AUTOMOTIVE TECHNOLOGIES IN JAPAN

Solutions for Greater Safety, Improved Environmental Performance and Increased User Convenience

Japan Automobile Manufacturers Association, Inc.
Since its introduction more than a century ago, the automobile has been in a state of continuous development in response to society’s needs and expectations. It continues to evolve today in line with contemporary requirements, not only as a vital element in global economic activity as a means of commercial and passenger transport, but also as a means of enhancing people’s lives.

As a result of its constant evolution, the automobile is today a comfortable and convenient means of transportation that offers greater safety than ever before and significantly reduced environmental impact, in addition to highly improved operational performance.

Particularly in the areas of safety, environmental performance and user convenience, major progress has been made thanks to breakthroughs in vehicle-based electronic technologies, engine technologies and in the information and communication technologies that underpin ITS (Intelligent Transport Systems). Advanced and expanded applications are expected in the future.

The purpose of this booklet is to introduce and explain these state-of-the-art technologies, focusing on those which are currently in application in Japan. Developments or applications anticipated for the near future are discussed or referred to briefly.

We hope this publication will increase the general understanding of readers in regard to contemporary automotive technologies and their advancement and application by the Japanese automobile industry.

Japan Automobile Manufacturers Association, Inc. (JAMA)
March 2008

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Timeline for the Introduction in Japan of Automotive Technologies for Greater Safety, Improved Environmental Performance and Increased User Convenience (1993-2008)

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* ICT = Information & communication technologies

- HELPNET™ (emergency call system)
Automotive Technologies Currently in Application (In-Vehicle View)

Applications of technologies for greater safety, improved environmental performance and increased user convenience in currently in-use passenger cars are illustrated here. (Abbreviations are spelled out on pages 1-2.)

- Three-point seatbelt
- ISOFIX anchorage (for a child safety seat)
- Split-folding seat
- Rear power seat
- Heated seat
- Electric power steering
- Plastic resin fender
- Pedestrian protection front-end design
- AFS
- Discharge headlamp
- Projector headlamp
- Fog lamp
- Cornering lamp
- Front air dam
- Inter-vehicle distance warning
- Adaptive cruise control
- Blind-corner monitoring
- Idling prevention
- Lean-burn engine
- Mirror cycle engine
- Twin camshaft
- Multi-valve engine
- Electronically-controlled fuel injection
- Variable valve timing
- Variable turbocharger
- Intercooler
- Hollow camshaft/Aluminum cylinder block
- Liquid-filled engine mount
- Common-rail fuel injection
- Electric power steering
- Remote-control mirror
- Water-repellent side mirror
- Vehicle perimeter monitoring
- Head-up display
- UV-reducing glass
- Night vision monitoring
- In-vehicle terrestrial digital tuner
- Fog lamp
- Cornering lamp
- Front air dam
- Inter-vehicle distance warning
- Adaptive cruise control
- Blind-corner monitoring
- Power window with jamming-prevention mechanism
- Water-repellent glass
- UV-reducing glass
- HELPNET™ (emergency call system)
- ICT applications in navigation system
- Lane deviation warning/Lane-keeping assist
- Driver inattention warning
- Head-up display
- UV-reducing glass
- Night vision monitoring
- In-vehicle terrestrial digital tuner
- Fog lamp
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- Front air dam
- Inter-vehicle distance warning
- Adaptive cruise control
- Blind-corner monitoring
II. TECHNOLOGIES FOR GREATER SAFETY

Vehicle-based safety technologies comprise (a) technologies for active safety to help prevent accident occurrence and (b) technologies for passive safety to mitigate injury when accidents do occur. Recent years have seen important advances in pre-crash safety intelligent technologies aimed at boosting active safety and reducing damage and injury from unavoidable collisions. Many of the following technologies were developed as a result of research conducted on the Advanced Safety Vehicle (ASV) concept.

A. Active Safety Technologies

1 Driver Assist Technologies

Electronic Stability Control (ESC)
ESC is a system that automatically helps control vehicle skidding—resulting, for example, from too sharp a turn at relatively high speed or from a suddenly slippery road surface—by activating braking for the individual wheels as needed and controlling engine output to put the vehicle back on course.

To counter understeering when taking a turn, ESC automatically applies the brakes to the inner rear wheel and reduces engine output. To counter oversteering, the brakes are automatically applied to the outer wheels and engine output is reduced, thereby maintaining stability and keeping the vehicle on course.

Driver Inattention Warning
This system monitors slight lateral deviations from the vehicle’s course or trajectory and alerts the driver through visual and auditory warnings when such deviations occur.

The system makes use of an onboard camera and a vibration gyrosensor (steering angle sensor) to detect lateral deviations caused by driver inattention or, for example, a cross wind, and warns the driver accordingly.

To avoid the risk of false alarms, system application can be customized for individual drivers by pre-setting certain parameters including vehicle speed.

Tire Pressure Monitoring
This system monitors tire air pressure and air temperature by means of a sensor located inside each tire of the vehicle and informs the driver when tire air pressure is low (underinflation).

Maintaining tire pressure at appropriate levels helps prevent the occurrence of accidents (attributable to the loss of vehicle steerability and driving stability resulting from underinflated tires) as well as a decline in vehicle fuel-efficiency performance.

Adaptive Cruise Control (Inter-Vehicle Distance Monitoring)
This technology automatically maintains a safe distance from the vehicle ahead using radar and an onboard camera and by controlling vehicle speed.

The radar and camera provide the data needed for computerized calculation of the distance to the vehicle ahead. When that distance becomes unsafe based on real-time speed calculations, the driver is alerted accordingly and automatic auxiliary braking is performed as needed.

Lane Deviation Warning & Lane-Keeping Assist
With this technology, an onboard camera monitors the road ahead and alerts the driver with visual and auditory warnings when the vehicle is about to deviate from its lane.

If no corrective action is taken by the driver, the lane-keeping assist function activates steering torque control to keep the vehicle running in its proper lane.

