% of the batteries. This vehicle is waiting to receive the Delco modification to the power control unit to incorporate the new charge algorithm and is also waiting for new batteries.

The last vehicle with modern technology is the Solectria 1993 Geo Metro sedan with an AC motor operating at 144 volts with Sonnenshein lead-acid batteries. These batteries provided approximately 7.8 kwhr of energy which provides a range of about 40 to 45 miles. This vehicle has over 7,500 miles and is still operating. It has required very little maintenance and has proven to be very dependable.

As everyone knows, the batteries are the issue. Not only are improved batteries needed for greater range, but greater reliability and longer life is

needed. There is a niche market for both fleets and the private citizen, for reliable vehicles with ranges on the 50 to 80 miles. But this range must be attainable every day for the life of the car. Also the life of the battery pack must be increased and the cost of the vehicle must be decreased if this niche market is to develop.

Training

The main thrust of the DOE Site Operator Program at York Technical College was focused on electric vehicle training and public education. Over the life of the contract, York Technical College has developed, published and offered a number of training and public education workshops on various aspects of electric vehicle technology and their impact on the environment.

In 1992, York Technical College assembled the leading experts in the field of electric vehicle maintenance and repair to conduct a "Develop a Curriculum" (DACUM) workshop to identify and define the duties, tasks and competency levels required for an electric vehicle maintenance and repair technician. A copy of the complete DACUM and workshop participants is shown in attachment A. This workshop identified the following duties as necessary for an electric vehicle maintenance and repair technician.

- basic awareness of electric vehicle technology
- basic electronic skills
- maintain and monitor batteries
- repair ancillary equipment
- maintain, repair and/or replace AC and DC traction motors
- maintain, repair and/or replace AC and DC controllers
- maintain, repair and/or replace converters
- maintain, repair and/or replace battery chargers
- maintain and repair auxiliary equipment
- maintain and repair climate control systems
- maintain and repair brakes
- maintain and repair power steering
- develop driver training skills

As a result of the Electric Vehicle Technician Competency profile, York Technical College developed the curriculum requirements leading to a two year associate degree as an electric vehicle technician. This curriculum is shown in

attachment B. This curriculum has not yet been implemented since the demand for electric vehicles does not warrant the two year program yet.

However, this DACUM competency profile was used as the basis for developing a number of continuing education short courses and workshops to meet the immediate demand for a skilled workforce to support the electric vehicles entering the fleets of a number of utilities.

To support this need, York Technical College with the support of DOE through the Site Operator Program, and with the support of our partners, developed and offered a number of continuing education workshops on all aspects of electric vehicle technology. Shown in attachment C are some of the partners who assisted York Technical College with these continuing education courses.

The following are the electric vehicle continuing education courses developed and offered by York Technical College.

Basic Electric Vehicle Operator Training

This basic operator training was designed to familiarize the electric vehicle operator with the fundamentals of driving an electric vehicle safely and efficiently. It covered the factors that affect the electric vehicle range and the driving techniques to obtain maximum performance and range. This course covered identifying and using the electric vehicle specific instruments and controls. It also included the proper techniques to safely and properly charge the electric vehicle. This course was designed to be a half day duration which included practical driving experience in an electric vehicle.

Introduction to Electric Vehicle Technologies

This course on electric vehicle technologies was designed to provide the individual with little or no background on electric vehicles the fundamentals of electric vehicle technology. The purpose is to better prepare individuals who are considering the use of electric vehicles with information on the pros and cons of electric vehicles and their impact on the environment and on the economy.

This course can be either two or three days duration and covers

- a. history of electric vehicles
 - show how electric vehicle technology has progressed
- b. environmental issues
 - discuss the impact electric vehicles can have on air quality, particularly in large metropolitan areas
- c. legislation, mandates, and incentives
 - review the Clean Air Act of 1990 and the Energy Policy Act of 1992 and discuss their potential impact on both public and private fleet operators
 - review applicable state mandates on air quality restrictions
- d. technology of electric vehicle components
 - provide fundamental information on the function and types of components used in electric vehicles
- e. availability of electric vehicles
 - provide information on the types and models of electric vehicles that are available
 - discuss the pros and cons of the available electric vehicles
 - provide information on the types and performance of electric vehicles that are in development
- f. maintenance issue
 - provide information on the reliability and maintainability of electric vehicles
 - discuss the types of maintenance that will be required
 - define the type of expertise that EV maintenance technicians will require

Introduction to EV Maintenance and Repair

This introductory continuing education course is designed to prepare the maintenance technician with the minimum skills to conduct simple testing and repair of the most common problems encountered with electric vehicles. This course is two and one half days in duration and covers

- a. electric vehicle familiarization
 - the technology and operation of the major electric vehicle components (motor, controller, converter, batteries, and charger)
 - identification of these electric vehicle components and their interrelationship
- b. electric vehicle test equipment familiarization
 - covers the identification and operation of the test equipment needed to perform basic troubleshooting task
- c. electric vehicle component test procedures
 - covers the test procedures necessary to test the major electric vehicle components
- d. troubleshooting electric vehicle faults
 - provides the troubleshooting procedures to identify the major component that is not working properly
- e. electric vehicle component remove and replace procedure
 - provides the procedures to remove and replace the major components such as the motor, battery pack, controller, converter and charger
- f. electric vehicle safety
 - covers the safety issues associated with high voltage and handling hazardous materials

In addition to the developing and offering continuing education programs on electric vehicle technology and maintenance and repair, York Technical College also developed and published a number of educational brochures and information sheets to educate the public about electric vehicles.

These educational brochures focused on various aspects of electric vehicles

a. The Technology of Electric Vehicles

This group of brochures focused on the function and operation of the components used in electric vehicles. These components included the battery pack, electric motor, battery charger, controller, auxiliary equipment and a comparison between conventional gasoline powered vehicles and electric vehicles. These educational brochures are shown in attachment D.

b. The History of Electric Vehicles

These brochures cover the changing technology used in electric vehicles from the early 1900's to the present and are shown in attachment E.

c. The Effect of Electric Vehicles on the Environment

These brochures covered the types of pollutants caused by vehicles, the impact on air quality and the benefits of electric vehicles. These brochures are shown in attachment F.

Working with experts in developing, manufacturing and operating electric vehicles, York Technical College has developed a series of training programs to support the operation of electric vehicles. Availability of additional programs and courses is needed. York Technical College has identified five levels of training needed to support the electric vehicles. They are

- a. Basic
 - operator training and electric vehicle familiarization
- b. Intermediate
 - fundamental EV maintenance and repair
- c. Advanced
 - advanced EV maintenance and repair
 - maintenance procedures laboratory
 - electric vehicle component repair (i.e. motors, controllers, etc.)
- d. Vehicle specific training on troubleshooting, component removal and replacement and component repair
- e. Two-year associate degree programs in electric vehicle maintenance and repair

Public Awareness

One of the major objectives of the Site Operator Program at York Technical College has been to increase the public and corporate awareness and interest in electric vehicles.

At the start of the program, York Technical College and Duke Power Company were the only organizations in the Carolina's interested in the development of electric vehicle technology and the applications and impact electric vehicles could have on the economy and environment.

As part of the Site Operator program, York Technical College began an aggressive program to increase the public awareness of electric vehicles and their benefits to increase the number of partners interested in promoting electric vehicles. The York Technical College Program included:

- a. presentations at local civic meetings
- b. displays and information booths at local events
- c. displays at the local science museum featuring electric vehicles
- d. tours of the electric vehicle laboratory for elementary, secondary and post-secondary students
- e. elementary and secondary school teacher workshops on the electric vehicle technology and the impact on the environment
- f. presentations to students at elementary and secondary schools
- g. electric vehicle ride and drives

In addition to these public awareness activities, electric vehicles were strategically placed with partners throughout the region to not only get greater visibility for electric vehicles, but to also demonstrate the utility of electric vehicles for certain applications. Electric vehicles were used by the

- a. City of Rock Hill
- b. Palmetto Electric Coop
- c. SC State Government

- d. Florence School District
- e. Coastal Center
- f. Discovery Place Science Museum
- g. Duke Power Company
- h. City of Charlotte

As a result of these efforts, the number of local partners working with York Technical College has increased and now include (see attachment G).

- a. York Electric Coop
- b. City of Rock Hill
- c. SC State Energy Office
- d. Palmetto Electric Coop
- e. Santee Cooper
- f. SC Coastal Center
- g. Florence School District
- h. NC Alternative Energy Center
- i. Discovery Place Science Museum
- j. City of Charlotte

Lessons Learned

The most significant lesson learned in this program is when working with a technology that is changing rapidly, vehicle testing, maintenance training programs and public educational materials must be reviewed and updated regularly.

In the area of field testing, accelerated tests should be used to collect high milage data in a short time. This is needed so that timely feedback can be given to the developers of the next generation vehicle. With long time associated with the typical field test program, useful data often was obsolete before it could be used. During the second and third year of a typical field test program, the electric vehicle would only have 10,000 to 20,000 miles, accumulating far too little to getting meaningful information on the life of the battery pack or on the reliability of the EV components. Also with the rapid changes being made, after two to three years, the electric vehicle technology has changed that additional data collection on the older vehicles may not have relevance to the currently available electric vehicles.

The lack of service manuals, electrical schematics and vehicle specific training limited the availability of functioning electric vehicles. When maintenance problems occurred, each operator had to develop the maintenance and troubleshooting procedures to repair his vehicle. In many cases this was done by trial and error and increased the vehicle down time. For future electric vehicle purchases, a service manual with schematics should be provided with each vehicle.

