Table 4. Percentage comparison of unnecessary repair costs.

Repair	California	Missouri	Alabama (overall)	Alabama (after prescription)	Survey
Brakes	18	18	28	20	43
Emissions	7	6	35	20	62
Alignment	6	4	8	4	0[a]
Suspension	21	15	37	24	48
Steering	2	0	23	-	72[b]
Total	12	10	29	19	53

[a]Sample of five repairs. [b]Sample of three repairs.

the users of the centers, but may not have an effect on entire cities (9).

2. Diagnostic centers probably have an effect on reducing unnecessary automobile repairs. This effect probably increases with the length of operation of the facility, until some fairly stable level is achieved.

3. The industry's knowledge of the after-repair inspection may have an effect on the quality of repairs.

4. A learning effect probably exists while the repair industry becomes aware of diagnostic centers. The low unnecessary repair frequency for the Missouri center, which has been in operation for many years, by itself does not make that conclusion evident.

5. Unnecessary repair frequencies may be reduced by providing the motorist with understandable repair information for communicating with the repair industry.

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Electric Vehicle Technology Update

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Electric vehicles (EVs) may offer some advantages over gasoline and alternately fueled vehicles in terms of operating cost and as a hedge against future fuel shortages. However, existing EV technologies need to be advanced so that EVs will be as easy to operate and maintain as gasoline vehicles. An overview of some areas in which technology improvement is needed and is now being addressed by participants in the Electric Vehicle Demonstration Project of the U.S. Department of Energy is provided. These areas include state-of-charge monitoring, charging, battery capacity testing, electrolyte management, and battery connectors.

Given past experience with gasoline shortages and rising operating costs due to increased gasoline prices, vehicle owners, particularly fleet operators, have been looking into the potential of alternately fueled vehicles as a hedge against similar conditions in the future. Among the alternate-fuel options that have been tested are the following: diesel, propane, methane, methanol, and electricity. Of these, electricity may offer the most flexibility in that it is widely available, easily tapped, and not as susceptible to shortages as the others. Electricity may also perform well in terms of operating cost since it can be generated from a variety of fuels, and it should therefore not increase in price as rapidly as any one particular fuel.

Although ownership of an electric vehicle (EV) thus offers potential advantages, some obstacles need to be addressed. The transition from gasoline vehicles to EVs may not be as easy as the transition from gasoline to other fuels. Because electricity cannot be used in an internal-combustion engine, a significantly different propulsion system is required. Therefore, in a typical conversion of a gasoline vehicle to an EV, the propulsion system of the gasoline vehicle is removed and EV systems are added, which results in a purchase price about double that of the gasoline vehicle. As manufacturers gain production experience and demand allows large-scale production of EVs, this price gap can be expected to lessen.

In addition to its higher price, the operating and maintenance requirements of EVs differ more widely from gasoline vehicles than do those of other

alternately fueled vehicles. For example, there are few differences between a gasoline vehicle and one converted to run on propane, vis-à-vis the differences between gasoline and electric vehicles, which makes a mechanic's transition to servicing EVs more difficult.

Such obstacles to EV ownership are being identified by 42 private companies, federal agencies, and state and local governments that comprise the Electric Vehicle Demonstration Project of the U.S. Department of Energy. Demonstration participants have operated about 500 EVs more than 900 000 miles during the past three years. Several of the participants have formed a task force to study problem areas and to introduce technological improvements for EVs, which will make them easier to own and operate in the gasoline-vehicle environment in which we live. This paper provides an update on some areas in which technological improvement is needed and is being addressed by the task force.

First, however, a brief description of EVs may be useful. EVs do not have a fuel tank--they use a pack of batteries to store electrical energy aboard the vehicle. Between 16-20 battery modules are arranged in series to provide a 96- to 120-V pack. EVs have no carburetor through which acceleration and velocity can be controlled; instead, a controller is relied on to regulate the draw of electricity from the battery pack in response to the driver's use of the accelerator pedal. As mentioned earlier, EVs do not have an internal-combustion engine but rather a highly efficient electric motor that converts the electrical energy to mechanical energy. The motor, used as a generator, can even convert movement of the vehicle back to electrical energy through regenerative braking. The electric motor does not require a cooling system or an ignition system. Finally, electric vehicles are not "fueled" with electricity by anything that resembles a gasoline pump. Instead, a charger, in circuit between an electrical outlet and the battery pack, "pumps" electricity into the batteries at a programmed rate.