The lane-keeping assist function is automatically released by the driver’s operation of the directional signals whenever a lane change is intended.

Lane-Keeping Assist

Steering torque control is activated as necessary to prevent lane deviation.

The driver is alerted to imminent lane deviation by means of a camera monitoring the road ahead.

Vehicle trajectory (x-axis)
Lateral deviation

Vehicle trajectory (x-axis)
Benefits of Adaptive Front-Lighting System

Adaptive Front-Lighting System (AFS)
AFS assists driving at night by automatically adjusting the orientation of the front headlamps of the vehicle, taking into account steering angle and vehicle speed, in order to provide better nighttime visibility.

Because AFS interlocks automatic headlamp orientation adjustment with steering angle and vehicle speed, it is therefore especially helpful for drivers during cornering, when it provides a significantly wider range of visibility than fixed headlamps.

Night Vision Monitoring
Advanced night vision systems detect, by means of infrared cameras, infrared radiation-emitting objects in or approaching the vehicle’s forward path and determine whether the ‘objects’ are pedestrians. The driver is then alerted accordingly, with visual and auditory information, in order to prevent nighttime accidents involving pedestrians.

Example of Infrared Detection-Based Night Vision to Assist Vehicle Drivers

Vehicle Perimeter Monitoring
This technology uses cameras mounted on the exterior of the vehicle to transmit views of the vehicle’s periphery to the display screen inside the car. Because the cameras detect surrounding objects/obstacles that could otherwise not be seen by drivers, this safety feature is helpful on narrow roads, in tight spaces, and when parking.

Blind-Corner Monitoring
The purpose of this technology is to help reduce accident occurrence at intersections. When the vehicle approaches a blind intersection or “T” junction—that is, where visibility to the right and left is dangerously reduced—a camera with a built-in prism mounted on the front of the vehicle transmits views of about 20 meters (roughly 60 feet) in both directions to the in-cabin display screen. This greatly assists the driver in safely navigating the vehicle through the intersection.

Vehicle Perimeter Monitoring & Blind-Corner Monitoring

Collision-Mitigation Braking System
Based on the distance from and speed relative to the vehicle ahead obtained from radar information, as well as on the anticipated vehicle trajectory as determined by sensors (including cameras), the system’s electronic control unit calculates the risk of collision. When there is such a risk, visual and auditory warnings are emitted and the driver’s seatbelt is retracted gently a few times to alert him/her to the imminent danger.

When the driver applies the brakes, the system activates the brake-assist function (also referred to here as “automatic auxiliary braking”) to reinforce the driver’s own braking action. If the driver’s braking pressure is insufficient or if he/she fails to apply the brakes, the system applies full braking power, thereby reducing the speed at the time of collision. Furthermore, the vehicle’s occupants are effectively restrained in their seats by quickly-retracting seatbelts (or “pre-crash seatbelts”) which also optimize airbag deployment efficiency. In this way, the system mitigates the impact of the collision on vehicle occupants and on the vehicle itself, and thereby helps reduce injury and damage.

Collision-Mitigation Braking Using Millimeter-Wave Radar

Anti-Lock Braking System (ABS)
This system automatically regulates the hydraulic pressure applied to the brakes for all the vehicle’s wheels at the time of sudden, heavy braking, to prevent the wheels from locking. This allows the driver to maintain steering control and helps ensure vehicle stability. Most automobiles today are equipped with ABS as a standard safety feature.

Brake Technologies

Brake Assist
When a vehicle is equipped with both brake assist and an anti-lock braking system, the result is more rapid, and therefore safer, emergency braking (see diagram below).

Benefits of Brake Assist

Automatic Leveling
This technology automatically adjusts the up-and-down orientation (or “pitch angle”) of the vehicle’s front headlamps to prevent blinding the vision of the driver of an oncoming vehicle, taking into account vehicle speed and height.

Based on those variables, front headlamp orientation is tilted vertically, up or down, to an appropriate height for effective, non-blinding forward illumination.
B. Passive Safety Technologies

1. Occupant Protection Technologies

■ Active Head Restraint
This technology reduces whiplash injury to a front-seat occupant by moving the headrest upward and forward at the time of a rear-end collision. When such a collision occurs, a hinge incorporated into the seatback yields in response to the forward motion of the occupant’s torso, allowing the seatback to move rearward and a pressure plate inside it to move the headrest upward and forward based on the lever principle, cradling and protecting the occupant’s head and neck.

Active Head Restraint: Activation on Rear-End Collision

■ SRS Side Airbag
The SRS (Supplemental Restraint System) side-impact airbag serves primarily to protect front-seat occupants from injuries to the torso—specifically, to the chest and pelvis—at the time of a side (or “lateral”) collision.

Upon detection of a lateral collision by means of a sensor, the side airbag installed in the seatback deploys instantly. Side airbags designed for head protection and for rear seats have also been introduced.

■ SRS Curtain Airbag
At the time of a lateral collision, this system deploys an airbag installed in the side of the vehicle ceiling. This airbag instantly inflates to form a curtain between the front- and rear-seat occupants and the side window, running the entire length of the side of the cabin, to protect them against head and neck injuries.

Curtain airbags also help protect vehicle occupants from injuries caused by shattered side-window glass.

SRS Side Airbag & SRS Curtain Airbag

Chronology of SRS Airbag Introduction
Driver’s-seat airbags were the first to be introduced, with dual front airbags introduced soon thereafter to protect both front-seat occupants from injuries sustained in frontal collisions. Airbag installation has since been extended to the rear seats as well. Airbags are also used for occupant protection in side collisions, as described on this page.

All of these are Supplemental Restraint System airbags, which are designed to mitigate collision impact on vehicle occupants restrained by seatbelts (the primary restraint system) and are optimally effective in combination with correct seatbelt use.