With the current generation of lead-acid batteries, better coordination between the electric vehicle manufacturer and the battery manufacturer is needed. Most of the battery degradation experience at York Technical College can be attributed to an improper charging algorithm. Proper charging will not only extend the life of the battery pack, but will also provide for the maximum range on each charge cycle.

As a result of all of the public appearances and presentations, York Technical College found a great interest in electric vehicles. Many of the people said they would like to own an electric vehicle some day. However, all said before they would consider an electric vehicle, the purchase price would have to be competitive with the prices of conventional gasoline powered vehicles. Cost was the main issue. Range was another issue, but it did not seem as important as purchase price. Many people felt they could use a vehicle with 50-60 miles range. However, this has to be a true range under actual driving conditions. The number of interested people would increase if the public recharging infrastructure was available so that they could charge up while at work or shopping. Increased emphasis by the Department of Energy should be placed on developing the infrastructure, particularly a network of public access recharging stations and an integrated training program to support the operation and maintenance of electric vehicles.

Attachment A

Electric Vehicle Technician

Competency Profile

February 4-5, 1992

YORK TECHNICAL COLLEGE

452 SOUTH ANDERSON ROAD
ROCK HILL, SOUTH CAROLINA 29730

803-325-2865

ENTRY-LEVEL ELECTRIC VEHICLE TECHNICIAN

GENERAL SKILLS AND KNOWLEDGE	DESIRABLE WORKER BEHAVIORS/TRAITS
<p>Communication skills, telephone written oral</p> <p>Visual inspection</p> <p>Mechanical aptitude</p> <p>General automotive knowledge</p> <p>Problem-solving skills</p> <p>Listening skills</p> <p>Reading comprehension skills</p>	<p>Positive attitude</p> <p>Safety conscious</p> <p>Cooperative</p> <p>Good hygiene</p> <p>Sense of humor</p> <p>Patient</p> <p>Willing to learn</p> <p>Meticulous</p> <p>Responsible</p> <p>Flexible</p>
TOOLS, EQUIPMENT, SUPPLIES AND MATERIALS	RECOMMENDED COOPERATIVE EXPERIENCE
<p>Volt Ohm Meter</p> <p>MEGGAR</p> <p>Component diagnostic tools</p> <p>Basic mechanical tools</p> <p>Battery load tester</p> <p>Controller diagnostic equipment</p> <p>Battery equipment</p> <p>Oscilloscope</p> <p>Specific gravity measuring device</p> <p>Oxyacetylene welding equipment</p> <p>Strip recorders</p> <p>Ammeter</p> <p>Face shields</p> <p>Rubber gloves</p> <p>Eye washes</p> <p>Material Specification Data Sheet</p> <p>Capacitor charge eliminator</p> <p>Service manuals and schematics</p>	<p>Automotive and/or electronics</p>

PARTICIPANTS

Panelists:

R. R. (Dick) Bassett, Consultant & Manager Electric Vehicle Program, Sandia National Laboratories, Albuquerque, New Mexico.

John M. Hering, Marketing, Detroit Edison Company, Detroit, Michigan.

Ernie Holden, President, Solar & Electric Racing Association, Phoenix, Arizona.

Mert Houdek, Electric Vehicle Technician, Arizona Public Service Company, Phoenix, Arizona.

Dana O'Hara, Mechanical Engineer, US Department of Energy, Washington, DC.

Richard Roberts, Manager, Alternate Energy Programs, Naval Air Weapons Station, China Lake, California.

Joseph J. Salko, Electrical Test Engineer, Public Service Electric & Gas Company, Newark, New Jersey

Randy Stone, Engineer I, Southern California Edison, Pomona, California.

Facilitator:

Louise C. Rhyne, Instructional Developer, York Technical College, Rock Hill, SC.

Recorder:

Sylvia LaValle-King CPS, Administrative Secretary, York Technical College, Rock Hill, SC.

Program Manager:

Robert Ferrell, York Technical College, Rock Hill, SC.

ELECTRIC VEHICLE TECHNICIAN

An entry-level Electric Vehicle Technician maintains and repairs electric vehicles, using mechanical and electrical skills.

DUTIES

A. DEVELOP BASIC AWARENESS OF ELECTRIC VEHICLE TECHNOLOGY AND RELATED ISSUES	A.1 Develop awareness of history and future of electric vehicles	A.2 Identify environmental issues related to electric vehicles	A.3 Identify energy issues related to electric vehicles	A.4 Recognize legislation related to electric vehicles, i.e., emission regulations, support programs
B. DEVELOP BASIC ELECTRONIC SKILLS	B.1 Demonstrate awareness of basic electrical safety	B.2 Demonstrate an understanding of basic theory of AC and DC electricity	B.3 Demonstrate basic understanding of digital theory and solid state theory	B.4 Read and interpret block diagrams, basic circuits, fault tree analysis and system logic
C. MAINTAIN AND MONITOR BATTERIES AND REPAIR ANCILLARY EQUIPMENT	C.1 Demonstrate electrical, physical and chemical safety	C.2 Identify types of batteries, i.e., lead acid, nickel-iron, ni-cad, sodium sulfur and metal air	C.3 Identify hazardous battery materials and other hazardous materials	C.4 Demonstrate proper procedure for handling hazardous materials and disposal of batteries
	C.10 Service batteries	C.11 Diagnose failure	C.12 Troubleshoot, maintain, and repair battery cables and connections	C.13 Troubleshoot, maintain and repair thermal control systems
D. MAINTAIN, REPAIR, OR REPLACE AC AND DC TRACTION MOTORS	D.1 Demonstrate awareness of high-voltage safety	D.2 Demonstrate basic understanding of AC and DC motors	D.3 Perform and interpret visual inspection	D.4 Utilize test equipment for motor inspection
E. MAINTAIN, REPAIR, OR REPLACE AC AND DC TRACTION CONTROLLERS	E.1 Demonstrate awareness of high-voltage safety	E.2 Demonstrate understanding of controller technology	E.3 Diagnose controllers for repair or replacement following manufacturer's specifications	
F. MAINTAIN, REPAIR, OR REPLACE CONVERTERS	F.1 Demonstrate awareness of high-voltage safety	F.2 Demonstrate understanding of converter systems	F.3 Diagnose converter for repair or replacement	F.4 Repair or replace converter and adjust to manufacturer's specification
G. MAINTAIN, REPAIR, OR REPLACE CHARGERS	G.1 Demonstrate awareness of high-voltage safety	G.2 Demonstrate awareness of public safety	G.3 Identify types of chargers, i.e., smart, timed	G.4 Demonstrate an understanding of battery by type of charge and battery technology

-- TASKS ----->

A.5 Relate involvement of electric utilities with electric vehicle technology		A.6 Identify electric vehicle manufacturer and types of electric vehicles	A.7 Recognize vehicle design considerations, i.e., FMVSS, hybrid	A.8 Relate the use of solar energy to electric vehicles	
B.5 Read and interpret schematics	B.6 Develop skills with test equipment	B.7 Develop skills using digital and solid state devices	B.8 Recognize basic micro processes		
C.5 Demonstrate knowledge of batteries and battery chemistry	C.6 Demonstrate knowledge of battery characteristics, i.e., life cycle, charge and discharge rates, capacity, energy density, temperature, for each type of battery technology		C.7 Test and evaluate battery for replacement	C.8 Analyze and replace modules	C.9 Replace battery pack
C.14 Troubleshoot, maintain and repair battery ventilation systems	C.15 Troubleshoot, maintain and repair instrumentation, e.g., state of charge, volts, amps				
D.5 Interpret test data for repair or replacement of motor	D.6 Replace motor, bearings, or brushes	D.7 Diagnose motor failure, mechanical and electrical	D.8 Perform routine maintenance, i.e., air filters, fans	D.9 Maintain and repair cooling system	
E.4 Repair or replace controllers	E.5 Diagnose vehicle controller systems	E.6 Repair or replace vehicle controller systems			
F.5 Evaluate effect on battery capacity and overcharge	G.6 Demonstrate an understanding of charger electronics	G.7 Maintain, repair or replace charger and/or components	G.8 Install chargers and perform functional check	G.9 Relate economic benefits of charging to time of day	

DUTIES

TASKS

A
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S
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S
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M
S**H. MAINTAIN
AND REPAIR
AUXILIARY
SYSTEMS**H.1
Demonstrate
awareness of
high-voltage safetyH.2
Troubleshoot,
maintain and
repair
instrumentationH.3
Troubleshoot, maintain, repair or
replace auxiliary motorsH.4
Troubleshoot,
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AND REPAIR
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i.e., heat pumpsI.3
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problems as
related to
electric vehiclesI.4
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repair heating
systems of
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maintain, repair or
replace auxiliary
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Troubleshoot,
maintain and
repair auxiliary
controllers**J. MAINTAIN
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Identify types of
braking systems,
i.e., power,
regenerative, ABSJ.3
Demonstrate
an
understanding
of braking
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repair regenerative
brakingJ.8
Demonstrate an understanding of
anti-lock/regenerative interface
system**K. MAINTAIN
AND REPAIR
POWER
STEERING**K.1
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high-voltage safetyK.2
Demonstrate an
understanding of
power steering
systemsK.3
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maintain and
repair power
steering
systemsK.4
Troubleshoot,
maintain, repair
or replace
auxiliary motorsK.5
Troubleshoot,
maintain and
repair auxiliary
controllers**L. DEVELOP
DRIVER TRAINING
SKILLS**L.1
Identify electric
vehicle driving safety
requirementsL.2
Develop
awareness of
factors affecting
rangeL.3
Identify gauges
and controlsL.4
Develop starting
and stopping
skillsL.5
Develop driving
techniques, i.e.,
passing, braking,
acceleration,
decelerationL.6
Advise operators on (electric vehicle)
driving skills and charging proceduresL.7
Diagnose and evaluate electric
vehicle performance by test driving