In comparing an EV with a gasoline vehicle, we are comparing a product in its infancy with a mature one. The gasoline vehicle has benefited from almost a century of research, development, testing, user feedback, and refinement. EVs, however, must rely at the moment on a compilation of off-the-shelf technologies, originally designed for other applications. The result is that EVs are not yet as owner foolproof as gasoline vehicles.

An example of this can be seen by contrasting the fuel gauge of a gasoline vehicle with the equivalent in an EV. The gasoline fuel gauge is a simple device that provides relatively accurate information on the amount of gasoline remaining in the fuel tank. Since EVs have a shorter range (35-60 miles) and charging takes some time (about 8 h for a full charge), an accurate fuel or battery state-of-charge gauge is critical. Fully depleting the charge in an EV is not only inconvenient but can greatly reduce battery life. State-of-charge monitoring in currently produced EVs has proved to be inaccurate or misleading. The state-of-charge meter reading (based on measurement of the voltage across the battery pack) when the vehicle is stationary will differ from that when it is being driven and can also vary at different driving speeds. Further, even if the meter correctly indicates the state of the overall battery pack, it does not indicate the condition of individual battery modules. It is possible for some modules to be very weak while the overall state of charge of the pack appears adequate. In this case, the modules low on charge will impair the performance of the EV and are likely to suffer permanent damage if they become completely discharged.

Accurate monitoring of battery module charge is one of the key areas being addressed by the EV task force. The task force is considering the use of a microprocessor that uses individual battery module voltages and current measurements to determine state of charge. The next step would be to allow depleted battery modules to be removed from the circuit while driving, to protect them and the performance of the vehicle.

The differences that often exist in state of charge among battery modules in a pack has led the EV task force to take several other initiatives. First, a battery module can be ruined not only by overdischarging but also by overcharging. When an EV is plugged in to charge, the charger provides all battery modules with the same number of ampere hours, regardless of each module's state of charge. As a result, some battery modules are overcharged while others are insufficiently charged. This not only shortens battery life but also wastes electric power. A possible solution, which is being investigated by the EV task force, is "smart" chargers. In concept, these chargers, along with appropriate wiring of the battery modules, will be capable of metering the correct current to each module, thus equalizing the level of charge among them.

Another initiative to address the problem of battery modules with dissimilar characteristics in a pack is currently being implemented by several demonstration project participants. This effort involves the use of diagnostics to weed bad battery modules out of the battery pack. After such modules have been replaced, all the modules are brought up to full and equal charge. They should then all charge and discharge to the same level, thus greatly reducing the risk to battery life and also improving performance. The diagnostic tool being used to identify weak battery modules is a load bank. The testing method involves fully charging each battery module and discharging the pack into the load bank at a constant rate. The voltage of each module is monitored. By comparing the time it takes each module to reach a certain voltage to the battery manufacturer's specifications, the capacity of each module can be determined.

Another area of interest to the EV task force is battery electrolyte management. To constrast this area to gasoline vehicles, consider the single battery used to start a gasoline vehicle. Typically, this battery requires little attention--occasional checking of the electrolyte level in six cells is generally all that is done. EV batteries are different. They are deeply discharged, overcharged, and lose a lot of water by evaporation in the process. Regular inspection and replenishment of water is required, and inspecting and adding water to a 120-V battery pack that has 60 battery cell caps is a time-consuming task that needs frequent repetition. Filling batteries cannot be put off because their life depends on it. Cell caps with glass inserts are made by one manufacturer to simplify electrolyte inspection. The task force is looking to reduce the time required to add water; one possible solution may be to advance the state of the art of single-point watering systems. Such systems allow all battery cells to be filled by adding water to a single reservoir--somewhat like filling one corner of an ice cube tray and letting the water spill over to the other compartments.

In addition to electrolyte management, battery connectors constitute an important maintenance concern to EV owners. Although dirt and deposits on the battery of a gasoline vehicle may occasionally interfere with the starting circuit or loose cable

clamps may result in an open circuit, these are relatively infrequent and minor problems. In an EV, however, they are serious. Dirty or loose connections on any of the 40 battery posts can significantly degrade performance, cause improper charging, and sometimes generate enough heat (because of the high resistance) to melt the battery posts. Currently, most connectors used in EVs are similar to those used for gasoline-vehicle starting batteries. They were not designed to carry high currents with a minimum voltage drop for long periods. Tightening and cleaning connections has been a regular and time-consuming maintenance item on EVs in the demonstration project. The EV task force efforts in this regard are directed toward testing new connectors and developing other alternatives. One recently manufactured type of connector is spring loaded to maintain a tight connection and has a plastic cap to keep the connection clean.