■ Seatbelt Technology
Seatbelts secure vehicle occupants in their seats at the time of a collision or an abrupt stop. Their purpose is to reduce injury and prevent occupants from being ejected from the vehicle.

Seatbelt pretensioners and force limiters (also called “load limiters”) are now standard equipment. Pre-crash seatbelts have also been introduced which work in conjunction with the brake-assist function (or “automatic auxiliary braking”) to hold vehicle occupants more securely in place when a collision is unavoidable.

Benefits of the Seatbelt Pretensioner & Force Limiter

■ Pre-Crash Seatbelt
Quickly-retracting pre-crash seatbelts work in conjunction with the brake-assist function to restrain occupants in their seats when a collision is determined (by an electronic control unit) to be unavoidable. Pre-crash seatbelts also optimize airbag deployment efficiency.

■ Vehicle Compatibility
Advancing vehicle compatibility involves improving the safety performance of a vehicle in the event of a crash with another vehicle, with a particular focus on reducing the ability of larger vehicles to cause damage to smaller vehicles in a collision.

In vehicle-to-vehicle crashes, it is often the case that one vehicle sustains greater damage (usually resulting in greater injury to its occupants) because of differences in mass, size and geometry—including, among other factors, body shape, ride height and bumper height. Studies in vehicle compatibility seek to minimize injury to the occupants of both vehicles involved in a crash through improvements to body structure.

During vehicle development, crash tests involving a larger car and a smaller car are rigorously carried out in order to achieve structural compatibility that will enhance a vehicle’s collision impact-absorbing capacity by, for example, enabling the absorption of impact energy over surfaces rather than at specific points.

Examples of Incompatibility in Car-to-Car Collisions

A car with greater mass is likely to push back a lighter car.

Impact-absorbing capacity does not match because of incompatible body frames.

Crumpling is likely to occur in cars with weaker front ends.
Now under development, pedestrian protection-enhancing airbags will further buffer the impact of the collision on the pedestrian by covering hard spots and components in the lower windshield area such as the cowl and wiper bases, as well as the structural pillars on each side of the windshield.

Examples of Front-End Vehicle Design for Pedestrian Protection

Collision Impact-Absorbing Features
- Impact-Absorbing Hood
- Impact-Absorbing Fenders
- Impact-Absorbing Bumpers
- Airbags
- Pivots collapse easily under pressure
- Actuators instantly raise the back end of the hood, leaving a space between the hood and the engine to accommodate, enabling a “universal system” for child safety-seat installation.
- Lower windshield area such as the cowl and wiper bases, as well as the structural pillars on each side of the windshield.

Pedestrian Protection Vehicle Design
This is front-end vehicle design intended specifically to reduce injuries (particularly head and lower limb injuries) to a pedestrian involved in a pedestrian-vehicle collision.

To reduce the force of the collision’s impact on the pedestrian and therefore the extent of potential injury, various provisions are made in the design of the hood, fenders, wiper pivots and front bumper to allow for sufficient clearance, collapsibility, or even ejection off the vehicle.

2 Pedestrian Protection Technology

Environmental protection is a pressing global issue, and initiatives are being taken around the world to reduce the burdens imposed on the environment by human activity.

In road transport, environmental protection is being promoted through the adoption of wide-ranging measures aimed at, among other objectives; improving air quality and addressing climate change through the reduction of CO2 and other emissions. Such measures include the introduction of advanced vehicle technologies to reduce exhaust emissions and increase fuel efficiency; the stepped-up development of hybrid and electric vehicles and vehicles that run on alternative sources of energy, such as fuel cell vehicles; and the development of environmentally sound biofuels.

For Diesel Engines
Diesel engines pose a particular challenge because of the conflicting requirements involved in controlling the NOX and particulate matter (PM) they emit. Overcoming that challenge has involved various measures including combustion chamber improvements, exhaust gas recirculation (EGR), and the introduction of advanced fuel-injection technology.

Significant progress has been made a) in cutting NOX emissions from diesel engines through the use of ammonia in the chemical reduction process and b) in reducing PM emissions with the use of filters (DPFs).

1 Technologies to Reduce Exhaust Emissions

Catalyst Technology

For Gasoline Engines
Exhaust emissions are produced when fuel is burned in a vehicle’s engine. Emissions from gasoline engines include pollutants such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOX).

There are two different methods for reducing these emissions: One method is to reduce/eliminate them at the source (namely, the engine), and the other is to eliminate their toxicity using after-treatment technologies.

Emissions are reduced or eliminated at the source by means of electronically-controlled fuel injection and improvements to the engine’s combustion chamber, as well as through greater efficiency in the combustion process itself.

Catalytic converters serve to cleanse or “purify” the engine’s emissions. Three-way catalytic converters, which can simultaneously perform the twin emissions-reducing requirements of chemical oxidation and reduction, are now the standard for gasoline engines.

Another method uses an NOX storage-reduction (NSR) catalyst to temporarily store NOX emissions and reduce them later.
- Urea-Selective Catalytic Reduction (SCR)

This technology reduces the nitrogen oxides (NOx) in the diesel engine’s exhaust emissions by performing controlled injection of urea solution into the hot exhaust gas, which generates ammonia. The chemical reaction between the NOx and the ammonia reduces the NOx to harmless nitrogen (N2) and water vapor.

This method for NOx reduction in diesel engines successfully eliminates the NOx— even when the exhaust gas temperature is low. Moreover, the technology is cost-effective because, in addition to its durability, it does not require the use of precious metals.

Urea SCR

- NOx Catalytic Converters

The uniqueness of this breakthrough technology is characterized by the fact that the ammonia it uses in the NOx reduction process is generated by the catalytic converter itself.

NOx catalytic converters feature a two-layer structure: One layer absorbs NOx from the engine’s exhaust gas and converts a portion of it into ammonia; the ammonia (NH3) is then absorbed by the other layer, which uses it to convert the NOx remaining in the exhaust gas into nitrogen (N2). The ability of these catalytic converters to generate and store ammonia and efficiently reduce NOx in a lean-burn atmosphere enables diesel engines to rival gasoline engines in cleanliness.