Attachment B

ELECTRIC VEHICLE ENGINEERING TECHNOLOGY
ASSOCIATE IN ENGINEERING TECHNOLOGY

I. General Education Courses		Credits
A. Basic Economics (ECO 101) or Psychology (PSY 105)		3.0
B. English Composition I (ENG 101)		3.0
C. Technical Communications (ENG 160)		3.0
D. Technology and Society (HSS 205)		3.0
E. Technical Algebra and Trigonometry (MAT 173)		4.0
F. Technical Trigonometry and Calculus (MAT 174)		4.0
G. Physics I (PHY 201)		4.0
H. Physics II (PHY 202)		<u>4.0</u>
	Subtotal	28.0
II. Electronics/Electricity Courses		
A. Principles of Electronics With Applications I (XXX YYY)		4.0
B. Principles of Electronics With Applications II (XXX YYY)		4.0
C. Digital Circuits (EET 145)		<u>4.0</u>
	Subtotal	12.0
III. Electric Vehicles Technology Courses		
A. Introduction to Electric Vehicles (XXX YYY)		1.0
B. Energy Storage Systems (XXX YYY)		3.0
C. Traction Motors		
1. DC Machines (EEM 213)		3.0
2. AC Machines (EEM 211)		3.0
D. EV Motor Controllers and Drives (XXX YYY)		3.0
E. EV Auxiliary Systems (XXX YYY)		2.0
F. Beginning EV Repair (XXX YYY)		4.0
G. Advanced EV Repair (XXX YYY)		4.0
H. EV Driver Training (XXX YYY)		<u>2.0</u>
	Subtotal	25.0
IV. Other Required Courses		
A. Suspension and Steering (AUT 121)		3.0
B. Braking Systems (AUT 112)		4.0
C. Automotive Air Conditioning (AUT 241)		4.0
	Subtotal	11.0
	Total Credits	76.0

ELECTRONICS ENGINEERING TECHNOLOGY	CREDIT HOURS	4.0
PRINCIPLES OF ELECTRONICS W/APPLICATIONS I (EET 1BB)	LECTURE HOURS	3.0
INITIAL DRAFT	LAB HOURS	3.0

COURSE DESCRIPTION

This course is part two of a two part series and serves as a continuation of the theory and application of electricity and electronics. The scope is expanded to AC circuits and various electronic components to include active and passive solid state devices and their application in industrial circuits. Continued emphasis is made on those devices and circuits that have an industrial application to electric vehicle technology.

COURSE COMPETENCIES

Upon successful completion of this course, the student should be competent to perform the following:

- Demonstrate knowledge of high voltage electrical safety
- Be able to identify basic electrical devices and symbols
- Demonstrate an understanding of both AC and DC electricity
- Demonstrate an understanding of magnetism and induction
- Read and interpret block diagrams and schematics
- Develop skills with digital and analog test equipment
- Demonstrate basic understanding of solid state theory
- Develop skill using solid state devices
- Trouble shoot and repair instrumentation
- Demonstrate understanding of converter systems
- Diagnose converters for repair or replacement
- Adjust converter to manufacturer's specifications

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

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If a student misses an exam because of illness or urgent

emergency, he/she should notify the instructor prior to the class period, or at the earliest possible date. At that time a new date for a makeup test will be scheduled.

Students with unexcused absences during exams will be allowed to take a makeup exam at the discretion of the instructor.

The student has the burden of ensuring that some arrangement is made with the instructor for makeup exams.

ACADEMIC INTEGRITY/HONESTY:

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Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

PREREQUISITES

Principles of Electronics With Applications I (EET 1AA)

CO-REQUISITES

Technical Algebra and Trigonometry (MAT 174)

TOPIC/CONTENT OUTLINE

Principles of Electronics With Applications II

1. Alternating Voltage and Current
2. Inductance
3. Inductive Reactance
4. Inductive Circuits
5. Capacitance
6. Capacitance Reactance
7. Capacitance Circuits
8. Alternating-Current Circuits
9. Devices and Components
 - a. Transformers
 - b. Diodes/Rectifiers
 - c. LEDs
 - d. Transistors
 - e. Thyristors
 - 1) SCRS
 - 2) Triacs
 - f. Integrated Circuits
 - 1) Oscillators and Choppers and Timers
 - 2) Operational Amplifiers
 - 3) Instrumentation Amplifiers
 - 4) Comparators
 - 5) Thermistors
 - 6) Introduction to Logic Circuits and Devices
10. Applications
 - a. AC Power Supplies
 - 1) AC to AC
 - *. Variable Voltage AC Supplies
 - *. Variable Frequency AC Supplies
 - 2) DC to AC Conversion
 - *. Motor Generators Sets
 - *. Electronic Conversion Circuits
 - b. DC Power Supplies
 - 1) DC to DC Conversion
 - 2) AC to DC Conversion
 - c. Device Interfacing and Control
 - 1) Relay Drivers
 - 2) Indication and Alarms
 - 3) Motion Control
 - d. Basic Instrumentation
 - 1) Temperature Measuring Devices
 - 2) Level Measuring Devices
 - 3) Speedometers/Odometers
 - 4) Tachometers

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of three hours of classroom periods and three hours of practical laboratory exercises. The class instruction includes lectures, discussions, problem solving/trouble shooting sessions and both written and oral exams.

Laboratory experiments are designed to follow class lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain skills in trouble shooting and repair of industrial circuits and equipment.

ELECTRICAL CAR ENGINEERING TECHNOLOGY
INTRODUCTION TO ELECTRICAL VEHICLES
(EVT 1AA)
INITIAL DRAFT

CREDIT HOURS 1.0
LECTURE HOURS 1.0
LAB HOURS 0.0

COURSE DESCRIPTION

This course is a survey of electrically powered vehicles to include a history of electrical vehicles, current regulatory and environmental issues, electric vehicle types and a glimpse to the future of electric vehicles

COURSE COMPETENCIES

- Develop awareness of the history of electric vehicles
- Identify environmental issues related to electric vehicles
- Recognize legislation related to electric vehicles
- Relate involvement of electric utilities with electric vehicle technology
- Identify electric vehicle manufacturer and types of electric vehicles
- Recognize vehicle design considerations
- Relate the use of solar energy to electric vehicles

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

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Students are expected to participate in class discussions and complete all assigned homework, and reports.

LABORATORY REQUIREMENTS

None

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

<u>Grade</u>	<u>Score</u>
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	95%
Work Attitude	5%
-attendance	
-responsibility	

PREREQUISITES

None

CO-REQUISITES

None

TOPIC/CONTENT OUTLINE

Introduction to Electric Vehicles

1. A History of Electric Vehicles
 - a. Why EV?
 - b. Beginnings
 - c. Present Usage
2. Environmental Issues
3. Federal and State Regulations
4. Types of Electric Vehicles
 - a. Conventional Battery Powered
 - b. Heat Engine Hybrid
 - c. Solar/Battery Hybrid
 - d. Engine/Generator Hybrid
 - e. Flywheel Hybrid
5. A Look to the Future

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of one hour of classroom instruction. Instruction includes lectures, discussions, and both written and oral exams.

ELECTRIC CAR ENGINEERING TECHNOLOGY
ENERGY STORAGE SYSTEMS
(EVT 1BB)
INITIAL DRAFT

CREDIT HOURS 3.0
LECTURE 2.0
LAB HOURS 3.0

COURSE DESCRIPTION

This course addresses the various types of storage batteries, their theory of operation and related maintenance to include aspects of safety, routine servicing, trouble shooting (evaluation and testing) and replacement of batteries. Also covered is battery chargers, thermal control systems, ventilation systems, and converters.

COURSE COMPETENCIES

- Demonstrate electrical, physical and chemical safety
- Identify types of batteries
- Identify hazardous battery materials
- Demonstrate proper procedure for handling hazardous materials and disposal of batteries
- Demonstrate knowledge of batteries and their chemistry
- Demonstrate knowledge battery characteristics:
 - life cycles
 - charging/discharging rates
 - capacity
 - energy density
 - temperature restraints
- Test and evaluate batteries for replacement
- Analyze and replace modules
- Replace battery packs

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

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Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later) --

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

PREREQUISITES

Principles of Electronics With Applications I (EET 1AA)

Physics I (PHY 201)

TOPIC/CONTENT OUTLINE

Energy Storage Systems

1. Electrical/Chemical Electrical Storage
 - a. Primary Cells
 - 1) Carbon-Zinc Dry Cell
 - 2) Alkaline Cell
 - 3) Lithium Cell
 - b. Secondary Cells
 - 1) Lead-Acid Batteries
 - 2) Nickel/Iron Batteries
 - 3) Sodium/Sulfur Batteries
 - 4) Lithium/Iron Sulfide Batteries
 - 5) Nickel-Cadmium Cells
 - 6) Metal-Air Batteries
 - c. Battery Packs
 - 1) Configurations
 - *. Series Connections
 - *. Parallel Connections
 - 2) Current Drain
 - *. Internal Resistance
 - *. Terminal Voltage
 - 3) Maximum Usage Efficiency
 - d. Charging Systems
 - 1) Main Battery Charger (AC to DC)
 - *. Conventional Chargers
 - *. Timed Chargers
 - *. Smart Chargers (microprocessor controlled)
 - 2) Converters (DC to DC)
 - 3) Regenerative Charging (see controllers also)
 - e. Battery Management Systems
 - 1) Watering Systems
 - 2) Ventilation Systems
 - 3) Thermal Control Systems
 - 4) Instrumentation Systems
 - *. State of Charge
 - *. Terminal Voltage
 - *. Charge/Discharge Rates
 - 5) Electrolyte Management Systems
 - f. Battery Operation and Maintenance
 - 1) Safety Considerations and Procedures
 - 2) Battery Life Cycles
 - 3) Charging/Discharging Rates
 - 4) Routine Servicing
 - 5) Cell Load Tests and Evaluation
 - *. Resistive Load Cells
 - *. Pump Back Systems
 - *. Test Equipment
 - *. Procedures
 - g. Hazardous Material Management
 - 1) Hydrogen Generation and Control
 - 2) Electrolyte Handling/Storage
 - 3) Material Disposal
2. Mechanical Energy Storage
 - a. Flywheels
 - b. Compressed Gases
 - c. Springs

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of two hours of classroom periods and three hours of practical laboratory exercises. The class instruction includes lectures, discussions, problem solving/trouble shooting sessions and both written and oral exams.