An EV that is as owner foolproof as, and competitive with, a gasoline vehicle will depend on an overall systems approach rather than modification of off-the-shelf components. Such an EV will probably be produced by the same companies that now produce gasoline vehicles. The efforts of the EV task force are important to the near-term improvement of EVs and very possibly may contribute to the ultimate system design. The incentives for task force members to contribute are great since all members foresee an important role for EVs in their own vehicle fleets.

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Analysis of the Effectiveness of Bumper Standard FMVSS 215

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The primary objective of this paper is to evaluate the effectiveness of crash-protecting automobile bumpers as required by Federal Motor Vehicle Safety Standard 215—Exterior Protection, Passenger Cars. This study focused on three distinct versions of the standard: (a) the initial 1973 regulations that required compliance with a barrier test, (b) regulations after 1974 that required both a pendulum and an upgraded barrier test, and (c) regulations after 1978 that limited total vehicular damage as a result of the pendulum and barrier tests. Following the recommendations of several previous studies, insurance claims were used as the data base. A comprehensive data base provided by the State Farm Insurance Company was categorized by vehicle model years that represent four time periods—1972, 1973, 1974-1978, and 1979—and into vehicle-size classes, impact points, vehicle age, and repaired and replaced damaged bumper categories. By using reported claims and average cost of these claims as measures of effectiveness, it was shown that the model years with more protective bumper systems experienced significantly lower proportions of bumper-related claims relative to all property-damage claims. However, in general, these model years also had higher average repair costs. The reduced percentages of bumper-related claims were primarily attributable to decreased claims that involve bumpers being replaced rather than claims that involve bumper repair only.

In 1971, the National Highway Traffic Safety Administration (NHTSA) issued Federal Motor Vehicle Safety Standard (FMVSS) 215--Exterior Protection, Passenger Cars. The general purpose of this standard was to prevent low-speed accidents from impairing safe operation of the vehicle and to reduce the frequency of override and underride impacts in higher-speed collisions (i.e., collisions of two vehicles where the initial contacts slide over or below the bumper). It was also hoped that, as a consequence of FMVSS 215, the cost of repairs to vehicles involved in low-speed collisions would be reduced. Hence, an economic advantage to the consumer would be realized.

Bumper-performance tests used to determine that safety-related items (lights, fuel system, cooling system, etc.) are not rendered inoperable include pendulum and barrier-impact tests of the bumper system. The barrier tests consist of front and rear impacts against a flat rigid barrier at specified speeds. The pendulum-impact test consists of striking the bumper at specified heights and angles with a pendulum hammer. This test is designed to promote consistent bumper heights so as to reduce the likelihood of underride or override of bumpers in car-to-car collisions.

The performance testing for compliance with the safety-related requirements of FMVSS 215 has gone through various stages of development [see Table 1 (1)]. The initial standard model year (1973) was subject to barrier-impact testing only (5-mph front and 2.5-mph rear impacts). Beginning with the following model year (1974), the rear-barrier test was upgraded to 5 mph and the pendulum-impact test (longitudinal and corner impacts) was introduced. The pendulum-impact test was amended starting with the 1976 model year, which decreased the number of longitudinal pendulum impacts.

Title I of the Motor Vehicle Information and Cost Savings Act (P.L. 92-513, 1972) instructed NHTSA to develop property-damage bumper standards that would provide the maximum feasible reduction of costs to the public and to the consumer. The Part 581 standard issued under the authority of this Act required that, effective with the 1979 model year, front and rear bumpers must be capable of protecting vehicles from damage in barrier and pendulum longitudinal crash tests at 5 mph and pendulum corner impacts at 3 mph. In addition, damage criteria were upgraded to permit damage only to the bumper itself and the brackets, fasteners, etc., that attach the bumpers to the chassis framework and not to any other vehicle components or surfaces. For 1980 and future models, the standard also limited bumper face-bar damage.

In general, the objective of this study addresses the basic question, Has the imposition of a bumper standard resulted in reduced damage and overall cost to the motorist? The analysis attempts to answer this question by determining whether or not insurance claims and their estimated repair costs have been changed by the imposition of FMVSS 215. The major portion of the analysis is aimed at determin-