NOx Catalytic Converters for Diesel Engines: Schema of Operation

- Exhaust Gas Recirculation Technology (EGR)

EGR reduces NOx emissions by recirculating a portion of the engine’s exhaust gas and mixing it with intake air to lower the temperature in the engine’s cylinders (because higher combustion temperatures increase NOx formation).

In current EGR systems, the EGR valve that interlocks with the intake throttle valve is continuously controlled by a microprocessor for precision control of the ratio of recirculated exhaust gas and intake air.

A system has also been developed for heavy-duty trucks, which enables NOx reduction by cooling the hot recirculated exhaust gas with an EGR cooler and mixing it with intake air to further lower the temperature in the cylinders.

Example of a Cooled-EGR System for Heavy-Duty Trucks

- Diesel Particulate Filters (DPFs)

A diesel particulate filter is a device that is used to remove particulate matter (PM) from the exhaust gas of a diesel engine.

In turn, the PM accumulated in the filter must also be removed to prevent clogging—a process referred to as “regeneration.” Regeneration is carried out by various (mostly onboard) methods. A typical onboard method is the use of a fuel burner to increase the exhaust temperature, thus enabling PM combustion.

Example of a Continuous Regeneration-Type DPF

- Fuel Injection Technology

Advanced fuel injection technology provides highly sophisticated electronic control not only of the amount of fuel injected in the engine’s cylinders (or “fuel metering”), but also of the pressure and timing with which the fuel is injected. The benefits of this technology are more efficient engine performance and therefore increased fuel efficiency, as well as reduced emissions of pollutants (NOx and PM) in the engine’s exhaust.

Common-Rail Fuel Injection

Common-rail fuel injection is a technology for diesel engines that allows a pipe-shaped central accumulator—the common rail—to store high-pressure fuel (produced by an engine-driven pump) and then deliver it to all the individual injectors (of which there is one for each cylinder).

Controlled by the engine’s electronic control unit, this system makes possible high injection pressures at all times (for finer atomization of the injected fuel, to enhance combustion efficiency), in addition to precision control of fuel metering and of the timing of the fuel injections.

Common-Rail Fuel Injection
In-Cylinder Direct Injection

Technologies to Increase Fuel Efficiency

Road transport CO2 emissions represent a significant share of CO2 emissions generated by human activity. Technologies to increase fuel efficiency not only contribute to energy conservation but also help counter global warming through reductions in auto-emitted CO2, their further advancement must therefore be pursued. The various technologies described below are already in application.

High-Efficiency Engine Technologies

In-Cylinder Direct Injection

In conventional gasoline engine systems, fuel is injected into the intake valve (also referred to as the “cylinder port”) and then mixed with air before the air-fuel mixture is injected into the cylinders. In the case of in-cylinder direct injection engines, however, fuel is sprayed directly into each cylinder’s combustion chamber.

Extremely high-pressure (more than 20 times higher than in conventional systems) fuel injection enables very fine atomization of the fuel particles, which in turn enables combustion at very high air-to-fuel ratios (air is taken in directly into each combustion chamber): from 40- to 50- to as high as 60-to-1. This ultra lean-burn technology thus reduces fuel consumption.

Furthermore, direct injection of the fuel into the cylinders allows air to be taken in with less throttling resistance, which results in less pumping loss and, consequently, reduced fuel consumption in this respect as well. This technology therefore enables increased fuel efficiency and reduced levels of CO2 emissions.

Variable Valve Timing (VVT)

The flow of air and fuel into and out of (in the form of exhaust) vehicle engines is controlled by valves. The engine’s energy efficiency is affected by how long the valves open, referred to as “valve timing.”

Optimum valve timing varies depending on engine speed and load. Conventional engines rely on fixed valve timing settings, which are a compromise between the variable optimum timing settings.

VVT technology increases the engine’s energy efficiency by providing continuously variable timing—in other words, by automatically switching to optimum valve timing settings.

The engine’s efficiency is also affected by how much the valves move, referred to as “valve lift.” VVT technology can also feature valve lift control (VVT&L), which automatically switches to optimum valve lift settings.

Reduction of Engine Friction Loss

Friction loss, which is a mechanical loss, occurs when the engine’s moving metal parts—such as the pistons, crankshaft and valves (specifically, the valves and valve seats)—rub against each other. Friction loss results in reduced energy efficiency.

Various measures are taken in engine design to prevent friction loss, including the use of lighter parts (pistons, for example) and reduction of the valve spring load. Friction can also be reduced, particularly during engine warm-up, with the use of low-viscosity lubricating oil, which will help reduce fuel consumption.

Moreover, engines are now under development that will cut fuel consumption when engine load is low not only by closing and shutting down the operation of some intake and exhaust valves, but also by reducing engine pumping loss which occurs at the time of intake and exhaust.

Example of Friction Loss Reduction Technology

Electric Power Steering

With this technology, steering is assisted by an electric motor rather than by hydraulic pressure. This boosts fuel efficiency since the steering assistance does not place any load on the engine.

Reduction of Aerodynamic Drag (Improved Aerodynamics)

In addition to reducing mechanical loss, reducing vehicle drag is an important concern. Aerodynamic drag (that is, the force required to push a vehicle through the air) accounts for 80 percent of total vehicle drag.

Various measures have been taken in state-of-the-art vehicle design to improve the aerodynamics, such as ensuring that the external surfaces between windows and panels are flush.

Reduction of Rolling Resistance

While aerodynamic drag accounts for 80 percent of total vehicle drag, the rolling resistance of the tires accounts for the remaining 20 percent.

The challenge in reducing the rolling resistance of tires is, at the same time, to ensure optimal running performance and riding comfort. Tires with less rolling resistance are currently under development. For large vehicles, ultra-wide low-profile single tires are now in use. These tires represent a new level of tire technology, replacing the dual tires on rear wheels for a smoother ride and improving fuel economy by reducing unsprung mass.