Laboratory experiments are designed to follow class lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain experience in the servicing and maintenance of electrical storage systems.

ELECTRICAL VEHICAL ENGINEERING TECHNOLOGY	CREDIT HOURS	3.0
EV CONTROLLERS AND DRIVES	LECTURE HOURS	2.0
(EVT 2AA)		
INITIAL DRAFT	LAB HOURS	3.0

COURSE DESCRIPTION

This course is an in-depth look at the various types of motor controllers and their associated power supplies. Subjects include but are not limited to motor starting circuits, control devices and traction drives with microprocessors control.

COURSE COMPETENCIES

- Demonstrate awareness of high-voltage safety
- Demonstrate understanding of controller technology
- Diagnose controllers for repair or replacement
- Repair or replace traction controllers
- Diagnose vehicle controller systems
- Repair or replace auxiliary motor controllers

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

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ACADEMIC INTEGRITY/HONESTY:

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Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

PREREQUISITES

Principles of Electronics With Applications I (EET 1AA)

Principles of Electronics With Applications II (EET 1BB)

TOPIC/CONTENT OUTLINE

EV Motor Controllers and Drives

1. Control Devices
 - a. Switches
 - 1) Maintained
 - 2) Momentary
 - *. Limit Switches
 - *. Proximity Switches
 - *. Photoswitches
 - b. Relays
 - 1) Conventional

- 2) Solid State
- c. Solenoids
- d. Timers
- e. Protective Devices
 - 1) Overcurrent
 - 2) Overload
 - 3) Surge Protection
 - *. Capacitance (rise time protection)
 - *. Varsistors (peak protection)
- 2. Auxiliary Motor Starting Circuits
- 3. Traction Drives and Control
 - a. Electronic DC Motor Controllers
 - b. Electronic AC Motor Controllers
 - c. Digital Drives
- 4. Regeneration

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of two hours of classroom instruction and three hours of practical laboratory exercises. The classroom instruction includes lectures, discussions, problem solving/critical thinking sessions and both written and oral exams.

Laboratory experiments are designed to follow class lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain skills in trouble shooting and repair of motor controllers and drives.

ELECTRIC VEHICLE ENGINEERING TECHNOLOGY
EV AUXILIARY SYSTEMS
(EVT 1CC)
INITIAL DRAFT

CREDIT HOURS 2.0
LECTURE HOURS 1.0
LAB HOURS 3.0

COURSE DESCRIPTION

This course is an introduction to electric vehicle support systems. Subjects include but are not limited to automotive electrical systems, thermal protective systems, heating systems, auxiliary motors and instrumentation systems.

COURSE COMPETENCIES

- Demonstrate awareness of high-voltage safety
- Troubleshoot and repair instrumentation
- Troubleshoot, maintain and repair auxiliary motors
- Troubleshoot, maintain and repair auxiliary controllers

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

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Attendance:

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Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D --	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
--house keeping	
-safety	
-works independently	

PREREQUISITES

Principles of Electronics With Applications I (EET 1AA)

TOPIC/CONTENT OUTLINE

- EV Auxiliary Systems
- 1. Automotive Electrical Systems
- 2. Thermal Protective Systems
- 3. Heating Systems (Environmental)
- 4. Auxiliary motors
- 5. Instrumentation Systems

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of one hour of classroom period and three hours of practical laboratory exercises. The class instruction includes lectures, discussions, problem solving/trouble shooting sessions and both written and oral exams.

Laboratory experiments are designed to follow class lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain skills in trouble shooting and repair of electric vehicle support systems.

ELECTRICAL VEHICLE TECHNOLOGY
BEGINNING EV REPAIR
(EVT 2BB)
INITIAL DRAFT

CREDIT HOURS 4.0
LECTURE HOURS 3.0
LAB HOURS 3.0

COURSE DESCRIPTION

This is an introductory course in the servicing and repair of electrical vehicles. The scope ranges from the very basic of troubleshooting and repair/replacement of battery cables to the more complex auxiliary support systems found in today's electric vehicles (to include instrumentation systems).

COURSE COMPETENCIES

- Troubleshoot, maintain and repair/replace battery cables and connections
- Troubleshoot, maintain, repair thermal control systems
- Troubleshoot, maintain and repair/replace battery ventilation systems
- Troubleshoot, maintain and repair instrumentation
- Repair/replace converters
- Adjust converters to manufacturer's specifications
- Maintain, repair/replace battery chargers and/or components
- Install chargers and perform functional checks

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

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is made with the instructor for makeup exams.

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Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

ENTRY LEVEL SKILLS

Students must be able to read wiring diagrams and schematics. In addition he/she must be able to use multimeters and electronic calibrators to test for continuity and to generate/measure voltage and current.

PREREQUISITES

Principles of Electronics with Applications I (EVT 1AA)

Principles of Electronics With Applications II (EVT 1BB)

Digital Circuits (EET 145)

CO-REQUISITES

None

TOPIC/CONTENT OUTLINE

Beginning EV Repair

1. Electrical/High Voltage Safety
2. Manuals and Schematics
3. Test Equipment
4. Alignments
 - a. Mechanical
 - 1) Head Lamps
 - 2) Shaft and Drives
 - b. Electrical
 - 1) Controller Adjustments
 - 2) Converter Adjustments
5. Troubleshooting Techniques
6. Component Replacement
7. Preventative Maintenance

LABORATORY EXPERIMENTS

(later) --

METHOD OF INSTRUCTION

This course consists of three hours of classroom periods and three hours of practical laboratory exercises. The class instruction includes lectures, discussions, problem solving/trouble shooting sessions and both written and oral exams.

Laboratory experiments are designed to follow class lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain skills in trouble shooting and repair of electrical vehicles.

ELECTRICAL VEHICLE TECHNOLOGY
ADVANCED EV REPAIR
(EVT 2CC)
INITIAL DRAFT

CREDIT HOURS 4.0
LECTURE HOURS 3.0
LAB HOURS 3.0

COURSE DESCRIPTION

This course teaches the student how to diagnose, repair and replace both AC and DC traction motors and their controllers.

COURSE COMPETENCIES

- Perform and interpret visual inspection
- Utilize test equipment for motor inspection
- Interpret test data for repair or replacement of motor
- Diagnose motor failure, mechanical and electrical
- Replace traction motors, bearings and brushes
- Perform routine maintenance
- Maintain and repair cooling system
- Diagnose, repair or replace controllers and systems
- Test and evaluate battery for replacement
- Analyze and replace modules and battery packs

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

- Students should adhere to the attendance policy set forth in York Technical College Handbook. Students must attend 80% of the hours assigned the class for a semester to receive credit for the course.

In case a student does miss a class, he/she is responsible for obtaining the material that was covered during the absence. If a student is aware that he/she will miss a class, then the student should notify the instructor at the earliest possible date.

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Students with unexcused absences during exams will be allowed to take a makeup exam at the discretion of the instructor.

The student has the burden of ensuring that some arrangement is made with the instructor for makeup exams.

ACADEMIC INTEGRITY/HONESTY:

York Technical College adheres to the South Carolina TECH Student Code, approved by the State Board for Technical and Comprehensive Education on March 13, 1974 (revised April 25, 1984). Copies of this code are available in the Library and from Student Services. Any student caught cheating or involved in any other academic dishonesty will be given a grade of zero and will be subject to further disciplinary action. For further details refer to the student handbook section "Student Life", sub-heading "Student Conduct".

Students are expected to participate in class discussions and problem solving, complete all assigned homework, laboratory experiments and reports.

LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

The grading scale will be the standard for York Technical College (see the instructor or addendum for additional details)

Grade	Score
A	90-100
B	80-89
C	70-79
D	60-69
F	below 60

Evaluation Method

Tests/Homework	70%
Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

ENTRY LEVEL SKILLS

The student needs to be familiar with basic mechanical tools and their uses; in addition needs skills in using test equipment to measure circuit continuity, voltages and currents.

PREREQUISITES

Beginning EV Repair EVT 2BB

CO-REQUISITES

None

ELECTRICAL VEHICLE TECHNOLOGY
EV DRIVER TRAINING
(EVT 2DD)
INITIAL DRAFT

CREDIT HOURS 2.0
LECTURE HOURS 1.0
LAB HOURS 3.0

COURSE DESCRIPTION

This is a course designed to introduce the student to the safe operation of electric vehicles. Included is the required general maintenance and servicing of electrical vehicles, electrical and operator safety, proper operation of electrical vehicles, optimum mileage techniques and vehicle test driving and evaluation.