Reduction of Vehicle Weight

Lighter vehicle weight means that less energy is required to propel the vehicle.

Additional weight reduction will therefore enable further increases in fuel economy. This can be achieved without compromising safety through the use of lighter, stronger materials such as polymers and resins in vehicle components and by designing lighter vehicle architectures overall.

Reducing Weight through Increased Use of Aluminum

R&D to Improve Aerodynamics

In vehicle development, extensive studies and testing are carried out to reduce resistance to airflow.
Continuously Variable Transmission

This technology involves two pulleys—the driving pulley (which inputs engine power) and the driven pulley (which outputs to the powertrain)—and a belt that connects them, riding in a groove in the pulleys. When the cones of either pulley move outward, the diameter of the pulley decreases and the belt rides lower in the groove; when the cones move inward, the diameter increases and the belt rides higher. The varying diameters of the two pulleys in relation to each other (i.e., their ratios) determine the gear ratio. This “continuous variability” in power transmission enables increased fuel efficiency.

Automated Manual Transmission (AMT)

AMTs offer the excellent fuel efficiency of manual transmissions and the smooth shifting of conventional automatic transmissions, the basic difference compared to MTs being that a hydraulically-controlled automatic clutch makes clutch operation by the driver unnecessary. Some AMTs also offer fully automatic shifting.

Although AMT systems vary in terms of the specific technologies they incorporate, they all offer enhanced fuel efficiency and better shifting performance. The diagram below illustrates one type of AMT system.

The Twin Clutch-SSST AMT System

Idling Prevention

This technology, also called “stop-start,” reduces fuel consumption by shutting down the engine when the vehicle comes to a stop, thereby preventing it from idling, and starting it again when the driver applies the clutch.

Idling-prevention technology has been widely adopted in Japan in transit buses and delivery trucks because of their stop-and-go driving patterns.

How Idling Prevention Works (in a MT vehicle)

Engine Shutdown

Shift to neutral. Apply the hand brake.

When stopping, the engine automatically shuts down after the driver has set the hand brake to the maximum. When the engine automatically restarts after the driver applies the clutch.

Engine Restart

Apply the clutch.

A combined hybrid enables significantly increased fuel efficiency and reduced emissions by using only the electric motor at the time of start-up, as with the series type; by using both the engine and the electric motor when more power is needed, as with the parallel type; and, at steady cruising speeds, by storing the extra energy produced by the engine in the battery for later use. A special feature of combined hybrids is that they continuously optimize both the mechanical and electrical power flows by means of a power-splitting device.

Hybrid vehicles also incorporate regenerative braking technology, which recovers energy (that would otherwise be lost) during braking and stores it in the battery, to be used later to help move the vehicle down the road. Energy recovery with this fuel-economizing technology can be considerable, particularly in hybrid transit buses and other urban work vehicles, such as delivery trucks, that perform mostly stop-and-go driving.

Plug-In Hybrid Vehicles

Plug-in hybrid vehicles (referred to as “PHEVs” for plug-in hybrid electric vehicles) operate on batteries that can be recharged by hooking up to the electrical power grid—typically, through a conventional home outlet. They are powered exclusively by an electric motor for short trips (and are thus highly energy-efficient for city driving), but perform as hybrid vehicles for long-distance driving by reverting to the use of a combustion engine.

Expansion of the electric-only travel range for these vehicles should encourage their more widespread use in urban areas. PHEVs offer excellent environmental performance as well as significant reductions in overall fuel costs, particularly if they are recharged at night when the cost of electrical power is generally lower.
Fuel Cell Vehicles

A fuel cell vehicle is propelled by a motor that runs on electricity generated by onboard fuel cells assembled into a fuel cell stack. Fuel cells create electricity through an electrochemical reaction. The polymer electrolyte membrane (PEM) fuel cell used in automobiles generates electricity by means of a chemical process that uses only hydrogen gas and oxygen from the air and emits only water, producing no harmful emissions whatsoever.

The PEM is wedged between an anode and a cathode. Hydrogen gas is conveyed to the anode on one side, where a platinum catalyst splits the hydrogen into positively charged hydrogen ions, or protons, and electrons (always negatively charged). Only the hydrogen-ion protons can pass into the PEM and through to the cathode on the other side. Meanwhile, the electrons follow an external circuit to the cathode, generating electricity. At the cathode, the electrons and the hydrogen-ion protons combine with oxygen channelled in from the air to form water—or water vapor, to be precise—which then flows out of the cell.

Energy loss (in the form of heat) in fuel cell vehicles is minimal, which is not the case with conventional generators, where the energy conversion process is accompanied by significant mechanical/thermal loss.

The PEM is charged. Only the hydrogen-ion protons can pass into the PEM and through to the cathode on the other side. Meanwhile, the electrons follow an external circuit to the cathode, generating electricity. At the cathode, the electrons and the hydrogen-ion protons combine with oxygen channelled in from the air to form water—or water vapor, to be precise—which then flows out of the cell.

Powertrain Configuration in a Fuel Cell Vehicle (Example)

Electric Vehicles

Electric vehicles (EVs) operate on electric power exclusively and feature a power-generation system consisting of three elements: an electric motor, a controller, and batteries. The controller takes power from the batteries and conveys it to the motor, which in turn transmits it directly to the wheels. EVs are zero-emission vehicles. In addition, power generation in an EV creates much less vibration than it does in a vehicle equipped with an internal combustion engine.

The major problems previously posed by EVs were their limited travel range and the long time they required for battery-recharging. However, the development of batteries with higher energy density, such as nickel-metal hydride and lithium-ion batteries, now enables a travel range of up to 200 kilometers (120 miles). A further development is the use of a so-called quick charger in a 200-volt power supply, which enables a travel range of 60 kilometers after only 15 minutes of recharging.

Example of an Electric Vehicle and How It Recharges

Hydrogen Vehicles

Hydrogen vehicles are powered by hydrogen that is subjected to combustion. (Fuel cell vehicles are also powered by hydrogen which, without combustion, is converted into electricity by the fuel cells—see text and diagram on opposite page.) The hydrogen combustion process generates only water and some nitrogen oxides (NOX); no CO2, carbon monoxide, hydrocarbons or sulfur compounds are released.

However, major issues exist with respect to the commercialization of hydrogen-powered vehicles for widespread use. One problem, which of course also applies to fuel cell vehicles, is the production and supply infrastructure for this energy source; another problem is posed by the need for a compact solution to the in-vehicle storage of hydrogen.

A Hydrogen-Internal Combustion Engine Hybrid Vehicle

Clean Diesel Vehicles

A chief merit of diesel engines is that they are more fuel-efficient, and therefore emit fewer CO2 emissions, than gasoline engines. This is one reason why diesel passenger cars have, over time, steadily increased in popularity in Europe. Greater emissions of soot and nitrogen oxides were long perceived to be the disadvantages of diesel engines compared to gasoline engines. However, the overall emissions performance of diesel engines has improved dramatically in recent years in response to more stringent regulatory requirements. Clean diesel engines now provide significantly reduced emissions compared to conventional diesel engines and, in comparison with gasoline engines, considerably (up to 30 percent) greater fuel efficiency.

A Clean Diesel Engine

Natural Gas Vehicles

Natural gas vehicles, or NGVs, use either compressed natural gas (CNG) or liquefied natural gas (LNG) for propulsion. Most are CNG vehicles.

Natural gas is composed of methane and other hydrocarbon gases. Because NGVs generate roughly 20 percent fewer CO2 emissions than gasoline vehicles, they are likely to become a practical alternative to gasoline vehicles. NGVs also release fewer NOX emissions and, unlike diesel vehicles, no soot, resulting therefore in reduced particulate matter (PM) emissions.

CNG-powered commercial vehicles—transit buses and trucks, for example—are in relatively widespread use in Japan, and CNG passenger vehicles and minicars have recently been introduced to the market. CNG-powered hybrid buses are currently under development.

A CNG-Powered Small Truck

Diesel-Alternative LPG Vehicles

The primary component of liquid petroleum gas, or LPG, is either propane or butane, which is stored onboard a vehicle in liquefied form.

LPG vehicles are the norm for passenger-car taxi fleets in Japan. Because of its comparatively low cost and reduced NOx and PM emissions, LPG is also widely used today in Japan in small trucks, as an alternative to diesel power.
4 Other Alternative Fuels

In the interest of increased energy security and reduced environmental impact, the following fuels have been developed for use in automobiles as alternatives to gasoline and conventional diesel fuel. Research on alternative fuels is ongoing.

Coal-to-Liquid and Gas-to-Liquid (CTL/GTL) Fuels

Cutting-edge CTL/GTL technology converts carbon dioxide (CO₂) and hydrogen (H₂) derived from coal and natural gas into liquid fuels which can then be refined to produce diesel fuel for use in conventional diesel engines. In addition to their easy storage and handling, CTL/GTL fuels release essentially no sulfur emissions and no aromatics during combustion. These synthetic fuels are therefore considered a promising alternative to petroleum-based diesel fuel (or “petro diesel”) and are increasingly sought after today.

Biodiesel Fuel (BDF)

Biodiesel fuel consists of a vegetable oil (soybean, sunflower or rapeseed oil, for example) or animal fat feedstock which has undergone transesterification—a chemical process to reduce high viscosity—to produce a fuel whose properties are similar to those of petro diesel and that can be used in conventional diesel engines.

In addition, research and verification tests have recently been carried out in Japan on what is being called “bio-hydrogenated diesel” or BHD, a renewable synthetic diesel fuel. Produced using a vegetable oil feedstock and through the application of refinery-based hydrogenation technology, sulfur- and aromatics-free BHD has been shown to generate fewer toxic emissions than petro diesel.

Bioethanol

Bioethanol fuel is a renewable gasoline substitute that can be produced from a wide variety of plants through a process of decomposition into starch and sugars, fermentation, and distillation. It is environmentally friendly and, more specifically, carbon neutral, because the CO₂ produced during its use is balanced (or “offset”) by the CO₂ consumed in the photosynthetic growth of the plants. For this reason, CO₂ emitted in bioethanol combustion has been omitted from calculations of greenhouse gas emissions under the Kyoto Protocol.

However, the production of bioethanol from food crop feedstocks such as corn and sugar cane raises major issues including those of food supply and appropriate land use. In contrast, the potential for cellulosic ethanol made from waste residues and non-food crop feedstocks is promising, and efforts to promote its production and commercialization are underway worldwide.

In Japan, various initiatives launched in 2007 are being pursued across the country to promote the production and use of bioethanol. Currently in the Tokyo metropolitan area, bioethanol is available at 100 filling stations in gasoline-biofuel blends. At present, however, bioethanol content in such blends is not allowed to exceed 3 percent, owing to the concern that if used at a higher concentration in gasoline-biofuel blends, corrosion of vehicle parts could result.

DME is a synthetic fuel produced from natural gas, coal seam gas (also called “coalbed gas”) or biomass. It is clean-burning, generating virtually no soot and no sulfur oxides (SOₓ), with reduced emissions of nitrogen oxides (NOₓ) and particulate matter. Easy to handle, it can serve as an alternative to conventional diesel fuel and liquid petroleum gas (LPG).

Biofuel

Biofuel fuel can be produced from a wide variety of plants through a process of decomposition into starch and sugars, fermentation, and distillation. It is environmentally friendly and, more specifically, carbon neutral, because the CO₂ produced during its use is balanced (or “offset”) by the CO₂ consumed in the photosynthetic growth of the plants. For this reason, CO₂ emitted in bioethanol combustion has been omitted from calculations of greenhouse gas emissions under the Kyoto Protocol.