COURSE COMPETENCIES

- Identify electric vehicle driving safety requirements
- Awareness of factors affecting driving range
- Identify vehicle's operator gauges and controls
- Demonstrate proper driving techniques for the following:
 - Starting
 - Stopping
 - Passing
 - Braking
 - Acceleration/Deceleration
- Demonstrate knowledge of safe charging procedures

MINIMAL STANDARDS/PERFORMANCE OBJECTIVES

(later)

COURSE REQUIREMENTS

Students are responsible for attaining competencies through completion of the following course requirements.

Attendance:

Students should adhere to the attendance policy set forth in York Technical College Handbook. Students must attend 80% of the hours assigned the class for a semester to receive credit for the course.

In case a student does miss a class, he/she is responsible for obtaining the material that was covered during the absence. If a student is aware that he/she will miss a class, then the student should notify the instructor at the earliest possible date.

If a student misses an exam because of illness or urgent emergency, he/she should notify the instructor prior to the class period, or at the earliest possible date. At that time a new date for a makeup test will be scheduled.

Students with unexcused absences during exams will be allowed to take a makeup exam at the discretion of the instructor.

The student has the burden of ensuring that some arrangement

is made with the instructor for makeup exams.
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LABORATORY REQUIREMENTS

(later)

EVALUATION STRATEGIES/GRADING

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Evaluation Method

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Lab Work/Reports	25%
Work Attitude	5%
-attendance	
-responsibility	
-house keeping	
-safety	
-works independently	

ENTRY LEVEL SKILLS

The student must possess a valid driver licence.

PREREQUISITES

None

CO-REQUISITES

None

TOPIC/CONTENT OUTLINE

EV Driver Training

1. Operator Orientation
2. Safety
 - a. Electrical
 - b. Driver/Operating
3. Scheduled Maintenance
 - a. General
 - 1) Tires
 - 2) Brakes
 - 3) Transmission/Drive Mechanisms
 - b. Battery Operation and Special Maintenance
 - 1) Safety Precautions
 - *. During Charging
 - *. Hazardous Materials
 - 2) Preventive Maintenance
 - *. Watering Systems
 - *. Thermal Control
 - 3) Extending Battery Life
4. Corrective Maintenance
 - a. Cable Cleaning/Replacement
 - b. Electrolyte Maintenance
 - c. Cell Replacement
5. Other Related Information

LABORATORY EXPERIMENTS

(later)

METHOD OF INSTRUCTION

This course consists of one hour of classroom instruction and three hours of practical laboratory/driving exercises per week. The class instruction includes lectures, discussions, problem solving, critical thinking and both written and oral exams.

Practical exercises are designed to follow classroom lectures and to provide students with appropriate hands-on experience that is vital to both their understanding of the material and to gain skills in servicing, maintaining and operating electrical vehicles.

Attachment C

York Technical College's Electric Vehicle Program Partners

Attachment D

How Do Gasoline & Electric Vehicles Compare

From the outside, the electric vehicle looks like a conventional gasoline powered vehicle with the exception that the electric vehicle does not have an exhaust system nor a tail pipe. Internally, it is quite a different story.

According to CALSTART, the advanced transportation consortium in California, 70 percent of an electric vehicle's component parts may be different than a conventional vehicle. The electric vehicle has several

GASOLINE VEHICLE	FUNCTION	ELECTRIC VEHICLE
Gasoline Tank	Stores the energy to run the vehicle	Battery
Gasoline Pump	Replaces the energy to run the vehicle	Charger
Gasoline Engine	Provides the force to move the vehicle	Electric Motor
Carburetor	Controls acceleration and speed	Controller
Alternator	Provides power to accessories	DC/DC converter
	Converts DC to AC to power AC motor	DC/AC converter
Smog Controls	Lowers the toxicity of exhaust gases	

unique components that serve the same function as the more common components in a gasoline powered vehicle.

Another significant difference between electric vehicles and gasoline powered vehicles is the number of moving parts. The electric vehicle has one moving part, the motor, whereas the gasoline powered vehicle has hundreds of moving parts.

Fewer moving parts in the electric vehicle leads to another important difference. The electric vehicle requires less periodic maintenance and is more reliable. The conventional gasoline powered vehicle requires a wide range of maintenance, from frequent oil changes, filter replacements, periodic tune ups, and exhaust system repairs,

to the less frequent component replacement, such as the water pump, fuel pump, alternator, etc. The electric vehicle's maintenance requirements are fewer and therefore the maintenance costs are lower. The electric motor has one moving part, the shaft, and is very reliable and requires little or no

maintenance. The controller and charger are electronic devices and with no moving parts and require little or no maintenance. State of the art lead acid batteries used in current electric vehicles are sealed and are maintenance free. However, battery life is limited and periodic battery replacement will be required. New batteries are being developed that will not only extend the range of electric vehicles, but will also extend the life of the battery pack which may eliminate the need to replace the battery pack for the life of the vehicle.

Internal Combustion Vehicle		Electric Vehicle

Moving Parts		
Pistons	Water pump	Electric motor
Drive shaft	Cam shaft	
Alternator	Valves	
Fuel pump	Rotor	
Oil pump	Etc., etc.	
Hundreds of moving Parts		Only one moving part

Internal Combustion Vehicle

Ignition	— plugs, caps, rotors	— periodic tune ups
Cooling	— radiator, water pump, hoses	— cooling system flush, anti freeze replacement
Fueling	— fuel injectors, fuel pump, filters, hoses	— periodic replacement
Mechanical	— block, heads, oil pump, piston rings, alternator, starter	— periodic overhaul
Drive	— transmission, brakes, wheels, tires	— periodic system maintenance

Not only are electric vehicles easier and cheaper to maintain, they are also more efficient than the gasoline engine and are therefore cheaper to operate. Based on the efficiency of current electric vehicles of 3.5 miles/kwhr and an average of 30 mpg for gasoline vehicles, the distance that can be traveled for a fuel cost of \$1.00 is nearly three times as far with an electric vehicle.

While the electric vehicle will be cheaper to operate and maintain, a number of challenges still exist for the owner of an electric vehicle.

First and foremost is the limited range available with current battery technology. The driving range between recharging using existing lead acid batteries is between 50 to 100 miles. New battery systems are being developed that will increase this range and prototypes of these batteries have demonstrated ranges up to 375 miles between recharging.

Other challenges facing the owners of electric vehicles are the availability of skilled service technicians to service and maintain the electric vehicle and the infrastructure to recharge the batteries. Training programs are being developed and offered to upgrade the conventional automotive technician with the skills needed to maintain an electric vehicle and a two year associate degree program has been developed to train high school graduates to become skilled electric vehicle technicians

The most significant element of the recharging infrastructure already exists. Electric power is available in almost all locations. The remaining element needed is to ensure that charging stations, with the proper types of service (i.e. voltage and current), are available at strategic locations to support the electric vehicle. Arrangements must also be made to ensure off peak charging to get the lowest utility rates.

For further information, please contact:

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 U.S. Department of Energy
 1000 Independence Avenue, S.W.
 Washington, DC 20585

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Clean Cities Hotline

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When these goals are met, batteries will be able to provide electric vehicles with ranges greater than 200 miles and a battery life greater than 200,000 miles. The cost of these new batteries will be less than 2 cents per mile. The 1.5 cents per mile operating cost for electricity and the 2 cents per mile life cycle cost for the battery is less than the approximate cost of gasoline at 4 cents per mile.

New advances are also being made in the development of low rolling resistance tires and

nickel-metal hydride battery system. The USABC is also supporting battery systems to meet the long term goals. The two systems being investigated are the lithium polymer and the lithium ion battery systems.

Independent of the battery development efforts supported by the USABC, the Advanced Lead Acid Battery Consortium, an association of lead acid battery manufacturers and material suppliers, is supporting development programs to improve the near term performance of the lead acid battery.

Performance of Advanced EV Battery Systems

	Energy density (wh/kg)	Power density (w/kg)	Battery life (cycles)	Initial cost (\$/KWhr)	Est. Range (miles)	Est. life (miles)
Advanced lead acid	50	130	600	\$150	90	54,000
Nickel cadmium	60	200	1500	\$300	100	150,000
Nickel metal hydride	90	200	600	\$500	150	90,000
Lithium ion	140	200-300	1200	\$200	230	276,000
Lithium polymer	130	200	1000(est)	\$175	215	215,000

light weight structures. New electric vehicles, which are being designed and built from the ground up with light weight materials and advanced drive train systems, will become increasingly more efficient. A new car designed and built as an electric vehicle by Solectria recently traveled 375 miles on a single charge with nickel-metal hydride batteries.

The battery systems being supported by the USABC to meet the mid term goals is the

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EV Batteries

The electric vehicle battery pack performs the same function as the gasoline tank in a conventional vehicle, it stores the energy needed to operate the vehicle. Battery packs can contain 10 to 52 individual 6 or 12 volt batteries similar to the starter battery used in gasoline vehicles. While a gasoline tank can store the energy to drive 300 to 500 miles before refilling, the current generation of batteries will only store energy to drive 50 to 100 miles between recharging.

The range of an electric vehicle (the distance traveled between recharging) is dependent on the energy stored in the battery pack. Just as the amount of gasoline can be increased by installing a larger gas tank, the amount of stored electrical energy can also be increased by increasing the number and/or size of batteries in the battery pack. However, when batteries are added, the weight is increased and the space used by the battery pack increases. Because of this weight and space penalty, there is a physical limit to the number of batteries which can be used for any given vehicle.

To increase the range and improve the performance of electric vehicles, improved batteries are needed that can store larger amounts of energy with the

same weight and volume. The United States Advanced Battery Consortium (USABC) was established to develop the next generation battery for electric vehicles. The members of the USABC include the big three US automobile manufacturers, the Electric Power Research Institute (EPRI), some electric utilities and the United States Department of Energy.

The USABC has established mid-term and long-term goals for electric vehicle battery development. Mid-term batteries are scheduled to be in pilot production in 1996-1997 and in full production by 1998. Batteries meeting the long-term goals are scheduled to have prototype demonstration from 1995-1998, pilot scale production in 1999 - 2000 and full scale production in 2003.

The performance goals for these batteries are:

USABC Battery Performance Goals

	Battery Performance Factor			
	Energy Density (Whr/Kg)	Power Density (W/Kg)	Life (Cycles/years)	Cost
Current Lead Acid	33	100	400/3	\$100
USABC MidTerm Goals	80-100	150	600/5	\$150
USABC Long Term Goals	200	400	1000/10	\$100
Impact on Vehicle Performance	Range	Acceleration	Life cycle cost Replacement period	Acquisition cost Battery replacement cost

EV Power Systems (Motors and Controllers)

The power system of an electric vehicle consists of just two components, the motor which provides the power and the controller which controls the application of this power. In comparison, the power system of gasoline powered vehicles consist of a number of components, such as the engine, carburator, oil pump, water pump, cooling system, starter, exhaust system, etc.

As in the DC motor, an AC motor also has a set of coils (field) and a rotor or armature, however, since there is a continuous current reversal, a commutating device is not needed.

Both types of electric motors are used in electric vehicles and have their advantages and their disadvantages.

Motors

Electric motors are devices used to convert electrical energy into mechanical energy. Two basic types of electric motors are used in electric vehicles to provide power to the wheels, they are the direct current (DC) motor and the alternating current (AC) motor.

Electric Motor Comparison

AC Motor	DC Motor
Single speed transmission	Multi-speed transmission
Light weight	Heavier for same power
Less expensive	Higher cost
95% efficiency at full load	85%-89% efficiency at full load
More expensive controller	Simple controller
Motor/controller/inverter more expensive	Motor/controller - lower cost

DC electric motors have three main components:

1. a set of coils (field) that creates the magnetic forces which provide torque
2. a rotor or armature mounted on bearings that turns inside the field
3. a commutating device that reverses the magnetic forces and makes the armature turn, thereby providing horsepower

While the AC motor is less expensive and lighter weight, the DC motor has a simpler controller such that the DC motor/controller combination is less expensive. The main disadvantage of the AC motor is the cost of the electronics package needed to convert (invert) the battery's direct current to alternating current for the motor.

Motor Characteristics

Past generations of electric vehicles used the DC motor/controller system because they can operate off the battery current without complex electronics. The DC motor/controller systems is still used today on electric vehicles to keep the cost down.

However, with the advent of better and less expensive electronics, a large number of today's electric vehicles are using AC motor/controller systems mainly because of their improved motor efficiency and secondly because of their lighter weight.

These AC motors resemble motors commonly used in home appliances and machine tools, and are relatively inexpensive and robust. They are very reliable, and since they have only one moving part, the shaft, they should last the life of the vehicle with little or no maintenance.

As the cost of the electronics to convert (invert) battery direct current into alternating current decreases, AC motors will increase in popularity as the power system for electric vehicles.

	DC Brush Type	Brushless DC Permanent Magnet	AC Induction
Peak eff. (%)	85-89	95-97	94-95
Efficiency @ 10% load (%)	80-87	73-82	93-94
Max RPM	4,000-6,000	4,000-10,000	9,000-15,000
Cost per shaft HP *	\$100-150	\$100-130	\$50-75
Relative cost of controller to DC brush type	1	3-5	6-8
Weight		Heavier for same power	Lighter
Transmission		Multi-speed	Single speed

* 1 HP = 746 watts

Controllers

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle's speed and acceleration much like a carburetor does in a gasoline vehicle. The controller transforms the battery's direct current into alternating current (for AC motors only) and regulates the energy flow from the battery (both AC and DC motors). This energy flow determines the vehicle's acceleration and speed just as the flow of gasoline does in a conventional vehicle. The controller also has transmission and power management functions such as reversing the motor rotation (so the vehicle can go in reverse), and converting the motor to a generator (so that the kinetic energy of motion can be used to recharge the battery when the brake is applied).

In the early electric vehicles with DC motors, a simple variable resistor type controller was used to control the acceleration and speed of the vehicle. With this type of controller, full current and power was drawn from the battery all of the time. At slow speeds, when full power was not needed, a high resistance was used to reduce the current to the motor. With this type of system, a large percentage of the energy from the battery was wasted as an energy loss in the resistor. The only time that all of the available power was being used was at high speeds.

Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation. For AC motors switching devices such as silicone controlled rectifiers rapidly interrupt (turn on and turn off) the electricity flow to the motor. High power (high speed and/or acceleration) is achieved when the intervals (when the current is turned off) are short. Low power (low speed and/or acceleration) occurs when the intervals are longer.

The controllers on most vehicles also have a system for regenerative braking. Regenerative braking is a process by which the motor is used as a generator to recharge the batteries when the vehicle is slowing down. During regenerative braking, some of the kinetic

energy normally absorbed by the brakes and turned into heat is converted to electricity by the motor/controller and is used to recharge the batteries. Regenerative braking not only increases the range of an electric vehicle by 5 - 10 %, but it also decreases brake wear and reduces maintenance cost.

AC motor controllers also have an inverter which is used to convert the direct current from the battery into alternating current to run the AC motor.

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EV Battery Chargers

The function of the battery charger is to replenish the energy used by the electric vehicle much like a gasoline pump refills a gas tank. One significant difference is that an electric vehicle operator can fully charge the vehicle overnight, at home, rather than refueling at a gasoline station.

The battery charger is a device which converts the alternating current distributed by the utilities and available in almost all locations into the direct current needed to recharge the battery.

Constant Voltage

A constant voltage is applied and the current flows into the battery (high current when the battery is discharged, low current when the battery is nearly charged.)

Constant Current

A constant current is applied until the battery voltage reaches a set value.

Combination Constant Current/Constant Voltage

The charge cycle starts with a high constant current until the voltage reaches a set value, then changes to a constant voltage control.

Basic Battery Charger Operation

- ◆ Charger converts AC to DC
- ◆ Charger controls DC output to battery

There are a number of different types of battery chargers based on the way they control the charging rate.

Current Taper

Charging begins with a high current when the battery is discharged and decreases the current as the voltage nears its full charge state

Pulse

A series of very high current and voltage pulses are applied until the battery voltage reaches a set value

While there are many types of battery charger algorithms available, the vehicle manufacturer will supply or recommend the proper algorithm for the batteries in the electric vehicle.

Charger Location

Electric vehicle battery chargers may also be on-board (in the electric vehicle) or off-board (located at a fixed location). As with many options, there are advantages and disadvantages with both types. If the battery charger is in the electric vehicle (on-board), it is possible to recharge the batteries anywhere there is an electric outlet. This allows the electric vehicle owner to recharge the batteries at work, in a parking lot, at a restaurant, etc. The drawback with on-board chargers are that they are limited in their power output because of size and weight restrictions dictated by the vehicle design. Off-board chargers are limited

in their power output only by the ability of the batteries to accept the charge. While the EV owner can shorten the time it takes to recharge the batteries with a high power off-board charger, the flexibility to charge at different locations is lost.

Coupling Alternatives

There are also two different ways to couple the battery charger to the utility power grid. The first is similar to the traditional plug (called conductive coupling). With this type of connection, the EV operator plugs his vehicle into the appropriate outlet (i.e. 120 or 240 volts) to begin charging. This type of coupling can be used with the charger in the car or out of the car. The second type of coupling is called inductive coupling. This type of

EV Charger Coupling Alternatives

coupling uses a paddle which fits into an inlet on the car. Rather than transferring the power by a direct metal connection as in the case of the conductive couple, power is transferred by induction, which is an electrical couple

between the windings of two separate coils, one in the paddle and the other mounted in the vehicle.

Charge Times

With existing electric vehicles and battery chargers, it usually takes several hours to recharge the electric vehicle's battery pack.

The time required to recharge the batteries in an electric vehicle is dependent on the total amount of energy that can be stored in the battery pack, and the voltage and current (i.e. power) available from the battery charger.

New developments in battery recharging may decrease the time required to recharge electric vehicle batteries to 10 - 15 minutes.

Prototype pulse battery chargers have been developed

which demonstrate that it is possible to recharge the EV battery pack in under 20 minutes without damaging the batteries. When this technology is fully developed, electric recharging stations, similar to gas stations, will be feasible where the electric vehicle operator will be able to quickly recharge the battery pack.

This new charger technology coupled with advanced batteries with a range of 300 miles between recharging, will allow the electric vehicle operator the same freedom of the road currently enjoyed by today's operators of gasoline powered vehicles.

EV Battery Pack Recharge Times

Estimated Range (miles)

Vehicle Type	Battery Capacity				
	7 kwhr	15 kwhr	20 kwhr	30 kwhr	40 kwhr
Compact car	25	54	72	108	144
Sedan		32	42	63	84
Full-size van			20	30	40

Recharge Time (hours)

voltage		current				
(volts)		(amps)				
Residential						
120	12	4.9	10.4	13.9	20.8	27.8
208	32	1.1	2.3	3.0	4.5	6.0
240	32	.9	2.0	2.6	3.9	5.2
Commercial						
240	48	35 min	1.3	1.7	2.6	3.5
480	48	20 min	40 min	50 min	1.3	1.7
Commercial Rapid Charge						
480	150	5 min	10 min	15 min	25 min	30 min

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EV Auxiliary Systems

As with conventional vehicles, electric vehicles have a number of auxiliary systems. Some systems, such as the radio/tape player, lights, horn, etc. operate the same way as they do on a conventional gasoline powered vehicle. Other systems, such as the power steering and power brakes, require the addition of a small electric motor to operate and may have minor impact on the vehicle range. However, the air conditioning and heating systems on electric vehicles are different and most likely will have a noticeable impact on the range.