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V. MOTORCYCLE TECHNOLOGIES

- **Anti-Lock Braking System (ABS)**
  An anti-lock braking system on a motorcycle prevents the wheels from locking at the time of braking, ensuring stability as the vehicle moves forward. Using sensors positioned on both the front and rear wheels, the system’s ECU monitors braking pressure and wheel speed and, when determining the start of a lock-up (resulting from overbraking), causes the ABS modulator (or “pressure modulator”) to adjust the braking pressure on each wheel to ensure vehicle stability.

Functional Diagram of Motorcycle ABS

- **Motorcycle Airbags**
  Motorcycle airbags were developed for the purpose of mitigating injuries to riders in frontal collisions. When a frontal collision occurs, crash sensors detect acceleration changes caused by the impact and convey that data to the airbag ECU, which instantaneously determines whether or not to deploy the airbag. In the event of deployment, an electronic signal from the ECU causes activation of the airbag inflator. The deployed airbag absorbs the rider’s kinetic energy, preventing him/her from being thrown forward from the motorcycle.

![Example of an Inflated Motorcycle Airbag](Image)

- **Dual Combined Braking System**
  So-called combined or dual combined braking systems (CBS or DCBS) actuate a motorcycle’s front as well as rear brakes when the rider applies either the front or the rear brake. Monitoring the braking pressure thereby created, the ECU calculates how much braking force should optimally be applied to the front and rear wheels and then causes the required amount of such force to be distributed over both wheels. This system ensures optimum braking while maintaining vehicle stability.

When CBS/DCBS is combined with ABS, the result is a braking system that performs with outstanding efficiency even when road conditions are slippery.

Functional Diagram of Motorcycle CBS

VI. TECHNOLOGIES FOR INCREASED USER CONVENIENCE

- **Park Assist**
  Park assist technology interfaces with electric power-assisted steering, front and rear side sensors and a back-up monitoring camera to enable a car to steer itself into a parking space with no steering-wheel operation by the driver. The driver needs only to position the vehicle, shift to reverse, press relevant buttons on the in-dashboard, camera image-supplied touchscreen and release the brake. The system will disengage if the driver touches the steering wheel or depresses the brake pedal. A visual or auditory signal informs the driver of the completion of the parking operation, whether parallel or reverse.

Recent advances in park assist technology have further simplified the procedures involved in readying a vehicle for a parallel or reverse parking maneuver. These advanced functions automatically identify and target a potential parking space through computer processing of sensor-obtained data, at the same time verifying sufficient clearance with respect to the positioning of vehicles parked adjacent to the targeted space.

Diagrammatic Representation of Ultrasonic Sensor-Based Park Assist in Operation

- **Automatic Closing**
  A motor-based mechanical system that automatically closes vehicle doors, sliding door and trunk when these are ajar. Automatic closing ensures that the doors and trunk are closed gently.

- **Smart Keys**
  “Smart key” is one among various terms for this technology, which allows automatic unlocking and locking of vehicle doors (by means of an electric pulse generated inside the car key) without conventional key operations or the use of a remote control button. It also enables electronic ignition activation—i.e., without insertion of the key into the ignition.

How a Smart Key Works

When a driver carrying the car key comes within a certain distance of the vehicle, the door is automatically unlocked by an electric pulse generated by the key, and locked when the key-carrying driver leaves the vehicle.

- **Motorcycle Technologies**
  - Functional Diagram of Motorcycle CBS when the rider applies or DCBS) actuate a motorcycle’s front as well as rear brakes
  - ABS modulator (or “pressure modulator”) to adjust the braking pressure on each wheel to ensure vehicle stability.
  - Monitoring the braking pressure and wheel speed and, when determining as the vehicle moves forward. Using sensors positioned on both the front and rear wheels, the system’s ECU monitors braking pressure and wheel speed and, when determining the start of a lock-up (resulting from overbraking), causes the ABS modulator (or “pressure modulator”) to adjust the braking pressure on each wheel to ensure vehicle stability.
  - Example of an Inflated Motorcycle Airbag

Along with technologies advancing safety and environmental protection in road transport, technologies that promote comfortable and more convenient vehicle use continue to evolve. Innovations in the area of vehicle user convenience have been made possible by advances in computer-controlled and communications technologies.
One principal benefit is a reduction in CO₂ emissions, which benefits derived from the resulting smoother traffic flow.

By enabling drivers to pass through tollgates without stopping, ETC offers multiple advantages including increased comfort and convenience for vehicle users and reduced congestion at toll plazas, as well as the environmental benefits derived from the resulting smoother traffic flow.

ETC was launched for large-scale use in Japan in March 2001. The cumulative total number of deliveries of in-vehicle devices exceeded 20 million units in November 2007 and continues to rise, as does the ETC use rate which, for the week of February 15 through 21, 2008, stood at 73.1 percent of all expressway users nationwide. During that same period, the ETC use rate reached 81 percent on the Tokyo Metropolitan Expressway road network.

ETC for motorcycles has been available in Japan since November 2006.

ETC Use & CO₂ Emissions Reduction

<table>
<thead>
<tr>
<th>Time (months)</th>
<th>CO₂ emissions (100,000 t CO₂/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to ETC Introduction</td>
<td>40</td>
</tr>
<tr>
<td>ETC use rate 50% (October 2005)</td>
<td>30</td>
</tr>
<tr>
<td>ETC use rate 60% (March 2008)</td>
<td>20</td>
</tr>
</tbody>
</table>

An estimated reduction of approx. 130,000 t CO₂/year

Conventional versus Smart Highway Toll Stations

A conventional set-up for highway toll collection, where a toll plaza typically services an interchange and comprises multiple tollbooths, requires considerable land allocation and infrastructure.

Because smart toll stations can be built at points directly accessing toll roads, they require significantly less land allocation. Construction costs are, comparatively, also much reduced.

HELPNET™ (Emergency Call System)

HELPNET™ is a service operating in Japan that, in the event of an emergency involving an automobile—whether an accident, breakdown, sudden driver incapacity or passenger illness—enables the communication (automatic or manual) of the vehicle's registration data and current location to the service's operations center. That information is then relayed to the police and emergency service providers with jurisdiction in the location concerned. HELPNET’s purpose is to reduce the interval of time between the reporting of an emergency and the arrival on site of rescue personnel. In the event of a collision, automatic communication of the HELPNET user’s vehicle registration data and location is activated by airbag inflation; in other types of emergencies, manual communication is carried out instantaneously by means of a one-touch device installed inside the vehicle cabin. Other possible communication channels are via a vehicle’s navigation system or a mobile (cell) phone.

HELPNET: How It Works

Onboard Emergency Notification

Emergency notification

Emergency notification of vehicle registration data and current location communicated automatically (airbag-interlocking device) or manually (one-touch device)

HELPNET Operations Center

Emergency notification data and current location relayed to the police and emergency service providers with jurisdiction in the location concerned

How VICS Works

Information on traffic conditions and road use restrictions is displayed on road traffic conditions and road use regulations and restrictions, alternate routes and parking facility availability to in-vehicle equipment enabling the display of this information on the navigator screen in text, diagrams and maps.

Example of a VICS Information-Enhanced Navigator Screen Display

Before VICS

Road traffic conditions and road use restrictions were displayed only on the navigator screen in text, diagrams and maps.

After VICS

Road traffic conditions and road use restrictions are displayed on the navigator screen in real-time.
VII. DRIVING THE AUTOMOTIVE FUTURE

Key elements in achieving sustainable mobility in the 21st century are greater safety and reduced environmental impact. In road transport, however, efforts to increase safety and decrease the environmental “footprint” involve a whole range of factors involving not only the automotive industry but also government, fuel suppliers, and vehicle users. Nevertheless, in the years ahead the expanding practical application in Japan of the continuously advancing vehicle safety, ITS and communication technologies described below is expected to play a crucial role in improving road safety and traffic flow by reducing accident occurrence and chronic congestion.

**ASV (Advanced Safety Vehicle) Technologies**

In the area of safe-driving assistance, many of the vehicle safety technologies described in this publication and in application in Japan today—including collision-mitigation braking systems, lane-keeping assist systems and adaptive cruise control systems—have been developed based on the results of research conducted on the Advanced Safety Vehicle concept.

The 1991 launch of the ASV project by what is now Japan’s Ministry of Land, Infrastructure, Transport and Tourism was spearheaded, as a national project, ITS development in a number of areas. ITS developmental guidelines aim to achieve progress with respect to (i) safety and security, (ii) fuel efficiency and environmental protection, and (iii) comfort and convenience. A wide range of ITS technologies and services have therefore been energetically promoted in parallel with the further development of AVS technologies (see opposite page).

Many of these ITS technologies/services, including electronic toll collection, VICS and HELIPNET (see pages 25 and 26), are already in extensive use in Japan. Scheduled for 2010, meanwhile, is the practical introduction of two intelligent communication-based emergency warning systems—one a safe-driving support system and the other an advanced cruise-assist system for highways/expressways (“DSSS” and “AHS,” respectively)—that use vehicle navigation system-integrated telematics. These and other ITS technologies are expected to see expanded development in the coming years.

**ITS (Intelligent Transport Systems) Technologies**

Intelligent Transport Systems use cutting-edge information and communication technologies to network data between road users, roads (i.e., infrastructure) and vehicles for the dual purpose of reducing road congestion—and, as a result, CO2 emissions—and accident occurrence. In 1996 the Japanese government formulated a comprehensive concept for the promotion of ITS, on the basis of which it spearheaded, as a national project, ITS development in a number of areas. ITS developmental guidelines aim to achieve progress with respect to (i) safety and security, (ii) fuel efficiency and environmental protection, and (iii) comfort and convenience. A wide range of ITS technologies and services have therefore been energetically promoted in parallel with the further development of AVS technologies (see opposite page).

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**Advanced Car Navigation Systems**

Car navigation systems equipped with digital road maps and integrating Global Positioning System (GPS) technology were first introduced in Japan in 1990. Initially, these systems used only a single CD-ROM, but subsequent systems enabled, first, the use of multiple CD-ROMs and, beginning in 1997, a DVD-ROM. Car navigation systems using hard-disc drives (HDDs), which obviously have a much larger capacity, have been commercially available since 2001.

The use of large-capacity media has made possible considerable progress in system functions. For example, the quality of voice guidance (for spoken directions, etc.) has improved significantly, the 3D screen indications and search function have become much faster, and the real-time transmission of information on road traffic conditions has also advanced with the use of a range of data sources, including VICS, that enables highly accurate optimal route guidance.

Screen displays have also become more complex. It is now possible to customize 2D map displays, to select 3D displays of major intersections and, with a touchscreen, to obtain an image showing the precise perimeter of a targeted parking space (see “Park Assist” on page 24).

Advanced car navigation systems also offer driver-assistance features such as lane deviation monitoring, navigator-based gearshift control, curve detection, voice recognition, advanced lane guidance, and handsfree calling, among other functions.

Car navigation systems will, in the years ahead, continue to become increasingly sophisticated with further advances in telematics.

An HDD-Operated Car Navigation Display Screen

**Telematics**

“Onboard telematics” refers to the integrated application of GPS and mobile communications technologies in automotive navigation systems. Telematics enables an Internet-accessing vehicle navigation system to deliver a broad spectrum of wireless functions and services: not only real-time traffic and weather information and route guidance, but also automatic reporting in the event and at the time of theft, automatic roadside assistance, remote diagnostics in the event of vehicle breakdown (by connecting with a diagnostics consultation service), entertainment and shopping information, voice recognition, e-mail and fuel-efficient driving guidance. Further applications in various areas are anticipated in the near future.

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**Features of the Advanced Safety Vehicle**

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