IMPACT OF EQUIPMENT ON EV PERFORMANCE

Accessory	Range Impact	Comments
Air conditioning	Up to 30%	Highly dependent on ambient temperature, desired cabin temperature, and air volume
Heating	Up to 35%	Highly dependent on ambient temperature and desired cabin temperature
Power steering	Up to 5%	
Power brakes	Up to 5%	
Defrosters	Up to 5%	Dependent on use
Other Lights, stereo, phone, power-assisted seats, windows, locks	Up to 5%	Dependent on use

Federal safety standards require all vehicles to have adequate heating and defrosting systems. The heater/defroster system is easily operated in a conventional gasoline powered vehicle because a supply of heated water from the engine cooling system is readily available. Electric vehicles do not have this heat source and therefore must provide the heat with an auxiliary heating system.

The heater systems on current electric vehicles are similar to existing automotive heating systems with one significant difference. Instead of using the waste heat of a gasoline engine to heat the water, an electric resistance heater, utilizing a heating element similar to the ones found in common hair dryers, is used which requires power. This power must come from the main battery pack with a corresponding decrease in vehicle range. Depending on the outside temperature and the desired temperature in the vehicle, the range reduction can be significant.

The air conditioning systems on electric vehicles also have a significant impact on the range. These are usually standard automotive air conditioning units which must be powered by an auxiliary electric motor instead of being powered by the engine. This additional motor requires power from the battery pack which therefore reduces the range of the vehicle. The amount of power needed for air conditioning is also dependent on the outside temperature and the desired inside temperature

Impact of Desired Vehicle Temperature on EV Energy Consumption

EV drivers will play a key role in determining range

<u>Outside Temp</u>	<u>Desired Vehicle Temp</u>	<u>Auxiliary Energy</u>
110 deg F	70 deg F	1.5 - 2 kw
110 deg F	77 deg F	1 kw
110 deg F	84 deg F	0.5 kw

Heat pumps are an efficient means of providing both heating and air conditioning. Heat pumps similar to the heat pumps used in homes are being developed for electric vehicles and are being used in some state-of-the-art electric vehicles to reduce the power requirements for heating and cooling.

The electric vehicle has a 12 volt auxiliary battery just as in the gasoline powered

vehicle to operate the lights, radio and other equipment. The 12 volt battery in a gasoline powered vehicle is recharged with an alternator driven by the engine.

In an electric vehicle, the auxiliary battery is recharged through the use of a DC to DC converter. This electrical device provides power to the 12 volt auxiliary battery from the high voltage battery pack used to power the vehicle.

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Attachment E

History of Electric Vehicles

The Early Years (1890 - 1930)

The electric vehicle is not a recent development to meet the needs of alternative fuel transportation. In fact the electric vehicle has been around for over 150 years and it has an interesting history of development that continues to the present.

France and England were the first nations to develop the electric vehicle in the late 1800's. It was not until 1895 that Americans began to devote attention to electric vehicles. The first electric vehicles were little more

1902 Wood's Electric Surrey

Many innovations followed and interest in motor vehicles increased greatly in the late 1890's and early 1900's. In 1897 the first commercial application was established as a fleet of New York City taxis.

1902 Woods Electric Phaeton

than electrified horseless carriages and surreys.

The 1902 Wood's Phaeton had a range of 18 miles, a top speed of 14 mph and cost \$2,000. The 1902 Wood's Surrey had a range of 25 miles, a top speed of 14 mph and cost \$2000.

New York City Electric Taxi's

By the turn of the century, America was prosperous and the motor vehicle, now available in steam, electric, or gasoline powered was becoming more popular. The years 1899 and 1900 were the high point of electric vehicles in America, as they outsold all other types of cars. Electric vehicles had many advantages over their competitors in the early 1900's. They did not have the vibration, smell, and noise associated with

gasoline cars. Changing gears on gasoline cars was the most difficult part of driving and was no easy task. Electric vehicles did not require gear changes. While steam powered cars also had no gear shifting, they suffered from long start up times of up to 45 minutes on cold mornings. The steam cars had less range before needing water than an electric's range on a single charge. The only good roads of the period were in town, causing most travel to be local commuting, a perfect situation for electric vehicles, since range was not an issue. The

1902 Wood's Electric Road Wagon

electric vehicle was the preferred choice of ladies because it did not require the manual effort to start, as with the hand crank on gasoline vehicles, and there was no wrestling with a gear shifter.

While basic electric cars cost under \$1000, most early electric vehicles were ornate, massive carriages designed for the upper class. They had fancy interiors, with expensive materials, and averaged \$3000 by 1910.

Electric vehicles enjoyed success into the 1920's with production peaking in 1912.

The decline of the electric vehicle was brought about by several major developments:

1918 Detroit

1. By the 1920's, America had a better system of roads that now connected cities, bringing with it the need for long range vehicles
2. The discovery of Texas crude oil reduced the price of gasoline so that it was affordable to the average consumer. Previously, the high cost of gasoline forced the use of less efficient fuels hindering the performance of the internal combustion engine
3. The invention of the electric starter by Charles Kettering in 1912 eliminated the need for the hand crank
4. The initiation of mass production of internal combustion engine vehicles by Henry Ford made these vehicles widely available and affordable in the \$500 to \$1000 price range. By contrast, the price of the less efficiently produced electric vehicles continued to rise. In 1912 an electric roadster sold for \$1750, while a similarly equipped gasoline car sold for \$650

The Middle Years (1930 - 1990)

Electric vehicles had all but disappeared by 1935. The years following until the 1960's were dead years for electric vehicle development and for use as personal transportation.

The 1960's and 1970's saw a need for alternative fueled vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil.

Many attempts to produce practical electric vehicles occurred during the years from 1960 to the present.

In the early 1960's, the Boyertown Auto Body Works jointly formed the Battronic Truck Company with Smith Delivery Vehicles Ltd of England and the Exide Division of the Electric Battery Company. The first Battronic electric truck was delivered to the Potomac Edison Company in 1964. This truck was capable of speeds of 25 mph, a range of 62 miles and a payload of 2,500 pounds.

1971 Battronic Truck

Battronic worked with General Electric from 1973 to 1983 to produce 175 utility vans for use in the utility industry and to demonstrate the capabilities of battery powered vehicles.

Battronic also developed and produced about 20 passenger buses in the mid 1970's.

Battronic Bus

1974 Battronic Van

Two companies were leaders in electric car production during this time. Sebring-Vanguard produced over 2000 "CitiCars". These cars had a top speed of 44 mph, a normal cruise speed of 38 mph and a range of 50 to 60 miles.

Sebring-Vanguard CitiCar

The other company was Elcar Corporation which produced the "Elcar". The "Elcar" had a top speed of 45 mph, a range of 60 miles and cost between \$4000 and \$4500.

Elcar

In 1975 the United States Postal Service purchased 350 electric delivery jeeps from the American Motor Company to be used in a test program. These jeeps had a top speed of

1975 Electric Postal Vehicle

50 mph and a range of 40 miles at a speed of 40 mph. Heating and defrosting were accomplished with a gas heater and the recharge time was 10 hours.

The Current Years (1990 to Present)

Three legislative mandates have renewed the efforts to develop a practical electric vehicle: the Clean Air Act Amendments in 1990, the Energy Policy Act in 1992, and the California Air Resources Board (CARB) regulations. In addition to more stringent emissions requirements and a reduction in the use of gasoline required by the Federal legislation, the CARB regulations also require Zero Emissions Vehicles (ZEVs).

The "Big Three" automobile manufacturers, and the Department of Energy, as well as a number of vehicle converters are actively involved in electric vehicle development. Electric versions of familiar gasoline powered vehicles are now available that reach super highway speeds with ranges of 50 to 100 miles between recharging.

Some examples of these vehicles are the

US Electricar S-10 Electric Pick Up Truck

Chevrolet S-10 pick up truck which is powered by dual alternating current induction motors and lead acid batteries. It has a range of 60 miles, can be recharged in less than 8 hours and can travel 55 miles on a dollar of electricity.

The Geo Metro is an electric powered 4 passenger sedan powered by an alternating

Solectria Electric Geo Metro

current induction motor and lead acid batteries. It has a range of 45 miles, can be recharged in less than 8 hours and can travel 115 miles on a dollar of electricity. During the 1994 American Tour de Sol from New York City to Philadelphia, a 1994 Solectria Geo Metro cruised 214.2 miles on a single charge using Ovonic nickel metal hydride batteries.

The "Big Three" automobile manufacturers are also developing electric vehicles.

Chrysler has modified their popular mini-van with a direct current electric motor and either

Chrysler Electric Van

nickel iron or nickel cadmium batteries. The top speed is 65 mph and the range is 60 to 80 miles.

Ford has modified their European design Ecostar utility van with an alternating current induction motor and sodium sulfur batteries. The top speed of this vehicle is 70 mph and it has a range of 80 to 100 miles.

Ford Ecostar

General Motors has designed and developed an electric car from the ground up instead of modifying an existing vehicle. This vehicle

GM Impact

called the Impact, is a 2 passenger sports car powered by 2 alternating current induction motors and lead acid batteries. The top speed is 75 mph with a range of 80 miles.

While the vehicles currently available will satisfy the driving requirements of many fleet operators and two car families, the cost of \$30,000 to \$40,000 makes them expensive. However, this cost can be considerably lower when tax credits are included.

Large volume production and improvements in the production process are expected to reduce this price to the range of current gasoline powered vehicles.

For further information, please contact:

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1000 Independence Avenue, S.W.
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Attachment F

The Effect of Electric Vehicles on the Environment

In spite of strict air quality controls since the 1970's, nearly 100 cities in the United States fail to meet the federal clean air quality standards. One third of all Americans (74 million) live in areas where air quality does not meet standards for at least part of the year. Since breathing this contaminated air can cause a number of health problems, finding solutions to air pollution is crucial. Of the available options, the electric vehicle with zero emissions is the most significant.

Pollutants

Pollution comes from heating our homes, providing electricity, driving our cars, and manufacturing products. The pollutants, which reduce air quality, come from both fixed and mobile sources.

Air Pollution Sources

- ◆ Burning of fuel for power & heat
- ◆ Industrial processes
- ◆ Solvents & aerosols

- ◆ Highway vehicles (cars, trucks, buses)
- ◆ Off-highway vehicles (aircraft, boats, trains, lawn mowers, etc.)

While these two types of sources may or may not be equal in the amount of pollution they produce, diesel and gasoline engine emissions produce more of the world's air pollution than any other single source.

Three gases from these automotive exhausts are the major contributors to poor air quality:

Carbon monoxide (CO) is a colorless and odorless gas generated by the incomplete combustion of fuel and air. It enters the bloodstream through the lungs and inhibits the blood's ability to carry oxygen. Even at low levels, carbon monoxide can affect the mental functions and visual acuity.

Nitrogen oxides (NO_x) result from the high temperature combustion processes associated with cars and utilities. Nitrogen oxides are a major contributor to smog and are the cause of its yellow brown color.

Volatile organic compounds (VOCs) are hydrocarbon compounds found in gasoline and diesel fuel and result from the combustion process and evaporation of the fuel.

In sunlight, volatile organic compounds combine with nitrogen oxides to form **ozone**, a major component of smog. Ozone is a severe irritant that can damage lung tissue, affect the respiratory system, and aggravate respiratory disease. High ozone levels can inhibit plant growth and can cause widespread damage to crops and forests.

Automotive manufacturers have made significant improvements in reducing the air pollution generated by vehicle emissions. However because the number of vehicles and the miles driven per vehicle are increasing each year, the air pollution generated by automobiles and trucks continues to be a major contributor to the nation's air quality problems.

Transportation's Share of U.S. Emissions

The pollutants stemming from transportation constitute a major portion of pollutant levels in the air. Each percentage reflects the portion that transportation contributes to the total amount of that pollutant in the atmosphere. For example, of all the carbon monoxide in the air, 78.7% stems from transportation.

Clean Air Initiatives

Air pollution affects **EVERYONE**, from the newborn to the elderly. It can create health problems such as coughing, shortness of breath, and chest pains. A study by the University of California at Davis estimates that 25,000 people per year die from pollution caused by automobiles.

The Clean Air Act and the Amendments of 1990 are efforts to control air pollution from all sources. This legislation authorizes the Environmental Protection Agency (EPA) to establish maximum concentration levels called National Ambient Air Quality Standards (NAAQS) for certain pollutants in the open air in order to protect our health. The Department of Energy has two programs supporting the reduction of air pollution through the use of alternative fuel vehicles. The first, the Energy Policy Act of 1992 requires fleet operators in large metropolitan areas (greater than 250,000 people) to purchase an increasing percentage of alternative fuel vehicles as they replace vehicles. The other program, called the Clean Cities Program, is a locally based government/industry partnership, coordinated by the Department of Energy to expand the use of alternatives to gasoline and diesel fuel. It is a voluntary local program for creating a sustainable, nationwide alternative fuels market.

Specifically, the Clean Air Act and the Energy Policy Act (EPACT) regulate the amount of carbon monoxide, nitrogen oxides, and volatile organic compounds in the air and therefore the amount of ozone (smog) produced.

Under the guidelines set forth in the Clean Air Act and the Energy Policy Act, 22 metropolitan areas have serious or extreme air quality problems from toxic levels of carbon monoxide, nitrogen oxides, and/or volatile organic compounds, and the Environmental Protection Agency has designated them "Non Attainment Metropolitan Areas."

1990 Clean Air Act Non-Attainment metropolitan Areas

Atlanta	Greater CT	Sacramento
Baltimore	Houston	San Diego
Baton Rouge	Los Angeles	San Joaquin Valley
Port Arthur	Milwaukee	Bakersfield
Boston	New York	Springfield
Chicago	Philadelphia	Ventura County
Denver	Providence	Washington, DC
El Paso		

These areas must establish and implement programs to improve the air quality and reduce the levels of air pollution by 3% per year. These programs may include new vehicle inspection requirements, new pollution control requirements for manufacturers, and in severe cases may restrict the expansion of manufacturing facilities. As part of this mandatory program, cleaner vehicles must be manufactured, and government and private fleet operators must begin purchasing these "clean fueled vehicles" beginning in 1998. Clean fueled vehicles are designed to operate on

fuels that significantly reduce the current levels of air pollution from vehicle exhausts. Electric vehicles are an attractive alternative vehicle to reduce air pollution because they produce no exhaust emissions and are classified as a zero emission vehicle (ZEV). Since they produce no tailpipe emissions, electric vehicles acquire more clean fuel vehicle credits than the other types of alternative fuel vehicles.

In addition to these 22 non-attainment metropolitan areas, 30 metropolitan areas have moderate levels of ozone (smog)

Metropolitan Areas with Moderate Ozone Pollution Levels

Atlantic City, NJ	Kewaunee Co, WI	Portland, ME
Charleston, WV	Knox & Lincoln Co, ME	Raleigh-Durham, NC
Charlotte, NC	Lewiston-Auburn, ME	Reading, PA
Cincinnati, OH	Louisville, KY	Richmond, VA
Cleveland, OH	Manitowoc Co, WI	Salt Lake City, UT
Dallas, TX	Memphis, TN	San Francisco, CA
Dayton, OH	Miami, FL	Santa Barbara, CA
Detroit, MI	Modesto, CA	Sheboygan, WI
Grand Rapids, MI	Nashville, TN	St. Louis, MO
Greensboro, NC	Pittsburgh, PA	Toledo, OH

and 38 have moderate levels of carbon monoxide.

Metropolitan Areas with Moderate Carbon Monoxide Pollution Levels

Albuquerque, NM	Greensboro, NC	Portland, OR
Anchorage, AK	Hartford, CT	Provo, UT
Baltimore, MD	Josephine Co, OR	Raleigh-Durham, NC
Boston, MA	Kiamath Co, OR	Reno, NV
Chico, CA	Las Vegas, NV	Sacramento, CA
Cleveland, OH	Medford, OR	San Diego, CA
Colorado Springs, CO	Memphis, TN	San Francisco, CA
Denver, CO	Minneapolis-St. Paul, MN	Seattle, WA
Duluth, MN	Missoula, MT	Spokane, WA
El Paso, TX	Modesto, CA	Stockton, CA
Fairbanks, AK	New York City, NY	Syracuse, NY
Fort Collins, CO	Philadelphia, PA	Washington, DC
Fresno, CA	Phoenix, AZ	

These areas must establish air quality improvement programs to reduce the level of these pollutants because they are alarmingly close to becoming classified as non-attainment areas. While these programs are not required to include the mandatory purchase of "clean fueled vehicles", they may include enhanced vehicle emission inspections and increased air pollution requirements on manufacturers.

For one third of all Americans living in these areas, these levels of ozone and carbon monoxide are far too high and must be reduced if public health is to be preserved.

A SOLUTION: The Electric Vehicle

The most significant solution to the nation's air pollution problem is the Electric Vehicle because it produces no exhaust emissions and is classified as a zero emission vehicle (ZEV).

In addition, they

- are compatible with the needs of fleet operators and two-car families
- have a range between recharging of 50 to 100 miles
- can be recharged overnight, and
- have top speeds compatible with the speeds allowed on most highways

According to one estimate, electric vehicles are ten times cleaner environmentally than gasoline powered vehicle, even when the emissions from the electric generation source are taken into account.

While electric vehicles produce no exhaust emissions, emissions are generated in the production of the electricity used to power the vehicle. This pollution must be included in any comparison of the impact electric vehicles and conventional gasoline powered vehicles have on our air quality.

The amount of pollution contributed by the generation of electricity is dependent on the type of fuel used to produce the electricity. While the burning of fossil fuels would generate more pollution than using hydroelectric generation, monitoring and controlling the emissions from a few hundred power plants can be done easier than controlling the emissions from 190 million vehicles burning fossil fuels.

When all sources for automotive exhaust pollution are taken into account, it is easy to understand that the pollution generated by electric vehicles is much lower than that generated by gasoline powered vehicles.

Alternative Fuel Emission Comparison

(gm/mile)

Vehicle	VOC	CO	NO _x
EPA Standard Car (1987)	0.41	3.4	1.0
California Standard Car (1995)	0.25	3.4	0.4
California Test Results			
Gas	0.39	1.40	0.66
Electric	0.006	0.008	0.07

Source: CARB Report May 1989

Based on a Department of Energy (DOE) study, replacing conventional powered vehicles with electric vehicles will **reduce**

- the carbon monoxide level by 99%
- the nitrogen oxide level by 60%
- the volatile hydrocarbon level by 99%
- the carbon dioxide pollution by 60%

Widespread use of electric vehicles offers the greatest opportunity to improve air quality and to reduce health problems caused by smog and carbon monoxide.

For further information, please contact:

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National Alternative Fuels Hotline
(800) 423-1DOE

<http://www.afdc.doe.gov>

Clean Cities Hotline

(800) CCities

<http://www.ccities.doe.gov>

Attachment G

York Technical College's Regional Partners

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